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TWENTY-THIRD ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL
EXPERIMENT STATION.

PART I.,

BEING PART III. OF THE FORTY-EIGHTH ANNUAL REPORT
OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

JANUARY, 1911.



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WRIGHT & POTTER PRINTING CO., STATE PRINTERS,
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THE STATE BOARD OF PUBLICATION.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

PART I.

DETAILED REPORT OF THE EXPERIMENT STATION.

INTRODUCTION.

In accordance with the provision of the act of the Legislature relative to the publication of the reports of the Massachusetts Agricultural College, the report of the experiment station, which is a department of the college, is presented in two parts. Part I. contains the formal reports of the director, treasurer and heads of departments, and papers of a technical character giving results of experiments carried on in the station. This will be sent to agricultural colleges and experiment stations and to workers in these institutions, as well as to libraries. Part I. will be published also in connection with the report of the Secretary of the State Board of Agriculture, and will reach the general public through that channel. Part II. will contain papers of a popular character, and will be sent to persons on our mailing list.

WM. P. BROOKS,
Director.

CONTENTS.

PART I.

	PAGE
Station organization,	11
Report of the director,	13
Changes in staff,	13
Lines of work,	16
Dissemination of information,	16
Publications,	16
Publications during 1910,	16
Publications available for free distribution,	17
Circulation of publications,	18
Correspondence,	20
Lectures and demonstrations,	20
Future provision for extension work,	20
General experiments,	21
Co-operative experiments with alfalfa,	22
Research,	23
Asparagus substitution, Concord,	24
Breeding experiments,	24
Fertilizer experiments,	25
Chemical work on asparagus roots,	25
Cranberry substations,	26
Fertilizer experiments,	27
Insect work,	28
Control work,	28
Fertilizer law,	28
Dairy law,	29
Feed law,	29
Inspection of apiaries,	30
Buildings,	30
Report of the treasurer,	32
Report of the agriculturist,	34
Comparison of different materials as a source of nitrogen,	34
Muriate compared with sulfate of potash,	36
Nitrogen fertilizers and potash salts for garden crops,	38
Relative value of different potash salts,	40
Comparison of different phosphates,	42
Manure alone compared with manure and sulfate of potash,	44
Average corn fertilizer compared with fertilizer richer in potash,	45
South acre soil test,	46

	PAGE
Report of the agriculturist — <i>Con.</i>	
North acre soil test,	47
Top dressing for hay,	48
Winter <i>v.</i> spring application of manure,	49
Report of the chemist,	51
Correspondence,	51
Numerical summary of work in chemical department,	51
Laboratory work of the research section,	52
Research work in animal nutrition,	53
Tabulations,	53
Report of the fertilizer section,	54
Fertilizers licensed,	54
Fertilizers collected,	55
Fertilizers analyzed,	55
Trade values of fertilizer ingredients,	56
Summary of analyses and guarantees of licensed complete fertilizers,	57
Commercial shortages,	59
Quality of plant food,	60
Grades of fertilizer,	60
Composition according to grade,	61
Unmixed fertilizers,	63
Miscellaneous substances,	63
Nitrogen compounds,	65
Potash compounds,	65
Phosphoric acid compounds,	66
Miscellaneous work,	66
Report of the feed and dairy section,	67
The feed law,	67
Analytical work,	67
Compliance with the law,	68
New law,	68
Definitions,	69
Weight of sacked feeds,	69
The dairy law,	69
Examination of candidates,	69
Examination of glassware,	70
Inspection of Babcock machines,	70
Creameries,	71
Milk depots,	72
Milk, cream and feeds sent for free examination,	72
Analysis of drinking water,	72
Miscellaneous work,	73
Testing of pure bred cows,	74

	PAGE
Report of the botanist,	75
Diseases more or less common during the year,	75
Report of the entomologist,	77
Goessmann, Charles A., tribute to,	80
Studies in milk secretion,	86
The effect of protein upon the production and composition of milk,	86
The determination of arsenic in insecticides,	122
Methods,	122
Iodine method,	124
New processes,	125
Practice at Massachusetts station,	127
Iodine methods for arsenates,	129
Purification of insoluble fatty acids,	131
Distillation of the fatty acids in vacuo,	131
Crystallization from alcohol,	132
Distillation of the ethyl esters in vacuo,	133
The soluble carbohydrates in asparagus roots,	135
Seed work, 1910,	141
An outbreak of rusts,	144
Sweet pea troubles,	145
A spinach disease new to Massachusetts,	146
Abnormalities of stump growths,	149
Description of mosaic disease,	150
Relation to mosaic disease,	154
Experiments in inoculation,	154
Relation of root area to intensity of disease,	156
Chemical tests of abnormal leaves,	157
Conclusions,	159
Peach and plum troubles,	161
Brown rot, scab, gummosis, etc.,	161
Climatic adaptations of apple varieties,	177
I. Introduction,	177
II. The causes of varietal variation,	179
Cultural variation,	179
Soil variation,	180
Climatic variation,	180
The mean summer temperature,	182
III. The development of the apple,	183
IV. The perfectly developed apple,	186
V. The individuality of the tree,	194
VI. The modifying effect of climate on the development of the apple,	199
On form,	199
On size,	204

Climatic adaptations of apple varieties — *Con.*

VI. The modifying effect of climate on the development of the apple — <i>Con.</i>	
On general development,	205
Apple belts in North America,	205
Distribution of varieties,	207
The relation of temperature to development,	221
The mean summer temperature,	221
The winter minimum,	221
The heat of summer,	222
The effect of low and of high mean summer temperatures,	222
The optimum mean summer temperature,	227
Chemical determinations,	232
VII. Summary,	243
Compilations,	246
Analyses of fodder articles and dairy products,	247
Composition and digestibility of fodder articles,	249
Fertilizer ingredients of fodder articles,	266
Analyses of dairy products,	272
Coefficients of digestibility of American fodder articles,	273
Analyses of agricultural chemicals, refuse salts, phosphates, guanos, ashes, lime compounds, marls, by-products, refuse substances and animal excrements,	304
Chemicals and refuse salts,	306
Phosphates and guanos,	308
Ashes, lime compounds and marls,	310
By-products and refuse substances,	314
Animal excrements,	322
Insecticides,	323
Analyses of fruits and garden crops,	324
Fruits,	325
Garden crops,	327
Relative proportions of phosphoric acid, potassium oxide and nitrogen in fruits and garden crops,	334
Composition of some Massachusetts soils,	339
Description of types,	339
Miscellaneous soil analyses,	341
European standards for comparison,	346

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION
OF THE
MASSACHUSETTS AGRICULTURAL COLLEGE,
AMHERST, MASS.

TWENTY-THIRD ANNUAL REPORT.
PART I.

ORGANIZATION.

Committee on Experiment Department.

CHARLES H. PRESTON, *Chairman.*
J. LEWIS ELLSWORTH.
ARTHUR H. POLLARD.
CHARLES E. WARD.

HAROLD L. FROST.
THE PRESIDENT OF THE COLLEGE, *ex officio.*
THE DIRECTOR OF THE STATION, *ex officio.*

Station Staff.

WILLIAM P. BROOKS, Ph. D., Director, 28 Northampton Road.
JOSEPH B. LINDSEY, Ph. D., Vice-Director, 47 Lincoln Avenue.
FRED C. KENNEY, Treasurer, Mount Pleasant.
CHARLES R. GREEN, B.Agr., Librarian, Mount Pleasant.

Department of Plant and Animal Chemistry.

JOSEPH B. LINDSEY, Ph.D., Chemist, 47 Lincoln Avenue.
EDWARD B. HOLLAND, M.Sc., Associate Chemist, in charge of Research Division, 28 North Prospect Street.
FRED W. MORSE, M.Sc., Research Chemist, 44 Pleasant Street.
HENRI D. HASKINS, B.Sc., In charge of Fertilizer Section, 87 Pleasant Street.
PHILIP H. SMITH, B.Sc., In charge of Feed and Dairy Section, 102 Main Street.
LEWELL S. WALKER, B.Sc., Assistant, 19 Phillips Street.
JAMES C. REED, B.Sc., Assistant, Nutting Avenue.
JOSEPH F. MERRILL, B.Sc., Assistant, North Prospect Street.
CLEMENT L. PERKINS, B.Sc., Assistant, 32 North Prospect Street.
JOSEPH P. HOWARD, Collector, North Amherst, Mass.
HARRY J. ALLEN, Laboratory Assistant, 89 Main Street.
JAMES R. ALCOCK, Assistant in Animal Nutrition, North Amherst, Mass.

Department of Agriculture.

WILLIAM P. BROOKS, Ph.D., Agriculturist, 28 Northampton Road.
H. J. FRANKLIN, Ph.D., In charge of Cranberry Investigation, Wareham, Mass.
ERWIN S. FULTON, B.Sc., First Assistant, North Amherst, Mass.
EDWIN F. GASKILL, B.Sc., Second Assistant, North Amherst, Mass.

Department of Horticulture.

FRANK A. WAUGH, M.Sc., Horticulturist, Massachusetts Agricultural College.
FRED C. SEARS, M.Sc., Pomologist, Mount Pleasant.
JACOB K. SHAW, M.Sc., Assistant Horticulturist, 1 Allen Street.
DAVID W. ANDERSON, B.Sc., Graduate Assistant, 32 North Prospect Street.

Department of Botany and Vegetable Pathology.

GEORGE E. STONE, Ph.D., Botanist and Vegetable Pathologist, Mount Pleasant.
GEORGE H. CHAPMAN, M.Sc., Assistant Botanist, 13 Fearing Street.
SUMNER C. BROOKS, B.Sc., Assistant Botanist, 28 Northampton Road.

Department of Entomology.

HENRY T. FERNALD, Ph.D., Entomologist, 44 Amity Street.
BURTON N. GATES, Ph.D., Apiarist, 42 Lincoln Avenue.
ARTHUR I. BOURNE, B.A., Assistant in Entomology, 66 North Pleasant Street.

Department of Veterinary Science.

JAMES B. PAIGE, B.Sc., D.V.S., Veterinarian, 42 Lincoln Avenue.

Department of Meteorology.

JOHN E. OSTRANDER, A.M., C.E., Meteorologist, 35 North Prospect Street.
CHARLES M. DAMON, Observer, Massachusetts Agricultural College.

Other Officers of the Experiment Station.

MISS ROSE J. BROWN, Secretary to the Director, Draper Hall.
MISS JESSIE V. CROCKER, Stenographer, Department of Botany and Vegetable Pathology, Sunderland, Mass.
MISS HARRIET COBB, Stenographer, Department of Plant and Animal Chemistry, 35 North Pleasant Street.
MISS BRIDIE O'DONNELL, Stenographer, Department of Entomology, Hadley, Mass.
MISS ALICE M. HOWARD, Stenographer, Department of Plant and Animal Chemistry, North Amherst, Mass.

REPORT OF THE DIRECTOR.

CHANGES IN STAFF.

The experiment station staff during the past year has suffered the loss of two of its oldest and strongest men: Dr. C. A. Goessmann, who died in September, and Dr. C. H. Fernald, who retired on a Carnegie pension at about the same time.

Dr. Goessmann had been connected with the experiment station from the very first inception of station work in the State, in 1882. He was director of the State Experiment Station until it was combined with the station later organized under the Hatch act, in 1895. Dr. Goessmann, however, although giving up his duties as director at that time, retained active supervision of the inspection of commercial fertilizers and the general work in the fertilizer and soil laboratory until his retirement in 1907. Subsequent to retirement he was retained as consulting chemist, and continued his active interest in the station and its work until almost the end of his life. Goessmann was one of the great pioneers in the work of agricultural investigation. It seems eminently fitting, therefore, to present at this time a brief account of his life and work. Dr. J. B. Lindsey, vice-director and chemist of the station, one of Dr. Goessmann's pupils, peculiarly fitted through long and close association with him to write such an account and estimate, has at my request kindly prepared a tribute which will be found in following pages.

Dr. Charles H. Fernald, head of the entomological department of the college and station, became connected with the station work at the time of organization under the Hatch act, and continued at the head of the entomological department until his retirement, the first of September last. Dr. Fernald's work was of great value to the station. Of him, as of Goessmann, it is largely true that to a considerable extent his work was of a pioneer character. He was one of the earliest station entomologists, and as such he had much to do with the establishment of a

general policy for station entomological work. It was in considerable measure due to his influence that the policy that original descriptions of insects should not be published in ordinary station bulletins was adopted. During the early years of his station activities he devoted a large amount of time to the study of the gypsy moth, and the recognition of this insect and the scientific work connected with it were due to his efforts. His work in connection with the gypsy moth greatly strengthened the entomological department of the station, and resulted in making its work better understood and appreciated. Dr. Fernald's bulletin on household insects is believed to have been the first of its kind; but the value of such work was promptly recognized. His monograph papers, which have been published as station bulletins, are constantly quoted as standard works on the subjects of which they treat. He was the first to undertake investigations on cranberry insects, and the work he did in relation to them proved of great value to cranberry growers. His work in systematic and economic entomology has been extensive, and he instituted numerous lines of investigation which have since been greatly extended and developed by others better situated to prosecute them. While Professor Fernald did a very large amount of strong original work, I think it will be generally admitted by those who know him and his influence that his greatest work was in the line of stimulating others by his personality to accomplish what he himself had no opportunity to do.

The death of Dr. Goessmann did not involve important changes in the chemical department as his services during the past few years had been simply advisory, and, owing to failing health, largely nominal during the last year or two.

On the retirement of Dr. C. H. Fernald, his son, Dr. H. T. Fernald, was made head of the entomological department. The retirement of the elder Fernald imposed additional duties on his son, and some reorganization of the department became necessary. Mr. John N. Summers, a graduate assistant, who had been giving one-half his time to the experiment station, retired, and in his place, Mr. A. I. Bourne, B. A., who has had a valuable experience in graduate and investigational work, was made assistant. Mr. Bourne is allowed a certain amount of time for

graduate study, but he will give nearly all his attention to the work in the experiment station. His employment relieves Dr. H. T. Fernald of almost all of the routine work of the entomological department, and of the necessity of giving direct personal attention to the experimental work in its simpler phases. This will make it possible for Dr. Fernald to devote a very large proportion of his time to research work in entomology.

In this connection attention should be called to the extremely valuable work which Mrs. C. H. Fernald, with some clerical assistance, carried on for a period of more than twenty years, in editing the index cards with references to entomological literature. The work of Mrs. Fernald has been characterized by extreme accuracy and thoroughness, and up to the present time no less than 50,000 cards, with many times that number of references, have been prepared. A large proportion of the entries on these are in Mrs. Fernald's own hand. Advancing years have led Mrs. Fernald to desire to be relieved of this work, so important to all investigators in all lines of entomology, and arrangements have been completed whereby it will be continued under Dr. H. T. Fernald's supervision by his stenographer and clerk, Miss O'Donnell.

The retirement of Dr. R. D. MacLaurin, referred to in my last annual report, left a vacancy in the research division of the chemical department. This place was filled in January by the temporary appointment of Fred W. Morse, Ph.D., for many years chemist of the New Hampshire Experiment Station. His appointment was made permanent in July. Mr. Morse is devoting himself entirely to research problems connected with the nutrition of crops and the productive capacity of soils.

The staff of the station has been strengthened by the addition of two men; David W. Anderson, B.Sc., has been made graduate assistant in the department of horticulture; Sumner C. Brooks, B.Sc., has been made assistant in the department of botany and plant pathology. The appointment of these men relieves their superiors in these departments of routine work, and will enable them to devote their time in larger measure to research.

The work of the station has been broadened in scope and fur-

ther strengthened by the appointment of Dr. B. N. Gates, Ph.D., as apiarist. It is the expectation that Dr. Gates will devote about one-quarter of his time, so far as possible consecutively, to research work on problems connected with beekeeping.

Mr. James Alcock replaces Mr. Roy Gaskill in charge of the animals used in feeding and digestion experiments, and Clement L. Perins, B.Sc., has taken the place of Carl D. Kennedy as assistant in the chemical laboratory.

LINES OF WORK.

There has been no essential change in the character of station work during the year. It covers a field of constantly broadening scope and increases steadily in amount. As heretofore, our efforts may be classed under the following principal heads: general experiments, research, control and dissemination of information.

The relation of the lines of work which come under the last class to the possibility of adequate attention to and of financial support for the experiment and research, for carrying on which the funds for the support of the station which come from the federal government are designed, is so vital that while in logical sequence these lines of work would seem to come last, they will be considered first.

DISSEMINATION OF INFORMATION.

The principal methods whereby the station now endeavors to serve the public by dissemination of information are by means of its publications, through private correspondence, through lectures by members of its staff and by demonstrations.

Publications. — Our publications are of three kinds, an annual report in two parts, bulletins and circulars. The following tables show the publications of the year 1910 and those still available for distribution: —

Publications during 1910.

Annual report: —

Parts I. and II. 338 pages.

Bulletins: —

No. 132. Inspection of Commercial Feed Stuffs, P. H. Smith and J. C. Reed. 64 pages.

- No. 133. Green Crops for Summer Soiling, J. B. Lindsey. 20 pages.
No. 134. The Hay Crop, William P. Brooks. 68 pages.
No. 135. Inspection of Commercial Fertilizers, H. D. Haskins, L. F. Walker and J. F. Merrill. 76 pages.
Meteorological bulletins, 12 numbers. 2 pages.

Circulars:

- No. 26. Fertilizers for Potatoes, William P. Brooks. 4 pages.
No. 27. Seeding Mowings, William P. Brooks. 8 pages.
No. 28. Rules relative to Testing Dairy Cows. 8 pages.
No. 29. Chemical Analysis of Soils, William P. Brooks. 4 pages.

Miscellaneous circulars (unnumbered):—

- Fertilizers for Corn, William P. Brooks. 2 pages.
Home-mixed Fertilizers, William P. Brooks. 4 pages.
Fertilizers for Turnips, Cabbages and Other Crucifers, William P. Brooks. 2 pages.
Dairymen losing Money on Low-grade Feeds, J. B. Lindsey. 2 pages.
Orchard Experiment, William P. Brooks. 2 pages.
Summer Soiling Crops, P. H. Smith. 1 page.
Balanced Rations for Business Cows, J. B. Lindsey. 2 pages.
Corn for the Silo. 2 pages.

Publications Available for Free Distribution.

Bulletins:—

- No. 33. Glossary of Fodder Terms.
No. 68. Fertilizer Analyses.
No. 76. The Imported Elm-leaf Beetle.
No. 83. Fertilizer Analyses.
No. 84. Fertilizer Analyses.
No. 89. Fertilizer Analyses.
No. 90. Fertilizer Analyses.
No. 103. Fertilizer Analyses.
No. 113. Fertilizer Analyses.
No. 115. Cranberry Insects.
No. 121. Seed Separation and Germination.
No. 123. Fungicides, Insecticides and Spraying Directions.
No. 124. Bee Diseases in Massachusetts.
No. 125. Shade Trees.
No. 126. Insects Injurious to Cranberries and how to fight them.
No. 127. Inspection of Commercial Fertilizers, 1908.
No. 130. Meteorological Summary — Twenty Years.
No. 131. Inspection of Commercial Fertilizers, 1909.
No. 132. Inspection of Commercial Feed Stuffs, 1910.
No. 133. Green Crops for Summer Soiling.
No. 134. The Hay Crop.
No. 135. Inspection of Commercial Fertilizers, 1910.

No. 136. Inspection of Commercial Feed Stuffs, 1911.

Technical Bulletin No. 2. The Graft Union.

Technical Bulletin No. 3. The Blossom End Rot of Tomatoes.

Index to bulletins and annual reports of the Hatch Experiment Station previous to June, 1895.

Index to bulletins and annual reports, 1888-1907.

Annual reports: 10th, 11th, 12th, 13th, 14th, 15th, 16th, 17th, 20th, 21st, Part II., 22d, Parts I. and II.

So far as our publications treat primarily of the results of station observation, experiment and research, they are to be looked upon as a necessary and important feature of station activity, — indeed, to be the crowning result of such activity; but the demand for bulletins and circulars of information of a general character, already widespread, is most active, insistent and growing, and the force of circumstances has seemed to compel us to make at least some effort to meet it. To fully do so has been impossible; indeed, must probably be recognized as in the very nature of things always likely to remain so, since nothing less than a complete library covering every conceivable agricultural topic would enable us to meet the demand.

A considerable share of the contents of the popular part of our annual report (Part II.), most of our circulars and some of our bulletins have, however, aimed to furnish information of a more or less general character on topics of immediate interest to the public. These papers have, it is true, been based upon our own observations and experiments in so far as possible, and to that extent are to be regarded as legitimate station publications. To a considerable extent, however, they are of a general character. United States funds cannot be used in their publication, and since the demands for other purposes upon the relatively small appropriation which comes to the station from the State are heavy, and since, further, furnishing this literature is rather extension than experiment, provision to carry the costs should be made in the extension department of the institution.

Circulation of Publications. — In accordance with an act of our Legislature Part I. of our annual report is printed with the report of the secretary of the State Board of Agriculture, and those on the mailing list of that Board will receive this publication. Five thousand copies of Part I. of our annual report also

are furnished to the station. These are sent to libraries and directors of agricultural experiment stations, to presidents and libraries of agricultural colleges, to the public libraries of Massachusetts, and all other libraries on our mailing list, to the mailing list of the United States Department of Agriculture and to those on our exchange list. This part of our annual report contains technical monographs giving the results of research work, and a large number of copies are reserved to meet future demands. Part II. of our annual report, which contains the more popular papers, and our bulletins are sent to all those on our general mailing list, to the public libraries of the State, to those on the mailing list of the United States Department of Agriculture likely to be interested, and to experiment stations and agricultural colleges. It is our aim to reserve a considerable number of each publication to meet subsequent demands, but the demand has grown so rapidly that the supply of most, as will be noted from the above list of available publications, has been exhausted. The meteorological bulletins are sent only to agricultural college and experiment station libraries, presidents and directors, to the Department of Agriculture and Office of Experiment Stations, to newspapers and to libraries and individuals who have especially requested them.

Our circulars are printed for use in connection with the correspondence of the station. It is only by the use of such circulars that we are able to give information and advice on the many problems on which we are consulted. These circulars are sent only as above stated or on request. An abstract of all important publications is furnished to the press, and requests for any issued will be met as long as the supply permits.

During the past year the revision of our general mailing list has been completed. As a result, 1,502 names were dropped from the list. The additions of the year have numbered 1,663 names. The total numbers on our general list and on the few special lists are shown by the following: —

Residents of Massachusetts,	13,361
Residents of other States,	2,381
Residents of foreign countries,	223
Newspapers,	524

Libraries,	292
Exchanges,	137
Cranberry growers,	1,437
Beekeepers,	2,638
Meteorological,	379

Correspondence. — The correspondence with private individuals who seek information or advice grows constantly and rapidly. During the year 1910 the number of letters of inquiry answered by the members of the station staff was 16,650. Replies to many of these involve investigation, and the demands upon the college and station men giving attention to this work are heavy and growing. There can be no doubt that such work is most helpful; numerous letters of appreciation testify to this fact. The work should be continued, but it is neither experiment nor research. It is rather a branch, and a most important one, of the extension propaganda, and should be provided for in that department.

Lectures and Demonstrations. — The demand for lectures and demonstrations by members of the station staff has much increased during the year. Relatively few of the requests for such services have been accepted. The number of such engagements met during the year has been 48. Work of this kind properly comes under the head of extension service, and yet as it helps in some measure to keep the station men, whose duties are for the most part of a character which keeps them closely confined, in touch with the public and its most vital problems, these opportunities are accepted in so far as is consistent with proper attention to the prosecution of those investigations and studies for which especially the station is maintained.

Future Provision for Extension Work. — The facts stated concerning the various lines of work which have for their object the dissemination of information must have made it apparent that this work now makes very heavy demands upon the time of station men. It already encroaches upon resources which would more properly be devoted to experiment and research. The authorities in Washington charged with the general oversight of the methods of expenditure of United States funds are most zealous, and rightly so, in their efforts to pre-

vent the diversion of these funds from the uses for which they are intended. The funds appropriated to the station by the State are not sufficient to cover this line of work and at the same time to provide funds to pay the costs of other lines of work now in progress which should be continued.

The desired relief may be obtained either by transfer of the lines of work under consideration to the extension department of the institution, or by the appropriation of funds from that department to cover the cost of employing competent secretarial assistants. The latter plan would, for a time at least, seem to have advantages, as with secretarial assistance the members of the station departments whose experience gives them the best foundation for it would be able to direct the work and to exercise a close oversight over it.

GENERAL EXPERIMENTS.

Under this class are included a large number of experiments relative to the following subjects: soil tests with fertilizers, with different crops in rotation; comparisons of different materials which may be used as sources, respectively, of nitrogen, phosphoric acid and potash for different field and garden crops; the results of the use of lime; systems of fertilizing grass lands, both mowings and pastures; comparisons of fertilizers for both tree and bush fruits; different methods of applying manures; variety tests of field and garden crops and of fruits; trials of new crops; determinations of the digestibility of feedstuffs; methods of feeding for milk; systems and methods of management in feeding poultry for eggs; and co-operative work with selected farmers in the trial of crops and systems of fertilizing them. Few of these lines of experiment call for special comment here. Brief reports on some of them will be found under the departments in which they are being prosecuted.

Particular attention is directed to the fact that the plots used in the various experiments, involving the highly varied use of manures and fertilizers, and the many comparisons in progress, become increasingly valuable with the passing years. Many of these plots have been under definite and differing

mammial treatment for periods of time ranging from twelve to twenty-one years. They have taught many important lessons. If undisturbed, they will teach many more. They are teaching new lessons yearly as to the ultimate effects of differing treatments.

These facts are pointed out because the development of the institution on its educational side appears to threaten the integrity of important series of plots. They cannot, of course, be moved, nor indeed, in any true sense, can they be replaced. It is urged, therefore, that their value and the extreme undesirability of disturbing them be recognized in all plans for future growth and development.

Co-operative Experiments with Alfalfa. — During the past year thirty-three experiments with alfalfa have been made in ten different counties. Arrangements were completed for one experiment also in each of the counties Barnstable, Bristol and Dukes, but local conditions prevented the carrying out of the plans formed. Northern-grown seed treated with farm-germ for inoculation with nitrogen-fixing bacteria was used. The following extract from the directions sent to co-operating farmers will indicate what is believed to be a satisfactory method of preparing for the crop: —

(1) Plow in spring just as soon as possible after the ground can be worked.

(2) Apply lime at the rate of about $1\frac{1}{2}$ tons to the acre and disk in at once.

(3) About ten days later apply the following mixture per acre: basic slag meal, 1,500 pounds, high-grade sulfate of potash, 400 to 500 pounds, and disk that in.

(4) Thereafter harrow about once in ten to twelve days, until you are ready to sow the seed, which should not be later than about July 27.

(5) When ready to sow the seed, apply per acre: nitrate of soda, 100 pounds, basic slag meal, 300 pounds, mixing them, and harrowing in lightly.

(6) Sow 30 pounds of seed per acre, in showery weather if possible, and cover as you would grass seed.

The fall months were exceptionally dry and therefore somewhat unfavorable, but in most cases the crops made a good start

and went into the winter in good condition, having made sufficient growth to afford the needed protection.

RESEARCH.

More research work has been done in the station during the past year than in any previous year of its history. The additions to our staff which have made this possible have already been referred to. Work still continues upon the various research problems which have been mentioned in earlier reports,¹ but the studies of Pyralidæ and Tortricidæ which Dr. C. H. Fernald has been conducting have been nearly brought to a conclusion, and the results in part already privately published.² The scope of our research work has been broadened during the year by the addition of two new lines of work, *i.e.*, an investigation of the solubility effect of ammonium sulfate on the soil of field A; and color vision in bees. The progress made in most of these lines of investigation has been satisfactory, but there has been some interruption on account of moving the entomological work into the new building, and on account of ill health of members of our staff, apparently due to overwork. In both departments in which such interruption has occurred changes (already referred to) have been made, including the provision of an additional assistant in each, which, it is believed, will make it possible to push the work of investigation more rapidly.

In the later pages of this report will be found a number of valuable technical papers based upon some of the investigations in progress. The more important of these are as follows:—

Studies in Milk Secretion.

The Determination of Arsenic in Insecticides.

The Purification of Insoluble Fatty Acids.

The Soluble Carbohydrates in Asparagus Roots.

Abnormalities of Stump Growth.

Climatic Adaptations of Apple Varieties.

The progress which has been made in our work with asparagus and cranberries, and the greatly increased facilities for

¹ For full list see Part I., twenty-second annual report.

² On the Dates of Jacob Hübner's Sammlung europäischer Schmetterlinge and Some of His Other Works, C. H. Fernald, Ph. D., author and publisher; The Genera of the Tortricidæ and their types, C. H. Fernald, Ph.D., author and publisher.

investigation in the interest of cranberry growers, are made the subjects of special comment which follows.

ASPARAGUS SUBSTATION, CONCORD.

The details of the work in progress in the substation, maintained in the interest of asparagus growers in Concord, have been carefully looked after by Mr. Charles W. Prescott, to whom, as heretofore, we are greatly indebted for his lively interest and efficient supervision. The work has already given results of much interest, and is likely, I believe, to prove of great value. It will be remembered that it follows two rather distinct lines: (1) breeding experiments, with the hope of producing a rust-resistant type of asparagus; (2) fertilizer experiments, designed to throw light upon the special plant food requirements of the crop.

Breeding Experiments.—In the breeding work which is done at Concord the station is fortunate in enjoying the co-operation of the Bureau of Plant Industry of the United States Department of Agriculture. Mr. J. B. Norton of the Bureau has been assigned by Dr. B. T. Galloway to look after the asparagus breeding experiments. It is a pleasure to testify to the enthusiasm and faithful attention of Mr. Norton, who has not only most energetically prosecuted the breeding work, but has proved of much assistance in making observations and records on the fertilizer plots.

A very large number of crosses between selected plants have been made, and among these different crosses a few have resulted in offspring which seem to be almost absolutely immune to rust. These plants will be propagated and seed raised from them as rapidly as possible, with the object of producing stock for trial upon a more extended scale. If, however, the plants produced by some of the crosses continue to show the immunity exhibited by the seedlings, and if they have, as may be anticipated, the capacity to transmit their characteristics, a very gratifying forward step has certainly been made, and we may confidently anticipate complete success in attaining the end in view. At as early a date as possible, seed and young plants will be produced in quantities sufficient for trial by growers in different localities.

Fertilizer Experiments. — It remains true, as was stated to be the case in earlier reports concerning these experiments, that the growth and development of the crops, even upon the no fertilizer plots, owing to the very thorough preparation which the soil received, is still remarkably vigorous. Naturally, therefore, the varying fertilizer treatment does not as yet show the differences which may be confidently looked for. A few points, however, seem to be sufficiently well established to deserve mention.

The field contains 40 plots of one-twentieth acre each. The crop of 1910 was rather seriously injured by frost, but it was nevertheless fairly satisfactory as to quantity and quality. The past season was the fourth since the plants were set. The first cutting was made on April 23, the last on June 29. The total yield of all the plots was 9,020 pounds and 6 ounces.

Attention is called to the following conclusions, based upon results, as of possible interest: —

(1) The use of fertilizer made up of a combination of nitrate of soda, acid phosphate and muriate of potash, in addition to an application of manure at the rate of 10 tons per acre, has not materially increased the crop in whatever quantity applied.

(2) The use of nitrate of soda in addition to manure at the rate above named, in quantities ranging between the rate of from 311 pounds to 622 pounds per acre, has not increased the crop.

(3) The use of nitrate of soda in addition to a fairly liberal application of acid phosphate and muriate of potash has somewhat increased the crop, but a quantity in excess of 311 pounds has not resulted in further increase.

Chemical Work on Asparagus Roots. — It is a part of the plan of the experiments with fertilizers to study the effects of varying treatment upon the composition of the roots. This investigation on the chemical side is being carried on by Prof. F. W. Morse, who will in due time report fully upon the results of the analytical work. It was thought that a study of the reserve material stored in the roots in the autumn might offer results of especial interest and importance, and although the

investigation is not yet completed, this expectation has been largely realized. The special object in view in the first collection of roots made was to study the effect of the varying use of nitrogen in the form of nitrate of soda upon the reserve material in the roots in the autumn. The following points appear to have been well established by the analyses so far made:—

The amount of nitrogen in the roots in the fall: (1) is increased by application of nitrate of soda; (2) is greater where nitrate was used at the rate of 466 pounds per acre than where it was used at the rate of 311 pounds per acre; (3) is not greater where the nitrate of soda was used at the rate of 622 pounds per acre than where it was used at the rate of 466 pounds per acre.

It is believed, although this has not yet been proved, that the crop of the following season must bear a rather close relation to the amount of reserve material in the roots in the fall. If this be so, and if further investigation gives results in agreement with those already obtained, the conclusion that the use of nitrate of soda among our growers is not infrequently in excess of the most profitable quantity would appear to be justified. This conclusion should, however, for the present be regarded as tentative rather than fully established.

CRANBERRY SUBSTATIONS.

✓ During the past year our work in the interest of cranberry growers has been put upon a much more satisfactory basis than heretofore, through a special appropriation by the Legislature to provide for the work. The amount of this appropriation was \$15,000. A bog containing about 12 acres, lying near Spectacle Pond in East Warcham, with a small amount of adjoining upland, two small buildings and a powerful gasoline engine and pump, were purchased for \$12,600. A building to contain screen and storage rooms, living and office rooms for an assistant, and a small laboratory will be erected early this year at a cost of about \$2,000. The balance of the appropriation will be used for the purchase of additional upland to provide readier access to the building above referred to, in the making of needed

improvements in the pumping machinery and in preparations for experiments.

The cranberry bog purchased is planted with Early Black and the Howe varieties. It lies a little above the usual level of the water in Spectacle Pond, the lift required to flood it usually varying between about 3 and 4 feet. The capacity of the power and pumping machinery is such that the bog can be completely flooded in about six hours. The area of Spectacle Pond is nearly 100 acres, and the supply of water is constant and abundant. Being a "great pond" the waters are under State control. Only one other bog, and that a relatively small one, draws water from the pond, so that there must always be water enough for any possible need for all kinds of experimental work. The bog when purchased was in exceptionally perfect condition. It is one which has the reputation of more than average fruitfulness. The crop last year, as was the case with most of the bogs in the cranberry districts of Massachusetts, was moderate, and the net revenue derived from it was small. It is, however, confidently anticipated that the product of the bog will, over a series of years, be sufficient to produce a considerable net income, which will be used in helping to meet the expenses connected with our experimental work. The crop of the past season brought \$1,255 more than the costs of ordinary maintenance, harvesting, packing, etc. The net sum available towards the costs of experimental work, however, was substantially \$100 less than this, that being the amount which we were compelled to pay for taxes, since the bog had not been the property of the Commonwealth on the first of May.

It will be remembered that our cranberry work thus far has followed two principal lines of inquiry relating (1) to the fertilizer requirements of the crop; (2) to insects affecting it.

Fertilizer Experiments. — The fertilizer experiments begun four years ago in Red Brook bog at Waquoit have been continued. The bog, however, gave only a very small crop during the past season, — a result which we believe to have been due in large measure to the effects of frost. The variations in yield caused by uneven amount of frost damage were so great that it

was impossible to draw conclusions as to the specific effects of the different fertilizer combinations. The fertilizer experiments in the Red Brook bog at Waquoit will be continued during next year, but meanwhile similar experiments will be begun in the Spectacle Pond bog. It is believed that it will be best to discontinue the Waquoit experiments after next year, since they lie at such a distance from the station bog in Wareham as to make proper attention to the work somewhat difficult and expensive.

Insect Work. — Dr. Franklin has devoted himself with great enthusiasm and faithfulness to observations and studies on the insects having a relation either injurious or beneficial to the cranberry industry. He has accumulated a large amount of valuable data, but his work is not advanced to the point where publication seems called for.

CONTROL WORK.

Detailed reports concerning the various lines of control work carried on by the station, prepared by the chemists in charge, will be found in the later pages of this report.

Fertilizer Law. — We have found it impossible during the past few years to exercise an efficient control over the trade in fertilizers and to publish the reports without expending an amount exceeding the sum brought in by the analysis or license fees required by our law. The expenditure in 1909 exceeded the amount of the license fees to the amount of nearly \$1,000. To provide for this excess expenditure by the use of other station funds seriously reduces the amount available for experimental work. Accordingly, the amount of analytical work in connection with the fertilizer control during the past year has been somewhat restricted, and the size of the bulletin giving the results has been reduced. These reductions, while for the time being necessary, are undesirable, and for this reason, as well as for other important reasons, it has been decided to ask for a revision of our fertilizer law. The preparation of the new draft has required a great deal of study and many conferences with parties affected by the law. The more important of the

changes which it provides are an increase in the analysis fee per fertilizer element from \$5 to \$8, and bringing the various grades of agricultural lime within its scope. The other changes which have been made have been designed to remedy defects from the standpoint of administration which the execution of the old law had disclosed, and to make it more definite and explicit on a number of rather important points. The fertilizer law at present in force requires us to publish the dealer's cash price and the percentage of difference between this price and the commercial valuation of the fertilizer. It is not proposed to retain this provision in the new law, as it is felt that it is on the whole likely to prove misleading to the farmer, almost inevitably unfair to dealers, and from no point of view apparently serves any important use.

Dairy Law. — Much time has been spent during the past year also in studying and rewriting the so-called dairy law. Besides various perfecting changes, the most important modification is to bring milk inspectors and the Babcock machinery and apparatus which they use within the scope of the law. There would seem to be equal reason that steps should be taken to insure accuracy of work on the results of which, if unfavorable, the milk dealer or farmer may be prosecuted for infringement of one of our State laws, as for bringing those testing milk and cream for determining its value within the scope of the law.

Feed Law. — The increasing number of feedstuffs in our markets, and the increased extent to which materials of complex character are purchased and used by our farmers, have greatly increased the amount of work required to exercise effective control over the trade in feedstuffs, and we find it to be impossible at the present time to properly execute the law and to publish the results of our inspection for the sum of money provided by the State legislative appropriation for the purpose. It will be necessary, therefore, in the near future, to ask for a revision of this law. The amount of the appropriation should be moderately increased to provide for the much greater amount of work now required than was necessary when the amount of

the appropriation was fixed some eight years ago. In the case of this law, also, practical experience in its execution has made it apparent that some perfecting amendments are necessary in order that it may operate smoothly and effectively.

INSPECTION OF APIARIES.

The great desirability of the passage of a law providing for the inspection of apiaries, with a view to the eradication and control of contagious diseases of bees, was set forth at some length in my last annual report. It seems proper, therefore, in this report to refer to the fact that the Legislature of 1910[✓] passed such an act. The execution of the law, however, was placed with the secretary of the State Board of Agriculture, but the experiment station and college are working in harmony with the secretary. He has named as inspector of apiaries the apiarist of the college and station, Dr. Burton N. Gates, whose appointment has already been referred to.

BUILDINGS.

The new building for the departments of entomology and zoölogy has been completed during the year and has been occupied since September. It is a commodious, fireproof structure, costing \$80,000, and paid for by special appropriation. It provides ample accommodations for the experimental work in entomology. The hothouse, a comparatively new and modern building used in connection with the old insectary for experimental work, has been moved on to new foundations and is connected with the new building.

The necessity for increased accommodations for the research chemical work of the station was pointed out in my last annual report, in which it was stated that plans for enlargement and modification of the old building for the purpose of securing the increased accommodations needed were under consideration. Mature study of the problem as to the best means of providing the needed room, in connection with more exact estimates of the cost of so enlarging and modifying our old laboratory as to meet the requirements, has led to the conclusion that it is unwise to make the relatively large expenditure required for such

enlargement and modification. It seems clear that the old building, however enlarged and improved, must still fail to be entirely adequate or satisfactory, and that therefore it is wiser at this time to make only the few absolutely necessary changes, involving relatively little expenditure, leaving full provision for our needs until such time as the State shall grant the money needed for a new building, which the growth of our work will render imperative in the very near future.

WM. P. BROOKS,

Director.

REPORT OF THE TREASURER.

ANNUAL REPORT

OF FRED C. KENNEY, TREASURER OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

For the Year ending June 30, 1910.

The United States Appropriations, 1909-10.

	Hatch Fund.	Adams Fund.
<i>Dr.</i>		
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1910, under acts of Congress approved March 2, 1887 (Hatch fund), and March 16, 1906 (Adams fund),	\$15,000 00	\$13,000 00
<i>Cr.</i>		
By salaries,	\$13,184 81	\$9,918 15
labor,	264 74	817 05
publications,	49 75	—
postage and stationery,	95 12	19 00
freight and express,	—	13 35
heat, light, water and power,	7 43	149 47
chemical supplies,	—	114 41
seeds, plants and sundry supplies,	250 19	496 08
fertilizers,	348 61	95 01
feeding stuffs,	406 48	—
library,	47 44	6 45
tools, implements and machinery,	—	—
furniture and fixtures,	117 00	328 50
scientific apparatus,	123 75	892 02
live stock,	48 00	—
traveling expenses,	56 68	105 51
contingent expenses,	—	—
building and land,	—	45 00
Total,	\$15,000 00	\$13,000 00

State Appropriation, 1909-10.

To balance on hand July 1, 1909,	\$5,538 50
Cash received from State Treasurer,	13,500 00
from fertilizer fees,	5,970 00
from individuals (cranberry con- tribution),	544 17
from farm products,	3,208 73
from miscellaneous sources,	6,387 84
	\$35,149 24
Cash paid for salaries,	\$8,434 28
for labor,	9,447 30
for publications,	2,313 60
for postage and stationery,	928 20
for freight and express,	381 42
for heat, light, water and supplies,	341 94
for chemical supplies,	542 26
for seeds, plants and sundry supplies,	2,348 15
for fertilizers,	532 83
for feeding stuffs,	1,468 03
for library,	188 46
for tools, implements and machinery,	26 70
for furniture and fixtures,	240 95
for scientific apparatus,	1,018 52
for live stock,	80 38
for traveling expenses,	2,299 51
for buildings and land,	358 33
Balance,	4,198 48
	\$35,149 24

REPORT OF THE AGRICULTURIST.

WM. P. BROOKS.

The work in the department of agriculture during the past year has been of about the usual scope and extent. The problems which are being investigated are for the most part related to questions connected with the maintenance of fertility. Various questions connected with the selection, adaptation and methods of application of manures and fertilizers are being investigated. Most of our experiments have continued for a considerable number of years. Some indication is afforded of the amount of work in progress by the following statements. The number of field plots on the station grounds used in experiments the past year was 356. Our vegetation experiments have involved the use of 352 pots; while as a check upon the work in the open field, and as a method of throwing light upon a few special problems, 167 closed plots have been used.

No attempt will be made in this report to discuss the work in detail. Attention is called, however, to a few of the more striking results.

I. COMPARISONS OF DIFFERENT MATERIALS AS A SOURCE OF NITROGEN.

These experiments, which are carried on in Field A, were begun in 1890. The materials under comparison as sources of nitrogen are manure, one plot; nitrate of soda, two plots; dried blood, two plots; and sulfate of ammonia, three plots. Nitrate of soda and dried blood are used on one plot with muriate of potash; on the other with sulfate. The sulfate of ammonia is used on two plots in connection with muriate and on one in connection with sulfate of potash.

The different materials furnishing either nitrogen or potash are used on the several plots in such amounts as to furnish, respectively, equal quantities per plot of nitrogen and of potash; two of the three no-nitrogen plots which serve as checks receive potash in the form of muriate, the other in the form of sulfate, and all the plots in the field receive an equal liberal application of dissolved bone black as a source of phosphoric acid.

The crops grown in the order of their succession have been: oats, rye, soy beans, oats, soy beans, oats, oats, clover, potatoes, soy beans, potatoes, soy beans, potatoes, oats and peas, corn and clover for the last three years. The clover crop of the past year, as was true of the two preceding years, was considerably mixed with grass. The seed was sown early in August, 1909, and just previous to the sowing of the seed one-half of each of the plots in the field received a dressing of lime, at the rate of a ton and one-half to the acre. It was thought that such an application of lime would increase the efficiency of the sulfate of ammonia as a source of nitrogen, and to some extent this expectation appears to have been realized. The differences, however, between the limed and unlimed halves of the plots were relatively small, and the yields on the two halves were not separately determined.

The best crop of the past year was produced where nitrate of soda was used as a source of nitrogen; but the yields on dried blood and on sulfate of ammonia used in connection with sulfate of potash were not much inferior. On the basis of 100 for nitrate of soda, the relative standing of the different nitrogen fertilizers and the no-nitrogen plots as measured by total yield during the past season was as follows: —

	Per Cent.
Nitrate of soda,	100.00
Dried blood,	93.73
Sulfate of ammonia,	95.53
Barnyard manure,	94.75
No nitrogen,	91.79

The relative standing of the different materials as indicated by total yield for the twenty-one years during which the experiment has continued is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	94.07
Dried blood,	92.38
Sulfate of ammonia,	86.87
No nitrogen,	71.96

On the basis of increase in crop as compared with the no-nitrogen plots, the average of the twenty-one years shows the following relative standing:—

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	78.85
Dried blood,	72.82
Sulfate of ammonia,	53.17

Nitrate of soda has given a much larger increase in crop than any of the other materials, and since the pound cost of the nitrogen of nitrate of soda is usually less than the pound cost in any other chemical fertilizer, the superior economy of its use is apparent.

II. MURIATE COMPARED WITH SULFATE OF POTASH.

Our long-continued experiments comparing muriate with high-grade sulfate as a source of potash have continued on Field B. It will be remembered that the two potash salts are used in such quantities as to furnish equal actual potash per acre. These experiments were begun in 1892. Five pairs of plots are under comparison. From 1892 to 1899 the potash salts were used in quantities (varying in different years, but always in equal amounts on the two members of pairs of plots) ranging from 350 to 400 pounds per acre. Since 1900 the quantity used has been uniform on all plots, and at the rate of 250 pounds per acre annually. Fine ground bone has been annually applied to each plot throughout the entire period of the experiment, and the rate of application is 600 pounds per acre. The season of 1910 is the nineteenth year of these experiments. The crops during that year were potatoes on one pair of plots, oats on one pair, and asparagus, rhubarb and blackberries. The rates of yield per acre on the different potash salts are shown in the following tables:—

	RATE PER ACRE (POUNDS).		
	Asparagus.	Rhubarb.	Blackberries.
Muriate of potash,	5,604	24,587	2,661
Sulfate of potash,	4,143	25,856	2,821

	RATE PER ACRE.		
	POTATOES (BUSHELS).		Oat Hay (Pounds).
	Merchantable.	Small.	
Muriate of potash,	204.6	11.15	3,716
Sulfate of potash,	255.4	13.02	3,345

These figures call for but little comment, as they are in general in full agreement with results previously obtained. The asparagus gives a larger yield on the muriate of potash, which indicates the correctness of the ordinary practice of asparagus growers, who usually employ the muriate as a source of potash.

The rhubarb gives a slightly larger yield on the sulfate, and it was noticed during this year, as it has usually been in previous years, that the proportion of leaf to stalk is greater on the sulfate than on the muriate, the figures for this year on total weight of leaf being at the following rates per acre: —

	Pounds.
Muriate,	18,410
Sulfate,	20,560

No explanation can at present be offered for this difference.

The blackberries gave a larger yield on the sulfate, but the difference is not great. This, however, is in accordance with our observations in the case of most fruits, strawberries alone excepted, that sulfate of potash gives a better yield than muriate.

The difference in yield in potatoes on the two plots amounts to rather over 50 bushels. Such differences have been common in our experiments in earlier years, not only in this field, but in others as well. The difference in character of foliage of the potatoes on the two plots was strikingly evident from a period very early in their appearance above ground. The foliage of

the potatoes on the muriate of potash plots was lighter in color, it may be described as a pea green, while that on the sulfate of potash plot was of a much darker shade. An attempt has been made to demonstrate whether there is a difference in the amount of chlorophyl developed in the foliage produced, respectively, by the different potash salts, but the efforts so far made have not demonstrated such a difference. It is perfectly clear, however, that the muriate of potash as compared with sulfate is distinctly unfavorable to the production of starch in the tubers, the percentage of this constituent being almost invariably considerably higher than in the potatoes produced on the muriate.

The yield of oat hay on the muriate is considerably heavier than on the sulfate, and this result seems to be somewhat in harmony with results which we have previously obtained with corn, in the case of which grain the yield of stover on the muriate appears to be usually heavier than on the sulfate under otherwise similar conditions.

III. NITROGEN FERTILIZERS AND POTASH SALTS FOR GARDEN CROPS.

Three different nitrogen fertilizers, sulfate of ammonia, nitrate of soda and dried blood, and two potash salts, muriate and high-grade sulfate, each salt being used with each of the nitrogen fertilizers, are under comparison on Field C. In connection with the fertilizers named dissolved bone black was used in liberal amounts, which are the same on all plots. The comparison of these different fertilizers in this field was begun in 1891, but up to 1898 they were used alone. Since that time all plots have received annually a dressing of stable manure, at the rate of 30 tons per acre. The nitrogen fertilizers are used in such quantities as to furnish nitrogen at the rate of 60 pounds per acre, the potash salts in such quantities as to furnish 120 pounds of actual potash per acre, and the dissolved bone black was applied at the rate of 320 pounds per acre. The crops of the past year were asparagus, strawberries and onions.

Yields per Acre.

Plot.	FERTILIZERS.	Asparagus (Pounds).	Strawberries (Pounds).	ONIONS (BUSHELS).	
				Large.	Picklers.
0,	No fertilizer, . . .	3,378	7,012	304.4	53.5
1,	Muriate of potash, . . .	3,984	7,661	173.1	39.3
	Sulfate of ammonia, . . .				
2,	Muriate of potash, . . .	5,057	5,088	258.3	69.0
	Nitrate of soda, . . .				
3,	Muriate of potash, . . .	5,052	6,697	259.2	40.2
	Dried blood, . . .				
4,	Sulfate of potash, . . .	3,764	6,087	150.0	34.6
	Sulfate of ammonia, . . .				
5,	Sulfate of potash, . . .	5,235	5,204	300.6	56.4
	Nitrate of soda, . . .				
6,	Sulfate of potash, . . .	5,417	7,488	253.4	37.9
	Dried blood, . . .				

Attention is called in commenting upon these results to the fact that manure is used on Plot O at the same rate as on the other plots.

Asparagus. — Asparagus has long been recognized as a rank feeding crop, requiring liberal application of manure and fertilizers. It will be noticed that this is the only one of the three crops which appears to have been materially benefited by the use of the fertilizers. The crop on Plot O, on manure alone, is materially smaller than on either of the other two plots. Particular attention is called to the highly unfavorable effect of the combinations containing the sulfate of ammonia. The yields where this fertilizer was used are much below those produced where the other nitrogen fertilizers are employed, and not materially greater than where no fertilizer is used.

Strawberries. — It will be noted that in marked contrast with the results obtained with asparagus the yields of strawberries are highest on plots where sulfate of ammonia is used. A similar result has been obtained in earlier years. The highest yield of all has been produced where muriate of potash is used in connection with sulfate of ammonia, a combination which for

most crops has always seemed to be peculiarly unfavorable. Whether a similar result would be obtained in soils less highly enriched is at present a matter of uncertainty, but I desire to point out that in my judgment, based not only upon the yields of strawberries, which are not as large on the best of our plots as are obtained in good practice, but also upon the growth and development of the vines, flowers and fruit, the rate of use of manure and fertilizer in Field C is much too high for the best results. The vines have been over-rank, the fruit has set rather imperfectly and ripened poorly.

Onions. — Comparison of the yields on the different plots shows that none of the fertilizers used in connection with manure have apparently been beneficial. The combination containing sulfate of potash and nitrate of soda has done best; but the most significant point in connection with these results is the distinctly unfavorable effect of the combinations which contain sulfate of ammonia. The yield where this fertilizer is used is much below that on the other plots. The onions where this fertilizer is applied appear to stand practically still for a number of weeks after germination. They become distinctly unhealthy and many die. By midsummer the unfavorable influence disappears, the remaining plants take on a rank growth, the tops are heavy, the necks of the bulbs are thick, and comparatively few well-ripened bulbs are produced. It is probable that a heavy application of lime in connection with the sulfate of ammonia will in large measure, perhaps altogether, correct the faulty conditions which appear to be due to the use of this fertilizer.

IV. RELATIVE VALUE OF DIFFERENT POTASH SALTS.

The experiments comparing different potash salts were begun in 1898. The following materials are under comparison: kainit, high-grade sulfate, low-grade sulfate, muriate, nitrate, carbonate and feldspar. There are 40 plots in all. Five have received no potash since the experiments began. Each potash salt is used on five different plots; in other words, there are five series of plots. The crop during the past year was hay (mixed timothy, redtop and clovers). The average yields on each treatment are shown in the following table: —

Average Yield per Acre (Pounds).

	Hay.	Rowen.
No potash, plots 1, 9, 17, 25, 33,	6,240	698
Kainit, plots 2, 10, 18, 26, 34,	6,656	966
High-grade sulfate, plots 3, 11, 19, 27, 35,	6,416	1,866
Low-grade sulfate, plots 4, 12, 20, 28, 36,	6,864	2,058
Muriate, plots 5, 13, 21, 29, 37,	6,976	1,752
Nitrate, plots 6, 14, 22, 30, 38,	7,784	1,916
Carbonate, plots 7, 15, 23, 31, 39,	6,280	1,984
Fine-ground feldspar, plots 8, 16, 24, 32, 40,	6,824	1,256
Average of all potash plots,	6,828	1,685

The various potash salts used are employed in such quantities as to furnish substantially equal actual potash to each plot. In the case of the feldspar, which is very fine ground, the quantity employed on Plot 8 furnishes the same amount of potash as that supplied by the different potash salts. Plot 16 receives the same amount as Plot 8, Plot 24 receives twice as much, Plot 32 three times as much, and Plot 40 four times as much. Particular attention is called to the fact that up to and including 1908 the plots now receiving feldspar had been annually receiving a potash salt which had given results indicating a high degree of availability. It is believed that the crops on these plots are still deriving considerable benefit from the residual potash applied in the earlier years of the experiment.

The following points seem especially worthy of notice:—

(1) The average yield of hay on all the potash plots exceeds the average yield on the no-potash plots by only 600 pounds. The average yield of rowen on the potash plots exceeds the yield on the no-potash plots by about 1,000 pounds. These figures indicate that the grasses, timothy and redbtop, which make up the bulk of the first crop, are not dependent in very high degree upon an application of potash, and the much larger increase in the yield of rowen on the potash plots is clearly to be attributed to the fact that clovers make up the greater part of the rowen.

(2) The kainit, while favorable to the grasses, such as timothy and redbtop, and therefore giving a first crop nearly equal

to the average for the potash salts, is distinctly inferior to any of the materials supplying potash in its effects upon the rowen. This is undoubtedly due to the large proportion of chlorides which kainit contains.

(3) It will be noticed that the yield of rowen on muriate of potash is considerably less than on either of the sulfates, the nitrate or the carbonate. We have noticed in our experiments that the muriate almost always proves distinctly less favorable to clovers than the sulfates. On the other hand, this salt appears to be highly favorable to the timothy and redtop, as is indicated by the relatively high yield of hay.

(4) The yield of rowen is highest on the low-grade sulfate of potash, and there is a noticeable difference in its favor in the yield of hay also. It is possible that the magnesium contained in this salt is proving of value for the hay crops.

The most marked result of the substitution during the past few years of feldspar for the silicate of potash used in the earlier years of the experiment on Plots 8, 16, 24, 32 and 40 has been the rapid disappearance of clover from these plots. This fact indicates that the claim of the manufacturers that the potash of the feldspar has been rendered available by the treatment to which it has been subjected is not justified by the facts. After two years the clover has disappeared from these plots almost as completely as from the plots to which no potash has been applied throughout the entire period of the experiment.

V. COMPARISON OF DIFFERENT PHOSPHATES.

Ten of the leading materials which may be used as a source of phosphoric acid have been under comparison in one of our fields since 1897. The different materials are applied to the separate plots in such quantities as to furnish equal amounts of actual phosphoric acid to each. There are three check plots to which no phosphate whatever has been applied during the entire period of the experiment. All the plots receive annually equal and liberal quantities of materials supplying nitrogen and potash in highly available forms. The field has been used for a large variety of crops, the succession having been as follows: corn, cabbages, corn, oats and Hungarian grass (followed by

rye plowed under), onions, onions, cabbages, corn, mixed grass and clover three years, cabbages and soy beans. The crop this year was potatoes. The results are shown in the following table:—

Comparison of Phosphates.

Plot.	FERTILIZER.	Yield Merchant- able Potatoes per Plot (Pounds).	YIELD PER PLOT (POUNDS).		Yield Merchant- able Potatoes per Acre (Bushels).	Loss or Gain per Acre (Bushels).
			Small.	Rotten.		
1.	No phosphate,	2,148	94	6	286.4	-
2.	Arkansas rock phosphate, . .	2,170	89	12	289.3	+40.9
3.	South Carolina rock, . . .	1,986	53	23 $\frac{1}{2}$	264.8	+16.4
4.	Florida soft rock,	1,761	107	24	234.8	-13.6
5.	Phosphatic slag,	1,841	76	18	245.5	-2.9
6.	Tennessee phosphate, . . .	1,773	109	34	236.4	-12.0
7.	No phosphate,	1,831	53	36 $\frac{1}{2}$	244.1	-
8.	Dissolved bone black,	1,859	90	12 $\frac{1}{2}$	247.9	-0.5
9.	Raw bone meal,	1,941	140	12	258.8	+10.4
10.	Dissolved bone meal,	1,982	121	15	264.3	+15.9
11.	Steamed bone meal,	1,964	101	11 $\frac{1}{2}$	261.9	+13.5
12.	Acid phosphate,	1,929	120	9 $\frac{1}{2}$	257.2	+8.8
13.	No phosphate,	1,610	107	11 $\frac{1}{2}$	214.7	-

The yield, as will be seen, was good on all plots. The average on the three check plots is 244.8 bushels of merchantable potatoes per acre. It will be noticed that the only one of the phosphates used which has given any very considerable increase in merchantable potatoes is the Arkansas rock phosphate, but I am convinced that the superiority of this phosphate is more apparent than real. The field declines somewhat in fertility from Plot 1 to Plot 13. It will be noticed that Plot 1 without phosphate gives a yield of merchantable tubers larger than any of the phosphate plots, with the exception of two, and that the crop on two is practically the same in amount as on one. The superior yield on these two plots is in my judgment merely a consequence of the fact that the soil texture in that part of the field is more favorable to the crop. The conclusions to which I would call particular attention may be stated as follows:—

(1) The potato would appear to be a crop relatively inde-

pendent of a supply of immediately available phosphoric acid. The result with potatoes offers a striking contrast to the result obtained in 1908 with cabbages, with which the crop on some of the best phosphate plots was more than six times greater than that produced on the no-phosphate plots.

(2) Although the phosphate used affected the total yield but little, it was noticed that during the first few weeks of their growth the vines on the plots to which the more available phosphates had been applied (phosphatic slag, dissolved bone black, dissolved bone meal and acid phosphate), made a much more rapid growth than on the other plots. The use of a little phosphoric acid, therefore, in highly available form, seems likely to prove a distinct advantage by pushing the crop more rapidly forward, so that it may better resist attacks of insects or unfavorable conditions which may occur later. It seems likely, further, that where the crop is cultivated for an early market the use of moderate amounts of highly available phosphoric acid may prove beneficial.

(3) The potatoes produced on the plot to which phosphatic slag has been annually applied for so many years were very scabby, although the seed planted was treated with formalin, as was that planted on the other plots also. So serious was this trouble that the market value of the crop was very greatly reduced, and the conclusion appears justified that a free use of phosphatic slag in the same season that land is to be planted with potatoes must in general prove highly undesirable. Slag meal is a strongly alkaline fertilizer, and this is undoubtedly the cause of the very scabby crop produced, since the scab fungus is known to be most troublesome in soils which are alkaline.

VI. MANURE ALONE COMPARED WITH MANURE AND SULFATE OF POTASH.

This experiment, which occupies what is known as the south corn acre, has been in progress since 1890. The field is divided into four plots of one-fourth acre each. Good barnyard manure from milk cows, at the rate of 6 cords per acre, has been applied annually, with the exception of those years when it was

feared so doing would cause the newly seeded grass and clover to lodge, to two of these plots. Manure at the rate of 3 cords per acre, together with high-grade sulfate of potash at the rate of 160 pounds per acre, was applied to the other two plots from 1890 to 1895. Since the latter date the manure has been applied to these plots at the rate of 4 cords per acre in connection with 160 pounds of high-grade sulfate of potash, and whenever, for the reasons above stated, the application of manure has been omitted from the other two plots, both the manure and the potash have been withheld from these plots. The plan of cropping this field for the last twelve years has been corn and hay in rotation in periods of two years for each. During the past season the crop on this field has been hay, and the average yields per acre have been as follows:—

	Pounds.
Manure alone:—	
Hay,	4,480
Rowen,	1,050
Manure and potash:—	
Hay,	4,400
Rowen,	940

The rowen crop of the past season was very small, owing to the marked deficiency in rainfall. The corn crops raised in this field throughout the entire period of the experiment have been very nearly equal under the differing manurial treatments. The hay crops have usually been somewhat larger with the manure alone. The difference during the past season is considerably less than the average.

VII. AVERAGE CORN FERTILIZER COMPARED WITH FERTILIZER RICHER IN POTASH.

These experiments occupy what is known as the north corn acre. They have been in progress since 1891. This field, like the south corn acre, is divided into four plots of one-fourth acre each. Two of the plots receive a mixture furnishing nitrogen, phosphoric acid and potash in the same proportions in which they are contained in the average corn fertilizers offered in our markets. The other two plots annually receive an ap-

plication of a home-made mixture, containing much less phosphoric acid and more potash than is applied to the other plots. For the past fifteen years corn and hay, two years each, have regularly alternated. The crop of the past season was hay. Owing to the marked deficiency in rainfall already referred to the rowen crop was almost an absolute failure. The average yields were at the following rates per acre:—

	Pounds.
On the fertilizer rich in phosphoric acid and low in potash:—	
Hay,	3,260
Rowen,	330
On the fertilizer low in phosphoric acid and rich in potash:—	
Hay,	3,500
Rowen,	240

The results of the past season are similar to those which we have usually obtained, except that owing to the protracted drought the production of rowen on the plots receiving the larger proportion of potash is much lower than usual. In an average season the yield of rowen on these plots has invariably been greater than on the others.

VIII. SOUTH ACRE SOIL TEST.

The crop raised in the south acre soil test which has continued in this field since 1889 was corn. The succession of crops grown on this field from the beginning of the experiment up to the present time has been as follows: corn, corn, oats, grass and clover, grass and clover, corn (followed by mustard as a catch crop), rye, soy beans, white mustard (plowed in), corn, corn, grass and clover, grass and clover, corn, corn, corn, grass and clover, grass and clover, corn, oats and clover, buckwheat plowed under, corn. During the continuance of the experiment the field has been limed at the rate of a ton to the acre three times. The results of the past season with corn were entirely similar to those which have usually been obtained with that crop. Potash is still the dominant element. The average yield on the no-fertilizer plots, three in number, was at the rate of 4.05 bushels per acre. Muriate of potash alone increases the crop to nearly 23 bushels. Nitrate of soda alone gives a crop of 9 bushels. Dissolved bone black alone gives a yield at the rate of 4.21

bushels. The average increases due to the application of the different fertilizers (used in each case on four plots) were as follows:—

	Bushels per Acre.
Nitrate of soda,	3.2
Bone black,	6.8
Potash,	28.3

If we represent the average increase in grain due to the nitrate at 100, that due to the bone black is 212, that due to the potash 880.9. Similar figures for the stover are:—

	Pounds per Acre.
Nitrate,	186.2
Bone black,	406.5
Potash,	1,922.7

IX. NORTH ACRE SOIL TEST.

The soil test in this field was begun in 1890, and the crops grown since that year in the order of succession have been as follows: potatoes, corn, soy beans, oats, grass and clover, grass and clover, cabbages and turnips, potatoes, onions, onions, onions, potatoes, grass and clover, grass and clover, corn, soy beans, grass and clover, grass and clover, grass and clover. The crop the past year was soy beans, for which the potash appears to be the dominant element. In this field one-half of each of the plots, which are long and narrow, has received three applications of lime, respectively, in 1899, 1904 and 1907. On the limed portion the increases due to the application of single fertilizer materials for the muriate of potash alone was 10.22 bushels per acre; for the nitrate of soda alone, 0.12 bushels; for the dissolved bone black alone, a loss of 4.45 bushels. The muriate of potash in combination with the other fertilizer elements did not give as large an increase in the crop as when used alone. The results will not be discussed in full at this time, but I may add that they are such as to suggest that the soda of the nitrate of soda is to a considerable extent either rendering the natural potash compounds of the soil available, or is itself to some extent taking the place of potash in the economy of the plant.

X. TOP-DRESSING FOR HAY.

The experiments in the production of hay, by using in rotation as top-dressing barnyard manure, wood ashes and a mixture of bone meal and muriate of potash, have been continued during the past year in the nine-acre field where these experiments have been in progress since 1893. The average yield for the entire area this year was at the rate of 5,853 pounds per acre. The yields on the different materials used in top-dressing were at the following rates per acre:—

	Pounds.
Barnyard manure,	5,641
Fine ground bone and muriate of potash,	6,076
Wood ashes,	5,523

The crops this year were lighter than usual, as a consequence, without doubt, of the marked deficiency in rainfall already referred to. The average yields to date under the different systems of top-dressing have been at the following rates per acre:—

	Pounds.
Barnyard manure,	6,343
Wood ashes,	5,789
Fine ground bone and muriate of potash,	6,159

The average yield of the 9 acres from 1893 to 1910 inclusive has been at the rate of 6,134 pounds per acre. The rates of application per acre are:—

1. Barnyard manure, 8 tons.
2. Wood ashes, 1 ton.
3. { Ground bone, 600 pounds.
- { Muriate of potash, 200 pounds.

XI. WINTER V. SPRING APPLICATION OF MANURE.

The experiments in progress for the purpose of testing the relative advantages of applying manure in the winter or in the spring were begun in 1899. There are five pairs of plots. In each pair the manure is applied to one plot some time during the winter. At the same time sufficient manure for the other and of the same quality is placed in a large heap, from which it

is spread in the spring. The field in which these experiments are in progress has a decided slope lengthwise of the plots, which lie side by side. The manure which is put on in the winter is applied to the various plots at different times. The crop of the past season was hay, mixed timothy, redtop and clovers. The supply of manure for use in the experiments this year was not as large as usual and Plot 4 was not top-dressed. The results on this plot, therefore, for this season illustrate simply the residual effects of the two systems of applying manure. It must be pointed out, also, that owing to the relatively slow accumulation of manure used in this experiment the quantity available for Plot 3 was not sufficient until the last of March, so that this year the manure was applied both to the north and south half of this plot on the same date, March 31. The results are shown by the following tables.

Yield per Acre (Pounds).

PLOT.	NORTH HALF. WINTER APPLICATION.		SOUTH HALF. SPRING APPLICATION.	
	Hay.	Rowen.	Hay.	Rowen.
1.	6,312	534	6,925	1,009
2.	6,252	1,049	6,826	950
3.	7,004	811	6,905	1,068
4.	5,857	534	6,114	752
5.	8,904	930	8,528	1,563

Relative Yields (Per Cent.).

PLOT.	NORTH HALF. WINTER APPLICATION.		SOUTH HALF. SPRING APPLICATION.	
	Hay.	Rowen.	Hay.	Rowen.
1.	100	100	109.7	188.9
2.	100	100	109.2	90.6
3.	100	100	98.6	131.6
4.	100	100	104.4	141.0
5.	100	100	95.8	168.1

Hay and Rowen (combined). — Average Yields.

Plot.	NORTH HALF. WINTER APPLICATION.		SOUTH HALF. SPRING APPLICATION.	
	Per Acre (Pounds).	Per Cent.	Per Acre (Pounds).	Per Cent.
1.	6,846	100	7,934	115.9
2.	7,301	100	7,776	106.5
3.	7,815	100	7,973	102.0
4.	6,391	100	6,866	107.4
5.	9,834	100	10,091	102.7

REPORT OF THE CHEMIST.

JOSEPH B. LINDSEY.

This report is intended to give an outline of the work accomplished and in progress in the department of plant and animal chemistry for the year 1910.

1. CORRESPONDENCE.

There have been substantially 5,000 letters sent out during the year ending Dec. 1, 1910, the estimate being made on the basis of stamps used. The correspondence divides itself into (*a*) answering letters of inquiry, (*b*) the execution of the fertilizer, feed and dairy laws, (*c*) the testing of cows, and (*d*) the ordering of supplies.

2. NUMERICAL SUMMARY OF WORK IN THE CHEMICAL LABORATORY.

From Dec. 1, 1909, to Dec. 1, 1910, there have been received and examined 101 samples of water, 459 of milk, 2,799 of cream, 151 of feed stuffs, 223 of fertilizers and fertilizer materials, 44 of soils and 48 miscellaneous. In connection with experiments made by this and other departments of the station, there have been examined 247 samples of milk, 115 of cattle feeds and 300 of agricultural plants. There have also been collected and examined 890 samples of fertilizer, in accordance with the requirements of the fertilizer law, and 1,055 samples of cattle feeds, in accordance with the requirements of the feed law. The total for the year has been 6,432. This summary does not include work done by the research division.

In addition to the above, 10 candidates have been examined

and given certificates to operate Babcock machines, and 4,047 pieces of Babcock glassware have been tested for accuracy of graduation, of which 41, or 1.01 per cent., were inaccurate.

3. LABORATORY WORK OF THE RESEARCH SECTION.

Messrs. Holland and Reed have continued work on the preparation of chemically pure insoluble fatty acids, and on the perfecting of methods for their quantitative determination. Investigations have also been continued relative to the cause of rancidity of fats, and upon the composition and preparation of chemically pure insecticides, particularly Paris green, arsenates of lead and arsenite of lime. Papers entitled "The Purification of Insoluble Fatty Acids" and "The Determination of Arsenic in Insecticides" are presented elsewhere in this report, and likewise in the "Journal of Industrial and Engineering Chemistry."

Mr. Morse has devoted his time to studying the effect of fertility on the chemical composition of asparagus roots, and presents a preliminary paper in this report and in the "Journal of the American Chemical Society" entitled "Soluble Carbohydrates of Asparagus Roots." Chemical analyses showed clearly that there was a marked increase in the total nitrogen in the roots, produced by the addition to the soil of different amounts of nitrate of soda. Low applications of nitrate gave an increase, medium still more, but high applications did not appear to be more effective than medium ones.

The carbohydrates in the reserve material of the roots consisted mainly of a soluble sugar, made up of fructose and glucose, the former decidedly in excess. Nitrogenous fertilizers apparently had no direct effect on the carbohydrates. In general the increase in protein accompanied a lower proportion of total carbohydrates, including fiber. Seventy-six samples of roots were gathered in November to repeat the nitrogen series and to extend the investigations to the effect of phosphorus and potassium.

Mr. Morse has also done some preliminary work in studying the character of the drainage waters from miniature cranberry bogs constructed under the direction of Director Brooks.

At intervals study has also been given to the chemistry of the soils on Field A, in hopes of ascertaining the cause or causes of clover sickness, but no definite results can be reported.

4. RESEARCH WORK IN ANIMAL NUTRITION.

Work is in progress to study the effect of lactic and butyric acids upon the digestibility of food. It has been shown that molasses is responsible for a decided digestion depression upon the foodstuffs with which it is fed. It being recognized that such material in the digestive tract is a large yielder of organic acids, it seemed at least possible that it is these acids which check the further action of the micro-organisms, and prevent their attacking the more difficultly digestible fiber, pentosans and gums.

A paper is presented elsewhere in this report attempting to show the protein requirements of dairy animals. Most dairy animals respond to increased amounts of protein over a protein minimum. By minimum is meant the amount required for maintenance plus that required in the milk. An excess of 25 per cent. over the minimum seems to give very satisfactory results, and is sufficient under most conditions.

Two experiments with dairy cows have been completed to note the comparative effects of corn meal, dried beet pulp and dried molasses beet pulp for milk production. Another experiment with corn meal versus ground oats has also been completed. The results have not been worked out.

The complete records of the station herd have been tabulated from 1896 through 1909, giving such data as food cost of milk production, dry and digestible matter required to produce definite amounts of milk, total solids and fat, relation of grain to roughage, etc. The food cost of 5 per cent. milk for 1909 was 3.3 cents per quart.

Tabulations.

There has been prepared and will be found elsewhere in this report the following tabulations:—

1. Analyses of all cattle feeds made in this laboratory through 1910.

2. Important ash constituents in cattle foods.
3. Composition of dairy products.
4. Digestion coefficients obtained from experiments made in the United States.
5. Composition of fertilizer materials and of natural and waste products.
6. Fertilizer constituents of fruit and garden crops.
7. Relative proportion of phosphoric acid, potash and nitrogen in fruit and garden crops.
8. Composition of some Massachusetts soils.

5. REPORT OF THE FERTILIZER SECTION.

Mr. H. D. Haskins makes the following report:—

The principal work of this section has had to do with the execution of the fertilizer law of the State. Our experience this season indicated a very active demand for both chemicals and factory-mixed commercial fertilizers. There was a larger number of brands licensed than ever before. The inspection did not include the collection of as large a number of samples as during the previous year, although about the same number of brands were analyzed. It has been necessary to curtail somewhat, in order to keep as nearly as possible within the income derived from the fertilizer analysis fees. The expense of the inspection work has increased from year to year, and necessitates a larger income. It has also become evident that the old law requires many changes in order to make it applicable to present conditions. An attempt to improve the law is now under consideration.

Fertilizers licensed.

During the season of 1910 analysis fees have been paid by 83 manufacturers, importers and dealers, including the various branches of the American Agricultural Chemical Company, upon 465 distinct brands of fertilizer, including agricultural chemicals and by-products. Five more certificates of compliance have been issued, including 34 more brands than during 1909. They may be classed as follows:—

Complete fertilizers,	316
Fertilizers furnishing phosphoric acid and potash,	14
Ground bone, tankage and dry ground fish,	53
Chemicals and organic compounds furnishing nitrogen,	82
Total,	<u>465</u>

Fertilizers collected.

With but few exceptions, representative samples of every brand of fertilizer sold in the State have been secured. The collection work was in charge of Mr. James T. Howard, the regular inspector, assisted by Mr. A. B. Harris. As a general rule an effort has been made to collect samples of the same brand in different parts of the State, and to make one analysis of a composite sample made up of equal weights of the several samples. It is believed that this method will prove more satisfactory than when the results are based upon the analysis of a single sample. In all cases at least 10 per cent. of the number of bags found present were sampled; in cases where only a small amount of any particular brand was found in stock a larger percentage of the bags was sampled (often 50 to 100 per cent.), and in no case were less than five bags sampled without the fact being stated on the guarantee slip which is sent to the station laboratory with every brand of fertilizer sampled. One hundred and fourteen towns were visited, and samples of fertilizers were taken from 291 different agents. Eight hundred and ninety samples were drawn, representing 487 distinct brands. Some of the brands represent private formulas which farmers have had manufactured for their own use. The analyses of such brands were published in the bulletin in a table by themselves.

Fertilizers analyzed.

A total of 612 analyses was made in connection with the inspection of 1910. They may be grouped as follows:—

Complete fertilizers,	418
Fertilizers furnishing potash and phosphoric acid, such as ashes, superphosphates and potash,	21
Ground bones, tankage and fish,	71
Nitrogen compounds,	50
Potash compounds,	32
Phosphoric acid compounds,	20
Total,	<u>612</u>

The analyses were made in accordance with methods adopted by the Association of Official Agricultural Chemists. The analysis of a composite sample was made whenever possible, and in instances where such an analysis has shown a brand to be seriously deficient in one or more elements, a new portion was drawn from each original sample collected and a separate analysis made. This was done to determine whether the shortage was confined to one sample or whether it was general in case of that particular brand.

Twelve samples of lava fertilizer, so called, were analyzed. Although these materials have not been offered for sale in Massachusetts, considerable literature concerning them has been circulated, and it was thought best to have representative samples examined and the results published.

Thirty-two more analyses were made than during the previous year.

Trade Values of Fertilizing Ingredients.

The following table of trade values of fertilizer ingredients was used. It was adopted by the experiment stations of New England, New Jersey and New York at a meeting held in March, 1910. For purposes of comparison the 1909 schedule is also given.

	CENTS PER POUND.	
	1909.	1910.
Nitrogen:—		
In ammonia salts,	17	16
In nitrates,	16½	16
Organic nitrogen in dry and fine ground fish, meat, blood, and in high-grade mixed fertilizers,	19	20
Organic nitrogen in fine ¹ bone and tankage,	19	20
Organic nitrogen in coarse ¹ bone and tankage,	14	15
Phosphoric acid:—		
Soluble in water,	4	4½
Soluble in neutral citrate of ammonia solution (reverted phosphoric acid), ²	3½	4
In fine ¹ bone and tankage,	3½	4
In coarse ¹ bone and tankage,	3	3½
In cottonseed meal, linseed meal, castor pomace and ashes,	3	3½
Insoluble in neutral citrate of ammonia solution (in mixed fertilizers),	2	2
Potash:—		
As sulfate, free from chlorides,	5	5
As muriate (chlorides),	4¼	4¼
As carbonate,	8	8

¹ Fine and medium bone and tankage are separated by a sieve having circular openings one-fiftieth of an inch in diameter. Valuations of these materials are based upon degree of fineness as well as upon composition.

² Dissolved by a neutral solution of ammonium citrate; specific gravity 1.09 in accordance with method adopted by the Association of Official Agricultural Chemists.

These trade values will be found to correspond fairly with the average wholesale quotations of chemicals and raw materials as found in trade publications for the six months preceding March 1, plus about 20 per cent. They represent the average pound cost for cash at retail of the various ingredients as furnished by standard unmixed chemicals and raw materials in large markets in New England and New York for the six months preceding March 1, 1910. The cost of the mineral forms of nitrogen (nitrate of soda and sulfate of ammonia) has been somewhat lower than for the previous year, which has led to a more general use of these forms of nitrogen. Nitrogen from organic sources has been a cent higher than for the season of 1909. The cost of phosphoric acid was one-half cent higher than for the previous season. There was no material change in the cost of the various forms of potash.

Summary of Analyses as compared with Guarantees of Licensed Complete Fertilizers.

MANUFACTURERS.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
W. H. Abbott,	3	1	3	1	1	-
American Agricultural Chemical Company,	78	55	75	19	3	-
Armour Fertilizer Works,	11	11	11	-	-	-
Baltimore Pulverizing Company,	4	-	2	4	-	-
Beach Soap Company,	5	3	5	2	-	-
Berkshire Fertilizer Company,	8	6	8	2	-	-
Bonora Chemical Company,	1	-	1	1	-	-
Bowker Fertilizer Company,	30	21	27	7	2	-
Joseph Breck & Sons Corporation,	3	1	3	2	-	-
Buffalo Fertilizer Company,	8	1	6	6	1	-
Coe-Mortimer Company,	13	6	10	3	3	1
Eastern Chemical Company,	1	1	1	-	-	-
Essex Fertilizer Company,	12	4	10	5	3	-
R. & J. Farquhar & Co.,	3	1	3	2	-	-
The Green Mountain Plant Food Company,	1	1	1	-	-	-

Summary of Analyses as compared with Guarantees of Licensed Complete Fertilizers — Con.

MANUFACTURERS.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
C. W. Hastings,	1	-	1	1	-	-
Lister's Agricultural Chemical Works,	6	3	6	3	-	-
James E. McGovern,	1	-	1	1	-	-
Mapes' Formula and Peruvian Guano Company,	17	6	17	9	2	-
National Fertilizer Company,	14	8	12	3	3	-
New England Fertilizer Company,	6	3	5	2	-	1
Olds & Whipple,	6	4	6	1	1	-
Parmenter & Polsey Fertilizer Company,	8	1	7	4	3	-
R. T. Prentiss,	4	-	1	2	1	1
Pulverized Manure Company,	2	1	2	-	1	-
W. W. Rawson & Co.,	1	1	1	-	-	-
Rogers Manufacturing Company,	9	3	9	5	1	-
Rogers & Hubbard Company,	8	6	8	2	-	-
Ross Bros. Company,	3	2	3	1	-	-
N. Roy & Son,	1	1	1	-	-	-
Sanderson Fertilizer and Chemical Company,	6	5	6	-	1	-
M. L. Shoemaker & Co., Ltd.,	1	1	1	-	-	-
Swifts' Lowell Fertilizer Company,	17	4	15	9	2	2
W. G. Todd,	1	1	1	-	-	-
Whitman & Pratt Rendering Company,	5	-	5	4	1	-
Wilcox Fertilizer Works,	6	5	6	1	-	-
A. H. Wood & Co.,	3	-	3	2	1	-

The above table shows that 306 distinct brands of licensed complete fertilizers have been collected and analyzed.

That 140 brands (45.75 per cent. of the whole number analyzed) fell below the manufacturer's guarantee in one or more elements.

That 104 brands were deficient in one element.

That 30 brands were deficient in two elements.

That 6 brands were deficient in all three elements.

That 24 out of the 306 brands (7.85 per cent. of the whole number) showed a commercial shortage; that is, they did not show the amount and value of the plant food as expressed by the lower guarantee, although the values of any overruns were used to offset shortages.

The deficiencies were divided as follows:—

60 brands were found deficient in nitrogen.

80 brands were found deficient in available phosphoric acid.

71 brands were found deficient in potash.

When the data furnished by the above summary are compared with those of previous years, it is clear that greater care has been exercised on the part of the manufacturers, the guarantees being more generally maintained.

More brands were deficient in potash than during the previous year, a fact which may be due to temporary shortage in the supply of German potash salts in this country and correspondingly higher prices. These conditions were due to German legislation, which prevented the carrying out of contracts with German mine owners held by American fertilizer manufacturers except on payment of heavy production taxes.

Commercial Shortages.

The brands having a commercial shortage were much fewer in number than for 1909, and the amount or value of the shortages was much less, as may be seen from the following table:—

Commercial Shortages in Mixed Complete Fertilizers for 1910, as Compared with the Previous Year.

COMMERCIAL SHORTAGES.	NUMBER OF BRANDS.	
	1910.	1909.
Over \$4 per ton,	None	1
Between \$3 and \$4 per ton,	None	2
Between \$2 and \$3 per ton,	None	5
Between \$1 and \$2 per ton,	6	14
Under \$1 but not less than 25 cents per ton,	18	35

There were a few brands showing rather serious deficiencies in some element of plant food, but which did not suffer a commercial shortage on account of an overrun of some other ingredient. Such brands, of course, may be seriously out of balance, and while not excusable, the manufacturer evidently had no intention to defraud.

Quality of Plant Food.

As a general rule the potash and phosphoric acid were furnished in the forms guaranteed.

It is hoped that methods of analysis may soon be perfected so that it will be possible to indicate the relative availability of the organic nitrogen in mixed fertilizers. The importance of this may, in a measure, be realized when it is remembered that nearly 45 per cent. of the nitrogen used in the complete fertilizers this year was derived from organic sources.

Grades of Fertilizer.

The following table shows the average comparative commercial values, the retail cash prices and the percentages of difference of the licensed complete fertilizers analyzed in Massachusetts during the season of 1909 and 1910, grouped according to commercial valuation. Those having a valuation of \$18 or less per ton are called low grade; those having a valuation of between \$18 and \$24 are called medium grade; and those having a valuation of over \$24 are called high grade.

	HIGH GRADE.		MEDIUM GRADE.		LOW GRADE.	
	1909.	1910.	1909.	1910.	1909.	1910.
Average ton valuation,	\$27 63	\$28 81	\$20 69	\$21 04	\$15 32	\$15 61
Average cash price,	\$39 05	\$38 40	\$33 85	\$33 51	\$29 51	\$27 80
Average money difference,	\$11 42	\$9 59	\$13 16	\$12 47	\$14 19	\$12 19
Percentage difference,	41.33	33.28	63.61	59.26	92.62	78.03

The percentage of difference column becomes a convenient method of comparing the commercial worth of fertilizers of the same grade and cost, and usually indicates fairly the most eco-

nomical fertilizer to purchase. It should never be interpreted as representing only the profit which the manufacturer makes on his fertilizer. It must include not only the profit, but all other expenses connected with the manufacture and delivery of the goods, such as grinding, mixing, bagging, transportation, agents' profits, long credits, interest and depreciation of factory plants.

Composition according to Grade.—The following table shows the average composition of the complete commercial fertilizers, according to grade, as sold in the Massachusetts markets during 1910:—

GRADE.	Number of Brands.	Per Cent. of Whole Number.	Per Cent. of Nitrogen.	PER CENT. OF PHOSPHORIC ACID.			Per Cent. of Potash.	Pounds of Available Plant Food in 100 Pounds of Fertilizer.
				Soluble.	Reverted.	Available.		
High,	151	44.67	4.22	3.88	3.26	7.14	7.63	18.99
Medium,	120	35.50	2.65	4.86	2.81	7.67	5.06	15.38
Low,	67	19.83	1.77	4.55	2.46	7.01	3.06	11.84

A study of the above tables shows:—

1. That the percentage difference or percentage excess of the selling price over the valuation in the low-grade fertilizer is over twice what it is in the high-grade goods.

2. That with a 38 per cent. advance in price over the low-grade fertilizer, the high-grade furnishes over 84 per cent. increase in commercial value.

3. The average high-grade fertilizers, with a 14.6 per cent. advance in price over the medium-grade goods, furnishes about 23 per cent. more plant food and about 37 per cent. increase in commercial value.

4. That with a 38 per cent. advance in price over the low-grade fertilizer, the high-grade furnishes more than 78 per cent. increase in available plant food.

5. The medium-grade goods cost about 20 per cent. more

than the low-grade goods and furnish over 34 per cent. greater commercial value.

6. That the per cent. of nitrogen and potash is very much higher in the high-grade goods than in the low or medium grade.

7. A ton of the average high-grade fertilizer furnishes about 49 pounds more nitrogen, $2\frac{1}{2}$ pounds more available phosphoric acid and 91 pounds more actual potash than does a ton of the low-grade goods.

8. A ton of the average high-grade fertilizer furnishes about 31 pounds more nitrogen and about 51 pounds more potash than does a ton of the medium-grade goods.

Table showing the Comparative Pound Cost, in Cents, of Nitrogen, Potash and Phosphoric Acid in its Various Forms in the Three Grades of Fertilizer.

ELEMENT.	Low-grade Fertilizer.	Medium-grade Fertilizer.	High-grade Fertilizer.
Nitrogen,	35.62	31.85	26.66
Potash (as muriate),	7.57	6.77	5.67
Soluble phosphoric acid,	8.01	7.17	6.00
Reverted phosphoric acid,	7.12	6.37	5.33
Insoluble phosphoric acid,	3.56	3.19	2.67

This table emphasizes the marked increase in the cost of plant food wherever the low and medium grade fertilizers are purchased. It shows that nitrogen has cost 8.96 cents, available phosphoric acid about 2 cents and potash 1.9 cents per pound *more* in the average low-grade fertilizer than in the high-grade goods. It shows that nitrogen has cost 5.19 cents, the available phosphoric acid 1.11 cents and the potash 1.10 cents *more* per pound in the average medium-grade goods than in the average high-grade fertilizer. A comparison with the previous year shows that more high-grade brands have been sold this season than for 1909. There is, however, altogether too large a proportion of low and medium grade brands sold at present (55.33 per cent. of the whole). It is evident that too many purchasers select a fertilizer for its low cost, and without much

regard for the plant food which they are getting. The object in buying a fertilizer should be to get the largest amount of plant food in the proper form and proportion for the least money. The high-grade goods approach as near this ideal as is possible in case of factory-mixed fertilizers. It costs just as much to freight, cart and handle the low-grade fertilizers as it does the high grade. Nitrogen and potash in low-grade fertilizers cost from a third to a half more than if obtained from high-grade goods. *The farmer cannot afford to buy low-grade fertilizers.*

Unmixed Fertilizers.

MISCELLANEOUS SUBSTANCES. — *Ground Bone.* — Thirty-nine samples of ground bone have been inspected and analyzed. Nine were found deficient in phosphoric acid and 5 in nitrogen. None of the brands, however, showed a commercial shortage of 50 cents per ton. The average retail cash price for ground bone has been \$31.13 per ton, the average valuation \$29.75, and the percentage difference 4.64.

Ground Tankage. — Twelve samples of tankage have been analyzed. Four were found deficient in nitrogen and 4 in phosphoric acid. The average retail cash price per ton was \$31.82, the average valuation per ton \$31.28, and the percentage difference 1.73. Nitrogen in fine tankage has cost on the average 20.34 cents, while nitrogen in coarse tankage has cost 15.25 cents per pound. Two samples have shown a commercial shortage of over 50 cents per ton.

Dissolved Bone. — Two samples of dissolved bone have been analyzed and both were up to the guarantee placed upon them. The average retail cash price per ton has been \$29.67, the average valuation \$26.17, and the percentage difference 13.37.

Dry Ground Fish. — Twenty-three samples of dry ground fish have been examined, of which 5 were found deficient in nitrogen and 4 in phosphoric acid. The average retail cash price per ton was \$39.65, the average valuation \$38.89, and the percentage difference 1.95. Nitrogen from dry ground fish has cost on the average 20.39 cents per pound. Two brands have been analyzed, which show a commercial shortage of over 50 cents per ton.

Wood Ashes. — Thirteen samples of wood ashes have been analyzed, of which 1 was deficient in potash and 2 in phosphoric acid, although none of the samples showed a commercial shortage. Three samples put out by H. C. Green & Co., importers, were simply guaranteed "Pure wood ashes." The agent for three cars of these ashes, Ross Bros. Company, Worcester, Mass., stated that the ashes were of such poor quality that no charge would be made for them. Under present conditions of price and quality, the purchase of wood ashes is of questionable economy. They should never be bought without a guarantee of potash, phosphoric acid and lime.

Ground Rock. — The Farmhood Corporation of Boston, Mass., has offered a product called "Farmfood" which is unquestionably a ground mineral. It was guaranteed 2 per cent. phosphoric acid and 5 per cent. potash, both "in bond," meaning presumably associated with silica and not soluble. An analysis reveals the presence of 2.55 per cent. phosphoric acid, of which only .38 per cent. was available (dissolved by neutral citrate of ammonia). Only .56 per cent. of potash was found soluble in boiling water, and only .66 per cent. was found soluble in dilute hydrochloric acid. The commercial value of the product was \$1.65 per ton, which would hardly pay cartage.

The New England Mineral Fertilizer Company¹ of Boston, Mass., has put out a product called "New England mineral fertilizer," which is apparently largely ground rock. The material was guaranteed .23 per cent. phosphoric acid and 1.50 per cent. potash. Our analysis showed .18 per cent. phosphoric acid, .10 per cent. water-soluble potash and .35 per cent. potash soluble in dilute hydrochloric acid. The plant food in a ton of this material is valued at 24 cents, although \$17 is the advertised price in ton lots. Aside from the guarantee of potash and phosphoric acid, the firm makes a claim for a given percentage of soda, lime, magnesia, iron, sulfur, silica, chlorine and alumina. Although some of these elements are essential to the growth of plants, yet they are found in most soils in sufficient quantities to meet the needs of growing vegetation, so that they

¹ The New England Mineral Fertilizer Company, 19 Exchange Place, Boston, should not be confused with the New England Fertilizer Company, 40 North Market Street, Boston. The latter is an old company which has done business in Massachusetts for many years, and disclaims any connection with the New England Mineral Fertilizer Company.

have no particular significance in this connection. The extravagant claims made by the company for this "New England mineral fertilizer" are overdrawn, and border somewhat upon the ridiculous.

NITROGEN COMPOUNDS. — *Sulfate of Ammonia.* — Two samples of sulfate of ammonia have been analyzed and found well up to the guarantee. The average cost of the pound of nitrogen in this form has been 15.65 cents.

Nitrate of Soda. — Sixteen samples of nitrate of soda have been analyzed and only 1 was found deficient in nitrogen. The average cost of nitrogen per pound in this form has been 16.56 cents.

Dried Blood. — Three samples of this material were examined, 2 of the brands showing a considerable overrun and 1 a slight deficiency in nitrogen, the latter containing, however, considerable phosphoric acid. The average cost of nitrogen from blood has been 20.16 cents per pound.

Castor Pomace. — Six samples of castor pomace have been inspected and the guarantee was maintained in each instance. The average cost of nitrogen in this form has been 22.29 cents per pound.

Cottonseed Meal. — Nineteen samples of cottonseed meal used for fertilizer have been examined. These were licensed by 6 companies doing business in Massachusetts. Nitrogen from cottonseed meal has cost on the average 28.47 cents per pound. Seven out of the 19 samples analyzed showed a commercial shortage amounting to over 50 cents per ton.

POTASH COMPOUNDS. — *Carbonate of Potash.* — Only 1 sample of carbonate of potash was analyzed during the season. It sold so that the pound cost of actual potash was 7.54 cents.

High-grade Sulfate of Potash. — Nine samples of high-grade sulfate of potash have been examined and the potash guarantee was maintained in every instance. The pound of actual potash in this form has cost, on the average, 4.64 cents.

Potash-magnesia Sulfate. — Seven samples of double sulfate of potash and magnesia have been examined, and all have been found well up to the guarantee. The pound cost of actual potash in this form has been 5.46 cents.

Muriate of Potash. — Eleven samples of muriate of potash

have been examined, and only 1 deficiency was found. The pound of actual potash as muriate or chloride has cost on the average 4.06 cents.

Kainit. — Two samples of kainit have been analyzed and found well up to the guarantee. The pound of actual potash from kainit has cost 4.21 cents.

PHOSPHORIC ACID COMPOUNDS. — *Dissolved Bone Black.* — Three samples of dissolved bone black have been examined. Two of these were found somewhat low in available phosphoric acid, although only 1 showed a commercial shortage of over 50 cents per ton. The pound of available phosphoric acid from this source has cost, on the average, 5.91 cents.

Acid Phosphate. — Ten samples of acid phosphate have been examined, all but 3 being found well up to the minimum guarantee. No commercial shortages of over 50 cents per ton were noticed. The pound of available phosphoric acid from acid phosphate has cost 5.76 cents.

Basic Slag Phosphate. — Five samples have been analyzed, and the phosphoric acid ran low in 2 instances. There were no commercial shortages of over 50 cents per ton. The pound of available phosphoric acid (by Wagner's method) from basic slag has cost, on the average, 5.01 cents.

The complete results of the fertilizer inspection may be found in Bulletin 135.

Miscellaneous Work.

During the early part of the year some two months were devoted to the detailed mineral analysis of asparagus roots, in connection with fertilizer experiments carried on by the agricultural department. There has also been examined a number of cases of abnormal soils due to over-fertilization; such conditions are found particularly in greenhouse and tobacco soils, and in the latter case is confined to soils possessing an impervious subsoil, which will not permit of the free circulation of soluble saline materials.

In addition to the above work the fertilizer section has analyzed home mixtures, chemicals, by-products, soils, insecticides, etc., for farmers and farmers' organizations. We have insisted that all such material be taken according to furnished directions, which is more likely to insure representative sam-

ples, without which an analysis is of little value. In case of soils, but few complete detailed analyses have been made, and those only when abnormal conditions pointed to malnutrition or over-fertilization. In many cases tests were made to determine the relative amount of organic matter present and the acidity. Advice as to the use of fertilizer on any particular soil has been based more particularly upon the general character of the soil, previous manurial treatment, crop rotation, cultivation, and upon the crop to be grown.

In the analysis of by-products, refuse salts and materials used as fertilizers, the report has included the relative commercial value of the material and the best method of utilizing the same. During the year 300 miscellaneous analyses were made for citizens of the State and for the various departments of the experiment station. They may be grouped as follows:—

Fertilizers and by-products used as fertilizers,	223
Soils,	44
Miscellaneous materials,	33
	—
Total,	300

As in the past, co-operative work was done in connection with the study of new methods of analysis for the Association of Official Agricultural Chemists. Much time and study were also given to perfecting a suitable method to determine the relative availability of nitrogen from organic sources in mixed fertilizers. Tests were also made on 80 brands of fertilizer selected from the 1910 official collection, to ascertain the efficiency of the improved alkaline-permanganate method in detecting the presence of low-grade organic ammoniates.

6. REPORT OF THE FEED AND DAIRY SECTION.

Mr. P. H. Smith reports:—

The Feed Law.

During the past year 1,055 samples of feedstuffs have been collected by Mr. James T. Howard, official inspector. These samples have been analyzed and are soon to be published, together with the necessary comments.

Analytical Work.—The analytical work has consisted of

protein and fat determinations on all samples, a fiber estimation in many cases and a microscopic examination when further information seemed desirable. A protein and fat guarantee are required by law. It is felt, however, that the protein and fiber content of a feedstuff are a much better index of its true value. Protein is the most valuable constituent, while fiber is of least value, and it is a fact that any feedstuff which contains a relatively high fiber percentage is quite apt to contain some inferior by-product. For this reason more fiber determinations have been made this year than ever before.

Compliance with the Law.—Fewer violations of the law have been noted than in previous years. Reputable manufacturers and dealers are coming to believe that the statute works no hardship in honest products. The time is not far distant when to neglect to brand a feedstuff will make the purchaser suspicious of its merits. In the future, violations of the feedstuffs law will be placed in our attorney's hands for settlement. In several instances this has already been done, and one case, where goods were not guaranteed, has been taken into court. The dealer entered a plea of guilty and the case was placed on file. It is not the intention of those having the enforcement of the law in charge to be overbearing in regard to this matter, but any law which is not enforced soon becomes inoperative. The benefits of the law are so obvious as to render it unwise to allow it to become a dead letter.

New Law.—At the time the present law was passed it was not possible to secure the requirement of a fiber guarantee. Since that time other States have enacted statutes which not only require a protein, fat and fiber guarantee on all feedstuffs, but in addition a statement of composition in the case of all compounded feeds. It is believed that Massachusetts should enact a law requiring every package of feedstuff sold or offered for sale to have attached the following information:—

1. The number of net pounds in the contents of the package.
2. Name, brand or trademark.
3. Name and principal address of the manufacturer or jobber responsible for placing the commodity on the market.
4. Its chemical analysis expressed in the following terms:

(a) minimum percentage of crude protein; (b) minimum percentage of crude fat; (c) maximum percentage of crude fiber.

5. If a compounded or mixed feed, the specific name of each ingredient therein.

A revision of the present statute is now under consideration which will include the above requirements, together with such changes as have from time to time suggested themselves.

Definitions. — At present there is more or less confusion between different States and different sections of the country in regard to names of commercial feedstuffs. A feedstuff which is recognized by one name in the west may be known by an entirely different name in the east. Again, manufacturers of low-grade goods often attach names which are misleading or at best mean nothing. The National Association of Feed Control Officials is considering uniform definitions for the different commercial feedstuffs. Such a group of definitions, if adopted by the feed control officials of the different States, will be of great benefit to the retailer and manufacturer.

Weight of Sacked Feeds. — There is a growing tendency on the part of some manufacturers to state the gross weight of a package instead of the weight of the contents. Others state both net and gross weights. The State law calls for the weight of the contents of the package. Purchasers who buy sacked feeds should see that they are getting full weight. The difference between gross and net weight will amount to about 1 pound per sack.

Co-operation. — It is a difficult matter to enforce the provisions of the feedstuffs law without the co-operation of both retailers and consumers. Consumers should refuse to buy goods which are not guaranteed, and retailers should refuse to handle goods which are received without a guarantee.

The Dairy Law.

The work required by this act is divided into three natural subdivisions: (1) the examination of candidates, (2) the testing of glassware, and (3) the inspection of machines.

(1) *Examination of Candidates.* — During the past year 10 candidates were examined for proficiency in the Babcock test.

All candidates are refused a certificate who fail to show proficiency in manipulation or who do not have a good working knowledge of the principles underlying the test. Eight candidates passed the examination at the first trial, and 2 certificates were withheld until further proficiency was acquired. The idea has been prevalent that the experiment station gives instruction in Babcock testing. Such is not the case; all candidates must, before presenting themselves for examination, have acquired a thorough knowledge of the test.

(2) *Examination of Glassware.*— During the past year 4,047 pieces of glassware were examined, of which 41 pieces, or 1.01 per cent., were inaccurate. This is the lowest percentage of inaccuracy found during the ten years that the law has been in force. Following is the summary of the work for the entire period:—

YEAR.	Number of Pieces tested.	Number of Pieces condemned.	Percentage condemned.
1901,	5,041	291	5.77
1902,	2,341	56	2.40
1903,	2,240	57	2.54
1904,	2,026	200	9.87
1905,	1,665	197	11.83
1906,	2,457	763	31.05
1907,	3,082	204	6.62
1908,	2,713	33	1.22
1909,	4,071	43	1.06
1910,	4,047	41	1.01
Totals,	29,686	1,885	6.34 ¹

The passage of this law has prevented 1,885 pieces of inaccurately graduated glassware, representing 6.34 per cent. of the entire number tested, from coming into use.

(3) *Inspection of Babcock Machines.*— Since the 1909 inspection 1 creamery has suspended operations. During the present inspection, recently completed, 28 places were visited, of which 15 were creameries, 12 milk depots and 1 a chemical laboratory. Ten of the creameries were co-operative and 5

¹ Average.

were proprietary. The 12 milk depots were in every case proprietary. Twenty-eight machines were examined, 2 of which were condemned, but on second inspection a few weeks later they were found to have been put in good condition. Those in use are 10 Facile, 6 Agos, 5 Electrical, 4 Grand Prize, 2 Wizard, 1 unknown. The glassware was, as a whole, clean, and with two exceptions Massachusetts tested. Where untested glassware was found in use, the provisions of the law were made plain, and it is not expected that there will be a repetition of the offense. Unless machines are set on firm foundation and the bearings kept well oiled, the required speed cannot be maintained economically, and machines will not give satisfaction. The Babcock machine should be as carefully looked after as the cream separator in order to give efficient service.

The creameries and milk depots where machines were inspected are as follows:—

1. Creameries.

LOCATION.	Name.	President or Manager.
1. Amherst,	Amherst,	W. A. Pease, manager.
2. Amherst,	Fort River, ¹	E. A. King, proprietor.
3. Ashfield,	Ashfield Co-operative,	Wm. Hunter, manager.
4. Belchertown,	Belchertown Co-operative,	M. G. Ward, manager.
5. Brimfield,	Crystal Brook,	F. N. Lawrence, proprietor.
6. Cummington,	Cummington Co-operative,	D. C. Morey, manager.
7. Egremont,	Egremont Co-operative,	E. A. Tyrrell, manager.
8. Easthampton,	Hampton Co-operative,	W. S. Wilcox, manager.
9. Heath,	Cold Spring,	F. E. Stetson, manager.
10. Hinsdale,	Hinsdale Creamery Company,	W. C. Solomon, proprietor.
11. Monterey,	Berkshire Hills Creamery,	F. A. Campbell, manager.
12. New Salem,	New Salem Co-operative,	W. A. Moore, president.
13. North Brookfield,	North Brookfield,	H. A. Richardson, proprietor.
14. Northfield,	Northfield Co-operative,	C. C. Stearns, manager.
15. Shelburne,	Shelburne Co-operative,	I. L. Barnard, manager.
16. Wyben Springs,	Wyben Springs Co-operative,	H. C. Kelso, manager.

¹ Pays by test. Testing done at Massachusetts Agricultural Experiment Station.

2. *Milk Depots.*

LOCATION.	Name.	Manager.
1. Boston,	D. W. Whiting & Sons,	Geo. Whiting.
2. Boston,	H. P. Hood & Sons,	W. N. Brown.
3. Boston,	Boston Dairy Company,	W. A. Graustein.
4. Boston,	Boston Jersey Creamery,	T. P. Grant.
5. Boston,	Walker-Gordon Laboratory,	G. Franklin.
6. Boston,	Oak Grove Farm,	C. L. Alden.
7. Cambridge,	C. Brigham Company,	J. R. Blair.
8. Cheshire,	Ormsby Farms,	W. E. Penniman.
9. Dorchester,	Elm Farm Milk Company,	J. K. Knapp.
10. Sheffield,	Willow Brook Dairy,	L. C. Smith.
11. Southboro,	Deerfoot Farm Dairy,	S. H. Howes.
12. Springfield,	Tait Bros.,	W. A. Pease.
13. Springfield,	Emerson Laboratory,	H. C. Emerson.

Milk, Cream and Feeds sent for Free Examination.

During the past year the experiment station has analyzed a large number of samples of dairy products and feedstuffs sent for examination. Such work, where the results are of general interest, is a legitimate part of the station work. The station will not, however, act as a private chemist for manufacturers. Correspondence is solicited before samples are shipped, as in many cases the required information can be furnished without resorting to a chemical analysis, which will save shipping expenses to the applicant and the expense of a costly analysis to the experiment station. Upon application, full instructions for sampling and directions for shipping will be furnished, which will often obviate the necessity of sending another sample for analysis in place of one improperly taken.

Analysis of Drinking Water.

During the past year 101 samples of drinking water have been analyzed for residents of the State. The greater part of these were farm supplies where pollution was suspected. On reporting an analysis, suggestions are in all cases made as to

improving the supply when necessary. Parties wishing for water analysis should observe the following points:—

1. Application should be made for analysis.
2. A fee of \$3 is charged for each analysis, payable with the application.
3. Only samples of water received in experiment station containers are analyzed (containers sent on application).
4. The experiment station does not make bacteriological examinations.
5. The experiment station does not undertake a mineral examination of waters for medicinal properties.

Miscellaneous Work.

In addition to the work already described, this section has conducted investigations and made other analyses as follows:—

1. It has co-operated with the Association of Official Agricultural Chemists in a study of the methods for the determination of acidity in gluten feeds.
2. It has co-operated with the officials of the New England Corn Exposition in making analysis of corn in connection with the awarding of prizes.
3. It has co-operated with the Bowker Fertilizer Company in making analyses of corn in connection with the awarding of prizes.
4. It has arranged and furnished exhibits and speakers in co-operation with the extension department for (*a*) the better farming special; (*b*) the better farming trolley special; (*c*) an exhibit for several of the Massachusetts fairs; (*d*) an exhibit for the New England Corn Show.
5. It has conducted an investigation in connection with cases of alleged arsenic poisoning of horses through eating sulfured oats, with negative results.
6. In connection with the experimental work of this and other departments of the experiment station, this section has made analyses of 247 samples of milk, 115 samples of cattle feeds and 300 samples of agricultural plants.

Testing of Pure-bred Cows.

The work of testing cows for the various cattle associations continues to increase. Such work is a tax upon the time of the head of this section, and, owing to the uncertainty of steady employment, it is often difficult to secure men to do the work. Two men are now employed permanently in connection with the Jersey, Guernsey and Ayrshire tests. The rules of the above associations require the presence of a supervisor once each month for two consecutive days at the farms where animals are on test. The milk yields noted by the supervisors at their monthly visits are used in checking the records reported by the owners to the several cattle clubs. The Babcock tests obtained at that time are likewise reported, and used as a basis for computing the butter fat yield for each month. Up to June 1, 1910, the supervisors were only required to spend one day in testing Guernsey cows. At the annual meeting of the American Guernsey Cattle Club, in May, 1910, the rules were changed so as to require a two-day monthly test. While this practically doubles the work for this breed, it is felt that a two-day basis is much more accurate in computing tests.

During the past year 1 214-day test and 44 yearly tests with Guernsey cows, 10 7-day and 88 yearly tests with Jersey cows, and a number of yearly tests with Ayrshire cows have been completed.

The Holstein-Friesian tests usually cover periods of from 7 to 30 days, and require the presence of a supervisor during the entire test. During the past year 16 different men have been employed at different times in conducting these tests, which give rather irregular employment during the winter months. On account of the uncertainty of the work such men are difficult to obtain, but thus far it has not been necessary for the experiment station to refuse an application. For the Holstein-Friesian association 112 7-day, 5 14-day, 11 30-day, and one semi-official year test have been completed.

There are now on test for yearly records 96 Jersey, 28 Guernsey and 8 Ayrshire cows.

REPORT OF THE BOTANIST.

G. E. STONE.

The routine and research work of the botanists and assistants for the past year followed similar lines to those of other years, except that perhaps the routine work has had a tendency to increase, leaving less time for research work. This has been remedied to a considerable extent, however, by the addition of Mr. Sumner C. Brooks as laboratory assistant. Mr. Brooks was graduated from the class of 1910, and his appointment as assistant relieves Mr. Chapman of much routine work and gives him time for research, for which he is well fitted. Miss J. V. Crocker has, as usual, been of much service in attending to the correspondence and records, and has given valuable assistance in the seed testing. Much assistance has, as formerly, been obtained from the undergraduate students, and Mr. E. A. Larrabee and Mr. Ray E. Torrey have devoted all their spare time to the department, and were employed during the whole summer vacation.

DISEASES MORE OR LESS COMMON DURING THE YEAR.

The season of 1910 opened unusually early, as is shown by the meteorological records and by the blossoming of trees, shrubs and flowers. The season was, on the whole, rather dry, and crops suffered to some extent from drought, a condition which was emphasized by the severe droughts of the two preceding years.

The peach leaf curl, which naturally follows a cold and rainy period, was quite common. Some frost occurred in May, and in some localities it was reported in June. The effects of this showed on asparagus, and frost blisters were common on apple foliage. An unusually large amount of apple foliage was sent in to this department for examination in early sum-

mer. This was affected not only with frost blisters, but considerable injury was caused by a mite, the effect being in many cases similar. An early outbreak of apple scab was also noticed on apple foliage.

Strawberries were of poor quality, and considerable rot of the fruit occurred, owing to excessive rainfall. The foliage of rock maples and oaks was affected to an unusual extent with *Glæosporium*. In many sections maples in general were affected with this fungus, causing a browning of the leaf and much defoliation, and many inquiries were received concerning this trouble.

Some of the diseases which were more common are as follows: hollyhock rust, sweet pea trouble, apple rust, hawthorne rust, quince rust, black rot of grapes, crown gall, sycamore blight, blossom end rot of tomatoes, pear blight and pear scab, corn smut and maple leaf spot (*Rhytisma*). Considerable interest is also manifest in the chestnut disease, which is becoming more noticeable in this State.

The following is a list of the less common diseases reported during the year: ash rust, bean rust, rose rust, pea mildew, rose mildew, currant Anthraenose, Anthraenose of melon, rust on strawberry leaves, cherry leaf spot (*Cylindrosporium*), potato rot, horse chestnut blight (*Phyllosticta*), apple scab, cane blight of raspberries (*Coniothyrium*), blackberry Anthraenose and cherry leaf blight (*Cercospora*). Besides these may be mentioned troubles with which no organisms are associated, namely, frost blisters, frost effect on asparagus, sun scald and sun scorch, malnutrition of cucumbers and aster yellows.

REPORT OF THE ENTOMOLOGIST.

H. T. FERNALD.

The year 1910 has been marked by numerous changes in this department. The resignation of Prof. C. H. Fernald in June, as station entomologist, marks the first change in the head of this portion of the station work since the department was established in 1888. The resignation, at the same time, of Mr. J. N. Summers from his connection with the station, and the poor health of the writer during the early part of the year, necessarily seriously affected the work accomplished, and the time taken in the fall by moving into new quarters has practically prevented anything besides routine work.

The development of a new line of investigation has been made possible by the appointment of Dr. B. N. Gates as station apiarist. Dr. Gates's work will be, at least for the present, entirely under the Adams fund.

Mr. Arthur I. Bourne has been appointed assistant in entomology, and is, in general, in charge of the correspondence and of considerable of the experimental work. His appointment will enable the head of the department to devote more time to the larger problems relating to insects in this State, both in general and in connection with Adams fund projects, than has heretofore been the case.

It has proved to be impossible to obtain an orchard near the station in which to continue the observations on the size and importance of the different broods of the codling moth. The movement for better fruit in Massachusetts has been nowhere more evident than in Amherst, and the results, though most desirable in general, have been disastrous for the continuation of this series of observations, which must now be discontinued. A long delay in moving the greenhouse to its new site, and in making it ready for use, has prevented taking up this year the

experiments on the resistance of muskmelons to fumigation. These can be resumed during 1911, however.

Further tests of methods of controlling wire worms attacking seed corn have been continued on Mr. Whitecomb's farm. The results of the tests already made were referred to in the last report, and were also published in the "Journal of Economic Entomology" for August, 1909. It was distinctly stated in the latter publication that these methods were still in the experimental stage, but that it seemed desirable to test them on a larger scale in different parts of the country. Several of the agricultural papers suggested this to their readers, and the reports received as to results varied from excellent to failure, by preventing germination. A few cases of failure have been investigated, and in every case so far appear to have been due to the use of coal tar instead of gas tar, or to giving the corn such a heavy coating of the tar as to, of itself, prevent germination. On the whole, the treatment can hardly be considered as having been fairly tested in all cases.

One objection to the method is that the seed must be treated first with tar and then with the Paris green. During the past season it has been attempted to avoid this, while obtaining equally good results, by the use of arsenate of lead. The particular brand used in these experiments was disparene, which comes in paste form. This was diluted till about as thick as paint. Then the corn was added and the whole thoroughly stirred. The corn was then spread out till dry.

Unfortunately, wire worms proved to be few in the fields where the treated corn was planted, so that the value of the test was restricted to a determination of the effect of the treatment on the germination of the seed. From this standpoint, however, it was a success, having no injurious effect whatever. Plans have already been made to continue this work another season, and fields badly infested with wire worms are to be made use of, so far as these can be found.

Dates of the hatching of the young of the oyster-shell scale, the scurfy scale and the pine-leaf scale have been continued as far as possible. The object of this has been stated in previous reports, and it need only be added here that the observations

should be continued for several years, if averages of value are to be obtained.

Nearly ten years ago a study of the Marguerite fly, a pest too familiar to many florists, was begun, but was soon dropped for lack of material. More having been obtained, this investigation has been resumed, and it is hoped that the entire life history of the fly may now be learned, together with effective methods for its control.

Observations on the distribution limits of insect pests in Massachusetts have been continued as opportunity has offered, and some interesting facts on this subject have been obtained. Work of this kind must, from its very nature, be fragmentary for a long time, and for years the gathering and preservation of the observations made are all which it will be possible to accomplish. As the time required for this is but a few moments per week, or even per month, however, the results are well worth the trouble.

Investigations on the importance of the Sphecidae as parasites have been continued, and a number of additions to our knowledge of the group have resulted. The subject is a large one, however, and the amount of time available for this purpose has been much less than could be desired. Experiments with insecticides have been almost at a standstill from their entomological side, waiting for pure materials of known composition to be provided by the chemical department. Some of these have been satisfactorily obtained during the fall and the tests of them can be begun in the spring of 1911. The chemical results of this work will be reported upon by that department.

CHARLES ANTHONY GOESSMANN.

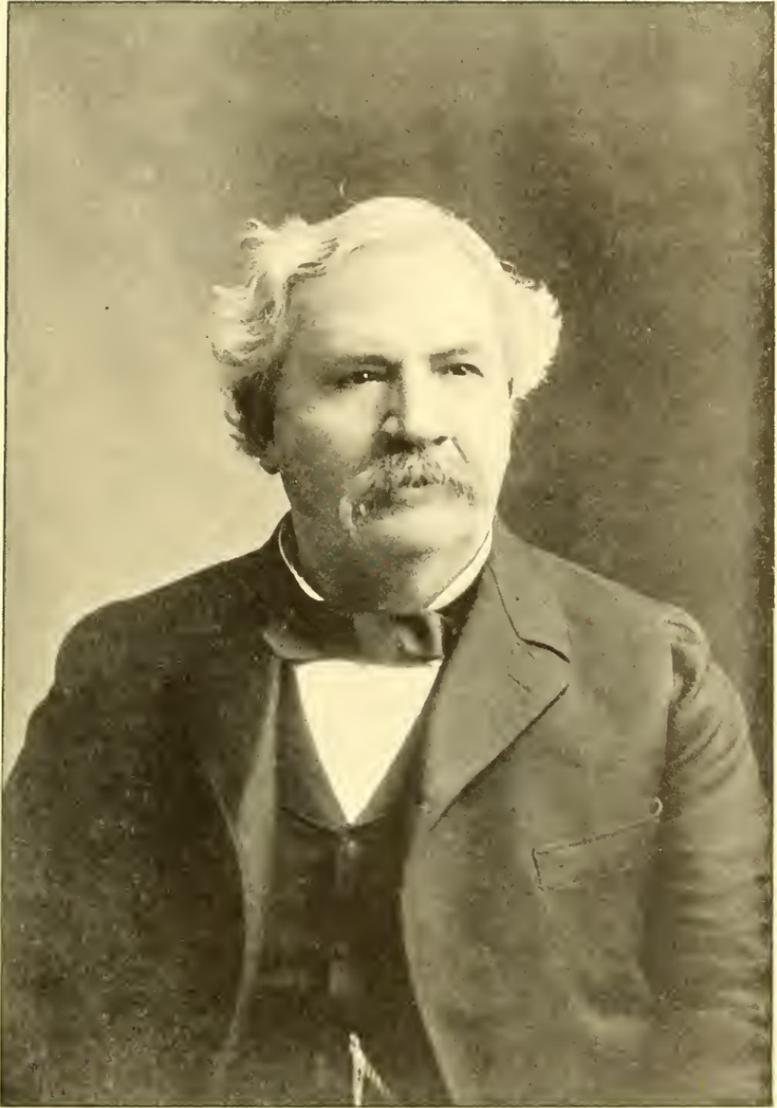
Charles Anthony Goessmann, chemist, investigator, teacher and philosopher, passed to the higher life Sept. 1, 1910.

Karl Anton Gössmann was born in Naumburg, in the Grand Duchy of Hesse, Germany, June 13, 1827. He was the son of Dr. Heinrich Gössmann, who was a fellow student of the noted chemist Frederick Wöhler. When the boy was seven or eight years of age the family moved to Fritzlar in Hesse and here young Gössmann spent his boyhood days. His father wished his son to become a pharmacist, and he received training in pharmacy previous to his becoming a university student. He entered the university of Göttingen in 1850, and studied chemistry, botany, physics, geology and mineralogy. He received the degree of Doctor of Philosophy in 1851 for a dissertation on the "Constituents of the Cantharides." Wöhler early recognized the ability and industry of the young chemist, and made him assistant in his laboratory, and upon the appointment of Limprecht to a professorship, Gössmann became a privatdozent and Wöhler's first assistant. He assumed charge of the chemical laboratory, and lectured on organic and technical chemistry as well as to students of pharmacy. His American students during the period were Chandler, Marsh, Joy, Nason, Caldwell and Pugh.

During his stay at Göttingen he received a number of flattering offers from other institutions, and made the acquaintance of Schönbein, the chemical physicist who discovered gun cotton and ozone; of Schrötter, noted for his researches in phosphorus; of A. W. von Hoffmann and of the celebrated French chemist Sainte Clair Deville.

In 1857 Gössmann left Göttingen on leave of absence, and visited the universities and a number of manufacturing establishments in Germany, Austria, France and England, and then journeyed to the United States upon invitation from Eastwich Brothers in order to become scientific director of their large sugar refineries. It was his intention eventually to return to Germany and teach technical chemistry, but he became so interested in the new country, and observed such a wide field of future usefulness for the technical chemist, that he decided to make the United States his permanent home.

After completing his work at Philadelphia he went to Cuba in order to study the methods of handling sugar then in vogue. On returning to the United States he was engaged as chemist by the Onondaga Salt Company of Syracuse, a position which he retained until 1869.



C. A. Goessmann

BORN JUNE 13, 1827. DIED SEPT. 1, 1910.

[Brief sketch of life, page 80.]

While in its employ, he visited and examined the salt springs in Canada, Michigan and Louisiana. During the latter part of this Syracuse period he spent a portion of each year as professor of chemistry and physics at the Rensselaer Polytechnic Institute at Troy, and he was invited to occupy the position permanently.

In 1868, at the earnest solicitation of his friend, the late Col. William S. Clark, he accepted the professorship of chemistry at the Massachusetts Agricultural College, and held it continuously until his retirement in June, 1907. He was placed at the head of the Massachusetts Experiment Station, a private enterprise started in 1878, and was instrumental in securing the establishment of the Massachusetts State Agricultural Experiment Station in 1882, being made its director and chemist, — positions which he held until it was merged with the Hatch Experiment Station by act of the Legislature in 1895.

Professor Goessmann served as chemist to the Massachusetts State Board of Agriculture from 1873 until his retirement, and for many years also acted as associate analyst of the Massachusetts State Board of Health. He became the first president of the Association of Official Agricultural Chemists, and was a charter member of the American Chemical Society, which he also served as president and vice-president. He was a member of the German society of naturalists and physicians, of the Physico-Medical Society of Erlangen University, a fellow of the American Association for the Advancement of Science, and a member of the Massachusetts Horticultural Society and of the Massachusetts Meteorological Society.

In 1889 Amherst College conferred upon him the degree of Doctor of Laws.

In this connection space forbids any extended reference to his work. Briefly it may be classified into four periods: —

1. The Göttingen Period of Seven Years, 1850-57.

In addition to his work as teacher in the university he found time to make and publish the results of twenty-five distinct investigations, all of which may be found in the "Annalen der Chemie u. Pharmacie." Among the most important of these papers may be mentioned the discovery of arachidic and hypogæic acids in the peanut oil, the constituents of the cantharides, the composition of cocoa oil and the constitution of leucine. This latter paper was considered of so much importance that it drew forth a letter of commendation from Wöhler to Dumas and secured for Gössmann membership in the Physico-Medical Society of the University of Erlangen, an honor which he highly prized.

2. *The American Period of Eleven Years previous to the Massachusetts Agricultural College, 1858-69.*

He made a number of contributions to the "American Journal of Science" on the chemistry of brine and salt, and while in the employ of the salt company at Syracuse devised a process for the removal of calcium and magnesium chlorides from salt which was of inestimable value to the salt industry of the United States. He also contributed papers to the "London Chemical News" on sugar refining.

3. *The Massachusetts First Period, 1869-86.*

During this period, in addition to teaching, Professor Goessmann made a study of the agricultural conditions in the State, was a frequent contributor to the agricultural press, and gave numerous lectures before the State Board of Agriculture.

His more prominent investigations may be briefly referred to under the following headings:—

(a) *Beets for Sugar, and Sugar Beets as an Agricultural Enterprise.*—He carried on investigations with the sugar beet both in the field and laboratory, and demonstrated the feasibility of growing beets for sugar in certain sections of Massachusetts, and concluded that, with the proper education of the farmer and capitalist, the production of sugar from the beet should prove a profitable American industry. (Reports of the Massachusetts Agricultural College, 1871, 1872, 1873, 1874, 1876.)

(b) *The Value of Early Amber Sorghum as a Sugar-producing Plant.*—His study of the plant as a possible source of sugar led him to conclude that "the presence of a large amount of grape sugar in all the later stages of growth . . . is a serious feature in the composition of the juice, impairing greatly the chances for a copious separation of the cane sugar by simple modes of treatment." *This prophesy has been literally fulfilled*, in spite of the later efforts to utilize this plant as a commercial source of sugar.

(c) *Reclamation of Salt Marshes.*—Goessmann made a thorough investigation of the condition of the marshes in southeastern Massachusetts, and embodied his results in a number of valuable papers before the Massachusetts State Board of Agriculture. His studies included the chemical conditions of the soils, and he recommended diking when necessary, suitable fertilizers and especially thorough drainage and cultivation. (Reports of the Massachusetts State Board of Agriculture, 1874, 1875, 1876.)

(d) *The Application of Chemistry to Fruit Culture.*—His studies were devoted particularly to the composition of the ash of different fruits, and to the influence of the various forms of mineral fertility upon yield and quality. He emphasized the need of a thorough study of the functions of the several mineral elements in plant growth, a

subject still calling for much careful investigation. He proved to his own satisfaction that muriate of potash promoted particularly the growth and improved the quality of fruit; and, further, that an increase of potash was accompanied by a corresponding decrease in lime and phosphorus. He called attention to the fact that the young branches of peach trees affected with "yellows" contained excessive amounts of lime and phosphoric acid, and that a judicious pruning, together with liberal applications of muriate of potash, restored the affected trees to a vigorous growth, which contained normal amounts of potash, lime and phosphoric acid. (Twenty-seventh and thirty-second reports of the Massachusetts State Board of Agriculture.)

(e) *The Chemical Composition of Different Varieties of Corn, and the Preservation of Corn in Silos.*—Goessmann gave considerable attention to the value of corn for cattle, and in a comprehensive paper published numerous analyses of different varieties of the entire corn plant, as well as of the stalks, ears and cobs. About 1880 attention was being given to the method of preserving corn in the silo, and the claim was made by Dr. J. M. Bailey and others that corn thus preserved (ensilage) did not suffer loss by the process, but was actually superior in feeding value to the original product. Goessmann in two admirable papers explained and discussed the principles of animal nutrition founded upon the researches of German investigators, showed the place of corn in the animal economy, pointed out the changes that took place during the process of fermentation, and made clear the relative merits of the dry and preserved corn. His statements concerning the relative value of silage and dry corn, made in 1880, hold true at the present time. (Reports of the Massachusetts State Board of Agriculture, 1879–80, 1880, 1881.)

(f) *The Inspection of Commercial Fertilizers.*—Goessmann was instrumental in securing the passage of a law authorizing the inspection of commercial fertilizers, which became operative Oct. 1, 1873, and as State Inspector of Fertilizers under the new law he made a preliminary report the same year. (Twenty-first report of the Massachusetts State Board of Agriculture.) It is believed that this was the first law enacted in the United States requiring an official inspection of fertilizers. He found many of the materials offered to be of uncertain composition, and to vary greatly in price; "these same articles cost the farmers . . . about one-half the amount more than they ought to". His work along this line from year to year corrected most of these abuses, and was unquestionably of great pecuniary value to the farmers of the State and nation.

4. *The Massachusetts Second Period, 1886–1907.*

The Massachusetts State Agricultural Experiment Station was established by act of the State Legislature, and Goessmann was made

director and chemist. The yearly grant of \$5,000 was soon increased to \$10,000, and in 1885-86 a new chemical laboratory was completed. He relinquished most of his college work, and devoted his energies to a thorough organization of the station.

The chief lines of work pursued by the station under his guidance are mentioned under the following general headings:—

1. The free analyses of fertilizers, refuse materials suitable for fertilizing purposes, coarse and concentrated feeds and drinking waters.

2. Experiments with dairy cows to test the relative feeding values of home-grown fodders and of commercial feedstuffs.

3. Feeding experiments with soiling crops, and the introduction and testing of new fodder crops.

4. Experiments with pigs to determine the rations best suited for pork production.

5. Feeding experiments with steers and sheep to determine the cost of beef and mutton, and to study the rations best suited for such purposes.

6. Field experiments to determine the nitrogen-acquiring power of the legumes.

7. Field experiments to study the best fertilizer combinations for market-garden crops.

8. Field experiments to ascertain the relative values of different forms of phosphoric acid.

9. Fertilizers best suited for permanent grass lands.

10. The effects of various forms of plant food in modifying the quality of the product.

11. Compilation of tables of analyses of fertilizers, cattle feeds, dairy products and fruits made at the station.

He devoted himself to the executive work of the station, and carefully supervised all of the experimental work as well. While not a rapid worker, he succeeded in accomplishing a great deal because of his steady and long-continued application. Since 1886 practically all of his papers were published in the annual reports of the experiment station.

After the merging of the State and Hatch stations, in 1895, advancing years made it necessary for him to relinquish many of his responsibilities. He continued, however, until his retirement to supervise the inspection of fertilizers and the general work in the fertilizer and soil laboratory.

Aside from his services as investigator and teacher, it is important to remember that he inspired in others a zeal for further study and accomplishment. There are to be found among his pupils presidents of colleges and schools of agriculture, directors of experiment stations, research and technical chemists, teachers, as well as workers in many lines of industry having a direct bearing upon agriculture.

Professor Goessmann possessed a wonderfully retentive memory, and being a great reader he was especially well informed on a wide variety of topics. He was a good conversationalist, and if interested in a subject poured forth a torrent of information, interspersed with opinions of his own. He had a genial disposition, a winning personality, and when he was amused his smile of appreciation was not soon to be forgotten. One did not need to be long associated with him to feel his influence for good and to realize that he was much more than an ordinary man. In fact, his very presence seemed to exhale a sort of spiritual essence which lifted one to a higher level of thought and feeling.

Goessmann was indeed a pioneer in the cause of agricultural investigation in the United States, or, as one of his students expressed it, he was a foundation builder. He was a leader, and pointed the way to a fuller understanding of the principles of science as applied to agriculture. Every experiment station worker, every tiller of the soil, and in fact every citizen in our great country, either directly or indirectly, has been benefited by this man who has recently passed into the Great Beyond.

J. B. LINDSEY.

STUDIES IN MILK SECRETION.

BY J. B. LINDSEY.

THE EFFECT OF PROTEIN UPON THE PRODUCTION AND COMPOSITION OF MILK.

Investigations and observations indicate that milk is not a simple fluid secreted directly by the blood, but a complex substance resulting from the activity of the milk cells. The cells and milk glands take from the blood and lymph vessels substances suited to their purposes, and by chemical and physiological processes convert them into a different substance, namely, milk. Milk, therefore, consists for the most part of reconstructed cell substance, and it is not possible, by any system of feeding, to produce very great modification in its composition. The composition of milk depends principally upon the breed and individuality of the cow, stage of lactation and development of the milk cells.

G. Kuhn,¹ M. Fleischer¹ and E. Wolff,² during the years 1868 to 1876, studied the additions to the different basal rations of increasing amounts of protein upon the composition of the milk, and noted only very slight variations. They observed that of all the milk components the percentage of fat was the most influenced by the food supply. N. J. Fjord and F. Friis,³ as a result of experiments by the group method with 1,152 cows, concluded that the protein was practically without influence in varying the proportions of the several milk ingredients. W. H. Jordan⁴ has conducted a number of trials, and failed to note any specific influence of the protein in

¹ Landw. Versuchsstationen 12 Bd., 1869; Journal für Landw., 1874.

² Die Versuchsstationen Hohenheim, Berlin, 1870; Résumé in Die Ernährung der Landw. Nutztbiere, E. Wolff, 1876.

³ Beretning fra den Kgl. Veterinær. og Landbohoiskole Lab. for landøkonomiske Forsøg. Kopenhagen, 1892; Résumé in Centralblatt f. Agricultur Chemie, 22 Jahrg., 1893. s. 601.

⁴ Maine Experiment Station, reports for 1885-86, 1886-87; New York Experiment Station, Bulletin 197, 1906.

varying the proportion of the milk constituents. Arnsby,¹ as well as Whiteher and Wood,² has drawn similar conclusions. Morgan *et als.* conclude from numerous investigations that protein is without specific influence in the formation of milk fat.³ Kellner,⁴ in summing up the results of numerous experiments, especially of German origin, says "in so far as it is possible by means of food to effect the action of the milk glands, the protein of the several food groups exerts a very pronounced influence. This influence is especially noticeable in increasing the *quantity* of the milk. Only after the long-continued feeding of a ration known to be deficient in protein does the water content of the milk increase, and the dry matter and fat show a noticeable decrease."

This station from time to time has conducted a number of experiments to observe the influence of different amounts of protein in increasing the quantity of milk, to note the protein requirements of dairy animals and also to study its influence in modifying the proportions of the several milk ingredients. Some of these results have been published in reports of the station. It is proposed to briefly summarize the results already given publicity, and to describe somewhat in detail our more recent observations.

Experiment I.⁵ — 1895.

This experiment was undertaken with six cows by the reversal method. The animals were from five to ten years of age, had all calved in the early autumn, and none had been served when the experiment began.

Weighing Animals. — The animals were weighed once before feeding and watering at the beginning and end of each half of the trial, and once each week during the continuance of the experiment. It would have been better to have weighed each animal for three consecutive days at the beginning and

¹ Wisconsin Experiment Station, reports for 1885-86, New Hampshire Experiment Station, Bulletin 90, pp. 12-14; Bulletin 18, p. 13.

² *Ibid.*

³ Landw. Vers. Stat., 62 (1905), nos. 4, 5; pp. 251-286; Abs. Experiment Station Record Vol. 17, p. 286.

⁴ Die Ernährung d. Landw. Nützthiere, erste Auflage, p. 519; also, fünfte Auflage, p. 539.

⁵ Ninth report of the Hatch Experiment Station, pp. 100-125.

end of the experiment; the weights, however, were probably sufficient to give an accurate *average weight* of each animal.

Sampling and Testing the Milk.—A composite sample of each cow's milk was made for five consecutive days, and preserved with bichromate of potash. Great care was used to secure representative samples. The total solids and fat were determined by approved gravimetric methods.

Dates of the Experiment.

DATES.	Days.	High Protein.	Low Protein.
Oct. 24 through Nov. 18, 1895,	26	Cows I., IV., VI.	Cows II., III., V.
Nov. 28 through Dec. 23, 1895,	26	Cows II., III., V.	Cows I., IV., VI.

At least a week elapsed after the animals were placed upon full rations before the experiment proper began.

Average Daily Rations fed to the Six Cows (Pounds).

CHARACTER OF RATION.	Wheat Bran.	Chicago Gluten Meal.	Corn Meal.	Hay.	Sugar Beets.
High protein,	3	5.83	-	15.17	12
Low protein,	3	-	5.83	16.17	12

Each of the cows received 3 pounds of bran and 12 pounds of beets daily. One of the cows, Ada, received only 5 pounds of corn or gluten meal per day, while the others received each 6 pounds. The amount of hay fed differed slightly in the case of individual cows, depending upon their ability to utilize it. The hay was of good quality, containing 9.73 per cent. of crude protein; the bran 19.20 per cent.; the gluten meal 42.73 per cent., and the corn meal 11.36 per cent., all on a dry-matter basis.

It will be seen that the basal ration consisted of hay, beets and bran, and that the variable factor was the corn or gluten meal.

Average Weight of Animals and Average Digestible Nutrients in Daily Rations (Pounds).

CHARACTER OF RATION.	Weight of Animal.	DIGESTIBLE NUTRIENTS.				Nu- tritive Ratio.
		Protein.	Fat.	Fiber and Extract Matter.	Total.	
High protein,	941	3.07	.59	10.23	14.06	1:3.86
Low protein,	938	1.46	.52	12.45	14.43	1:9.43

Three of the cows varied in weight from 800 to 900 pounds, and three others from 1,000 to 1,060 pounds. During the high-protein period the cows gained in total 101 pounds, and during the low-protein period there was a total loss of 64 pounds. The average weight of the herd during each of the two halves of the experiment was substantially the same.

The figures for digestible nutrients were secured from actual analysis of the feedstuffs used, together with average digestion coefficients, actual digestion tests not being made. The total digestible nutrients consumed was the same in case of each of the halves of the experiment, the difference being in the excess of digestible protein and the corresponding deficit of carbohydrates. The high-protein ration had evidently too narrow a ratio, and the low-protein ration too wide a ratio for the best results.

Protein Balance (Pounds).

CHARACTER OF RATION.	Cows.	Protein digested.	Protein required for Maintenance.	Protein contained in Milk (N. x 6.25).	Protein Excess over Maintenance and Milk Requirements.
High protein,	Ada,	69.16	14.56	20.31	34.29
	Una,	79.56	16.38	18.66	44.52
	Bessie,	81.12	15.60	26.03	39.49
	Beauty,	84.24	18.98	22.28	42.98
	Red,	82.16	19.24	24.26	38.66
	Spot,	82.16	17.94	28.00	36.22
Low protein,	Ada,	33.54	14.56	17.84	1.14
	Una,	36.40	16.12	17.84	2.44
	Bessie,	37.96	15.60	22.51	— .15
	Beauty,	40.82	18.98	17.92	3.92
	Red,	39.00	18.72	22.08	—1.80
	Spot,	39.00	18.20	20.72	.08
Total high,	—	478.40	102.70	139.54	236.16
Total low,	—	226.72	102.18	118.91	5.63
Average per cow, high,	—	79.73	17.12	23.26	39.36
Average per cow, low,	—	37.79	17.03	19.82	.94

¹ Calculated by allowing .7 of a pound digestible crude protein per day per 1,000 pounds live weight.

In this experiment the percentage of protein in the milk was not determined, and the average figures secured for the experiment immediately following were employed. Calculations show that in the high-protein period there was a surplus of nearly 100 (97.5) per cent. of digestible protein over that required for maintenance and milk production, while in the low-protein period the total digestible protein consumed and the amount required were about equal.

Influence of Protein on the Milk Yield.

Herd Results in Pounds.

CHARACTER OF RATION.	Average Weight of Cow.	Yield of Milk.	Protein digested.	Protein required for Maintenance and Milk.	Protein Excess over that required for Maintenance and Milk.	Percentage Excess.
High protein,	941	4,241.5	478.40	242.24	236.16	97.5
Low protein,	938	3,695.5	226.72	221.09	5.63	2.3

It is quite evident that the ration with the large excess of digestible protein exerted a marked influence on the milk-secreting organs, causing an increase of approximately 15 per cent. in the milk yield. The average daily milk product per cow during the high-protein period was 27.2 pounds, and during the low-protein period 23.7 pounds, and it therefore may be said that both rations produced a fair yield. The period was too short to note the effect of the larger amount of protein on the general condition of the animal; it is believed, however, that if such an amount had been fed for a long period of time, the result would have been over-stimulation, indigestion and a refusal to eat the large amount of gluten meal.

Effect of the Rations on the Composition of the Milk (Per Cent.).

CHARACTER OF RATION.	Total Solids.	Fat.	Solids not Fat.
High protein,	13.67	4.51	9.16
Low protein,	13.45	4.28	9.17

Composite samples of each cow's milk were secured for five days of each week. These composites were averaged, and this average represented the composition of the milk of each cow for the period. The average percentage produced by each cow was multiplied by the pounds of milk she produced, thus securing the weight of total solid matter and fat yield by each animal in the herd. These totals were added and the amount divided by the total amount of milk given by the herd, and the quotient represents the average percentage of total solids and of fat, as stated in the table.

The results indicate that during the low-protein period, the cows produced milk containing .23 per cent. less fat than in the period when the high protein was fed. The difference is not pronounced and may be considered within the limit of a reasonable experimental error.

*Experiment II.*¹

This experiment immediately succeeded experiment I. and was conducted with the same cows, excepting that cow II. (Una) was replaced by Guernsey. The general plan of the experiment, methods of caring for the cows, feeding and sampling of milk were all identical with the preceding experiment.

Dates of the Experiment.

DATES.	Days.	High Protein.	Low Protein.
Jan. 27 through Feb. 16, 1896,	21	Cows I., II., VI.	Cows III., IV., V.
Feb. 29 through March 20, 1896,	21	Cows III., IV., V.	Cows I., II., VI.

It will be seen that each period lasted twenty-one days, with a preliminary feeding of seven or more days.

Average Daily Rations fed to the Six Cows (Pounds).

CHARACTER OF RATION.	Wheat Bran.	Chicago Gluten Meal.	Linseed Meal.	Corn Meal.	Hay.	Millet and Soy Bean Silage.
High protein,	2.83	3.00	1.92	-	10.33	28.33
Low protein,	1.92	-	-	5.83	10.33	28.33

¹ Ninth annual report of the Hatch Experiment Station, pp. 100-125.

The bran contained 18.87 per cent., the Chicago gluten 39.75 per cent., the old-process linseed meal 41.99 per cent. and the corn meal 11.36 per cent. of protein in dry matter. The silage was a mixture of baryard millet and soy beans, the latter being quite well podded; it contained about 81 per cent. of water and 12 per cent. of protein in dry matter. Each animal received from 9 to 11 pounds of hay, 20 to 30 pounds of silage, during each half of the experiment. In the high-protein ration from 2 to 3 pounds of bran were fed, 3 pounds of gluten and 1.5 to 2 pounds of linseed meal. In the low-protein ration 1.5 to 2 pounds of bran were given and 5 to 6 pounds of corn meal. The above table shows the averages. The cows ate their rations clean in every case.

Average Weight of Animals and Average Digestible Nutrients fed daily (Pounds).

CHARACTER OF RATION.	Weight of Animals.	Protein.	Fat.	Fiber and Extract Matter.	Total.	Nutritive Ratio.
High protein, . . .	899	2.85	.65	9.96	13.46	1:4.04
Low protein, . . .	900	1.45	.54	11.44	13.42	1:8.85

The individual weight of the individual cows varied from 763 to 1,004 pounds. The cows changed very slightly in weight during each half of the experiment.

The digestible nutrients were calculated from the analyses of the feed, with the aid of average digestion coefficients. The high-protein ration contained substantially twice as much digestible protein as the low-protein ration. The fat varied but slightly, and the difference in the amount of carbohydrate matter depended naturally upon the different amounts of protein fed. The total nutrients consumed in two rations were the same.

Protein Balance (Pounds).

Periods of Twenty-one Days.

CHARACTER OF RATION.	Cows.	Protein digested.	Protein required for Maintenance.	Protein contained in Milk (N x 6.25).	Protein Excess over Maintenance and Milk Requirement.
High protein,	Ada,	50 61	11 21	15 42	23 98
	Guernsey,	60 61	12 60	19 52	28 49
	Bessie,	61 53	12 18	18 98	30 37
	Beauty,	62 58	14 41	16 22	31 95
	Red,	62 58	14 91	17 37	30 30
	Spot,	62 58	13 86	20 29	28 43
Low protein,	Ada,	25 20	11 34	12 83	1 03
	Guernsey,	31 50	12 30	16 36	2 84
	Bessie,	30 24	12 09	15 90	2 25
	Beauty,	31 29	14 07	15 08	2 14
	Red,	31 29	14 70	16 05	51
	Spot,	32 55	13 84	16 65	2 06
Total high,	-	360 49	79 17	107 80	173 52
Total low,	-	182 07	78 34	92 87	10 86
Average per cow, high,	-	60 08	13 19	17 97	28 75
Average per cow, low,	-	30 34	13 06	15 48	1 81

Influence of Protein on Milk Yield.

Herd Results in Pounds.

CHARACTER OF RATION.	Average Weight of Cows.	Yield of Milk.	Daily Yield of Milk per Cow.	Protein digested.	Protein required for Maintenance and in Milk.	Protein Excess over that required for Maintenance and Milk.	Percentage Excess.
High protein,	899	3,261.0	25.82	360.49	186.97	173.52	92.8
Low protein,	900	2,877.0	22.73	182.02	171.21	10.86	5.1

It will be seen that on the high-protein ration the cows received 92.8 per cent. more digestible crude protein than was required for maintenance and for the milk produced, while in low-protein ration the excess was only 5 per cent., the amount digested and the amount fed being substantially equal.

The figures show that for a period of twenty-one days, while not changing in weight, the herd produced 13.3 per cent. more milk on the high-protein diet, showing very distinctly the influence of the excess of protein. This experiment exactly confirms the experiment immediately preceding.

Composition of the Herd Milk (Per Cent.).

CHARACTER OF RATION.	Total Solids.	Fat.	Solids not Fat.	Nitrogen.	Protein Equivalent.
High protein,	13.82	4.83	8.99	.526	3.28
Low protein,	14.10	5.02	9.08	.518	3.23

The samples were taken and averages secured in the same way as in the previous experiment. Here we have a direct reversal of the results, the low-protein ration showing a trifle higher average fat percentage than the high-protein ration. This may also be regarded as within the limit of error. The percentage of nitrogen in the milk produced during each half of the experiment is substantially the same, and this in spite of the fact that the low-protein ration contained but 1.45 pounds of digestible protein, and the high-protein ration 2.85 pounds.

Experiment III.¹

This experiment was one of a series designed to study the effect of food stuffs upon the composition of milk and of butter fat. Only that portion of the experiment is here published which shows the influence of protein upon the yield and composition of the milk. It was planned on the group system, five cows composing each group. The first two periods of the experiment only are needed in this connection.

Duration of Experiment.

PERIODS.	Dates of Experiment.	Length in Weeks.
First period: both herds standard ration,	Nov. 17, through Dec. 7, 1900,	3
Second period: { Herd I., standard ration, Herd II., cottonseed ration, }	Jan. 5, through Feb. 8, 1901,	5

¹ See résumé in fourteenth report of the Hatch Experiment Station, pp. 162-168.

Average Daily Rations (Pounds).

First period: both herds, standard grain ration.

HERDS.	Standard Grain Ration.	Cottonseed Meal.	First-cut Hay.	Rowen.
Herd I.,	9	-	8-12	10
Herd II.,	9	-	8-12	10

Second period: Herd I., standard ration; Herd II., cottonseed ration.

Herd I.,	9	-	8-12	10
Herd II.,	5	3	8-12	10

The standard ration consisted of 3 pounds of wheat bran, 5 pounds of ground oats and $\frac{1}{2}$ pound each of cottonseed and gluten meals. The cottonseed meal contained some 9 per cent. of oil and 54.54 per cent. of protein in dry matter.

Average Dry and Digestible Nutrients in Daily Rations (Pounds).

First period: both herds, standard grain ration.

HERDS.	Dry Matter.	Protein.	Fiber and Extract Matter.	Fat.	Total.	Nutritive Ratio.
Herd I.,	26.15	2.44	12.84	.68	15.95	1:5.8
Herd II.,	26.97	2.49	13.25	.69	16.42	1:5.9

Second period: Herd I., standard grain ration; Herd II., cottonseed ration.

Herd I.,	25.00	2.34	12.27	.66	15.27	1:5.8
Herd II.,	25.69	3.20	11.62	.73	15.55	1:4.1

The digestibility of the standard grain mixture was ascertained by actual experiment. Average coefficients were used for the other feeds. Both herds received substantially the same amounts of protein and total digestible nutrients in the first period. Each herd averaged in live weight about 950 pounds. In the first period the amount of digestible protein was ample to enable the cows to do good work. In the second period Herd II. received .86 of a pound more of digestible protein than did Herd I.

Total and Average Daily Yield of Milk (Pounds).

First period: both herds, standard grain ration.

HERDS.	Total Herd Yield.	Average Daily Yield.
Herd I.,	2,332.5	22.2
Herd II.,	2,405.3	22.9

Second period: Herd I., standard ration; Herd II., cottonseed meal ration.

Herd I.,	3,856.3	21.9
Herd II.,	3,898.1	22.2

In the first period Herd II. produced 3.1 per cent. more milk than Herd I., and in the second period 1 per cent. more. It would appear, therefore, that the amount of protein fed in the first period was ample, and that the increase given to Herd II. in the second period was not needed and did not increase the milk flow. In the first period Herd I. gained 6 pounds in live weight, and Herd II., 83 pounds. In the second period Herd I. lost 87 pounds, and Herd II., 73 pounds.

Average Composition of the Herd Milk (Per Cent.).

First period: both herds, standard grain ration.

HERDS.	Total Solids.	Fat.	Solids not Fat.	Nitrogen.	Protein Equivalent.	Ash.
Herd I.,	14.15	5.00	9.15	.538	3.36	.73
Herd II.,	14.27	4.93	9.31	.546	3.41	.72

Second period: Herd I., standard ration; Herd II., cottonseed meal ration.

Herd I.,	14.16	5.06	9.10	.550	3.44	.73
Herd II.,	14.30	4.98	9.32	.562	3.51	.71

The analyses for the first period represent the average of 3 separate samples, each covering a period of five days; those for the second period represent the average of 5 separate samples, each covering a period of five days. Each five-day composite represented the average composition of the herd milk for one week. The separate analysis of each cow's milk was not made.

In the first period the milk of the two herds showed itself to be practically identical in composition. In the second period the substitution of 3 pounds of cottonseed meal for 4 pounds of the standard ration, thereby increasing the digestible protein in the ration .86 of a pound, had no effect whatever in varying the proportions of the milk. It is well to remember in this connection that nearly a month intervened between the first and second periods¹, and that the period itself covered five weeks. It is possible that, if the standard ration had contained a pound less of digestible protein daily, some difference may have been observed in the composition of the milk produced by the two herds in the second period.

Influence of Protein on the Milk Yield (Pounds).

Herd Results, Second Period.

CHARACTER OF RATION.	Average Weight of Cow.	Total Yield of Milk.	Protein digested.	Protein required for Maintenance.	Protein in Milk.	Protein Excess over that required for Maintenance and Milk.	Percentage Excess.
Standard,	946	3,856.3	409.5	115.5	132.6	161.4	65.0
Cottonseed meal,	939	3,898.1	560.0	115.5	136.8	307.7	122.0

In so far as this experiment throws any light on the protein requirements, it indicates that Herd I. was receiving ample protein (65 per cent. above the minimum requirement), and that the addition of more protein (122 per cent. above the minimum) was without any noticeable influence upon the milk yield.

Experiment IV.

This experiment was completed during the winter of 1897-98, although the results have not been published. It was conducted on the reversal method, with twelve mature grade Jersey cows, all of which had freshened the previous summer and autumn.

Weighing Animals.—Each animal was weighed for three

¹ This excessive lapse of time was due to some of the cows not being in best of condition.

consecutive days, before feeding in the afternoon, at the beginning and end of each half of the experiment.

Weighing and Sampling the Milk.—The weight of each milking was taken on a spring balance sensitive to 1 ounce, and the weights preserved on prepared record sheets. The milk was sampled for five consecutive days by the usual method, as described in accounts of the many feeding experiments given in previous reports. It was preserved with bichromate of potash and analyzed by gravimetric methods.

Character of Feeds.—The feeds used were all of good quality and of average composition. The hay was composed largely of Kentucky blue grass, sweet vernal grass and a liberal admixture of clover.

Dates of the Experiment.

First Half.				
DATES.	Weeks.	High-protein Cows.	Low-protein Cows.	
Nov. 13, 1897 to Jan. 14, 1898,	9	Guernsey, Midget, Susie, Beauty, Sadie, Alice.	Bessie, Mary, Mildred, Nina, Blossom, Jennie.	
Second Half.				
Jan. 24 to March 27, 1898,	9	Bessie, Mary, Mildred, Nina, Blossom, Jennie.	Guernsey, Midget, Susie, Beauty, Sadie, Alice.	

It will be observed that ten days were allowed for changing the feeds given the animals.

Average Daily Rations fed to Each Cow (Pounds).

CHARACTER OF RATION.	Wheat Bran.	Gluten Feed.	Corn Meal.	English Hay.	Corn Silage.
High protein,	3	5.5	-	10.9	25.7
Low protein,	3	1.5	4	11.0	25.7

It will be seen that the two rations were practically identical, excepting that 4 pounds of corn meal were substituted for a like amount of gluten feed. Different cows received from 10 to 12 pounds of hay and from 20 to 30 pounds of silage. Each animal received exactly the same amount of grain daily.

Average Dry and Digestible Nutrients in Daily Rations (Pounds).

CHARACTER OF RATION.	Dry Matter.	DIGESTIBLE ORGANIC NUTRIENTS.				Nutritive Ratio.
		Protein.	Carbo-hydrates.	Fat.	Total Nu-trients.	
High protein,	24.17	2.10	13.00	.50	15.60	1:6.7
Low protein,	24.24	1.67	13.70	.53	15.90	1:8.9

The herd averaged about 900 pounds in weight. The amount of dry matter and of total digestible nutrients fed in each ration was substantially the same; the high-protein ration contained about .4 of a pound more digestible protein than the low-protein ration. The excess over the low-protein ration is not marked and is very much less than that fed in experiments I. and II., previously mentioned.

Herd Gain in Live Weight (Pounds).

CHARACTER OF RATION.	Gain or Loss.
High protein,	+353
Low protein,	+223

Both rations caused a gain in weight, the excess being in favor of the high-protein ration. This may have been expected, as the low-protein ration had rather too wide a ratio to be productive of the best results.

Protein Balance (Pounds).

Herd Results; Periods of Sixty-three Days.

CHARACTER OF RATION.	Protein digested.	Protein required for Main-tenance.	Protein contained in Milk (N. x 6.25).	Protein Excess over Main-tenance and Milk Requirements.
High protein,	1,587.6	476.28	591.76	519.6
Low protein,	1,262.5	476.28	563.23	223.0

Influence of Protein on Milk Yield.

Herd Results in Pounds.

CHARACTER OF RATION.	Average Weight of Cow.	Yield of Milk.	Daily Yield of Milk Per Cow.	Protein digested.	Protein Excess over that required for Maintenance and Milk.	Percentage Excess.
High protein, . . .	900	16,257	21.5	1,587.6	519.6	48.6
Low protein, . . .	900	15,347	20.3	1,262.5	223.0	21.4

The average amount of digestible protein fed daily per cow in the high-protein ration — 2.10 pounds — could not be considered excessive, although it was 48.6 per cent. more than was required for milk and maintenance. The average amount of digestible protein fed daily per cow in the low-protein ration was 1.67 pounds, which was 21.4 per cent. above that necessary for milk and maintenance. The high-protein ration, being 48.6 per cent. in excess of the protein minimum, produced 5.9 per cent. more milk than did a ration made up of similar feedstuffs which was 21.4 per cent. in excess of the minimum. Such a difference in an experiment extending over a period of sixty-three days is believed to be too pronounced to be attributed to an experimental error, and is evidently the result of the increased amount of protein fed. In this connection it may be remarked that if the practical feeder purchased all of his grain, it would be to his advantage to buy gluten feed rather than corn meal. If he produces his own corn, the feeding of one-third bran, one-half corn and cob meal and one-sixth gluten feed would be advisable.

Composition of the Herd Milk (Per Cent.).

CHARACTER OF RATION.	Total Solids.	Fat.	Solids not Fat.	Nitrogen.	Protein Equivalent (N. x 6.25).	Ash.
High protein, . . .	14.55	5.11	9.44	.58	3.64	.75
Low protein, . . .	14.44	5.01	9.43	.59	3.67	.74

Samples of milk from each cow were taken weekly for five consecutive days, and tested for total solids and for fat. The average percentage produced by each cow for the nine weeks was multiplied by the amount of milk produced during the same period, and the amounts of total solids and of fat produced by the entire herd on each of the two rations calculated. These amounts, divided by the total milk yield, gave the average percentages of total solids and fat produced by each herd for the entire period.

The product of each milking of the six cows receiving the two different rations was also mixed, and composite five-day samples tested for total solids, fat, nitrogen and ash. In case of total solids and fat the average results varied less than .1 per cent. from those secured by the other method. The average results stated in the table above represent those secured by the last-described method.

It will be seen that the two rations produced milk of substantially the same composition. While the excess of protein appeared to have noticeably influenced the amount of the milk produced, it was without influence on its composition.

Experiment V. — 1898.

This experiment was conducted on the same plan as experiment IV., and the conditions were substantially the same. Nine cows only were used, being divided into herds of five and four.

Dates of the Experiment.

First Half.

DATES.	Days.	High-protein Cows.	Low-protein Cows.
April 4 to April 29, 1898, . . .	26	Blossom, Jennie, Bessie, Mary, Mildred.	Beauty, Alice, Guernsey, Midget.

Second Half.

May 8 to June 2, 1898, . . .	26	Beauty, Alice, Guernsey, Midget.	Blossom, Jennie, Bessie, Mary, Mildred.
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Nine days elapsed between halves, and the halves themselves lasted twenty-six days each. The "cow balance" was hardly

satisfactory in this experiment, five cows receiving one ration at the same time four were receiving the other, and *vice versa*. These were the only animals at the time that were in suitable condition.

Average Daily Rations fed to the Nine Cows (Pounds).

CHARACTER OF RATION.	Wheat Bran.	Gluten Feed.	Corn Meal.	English Hay.	Rowen.
High protein,	3	5	-	9.3	9.3
Low protein,	3	1	4	9.3	9.4

These two rations differ only in that 4 pounds of corn meal took the place of a like amount of gluten feed.

Average Dry and Digestible Nutrients in Daily Rations (Pounds).

CHARACTER OF RATION.	Dry Matter.	DIGESTIBLE ORGANIC NUTRIENTS.				Nutritive Ratio.
		Protein.	Carbo-hydrates.	Fat.	Total Nutrients.	
High protein,	23.62	2.41	11.97	.43	14.81	1:5.4
Low protein,	23.44	1.96	12.39	.44	14.79	1:6.8

In the so-called low-protein ration the herd received substantially 2 pounds of digestible protein daily; in the high-protein ration this was increased .4 of a pound. The total digestible nutrients fed were the same in each case. The cows averaged 970 to 960 pounds in live weight during the two halves of the experiment. In the low-protein ration the amount of protein fed was sufficient to give satisfactory results.

Herd Gain in Live Weight (Pounds).

CHARACTER OF RATION.	Gain or Loss.
High protein,	+76
Low protein,	+115

Protein Balance (Pounds).

Herd Results; Periods of Twenty-six Days.

CHARACTER OF RATION.	Protein digested.	Protein required for Maintenance.	Protein contained in Milk.	Protein Excess over Maintenance and Milk Requirements.
High protein,	563.9	156.8	184.4	222.7
Low protein,	458.6	155.5	174.8	128.3

Influence of Protein on Milk Yield.

Herd Results in Pounds.

CHARACTER OF RATION.	Average Weight of Cow.	Yield of Milk.	Daily Yield of Milk Per Cow.	Protein digested.	Protein Excess over that required for Maintenance and Milk.	Percentage Excess.
High protein,	960	4,693.5	20.06	563.9	222.7	65.3
Low protein,	950	4,370.6	18.68	458.6	128.3	39.0

The average amount of digestible protein fed daily to each cow in the high-protein ration was 2.41 pounds, and the excess over that required for milk and maintenance was 65.3 per cent. In the low-protein ration each cow received 1.96 pounds daily, and an average excess of 39 per cent. above requirements.

During the high-protein feeding the herd produced 7.4 per cent. more milk than when it received the low-protein ration, showing the influence of the larger amount. Whether all of the milk increase was due to the extra protein consumed is uncertain. The low-protein ration naturally had a wider ratio, and evidently was rather better suited to fattening than to milk production, and was indicated by the increase in live weight.

Composition of the Herd Milk (Per Cent.).

CHARACTER OF RATION.	Total Solids.	Fat.	Solids not Fat.	Nitrogen.	Protein Equivalent (N x 6.25).	Ash.
High protein,	14.83	5.00	9.84	.63	3.93	.74
Low protein,	14.90	5.07	9.82	.66	4.00	.76

The above figures represent the average of five-day composite samples of the milk produced by the herd of nine cows while on the two different rations. Samples of *each cow's* milk were also tested five days in each week for total solids and fat. The average of the two herds by this method varied less than .1 per cent. from the above figures. It is, therefore, evident that the difference in the amount of protein in the ration did not vary the fat, solids not fat, nitrogen or ash content of the milk.

Experiment VI. — 1905-06.

This experiment, hitherto not reported, was carried out by the group method, six cows constituting each of two groups.

The object of the experiment was to note the effect of a ration low in digestible protein, — the amount required in the milk plus that for maintenance, — as compared with one containing approximately $\frac{1}{2}$ pound in excess. The effect of the two rations was to be noted (*a*) on the condition of the animals; (*b*) on the yield of milk, milk solids, fat and nitrogen; (*c*) on the relative shrinkage; (*d*) on the composition of the milk.

Plan of the Experiment. — The twelve cows were divided as evenly as possible into two groups. The first few weeks both groups received the low-protein ration in order to establish a basis for comparison. The record of the milk yield and its composition is reported for the last week of this preliminary period. At the beginning of the period proper, Group II. received the high-protein ration, and Group I. continued on that low in protein.

History of the Cows.

NAME.	Breed.	Age (Years).	Last Calf dropped.	Days with Calf, Beginning of Test.
Blanche,	Grade Guernsey,	10	October, 1905	57
Daisy,	Grade Jersey,	7	August, 1905	79
Fancy,	Grade Jersey,	6	August, 1905	79
Gladys,	Pure Jersey,	3	December, 1905	—
Maude,	Grade Guernsey,	2	December, 1905	18
May,	Grade Jersey,	10	July, 1905	68
Betty,	Grade Jersey,	2	November, 1905	—
Dora,	Grade Jersey,	12	August, 1905	—
May Rio,	Pure Jersey,	3	October, 1905	64
Molly,	Grade Jersey,	10	July, 1905	—
Red II.,	Grade Jersey,	10	November, 1905	20
Samantha,	Grade Jersey,	3	August, 1905	51

Weighing Cows. — Each cow was weighed for three consecutive days at the beginning and end of the period proper, before watering and feeding in the afternoon. These weights were also taken twice during the intervening time.

Sampling Feeds. — Samples of hay and silage were taken at the beginning of the period, and every two weeks thereafter. In case of the hay, forkfuls were taken here and there from the entire amount to be fed for the day, run through a feed cutter, subsampled, the final sample brought to the laboratory in glass-stoppered bottles, dry-matter determinations made at once and the sample saved for a composite. The silage was similarly sampled, excepting that it was not run through the cutter. The grain was sampled daily, preserved in glass-stoppered bottles, and at the end of the period analyzed.

Sampling Milk. — The milk of each cow was sampled for five consecutive days in each week by the usual method, and the composite tested for fat, total solids, nitrogen and ash.

Dates of the Experiment.

Preliminary Period.

HERD.	Character of Ration.	Dates.	Weeks.	Cows.
I.,	Low protein, .	January 27 through February 2.	1	Blanche, Daisy, Fancy, Gladys, Maude, May.
II.,	High protein, .	January 27 through February 2.	1	Betty, Dora, May Rio, Molly, Red H., Samantha.

Period Proper.

I.,	Low protein, .	February 10 through April 27.	11	Blanche, Daisy, Fancy, Gladys, Maude, May.
II.,	High protein, .	February 10 through April 27.	11	Betty, Dora, May Rio, Molly, Red H., Samantha.

Average Daily Rations consumed by the Two Herds (Pounds).

Preliminary Period.

HERD.	Character of Ration.	English Hay.	Corn Silage.	Wheat Bran.	Corn Meal.	Gluten Meal.
I.,	Low protein, .	12 6	22 5	3 4	3 3	—
II.,	Low protein, .	12 6	22 2	3 4	3 3	—

Period Proper.

I.,	Low protein, .	12 6	22 2	3 4	3 3	—
II.,	High protein, .	13 0	21 0	3 7	1 2	2 2

The amount of hay fed to the different cows varied from 11 to 15 pounds; silage, from 20 to 30 pounds; bran, from 3 to 4.5 pounds; corn meal, from 3 to 4.5 pounds, and gluten meal, from 2 to 3 pounds daily.

Average Amounts of Dry and Digestible Matter consumed by Each Cow daily (Pounds).

Preliminary Period.

HERD.	Character of Ration.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total.	Nutritive Ratio.
I.,	Low protein, .	21.75	1.22	3.58	8.39	.42	13.61	1:10.6
II.,	Low protein, .	22.51	1.27	3.63	8.68	.43	14.02	1:10.4

Period Proper.

I.,	Low protein, .	21.70	1.22	3.58	8.37	.41	13.58	1:10.5
II.,	High protein, .	22.18	1.76	3.60	8.14	.41	13.91	1:7.2

Herd I. averaged 912 pounds and Herd II. 903 pounds in live weight. On the basis of 1,000 pounds live weight, Herd I. would be receiving 1.34 pounds of digestible protein and 14.9 pounds total digestible matter, and Herd II., 1.95 pounds digestible protein and 15.4 pounds of total digestible matter daily in the period proper. The digestible matter was calculated from actual analyses of the feeds, and average digestion coefficients. It seems probable that the results are a trifle low, and that more material was actually digested than the calculations show, for the animals appeared well nourished, Herd I. gaining 225 pounds, and Herd II., 215 pounds during the eleven weeks of the period proper. The low-protein ration was evidently somewhat deficient in protein and too wide. The high-protein ration must have satisfied the protein requirements, and on the basis of 1,000 pounds live weight, it contained .6 of a pound more of digestible protein daily than did the other ration.

Weight of Animals at Beginning and End of Experiment (Pounds).

HERD.	Period.	Blanche.	Daisy.	Fancy.	Gladys.	Maude.	May.	Betty.	Dora.	May Rio.	Molly.	Red II.	Samantha.	Gain or Loss.
I.,	Beginning, .	1,167	837	835	732	778	1,010	-	-	-	-	-	-	-
	End, .	1,230	892	865	707	813	1,077	-	-	-	-	-	-	+225
II.,	Beginning, .	-	-	-	-	-	-	672	843	758	1,018	1,007	1,013	-
	End, .	-	-	-	-	-	-	712	877	808	1,088	1,063	978	+215

Judging from the above weights it would appear that both herds were well nourished and able to add slightly to their live weight.

Crude Protein Balance (Pounds).

Preliminary Period: One Week.

CHARACTER OF RATION.	Protein digested.	Protein for Maintenance.	Protein for Milk.	Protein Deficit.	Percentage Deficit.
Low protein, Herd I., . . .	51.3	30.4	27.18	-6.28	-11.0
High protein, Herd II., . . .	53.3	30.4	28.66	-5.76	-9.7

Crude Protein Balance (Pounds).

Period Proper, Eleven Weeks.

HERD.	Character of Ration.	Cows.	Protein digested.	Protein required for Maintenance.	Protein required in Milk (N. x f. 25).	Excess over Maintenance and Milk Requirements.	Percentage Excess.
II.,	High protein,	Betty, . . .	118.58	37.30	45.87	35.41	42.6
		Dora, . . .	124.74	46.35	53.55	24.84	24.9
		May Rio, . . .	128.59	42.20	49.82	36.57	39.7
		Molly, . . .	133.21	56.76	52.48	23.97	21.1
		Red II., . . .	174.02	55.79	70.01	48.22	38.3
		Samantha, . . .	133.21	53.68	56.54	22.99	20.9
I.,	Low protein,	Blanche, . . .	104.72	64.68	43.55	-4.51	-4.2
		Daisy, . . .	99.79	46.62	44.20	6.97	7.7
		Fancy, . . .	92.40	45.82	49.49	-2.91	-3.1
		Gladys, . . .	93.90	38.81	50.88	4.21	4.7
		Maude, . . .	77.77	42.85	34.98	-06	±
		May, . . .	96.25	56.27	49.49	-9.51	-9.0

Influence of Protein on Milk Production (Pounds).

Preliminary period; both herds, low-protein ration.

RATION.	Average Weight of Cow.	Digestible Protein consumed daily per Cow.	Percentage Deficit or Excess Protein over Requirements.	Total Milk Yield.	Average Daily Yield.	Yield of Solids.	Yield of Fat.	Yield of Protein (N. x 6.25).
Low,	-	1.22	-11.0	747.8	17.80	108.95	37.97	27.18
Low,	-	1.27	-9.7	821.3	19.55	115.66	40.67	28.66
Percentage excess, Herd IV, over Herd I.	-	-	-	9.8	-	6.20	7.00	5.50

Period proper: Herd I., low protein; Herd II., high protein.

Low,	912	1.22	±	7,415.6	16.05	1,102.10	398.90	272.60
High,	903	1.76	31.3	8,906.5	19.28	1,294.80	473.00	328.30
Percentage increase, high over low.	-	-	-	20.1	-	17.50	18.60	20.00

It was hardly possible, with the cows at our disposal, to select two herds of six each that would produce substantially equal amounts of milk. It will be seen, therefore, that Herd II. in the preliminary period was producing nearly 10 per cent. more milk and from 5.5 to 7 per cent. more protein and fat than Herd I.

In the second or period proper, covering eleven weeks, this percentage was increased from 9.8 to 20 in case of the milk; substantially similar increases were also noted in case of the milk ingredients. Otherwise expressed, Herd II., receiving the high-protein ration, nearly maintained its flow during the second period, while each cow in Herd I. showed an average daily decrease of 1.75 pounds, or practically 10 per cent.

In the preliminary period both herds were receiving from 10 to 11 per cent. less protein than was actually needed for maintenance and milk. In the second period the low-protein herd had approximately reached a balance between income and outgo, while the high-protein herd was receiving 31.3 per cent. of crude protein in excess of requirements. The effect

of this extra protein may be clearly seen in maintaining the flow of milk. It would be of interest to know whether it would have maintained its influence throughout the entire milking period. The herd receiving the shortage of protein was obliged to adjust itself to the low-protein diet. It was able to increase somewhat in live weight (fat?), but its milk flow was of necessity noticeably checked. It is quite probable that some cows of pronounced ability as milkers would not shrink as rapidly as others on a low-protein diet, but for a time would have taken the needed protein from that stored in the body.

Effect of Protein on Average Composition of the Milk (Per Cent.).

HERDS.	Period.	Character of Ration.	Total Solids.	Fat.	Solids not Fat.	Protein.
I.,	I.,	Low protein, .	14.57	5.08	9.49	3.63
I.,	II.,	Low protein, .	14.86	5.38	9.48	3.69
Increase,	-	-	.29	.30	±	.06
II.,	I.,	Low protein, .	14.08	4.95	9.13	3.49
II.,	II.,	High protein, .	14.51	5.31	9.23	3.69
Increase,	-	-	.46	.36	.10	.20

The above average figures were secured by taking the average of the weekly analysis of the milk produced by each cow and multiplying it by the pounds of milk produced, the result being the pounds of the several ingredients produced by each cow. These were added, and gave the total milk and milk ingredients produced by each herd. The total ingredients divided by the total milk produced gave the average percentages. The fact that the milk produced by each herd did not show the same composition in the preliminary period prevents a direct comparison. It will be observed, however, that in case of Herd I. the milk in the second period changed but little in composition from that produced in the first period, the principal difference being a slight increase in the fat, due evidently to the advance in lactation. Herd II. produced milk also with only slight variations in the two periods. The fat increased .36 of 1

per cent., being about the same increase as with Herd I. The protein showed rather more of an increase than in case of Herd I., and this may possibly be attributed to the influence of the extra protein in the food. It must be remembered that Herd I. received a ration deficient in protein, and the increased amount given to Herd II. may have had a slight effect upon the milk protein. With this exception it is safe to state that the protein was entirely without influence upon the composition of the milk.

Experiment VII. — 1907-08.

This experiment was conducted with six cows, the only ones available at the time, and was by the group method.

The object of the experiment was primarily to note the effect of rations low and high in protein (a) upon the condition of the animals, (b) upon the yield of milk, and (c) upon the relative milk shrinkage.

The plan of the experiment consisted in dividing six cows into two herds of three each, which were known as Herds D and E. The first ten days were regarded as preliminary, to accustom the two herds to their distinct rations. Herd D received the low-protein ration and Herd E the one high in protein.

Weighing Cows. — Each of the cows was weighed for three consecutive days at the beginning and end of the experiment, and every fourth week during its progress. They were weighed in the afternoon before being fed or watered.

Sampling Feeds. — The hay was sampled in the usual way at the beginning of the experiment, and every two weeks thereafter. The grain was sampled daily and preserved in glass-stoppered bottles, and eventually tested for dry matter and for the ordinary ingredients.

Character of Feeds. — The hay was a mixture of grasses, the finer varieties, such as Kentucky blue grass, predominating. It contained a noticeable admixture of clover.

Sampling Milk. — The cows were milked twice daily, and the single milking of each cow in each herd was poured into a common receptacle, mixed and the herd mixture sampled. This method was continued for five consecutive days, each single

sample composited, and eventually tested for solids, fat and nitrogen. It will therefore be seen that herd samples only were analyzed, and not the product of individual cows.

History of Cows.

HERD.	Cows.	Breed.	Age (Years).	Last Calf dropped.	Days with Calf at Beginning of Trial.
D,	Samantha, . . .	Jersey-Holstein, . .	4	September 3	8
	May Rio,	Pure Jersey, . . .	4	September 12	-
	Daisy,	Grade Jersey, . . .	8	August 23	-
E,	Fancy,	Grade Jersey, . . .	7	September 1	-
	Gladys,	Pure Jersey, . . .	4	October 7	-
	Red III.,	Grade Jersey, . . .	2	October 27	-

Duration of the Experiment.

HERD.	Character of Ration.	Dates.	Number of Weeks.	Cows.
D,	Low protein, . .	Nov. 23, 1907, through May 8, 1908.	24	Samantha, May Rio, Daisy.
E,	High protein, . .	Nov. 23, 1907, through May 8, 1908.	24	Fancy, Gladys, Red III.

Rations consumed daily by Each Cow (Pounds).

HERD.	Character of Ration.	Cows.	Hay.	Wheat Bran.	Corn Meal.	Gluten Feed.
D,	Low protein, . .	Samantha, . . .	22	3.40	4.50	-
		May Rio,	20	3.00	4.00	-
		Daisy,	20	3.00	4.00	-
E,	High protein, . .	Gladys,	20	3.00	-	3.90
		Fancy,	22	3.40	-	4.60
		Red III.,	16	2.50	-	3.40
Average, Herd D,	-	-	20.7	3.13	4.16	-
Average, Herd E,	-	-	19.3	2.97	-	3.97

The difference in the two rations consisted in the substitution of corn meal for gluten feed. The latter, as is well known,

is a by-product of the former, hence the general character of the two variables was the same, and particularly the protein.

Digestible Matter in Daily Rations (Pounds).

HERD.	Character of Ration.	Cows.	DIGESTIBLE NUTRIENTS.				Nutritive Ratio.
			Protein.	Fat.	Carbohy- drates.	Total.	
D, . . .	Low protein, . .	{ Samantha, . . .	1.44	.48	14.27	16.19	1:10.7
		{ May Rio, . . .	1.29	.43	12.87	14.59	1:10.6
		{ Daisy, . . .	1.29	.43	12.87	14.59	1:10.6
E, . . .	High protein, . .	{ Gladys, . . .	1.88	.38	12.23	14.49	1:6.9
		{ Fancy, . . .	2.14	.43	13.65	16.22	1:6.8
		{ Red III., . .	1.58	.31	9.97	11.86	1:6.6
Average, Herd D,	-	-	1.34	.45	13.34	15.12	1:10.6
Average, Herd E,	-	-	1.87	.37	11.95	14.19	1:6.7

The above figures were secured from the actual analyses of the feeds and average digestive coefficients. It is clear that Herd D received a ration with a very wide nutritive ratio, while Herd E received a ration with a medium ratio.

Average Weight of Cows at Beginning and End of Period (Pounds).

	HERD D.			HERD E.		
	Daisy.	May Rio.	Samantha.	Fancy.	Gladys.	Red III.
Beginning, . . .	920	898	1,003	973	810	650
End,	923	907	1,063	1,013	818	782
Total gain, Herd D, 69 pounds.			Total gain, Herd E, 150 pounds.			

Herd E made a larger gain than Herd D, but this appears to be due largely to the gain made by Red III., a heifer with first calf.

Crude Protein Balance (Pounds).

HERD.	Character of Ration.	Average Weight.	Protein digested (N. x 6.25).	(Protein required for Maintenance (N. x 6.25.))	Protein required for Milk (N. x 6.25).	Protein Excess or Deficit.	Percentage Excess or Deficit.
D, . . .	Low protein,	935	675.36	328.00	351.50	-4.14	-6
E, . . .	High protein,	832	942.48	291.75	389.37	261.36	38.4

The total protein digested was calculated from the amount digested daily multiplied by the number of days of the experiment. The protein for maintenance was calculated from the average weight of each herd, allowing .7 of a pound of digestible protein per 1,000 pounds live weight. The protein in the milk was calculated from the actual analysis of the milk. It is admitted that the above results are only approximate, being secured partly from average figures, and on the basis of crude in place of true protein. They indicate, however, that Herd D was receiving a ration rather deficient in protein, and that Herd E was receiving at least 38.4 per cent. over that required for maintenance and milk.

Milk Yield and Milk Shrinkage.

HERD.	Character of Ration.	MILK PRODUCED AND SHRINKAGE.			
		Total Yield (Pounds).	First Week (Pounds).	Last Week (Pounds).	Per Cent. Shrinkage.
D.	Low protein, .	9,287.1	446.3	368.8	17.4
E.	High protein, .	11,161.5	514.5	401.6	21.9

In spite of the fact that the three cows comprising Herd D received hardly sufficient protein for maintenance and milk produced, they did not shrink as much during a period of twenty-four weeks as did the three cows in Herd E, which received substantially 38 per cent. protein in excess of supposed requirements. Such a result can only be explained on the ground that the animals were too few in number to give accurate results by the group method, and that individuality rather than food appeared to be the controlling factor. See also Experiment VIII.

Experiment VIII. — 1908-09.

This experiment was planned primarily to study the protein requirements of dairy animals. It will not show the effect of protein upon the chemical composition of the milk.

Plan of the Experiment. — Inasmuch as the cows in the herd calved at different times, the experiment was planned with pairs of cows, *i. e.*, each pair of cows, when ready, was started,

one on a diet approximately sufficient to furnish protein for maintenance plus that contained in the milk, and the other on a diet containing some $\frac{1}{2}$ pound more protein daily than the maintenance and milk requirements.

Duration of the Experiment. — The experiment was planned to continue substantially through a milking period, or until the animals were so far advanced in lactation as to cease to respond to the influence of food.

Weighing the Cows. — Each animal was weighed for three consecutive days at the beginning of the period, and for three days each two weeks thereafter.

Sampling Feeds. — The hay fed was sampled at the beginning of the period for each pair of cows, and each two weeks thereafter. The samples were placed in glass-stoppered bottles, taken to the laboratory and dry-matter determinations made at once. The method of sampling has been described in preceding experiments.

Each kind of grain was sampled daily during the process of weighing out, and the composite samples preserved in glass-stoppered bottles. Dry-matter determinations were made once each month, and the monthly samples composited.

Character of Feeds. — It was intended to procure one lot of hay of the same quality sufficient to last during the entire experiment. Owing to several unfortunate circumstances this was not possible. Three different lots were secured, and composite samples of each analyzed. The digestibility was not determined, but approximate coefficients applied, depending upon the analysis and general appearance of the hay. The several grains were procured in large amounts and average digestion coefficient applied.

Sampling Milk. — The milk of each cow was sampled for five consecutive days at the beginning of the period, and each two weeks thereafter. It was tested for total solids, for fat by the Babcock method in duplicate, and for nitrogen by the Kjeldahl method.

History of the Cows.

PAIRS.	Cows.	Breed.	Age (Years).	Last Calf dropped.	Daily Yield at Beginning of Experiment, Pounds.
I.,	Minnie,	Grade Holstein, . .	8	September 12,	26.0
	Mary,	Grade Holstein, . .	10	September 5,	26.0
II.,	Samantha,	Jersey-Holstein, . .	6	August 27,	26.0
	Chub,	Grade Holstein, . .	10	September 1,	20.0
III.,	Betty,	High-grade Jersey,	4	September 25,	26.3
	May Rio,	Pure Jersey,	6	October 13,	27.5
IV.,	Daisy,	High-grade Jersey,	11	October 22,	28.7
	Cecile,	Pure Jersey,	4	October 10,	25.7
V.,	Red III.,	High-grade Jersey,	2	October 30,	29.0
	Betty II.,	High-grade Jersey,	2	-	-

Duration of Experiment.

Cows.	Preliminary Period began.	Period Proper.	Number of Days.
Minnie,	October 10,	October 17 through April 30,	196
Mary,	October 10,	October 17 through April 30,	196
Samantha,	October 10,	October 17 through May 28,	224
Chub,	October 10,	October 17 through May 28,	224
Betty,	October 24,	November 14 through June 11,	210
May Rio,	October 24,	November 14 through June 11,	210
Daisy,	October 31,	November 14 through May 28,	196
Cecile,	October 31,	November 14 through May 28,	196
Red III.,	November 28,	December 12 through June 11,	182
Betty II.,	December 17,	December 26 through June 11,	168

Rations consumed daily by Each Cow (Pounds).

CHARACTER OF RATION.	Number of Days.	Cows.	Hay.	Wheat Bran.	Corn Meal.	Gluten Feed.
High protein, . . .	196	Mary, . . .	21.4	3.0	-	3.93
	224	Chub, . . .	17.6	3.0	-	3.51
	210	Betty, . . .	19.4	3.0	.80	3.87
	196	Cecile, . . .	17.0	3.0	.43	3.48
	168	Betty II., . . .	16.4	3.0	1.00	3.00
Low protein, . . .	196	Minnie, . . .	20.0	3.0	3.51	.51
	221	Samantha, . . .	22.0	3.9	3.90	-
	210	May Rio, . . .	19.6	3.0	4.80	-
	196	Daisy, . . .	19.3	3.0	4.00	.44
	182	Red III., . . .	19.5	3.0	4.00	.41
Average, high protein, . . .	-	-	18.4	3.0	.74	3.56
Average, low protein, . . .	-	-	20.1	3.2	4.10	.45

The substantial difference in the rations of the two lots of cows consisted in the fact that the high-protein cows received the gluten feed and the low-protein cows the corn meal.

Dry and Digestible Matter in Daily Rations (Pounds).

CHARACTER OF RATION.	Cows.	Dry Matter.	DIGESTIBLE.				Nu- tritive Ratio.
			Pro- tein.	Fat.	Carbo- hy- drates.	Total.	
High protein, . . .	Mary, . . .	25.1	2.05	.55	12.26	14.86	1:6.57
	Chub, . . .	21.3	1.79	.38	10.41	12.58	1:6.28
	Betty, . . .	23.9	1.95	.43	12.04	14.42	1:6.66
	Cecile, . . .	21.1	1.74	.38	11.06	13.18	1:6.84
	Betty II., . . .	20.7	1.61	.38	10.32	12.31	1:6.93
Low protein, . . .	Minnie, . . .	23.8	1.47	.42	12.23	14.12	1:8.95
	Samantha, . . .	26.0	1.44	.43	12.90	14.77	1:9.62
	May Rio, . . .	24.2	1.36	.44	12.70	14.50	1:10.51
	Daisy, . . .	22.7	1.34	.39	11.61	13.34	1:9.30
	Red III., . . .	23.7	1.36	.41	12.63	14.40	1:9.95
Average, high protein,	-	22.4	1.83	.42	11.22	13.47	1:6.65
Average, low protein.	-	24.1	1.39	.42	12.41	14.27	1:9.61

It will be seen that the cows receiving the larger amount of protein did not receive by .8 of a pound as much total digesti-

ble matter as the low-protein cows. The amount of food fed daily to each cow was gauged partly by the appetite of the animal. The high-protein cows received only .44 of a pound more digestible protein than the other herd.

Influence of Rations on Weight (Pounds).

CHARACTER OF RATION.	Cows.	Average Weight.	Weight at Beginning.	Weight at End.	Total Gain or Loss.
High protein,	Mary, . . .	1,074	1,047	1,102	+55
	Chub, . . .	1,011	955	1,067	+112
	Betty, . . .	869	843	895	+52
	Cecile, . . .	805	783	827	+44
	Betty II., . .	743	742	745	+03
Low protein,	Minnie, . . .	971	923	1,018	+95
	Samantha, . .	1,068	995	1,142	+147
	May Rio, . . .	826	825	827	+02
	Daisy, . . .	830	798	862	+64
	Red III., . .	837	807	867	+60
Herd average, high,	-	900	874	927	+266
Herd average, low,	-	906	869	943	+368

The cows receiving the low-protein ration gained rather more in weight than the other herd; whether this was due to the character of the ration, or whether it simply depended upon the individuality of the animal, it is difficult to say.

True¹ Protein Balance (Pounds).

CHARACTER OF RATION.	Cows.	True Protein digested.	Protein required for Maintenance.	Protein found in Milk. (N. x 6.25).	Excess over Maintenance and Milk Requirements.	Percentage Excess.
High protein,	Mary, . . .	350.97	147.35	143.10	60.52	20.8
	Chub, . . .	368.24	158.52	124.71	85.01	30.0
	Betty, . . .	380.61	127.74	156.35	96.52	34.0
	Cecile, . . .	316.38	110.45	136.07	69.86	28.3
	Betty II., . .	256.82	87.37	114.69	54.75	27.1
Low protein,	Minnie, . . .	277.15	133.22	143.73	09.20	+
	Samantha, . .	320.40	167.46	168.14	-15.20	-4.5
	May Rio, . . .	284.48	121.42	136.07	26.99	10.5
	Daisy, . . .	259.20	113.87	140.52	4.80	1.9
	Red III., . .	247.13	106.63	119.58	20.92	9.2

The high-protein cows received an average of 28 per cent. of protein over maintenance and milk requirements, while in case of the low-protein cows the percentage varied from an actual shortage of 4.5 per cent. to a surplus of 10.5 per cent.

¹ Amines were determined and deducted from the total protein, the above results being expressed as true albuminoids.

Milk Yield and Milk Shrinkage (Pounds).

CHARACTER OF RATION.	Cows.	MILK PRODUCED AND SHRINKAGE.					TOTAL SOLIDS PRODUCED AND PER CENT. SHRINKAGE.				
		Total.	First Two Weeks.	Last Two Weeks.	Per Cent. Shrinkage.	Weekly Shrinkage (Per Cent.).	Total.	First Two Weeks.	Last Two Weeks.	Per Cent. Shrinkage.	Weekly Shrinkage (Per Cent.).
High protein, . . .	Mary, . . .	4,224.7	341.4	173.6	49.2	2.0	567.3	44.3	25.7	42.0	1.7
	Chub, . . .	3,684.1	263.6	173.4	34.6	1.2	483.5	33.1	22.7	31.4	1.1
	Betty, . . .	4,086.0	343.4	208.4	39.3	1.5	599.6	49.9	29.7	40.5	1.6
	Cecile, . . .	3,677.1	306.4	206.4	32.6	1.3	533.5	43.6	29.7	31.8	1.3
	Betty II., . . .	3,235.3	286.0	234.8	17.6	.89	430.2	39.6	30.1	24.0	1.2
	Minnie, . . .	4,183.3	329.1	251.6	23.6	1.0	457.5	42.2	33.5	20.7	.9
Low protein, . . .	Samantha, . . .	4,370.0	305.5	231.9	24.1	.86	673.0	46.0	34.4	25.1	.9
	May Rio, . . .	4,323.0	368.7	228.6	38.0	1.50	627.7	53.1	33.1	37.7	1.5
	Daisy, . . .	3,643.5	352.9	202.4	42.6	1.8	545.9	50.1	30.0	40.2	1.7
	Red III., . . .	3,720.3	357.5	210.4	41.1	1.9	502.9	48.0	28.4	40.8	1.9
	Average, high, . . .	-	-	-	34.7	1.4	-	-	-	34.0	1.4
Average, low, . . .	-	-	-	33.9	1.4	-	-	-	32.9	1.4	

Influence of Protein on Milk Shrinkage (Average Results).

CHARACTER OF RATION.	Weight of Cow (Pounds).	Digestible Protein consumed daily per Cow (Pounds).	Percentage Excess of Protein over Requirements.	Total Shrinkage (Per Cent.).	Weekly Shrinkage (Per Cent.).
High protein, . .	900	1.83	22	34.7	1.4
Low protein, . .	906	1.39	3	33.9	1.4

The average amount of digestible protein consumed daily by each of the high-protein cows (1.83 pounds) was not quite as high as intended, hence the difference between the low and high protein rations was not particularly pronounced. Nevertheless, one would expect if the conditions were reasonably satisfactory that the low-protein cows would have shrunk in their milk yield (over an average of two hundred days) rather more than the high-protein cows. Such, however, was not the case, the shrinkage of both herds being substantially identical. The only explanation that can be offered is the undue influence of individuality and the small number of cows in each group. For example, Mary shrunk 49 per cent. during the experiment, it being characteristic of this animal to dry off quite rapidly after she had been four months with calf; Daisy also had such a tendency. The individuality of each animal, as well as its age and condition, all have a pronounced influence, especially when the experiment is extended over a long period of time, and in order to arrive at the truth a large number of animals must be used with as near similar conditions as it is possible to secure. Is it probable that if an animal receives sufficient protein to supply the daily demands of her body (maintenance) and of the milk produced, she will not shrink in her yield *during a milking period* any more than when she is receiving 25 to 50 per cent. protein in excess of the actual requirements? In other words, is it not possible that the excess protein acts as a stimulus for a time, after which the individuality of the animal becomes the more pronounced factor?

CONCLUSIONS.

The following general conclusions may be drawn from the experiments reported:—

1. A large excess of digestible protein (1.5 pounds, or 100 per cent.) above the protein minimum increased the flow of milk some 15 per cent. in experiments extending over periods of four weeks.

2. No particular difference was noted in the milk yield in case of two herds of cows receiving the same amount of total digestible matter, one receiving 65 per cent. and the other 122 per cent. of digestible protein above the protein minimum. Such a result indicates, at least, that the former excess was sufficient.

3. A 50 per cent. excess of digestible protein daily above the protein minimum in an experiment by the reversal method, extending over a period of nine weeks, produced some 5.9 per cent. more milk than did a ration with 21 per cent. excess protein.

4. Under similar conditions an excess, above the minimum, of 65 per cent. digestible protein produced 7.4 per cent. more milk than did an excess of 39 per cent. (experiment covered twenty-six days).

5. In experiment VI., extending over a period of eleven weeks with twelve cows, by the group method, an excess of .54 of a pound of protein, or 31.3 per cent., over the protein minimum, produced an apparent increase of 10 per cent. in the milk yield.

In experiment VIII., extending over periods of twenty-four to thirty weeks with ten cows, by the group method, the cows receiving the protein minimum did not shrink any more than those receiving each .44 of a pound, or 28 per cent., protein above the minimum.

6. The group method of experimentation is best suited for conducting experiments where a relatively large number of animals—twenty or more—is available. With a less number the influence of individuality is altogether too pronounced.

7. An excess of 30 per cent. of digestible crude protein above the protein minimum (equal to 1.80 pounds of protein per

day) will be productive of satisfactory results in case of cows weighing 900 pounds and producing daily 12 quarts of 4 per cent. milk.¹

An excess of 50 per cent. of digestible crude protein above the protein minimum is believed to be ample for all ordinary requirements.

8. Protein in excess of the above suggested amounts may temporarily increase the milk yield, but it seems probable that in many cases the influence of individuality is likely to be more pronounced than the effect of the protein consumed.

9. Under the usual conditions, varying amounts of protein appear to be without influence upon the composition of the milk.

¹ Armsby, in Farmers' Bulletin No. 346, United States Department of Agriculture, expresses substantially the same idea in allowing .05 of a pound of digestible true protein for each pound of average milk, in addition to the maintenance requirement of .5 of a pound of digestible true protein per 1,000 pounds live weight. It is possible that animals can even do very good work with .04 of a pound of protein for each pound of milk.

THE DETERMINATION OF ARSENIC IN INSECTICIDES.

BY E. B. HOLLAND.

During the past three years the writer ¹ has given considerable time to the study of arsenical insecticides, with special reference to their manufacture, composition and use, — the main object of which was to provide the entomological department of this station with chemicals of known composition, suitable for an extended investigation to determine their effect in practical application under varying climatic and atmospheric conditions.

For more than a decade the analysis of arsenicals has received marked attention because of the high value of a number of these salts as insecticides. The sale of inferior, adulterated or imitation products lacking in efficiency, or causing severe injury to foliage, has rendered necessary a certain amount of supervision by the agricultural experiment stations of the country. In several States special laws have been enacted to regulate the sale and to provide for an inspection of such materials. Arsenic as trioxide or pentoxide is the active constituent of these compounds, and various methods of several distinct types and numerous modifications have been proposed for its determination. Some of the methods are applicable to arsenous acid and others to arsenic acid.

METHODS.

As the work planned by the entomological department would require many analyses, it was desirable that the methods adopted should be reasonably short and simple, though accuracy would be the controlling factor. The literature on the determination of arsenic was reviewed at some length. The results, while somewhat overwhelming, can be roughly summarized under gravimetric methods, volumetric methods and processes for the elimination of substances liable to affect the determination. A

¹ Assisted by Dr. R. D. MacLaurin, Prof. S. F. Howard, C. D. Kennedy and J. C. Reed.

classification of this character is open to criticism, but will serve the purpose intended.

The gravimetric methods include the hydrogen sulfide precipitation of arsenous acid¹ weighable as arsenous sulfide after removal of the excess sulfur; the Nehler modification² of the Bunsen method,³ precipitating arsenic acid with hydrogen sulfide, weighable as arsenic sulfide; the modified Levöl method, precipitating arsenic acid with "magnesia mixture," weighable as magnesium pyro-arsenate; and the Werther method,⁴ precipitating arsenic acid with uranyl acetate, weighable as uranyl pyro-arsenate. The inherent faults of the sulfide methods render them impracticable. The modified Levöl method, the most prominent of the gravimetric, is complicated, tedious and tends towards low results. All of these methods are time consumers, and none of them appear to have met with favor, having of late been almost entirely superseded by volumetric.

The volumetric methods include the Kessler method,⁵ oxidizing arsenous acid with potassium bichromate and titrating the excess chromic acid with standard ferrous sulfate, using potassium ferri-cyanide to determine the end point; the permanganate method, titrating arsenous acid with standard potassium permanganate to a rose color; the Mohr method, titrating arsenous acid with standard iodine in the presence of sodium bicarbonate, using starch paste as indicator; the Bunsen method,⁶ based on the difference in amount of chlorine evolved from hydrochloric acid by a given weight of potassium bichromate in the presence of arsenous acid, the gas being conducted into potassium iodide and the free iodine titrated with standard sodium thiosulfate, using starch paste as indicator; the Krickhaus method,⁷ reducing arsenic acid to arsenous with hydrochloric acid and potassium iodide, and titrating the free iodine with standard thiosulfate; the Bennett modification⁸ of the Pierce method,⁹ precipitating arsenic acid with silver nitrate and titrating the silver in the precipitate with potassium sulphocyanate, according to Volhard;¹⁰ and the Bödeker method,¹¹ titrating arsenic acid with

¹ Fresenius, *Quan. Chem. Anal.*

² *Ztschr. Analyt. Chem.*, 32, 45 (1893).

³ *Ann. Chem. Pharm.*, 192, 305.

⁴ *Jour. Prakt. Chem.*, 43, 346 (1848).

⁵ *Poggend. Ann.*, 118, 17, Series 4 (1863).

⁶ *Ann. Chem. Pharm.*, 86, 290.

⁷ *Engin. and Min. Jour.*, 90, 357. See Sutton for earlier references.

⁸ *Jour. Amer. Chem. Soc.*, 21, 431 (1899).

⁹ *Proc. Col. Sci. Soc.*, Vol. 1.

¹⁰ *Liebig's Ann. Chem.*, 190, 1 (1878).

¹¹ *Ann. Chem. Pharm.*, 117, 195.

standard uranyl nitrate, using potassium ferrocyanide to determine the end point. The Kessler and Bödeker methods are objectionable in their requirement of an "outside" indicator. The Bunsen and Bennett methods are lengthy, and demand very careful manipulation. The permanganate titration is not as sensitive as the iodine, and the Krickhaus method offers no advantages in its application to arsenic acid over a similar reduction and titration with iodine. In other words, the iodine titration method (Mohr) seemed to us rather superior to any other in point of accuracy, manipulation and time, and was adopted for the work in view.

There are a number of processes that are noted more particularly as a means of eliminating impurities likely to effect the arsenic determination, among which may be mentioned the distillation processes of Fischer,¹ Piloty and Stock,² Stead,³ and Jannasch and Seidel,⁴ using hydrochloric acid in connection with reducing substances such as ferrous salts, hydrogen sulfide, and potassium bromide and hydrazine hydrochloride. The above list of methods is far from complete, but attention has been called to practically every type applicable to commercial products.

IODINE METHOD (MOHR).

As previously stated, the iodine method appeared to offer the greatest advantages, and was selected. A clear understanding of the character and limitations of the reaction underlying the method is necessary at the outset. Iodine is an indirect oxidizer, acting on the elements of water with the formation of hydriodic acid and the liberation of oxygen.



The oxidation cannot be conducted in an acid or neutral solution because of the reversible action of the hydriodic acid. If the latter is neutralized with sodium bicarbonate as rapidly as produced, the reaction will proceed to completion. Caustic alkali or carbonate cannot be employed, as they absorb iodine, the former being especially active. The reaction between starch

¹ Ztschr. Analyt. Chem., 21, 266 (1882).

² Ber. Deut. Chem. Gesell., 30, 1649 (1897).

³ Sutton, Vol. Anal., Edit. 9, 159 (1904).

⁴ Ber. Deut. Chem. Gesell., 43, 1218 (1910).

and iodine in the presence of hydriodic acid or soluble iodide is one of the most sensitive in analytical chemistry, forming the characteristic blue iodide of starch. A more delicate indicator could not be desired. Since the method was first applied to the analysis of arsenicals numerous modifications have been devised to insure complete solution of the arsenic, to prevent oxidation, to eliminate or render innocuous substances that might effect the titration, and to enlarge its field of application so as to readily include the arsenates. The Association of Official Agricultural Chemists began work on insecticides in 1899 and has rendered valuable service.

NEW PROCESSES.

The introduction of the Thorn Smith process ¹ marked a turning point in the analysis of arsenicals. It was intended particularly for Paris green, and is the official method for that substance. Solution of the arsenic is effected by boiling the sample with a slight excess of sodium hydrate, which readily unites with the free arsenous acid, and also with the combined after displacing the copper. In presence of a reducing substance like sodium arsenite, the copper is precipitated as cuprous oxide and a portion of the arsenous acid oxidized to arsenic. This oxidation necessitates a subsequent reduction of the filtrate with hydrochloric acid and potassium iodide (hydriodic acid), and the removal of the excess iodine with thiosulfate. The solution is neutralized with dry sodium carbonate, an excess of sodium bicarbonate added, and titrated with iodine. The process is accurate, though the double titration is objectionable.

Avery and Beans devised a very ingenious process ² noted for its simplicity. The Paris green is pulverized, solution effected with concentrated hydrochloric acid in the cold, neutralized with sodium carbonate, the precipitated copper redissolved with sodium potassium tartrate and titrated as usual. The copper held by the alkaline tartrate colors the solution but does not effect the titration. Hydrochloric acid, however, is a poor solvent for free arsenic, and unreliable, which constitutes a very serious objection to the process. Avery noted this error and advised ³ that samples showing a tendency to separate white

¹ Jour. Amer. Chem. Soc., 21, 769 (1899).

³ Jour. Amer. Chem. Soc., 25, 1096 (1903).

² Jour. Amer. Chem. Soc., 23, 485 (1901).

arsenic should be treated with $N/2$ hydrochloric acid, 5 to 10 cubic centimeters for each .1 of a gram, and boiled gently. In case arsenic remains undissolved, a cold saturated solution of sodium acetate, 3 grams salt for each .1 of a gram of substance, is added, and boiling continued until solution is effected. By another modification¹ suggested by Avery, and reported by Thatcher,² 1 gram sample is boiled five minutes with 25 cubic centimeters of sodium acetate solution (1-2), dissolving the free arsenic which is removed by filtration. The residue is dissolved in dilute hydrochloric acid and both solutions titrated.

Haywood attempted, in several ways,³ to modify the original Avery-Beans process so as to insure solution of the free arsenic. After treating the sample with a slight excess of hydrochloric acid at laboratory temperature, sodium carbonate was added and the solution boiled. In another case sodium bicarbonate was employed, but the results were unsatisfactory in both instances, due to more or less reduction of copper and accompanying oxidation of arsenous acid. Accurate results were secured, however, by filtering off the hydrochloric acid solution and boiling the residue with 5 grams of sodium bicarbonate, titrating both solutions.

Haywood proposed still another modification⁴ which might be considered a simplified Avery-Thatcher process;⁵ .4 of a gram sample is boiled ten minutes with 25 cubic centimeters sodium acetate solution (1-2) to dissolve free arsenic, and concentrated hydrochloric acid carefully added until solution is effected. After neutralizing with a solution of sodium carbonate, avoiding an excess, alkaline tartrate and sodium bicarbonate are added and titrated as usual.

The Avery, Avery-Thatcher and Avery-Haywood processes employ the same reagents, differing only in their application. The co-operative investigation⁶ of the association in 1904 showed that the three above modifications, together with the Haywood, gave closely agreeing results, with little, if any, advantage in the

¹ Optional official method, Assoc. Off. Agr. Chem.

² Proc. Assoc. Off. Agr. Chem., 20, 196 (1903).

³ Jour. Amer. Chem. Soc., 25, 963 (1903).

⁴ Proc. Assoc. Off. Agr. Chem., 20, 197 (1903). Optional official method of the association.

⁵ *Loco citato*.

⁶ Proc. Assoc. Off. Agr. Chem., 21, 98 (1904).

two-solution processes over the one. In 1905 the results¹ with the Avery-Thatcher and Avery-Haywood modifications were not as satisfactory though the average difference was not excessive.

In weighing the merits of the Thoru Smith process and various modifications of the Avery-Beans, with apparently little choice as to accuracy, the Avery or Avery-Haywood process, with one titration of a single solution, certainly appeals to chemists in "control" work from the standpoint of manipulation, possible mechanical losses and time. This does not warrant any less care in conducting the analysis, but, if anything, demands greater attention. The essential features of the Avery-Haywood process have been employed at the Massachusetts station for the work on arsenites, though considerably modified as to detail.

PRACTICE AT MASSACHUSETTS STATION.

Having adopted Thatcher's suggestion² as to ratio of sample to acetate solution, 1 to 25, and finding 25 cubic centimeters rather inadequate for proper boiling and agitation, double quantity of each is taken. To prevent slight loss of sample in transferring to flask, due to both adhesion and dusting, boats of folded filter paper are employed, and found very serviceable, particularly for Paris green and arsenic for standard solution. After boiling the solution five minutes with acetate, the directions call for the careful addition of concentrated hydrochloric acid until solution is effected. Such a procedure in our hands gave extremely variable results and generally a low test for arsenic. This error necessitated several weeks of experimenting, and was found to be due to the addition of *concentrated* acid, dilute acid (1-3) giving uniform results in practically every instance, and a higher test. Probably this has been one of the sources of trouble with the chemists reporting on association samples by the above process in past years. Neutralizing with sodium carbonate, in dry form or concentrated solution, will introduce an error if added in excess. The use of sodium bicarbonate is preferable for the purpose as the latter salt does not absorb iodine and eliminates an unnecessary reagent. As con-

¹ Proc. Assoc. Off. Agr. Chem., 22, 27 (1905).

² Proc. Assoc. Off. Agr. Chem., 21, 99 (1904).

centration has a certain influence on titration, it is advisable to maintain approximately the same volume in every case. The tendency of some solutions to become muddy on titration can often be relieved by additional bicarbonate, though the conditions involved seem to have no appreciable influence on the results. The quality of all reagents employed in the determination should be proved by blank tests, which should not exceed .10 of a cubic centimeter iodine solution for the amounts employed. Some lots of bicarbonate have been found unfit for such work. Due recognition should be given the blank in calculating results.

Considerable trouble is often experienced in determining insoluble matter with hydrochloric acid, due to the splitting off of white arsenic, especially with Paris green. To offset the difficulty it was found advisable to combine the determination with that of preparing the arsenic solution by simply filtering off the residue. The points noted above may be briefly summarized:—

Transfer 2 grams of finely ground sample, together with 50 cubic centimeters of sodium acetate (1-2), to a 500 cubic centimeter graduated flask, and boil five minutes. Cool under tap, add about 60 cubic centimeters of hydrochloric acid (1-3), and shake until solution is effected. Make to volume and filter. Pipette 25 or 50 cubic centimeters into an Erlenmeyer flask, neutralize with dry sodium bicarbonate, add 25 cubic centimeters of sodium potassium tartrate¹ (1-10), to redissolve precipitated copper, approximately 3 grams of sodium bicarbonate, water sufficient to make a volume of 100 cubic centimeters, 2 cubic centimeters starch paste (1-200), and titrate with N/20 iodine to a permanent blue color. Toward the end of the reaction cork the flask and shake vigorously, to insure proper end point. Calculate results as arsenous oxide. The residue in the graduated flask is brought onto the filter, well washed, calcined in a porcelain crucible and weighed as insoluble matter.

The above process has given excellent results with copper aceto-arsenite, copper arsenite and calcium arsenite. Sodium acetate does not prevent hydrolysis of copper and calcium arsenites, as in the case of Paris green, but serves to take up free

¹ Used only with the copper arsenites.

arsenic. The presence of such impurities as cuprous and ferrous compounds, sulfurous and nitrous acids or other oxidizable substances is a source of error by the iodine titration method.

IODINE METHOD FOR ARSENATES.

The increasing use of lead arsenate as an insecticide resulted in a demand for a rapid volumetric method for the determination of the arsenic acid. The Gooch and Browning process,¹ as modified by Haywood,² serves to readily reduce arsenic acid to arsenous, in which form the iodine titration method is applicable. The process in our hands did not at first prove satisfactory, but eventually yielded concordant results after minor changes. As the differences are largely a matter of detail, not involving principle, only the modified process will be given.

Transfer 2 grams of finely ground sample, together with 60 cubic centimeters of nitric acid (1-3), to a 500 cubic centimeter graduated flask; bring to boil, cool, make to volume and filter. Pipette 50 or 100 cubic centimeters into a 150 cubic centimeter Jena Griffin beaker, add 10 cubic centimeters of sulfuric acid (2-1), evaporate, heat in an air bath at 150-200° C. to expel last traces of moisture, and then on asbestos board, to the appearance of dense white fumes, to insure complete removal of nitric acid. Add a small quantity of water, and when cold, filter through a sugar tube under suction into a 300 cubic centimeter Erlenmeyer flask, and wash to about 150 cubic centimeters. Add 10 cubic centimeters of potassium iodide (165-1,000) and boil until *free iodine is expelled*, — solution practically colorless, — with the reduction of arsenic to arsenous acid.



Dilute, cool immediately, neutralize approximately three-quarters of the free acid with 20 per cent. sodium hydrate solution, add starch paste, and if any free iodine remains, add dilute (N/50) thiosulfate carefully, with vigorous shaking, to the absence of blue color.



¹ Amer. Jour. Sci., 40, 66 (1890).

² Proc. Assoc. Off. Agr. Chem., 23, 165 (1906). Provisional method of the association.

Make up to about 150 cubic centimeters, add excess of sodium bicarbonate and titrate as usual with N/20 iodine, reporting as arsenic oxide. The residue in the graduated flask is brought onto the filter, washed, calcined and weighed as insoluble matter.

Care should be taken to have sufficient sulfuric acid to cover the bottom of the beaker when heated on asbestos. A decided excess of acid is also necessary when boiling with potassium iodide to insure vigorous action and rapid volatilization of iodine. Undue concentration should be avoided. If free iodine persists add more water and continue the boiling. The use of caustic soda is permissible under the conditions described. The hydrate is a much more convenient and rapid agent than the carbonate. Practically no difference was noted in the titration when the lead sulfate was allowed to remain, but the data at hand do not cover a sufficient number of samples to warrant a statement that this will always hold true.

The iodine method, as modified for arsenites and arsenates, has been given a careful study, and proved repeatedly, in the work at the Massachusetts station, to yield excellent results in the analysis of the insecticides mentioned, if reasonable attention is paid in following the details. While no radical changes in the method have been recommended, this article is offered in hopes that some of the points noted may prove of assistance to other analysts working along similar lines.

PURIFICATION OF INSOLUBLE FATTY ACIDS.

BY E. B. HOLLAND.

Workers in oils and fats experience the same difficulty in obtaining chemically pure products as investigators in other lines of organic chemistry. The best insoluble fatty acids on the market — judging from our experience — are unsatisfactory in both physical characteristics and neutralization number. In general appearance the acids that are offered resemble granulated curd, though varying in color from white to yellow, and contain considerable dust and dirt. The molecular weight, as measured by titration in an alcoholic solution, may deviate from the theoretical by 10 to 15 points. These statements apply to chemicals marked "C. P." and bearing the name of a reputable manufacturer or dealer.

The writer required stearic, palmitic, myristic, lauric and oleic acids for certain tests, and, finding it impossible to purchase them of the desired quality, was forced to undertake a study of various methods for their purification. As the character of the unsaturated acids is so unlike that of the saturated, only treatment of the latter will be considered at this time. The methods that seemed the best adapted for the purpose were (*a*) distillation of the fatty acids in vacuo, (*b*) crystallization from alcohol, and (*c*) distillation of the ethyl esters in vacuo, and all were given extended trial.

A. DISTILLATION OF THE FATTY ACIDS IN VACUO.

Direct distillation under reduced pressure was successfully employed a few years ago by Partheil and Ferie,¹ starting with Kahlbaum's best acids. Upon careful test the writer found that the method possessed certain objectionable features which render it rather impracticable for ordinary use. If it was merely a

¹ Arch. Pharm., 241, 545 (1903).

question of distillation of the acids the process would be less difficult, but for fractionation, using a Bruehl or similar type apparatus, it proved almost impossible, in case of the higher acids, to prevent solidification in the side neck (outflow tube). The danger arising from a plugged apparatus at the high temperature involved has also to be taken into account. An attempt was made to heat the tube and keep the acids liquid by means of a hot-water jacket, also by an electrically heated asbestos covering, but neither process fully met the requirements of the case. The slow distribution of heat in vacuo is, of course, one of the obstacles in the way. For the distillation of solids of high melting point Bredt and A. van der Maaren-Jansen¹ devised an elaborate piece of apparatus having a flask and receiver of special construction, and an overflow tube heated by electricity, but it is hardly suited for a general laboratory or for handling any considerable quantity of material.

There are two other conditions necessary for a successful distillation of fatty acids, namely, absence of moisture and a current of hydrogen or carbon dioxide to prevent bumping and to lessen decomposition. Overlapping of the acids in different fractions cannot be obviated entirely, and if an unsaturated acid was present in the original, it will probably appear in nearly every fraction.

Students under the direction of Professor Burrows of the University of Vermont have applied this process for a partial separation of the insoluble acids of several oils with a fair measure of success. With all due allowance for the possibilities of the method in the production of pure saturated fatty acids, the inherent difficulties render it inadvisable in most instances.

B. CRYSTALLIZATION FROM ALCOHOL.

Crystallization in this connection is practically limited in its application to the removal of a small amount of impurities, especially unsaturated acids. It can hardly be considered other than a supplementary treatment, though excellent for that purpose, to follow either of the distillation methods. Dry neutral alcohol suitable for such work can be prepared by distillation after treatment with caustic lime. In dissolving the acids care

¹ Liebig's Ann. Chem., 354, 367 (1909).

should be taken to avoid heating to a higher temperature than is required for solution, or to prolong the heating unduly, as it will cause the formation of esters. Several minutes' boiling of the different fatty acids in alcohol caused the following loss in neutralization number:—

Stearic acid,	1.70
Palmitic acid, . . . . .	.56
Myristic acid,	2.24
Lauric acid, . . . . .	.89
Oleic acid, . . . . .	.28

Esterification undoubtedly causes a serious error by this process of purification. Under more careful treatment the change is not as rapid as shown above, but is evidently cumulative and may even exceed the figures given. Further study may warrant the substitution of a more stable solvent, such as acetone. For the filtration a water or ice jacketed funnel is almost necessary, particularly for the acids of low melting point, and suction is a time saver. Repeated crystallization is needed to bring out the true crystalline structure and silvery luster of the leaflet. Vacuum drying at a low temperature is one of the most efficient means for removing adhering alcohol and traces of moisture without injuring the structure. Crystallization as a whole is wasteful of acids and solvent unless both are recovered, but is essential for the production of a superior product.

C. DISTILLATION OF THE ETHYL ESTERS IN VACUO.

As ethyl esters distill freely in vacuo, the process admits of a more ready application, and to products of a greater range of purity, than does a distillation of the acids. After considerable experimenting it was found that the esters are easily prepared by heating in an open flask equal parts (100 grams) of fatty acids and alcohol, together with a small quantity (10 cubic centimeters) of concentrated hydrochloric acid, using capillary tubes to prevent bumping. The reaction requires about thirty minutes, after which the excess of hydrochloric acid can be removed with a separatory funnel. The distillation is conducted in a 500 cubic centimeter "low" side neck flask, with a small (8 inch) Liebig condenser and a large size Buchli frac-

tionation apparatus. Heat is furnished by means of a linseed oil bath, and suction by a pump of any type, using a mercury manometer to prove constancy of vacuum. The neck of the flask from the shoulder to an inch or more above the side tube should be wound with asbestos paper to prevent cracking, due to sudden changes of temperature. The condenser should be kept full of water, without circulation, to serve as a hot-water jacket. The vacuum should be as high as the flask will safely withstand, but above all uniform, otherwise the fractions are of questionable value. The temperature range of an ester also varies with the distance between surface of liquid and side tube. At least one redistillation of like fractions is necessary.

As the esters are very stable, more difficulty was experienced in finding some means for their quantitative decomposition than in any other portion of the work. Heating with mineral acids hydrolyzes the fatty acids very slowly, even under pressure. If, however, the esters are first saponified¹ by heating over a naked flame with twice their volume of glycerol and an excess of caustic potash until all the alcohol is expelled, and then the resulting soap dissolved in water and heated on a water bath with a slight excess of sulfuric acid, the separation is readily accomplished. This plan was suggested by the Leffmann-Beam saponification for volatile acids, and after extended trial proved the most thorough and rapid means for decomposing the esters. The resulting acid should be washed in a separatory funnel with boiling water until clear, and the cake allowed to drain. As previously stated, several crystallizations are necessary if a crystalline product of satisfactory melting point and neutralization number is to be secured. When crude acids are employed it is also advisable to crystallize at the outset to exclude a major part of the unsaturated acids, which otherwise would prove troublesome.

To summarize: saturated fatty acids may be purified by distillation of the acids or their ethyl esters. The latter method is less hazardous and easier to manipulate, although more steps are required. Crystallization is a finishing rather than an initial process of purification.

¹ Observing the usual precautions given for the determination of insoluble fatty acids, Massachusetts Agricultural Experiment Station, twenty-first report, p. 130 (1909).

THE SOLUBLE CARBOHYDRATES IN ASPARAGUS ROOTS.

BY FRED W. MORSE.

This paper is a simple statement of progress in a study of the composition of the asparagus plant, and is part of an investigation of the fertilizer requirements of asparagus now being conducted at this agricultural experiment station.

The nutrition of asparagus shoots in early spring necessarily depends on the material stored in the roots, since the mode of growth of the young shoots up to the time of cutting for the table renders assimilation from the atmosphere nearly impossible. Hence, roots were selected as the first portion of the plant to be studied.

A search of the literature of asparagus failed to show anything about the composition of the roots beyond a few scattering ash analyses and a brief article by Vines¹ on the reserve proteins.

Very recently, however, Wichers and Tollens² have reported an extensive study of asparagus roots, and called attention to similar work by Tanret,³ brief abstracts of whose articles had been overlooked.

Since the work has been wholly independent of that just mentioned, it is believed that this report of progress will be of value at this time.

All the material for the work here reported was prepared in other divisions of the department, and consisted of finely pulverized samples of individual root systems. All of the plant below the surface had been dug up, freed from earth and dried

¹ Proc. Royal Soc., 52, 130-132; Abstr. Jour. Chem. Soc., 64, 431.

² Jour. f. Landwirth., 58, 101-116.

³ Bul. Soc. Chem. (4), 5, 889, 893; Compt. Rend., 149, 43-50; Abstr. Jour. Chem. Soc. (1909), Abstr., 634; Chem. Abstr., 3, 2677.

at about 50° C. The roots were secured in November of the second year after setting, when translocation from the tops was believed to be complete. For subsequent study of the effects of different fertilizers the individual samples were separately analyzed; but for this report detailed results are unnecessary.

The average proximate composition of the dry matter of 16 roots was as follows:—

	Per Cent.
Protein (nitrogen x 6.25).	11.03
Fat.	1.00
Fiber.	15.39
Nitrogen-free extract.	66.34
Ash, ¹	6.24

The proximate composition showed clearly that the soluble non-nitrogenous matter included most of the reserve material of the roots.

The methods of the Association of Official Agricultural Chemists² for sugars, starch, pentosans and galactans were employed for estimating the different carbohydrates in the reserve material.

An examination of 25 roots showed 12 to contain no reducing sugars, while most of the others had only traces present; therefore reducing sugars were not estimated, but were reckoned with total sugars. The latter were especially abundant, and ranged from 26.4 per cent. to 50.8 per cent., only two samples containing less than 35 per cent. calculated to dry matter.

Pentosans were determined in 16 samples, and ranged from 7.32 per cent. to 10.68 per cent. in the dry matter. Galactans were determined in 4 individual samples and in a composite sample, but were insignificant in amount, averaging only 1.04 per cent.

In the estimation of starch by the diastase method, it was found that there was no more glucose obtained than was accountable from the diastatic extract. Subsequent examination revealed starch in only microscopic traces. Six different samples, after having undergone the diastase treatment as for starch,

¹ Ash determinations were made in the fertilizer division of the department.

² Bulletin No. 107, Bureau of Chemistry, United States Department of Agriculture, pp. 38-56.

were filtered and washed, and the residues then subjected to two hours' boiling under reflux condensers, with 100 cubic centimeters of HCl of approximately 6 per cent. After cooling the solutions they were nearly neutralized with NaOH, and made up to 250 cubic centimeters. The reducing sugars were then determined by Fehling's solution and the weights of copper calculated to glucose. The 6 samples averaged 8.6 per cent. of glucose by this hydrolysis; but since the same samples averaged 8.67 per cent. of pentosans, reckoned from furfural-phloroglucid, it is improbable that there are any hydrolyzable carbohydrates unaccounted for by the usual analytical methods.

From these different analyses it was found that the dry matter of 16 roots contained —

	Per Cent.
Sugars calculated as invert sugar,	41.43
Pentosans,	8.78
Galactans,	1.04

The carbohydrate forming over 40 per cent. of the dry matter was at first assumed to be sucrose. The analytical procedure had shown it to be soluble in cold water and inactive to Fehling's solution until hydrolyzed, which was easily accomplished by dilute acids. Repeated attempts to recover sucrose by means of strontium hydrate¹ resulted in securing only very small quantities of a straw-colored syrup which could not be crystallized, but did not reduce Fehling's solution.

Methyl alcohol was found to extract considerable quantities of the sugar from the roots, which suggested raffinose; but no mucic acid could be obtained by oxidation with nitric acid, although a parallel test with lactose under the same conditions yielded it in abundance.

Osazones were prepared from both methyl alcohol and water extracts, before and also after inversion. The characteristic yellow, crystalline precipitate was easily obtained in every case. Five such precipitates had their melting points determined, and they ranged between 203 ° and 210 °, and were accompanied by an evolution of gas. Glucosazone was evidently the only one formed.

¹ E. Schulze, *Zeitschr. Physiol. Chem.*, 20, 513-515.

About 100 grams of roots were extracted by cold water and the extract concentrated on the water bath to a thick, black, tenacious syrup, which was strongly reducing to Fehling's solution. Heat and probably acid salts had brought about a nearly complete hydrolysis during the evaporation. This extract failed to yield mucic acid, but oxalic acid was readily formed.

Portions of the syrup were subjected to distillation with HCl of 1.06 specific gravity, and yielded a small quantity of furfural. The furfural-phloroglucid, after being dried and weighed, was found to lose about two-thirds of its weight by solution in hot 93 per cent. alcohol, indicating that it was largely methyl-furfural.

The action of polarized light was observed upon freshly prepared water extracts of two different roots, and upon three syrups which had been fractionated by strontium hydrate. The solutions were clarified by lead subacetate, and the readings were made in a Schmidt and Haensch triple shade saccharimeter through a 200 millimeter tube. The solutions were then inverted and again polarized, together with two solutions of the dense water extract above mentioned.

Subsequent to the readings, the actual strength of sugar in each solution was determined with Fehling's solution. The solutions were necessarily dilute, because the roots on moistening swelled to a large volume and small charges had to be used. The three syrups were small in amount, as before mentioned, and the black syrup from the water extract was difficult to clarify to a point where light would pass through it.

Polarization before Hydrolysis.

	Sugar in 100 Cubic Centimeters (Grams).	Saccharimeter Reading.	Specific Rotatory Power (Degrees).
Root 34,	1.738	+0.5	+5.0
Root 40,	2.259	-1.4	-10.0
Syrup A,	2.623	+2.88	+18.9
Syrup B,	2.775	-1.6	-10.0
Syrup C, . . . . .	.858	zero	zero

Polarization after Hydrolysis.

	Invert Sugar in 100 Cubic Centimeters (Grams).	Saccharimeter Reading.	Specific Rotatory Power (Degrees).
Root 34, . . . . .	.893	-2.33	-45
Root 40,	1.189	-4.10	-59
Syrup A,	1.381	-3.45	-49
Syrup B,	1.461	-5.25	-62
Syrup C, . . . . .	.452	-1.30	-49
Extract 1, . . . . .	.936	-3.00	-55
Extract 2,	2.350	-7.80	-57

The action on polarized light both before and after inversion excludes the possibility of the carbohydrate being pure sucrose, while the failure to secure it with strontium hydrate renders its absence probable.

Fructose was clearly demonstrated by the osazone and the negative optical activity, also by fine reactions with resorcin and hydrochloric acid. Glucose is indicated by the osazone and the fact that the specific rotatory power of the inverted solutions is not high enough for pure fructose. Fructose clearly predominates over the glucose, and the non-reducing property before hydrolysis indicates some condensation product formed between them. The behavior of individual root extracts does not point to any fixed proportion of the two sugars.

These results are, on the whole, in close agreement with those of Wichers and Tollens. There was, however, a marked difference in the behavior of the water extract of the roots, which contained the sugar-like carbohydrate. Wichers and Tollens used boiling water, and state that only a portion of this carbohydrate was soluble in water when extractions were made on the water bath. Their solutions also reduced Fehling's solution before hydrolysis.

My extractions were all made with water at 20° C., and until hydrolyzed, had either no reducing action or precipitated no more than traces of copper.

This difference in solubility and reducing action is doubtless

due to the stage of development of the roots, since Wichers and Tollens worked upon roots gathered in April and July instead of in November.

Tanret isolated two distinct crystalline carbohydrates from the root sap, one of which had a rotation of -35.1 and the other $+30.3$. Syrups A and B fractionated with strontium hydrate showed opposite rotations before inversion, but lack of material has given no opportunity to confirm further his observations.

Grateful acknowledgment is made of suggestions received from Dr. Joseph B. Lindsey during the progress of this investigation.

SEED WORK, 1910.

BY G. E. STONE.

The seed work for 1910 includes seed germination, separation and the testing for purity. The number of samples of seed sent in for germination exceeded that of 1909, the total number being 296. This germination work seems to be on the increase from year to year, and a great many more varieties of seed are tested for germination than has been the case in the past. Of the total number of samples sent in this year, 152 were miscellaneous seeds, a trifle over 50 per cent. of the total number. The number of samples of onion seed sent in was a little less than in 1909, and tobacco averaged about the same. The average germination of the tobacco seed, 95 per cent., was slightly better than usual. The lowest germination of any sample of tobacco seed sent in was 89 per cent. On the whole, onion seed last year did not seem to be up to the previous year's standard, as the average germination of all samples was only 77.4 per cent., as against 82.2 per cent. in 1909. The germination of the tobacco seed, with a lowest percentage of 89, tends to prove the theory that large seeds produce large plants; therefore in succeeding years better crops are obtained, and, as a result, better seed.

TABLE 1. — *Records of Seed Germination, 1910.*

KIND OF SEED.	Number of Samples.	Average Per Cent.	PER CENT. OF GERMINATION.	
			Highest.	Lowest.
Onion,	75	77.4	100.0	3.0
Tobacco,	7	95.0	99.0	89.0
Lettuce,	41	77.7	100.0	15.0
Cucumber,	10	93.7	99.0	85.0
Alfalfa,	4	98.2	100.0	97.0
Clover,	4	93.0	97.0	88.0
Red clover,	3	100.0	99.5	98.5
Miscellaneous,	152	66.0	100.0	-
Total,	296	-	-	-

The work in seed separation for 1910 was carried on as usual, and although a smaller number of samples was separated than in 1909, the total amount of seed separated, 1,552 pounds, was greater. Of this, 1,183 pounds were onion seed. The principal varieties of seed separated were onion, tobacco and lettuce. The separation of onion seed also tends to show that the seed was not as good this year as it was in 1909, as the average percentage of good seed was only 88.7 per cent., while the amount of discarded seed was slightly larger than in 1909. As in years past, several growers have requested that this station test the germination of seed both before and after separation, and the results this year resemble those of previous seasons so closely that they will not be inserted in this report. In the case of the separation of lettuce seed, the grower sending the seed often requests that a certain amount, sometimes in excess of the actual need, be taken out. This, however, is believed to be a good practice in the case of lettuce or tobacco seed, as it is certain that better germination results from removing more than is absolutely necessary. Table 2 shows the records of seed separation for 1910.

TABLE 2. — *Records of Seed Separation, 1910.*

KIND OF SEED.	Number of Samples.	Weight (Pounds).	Per Cent. of Good Seed.	Per Cent. of Discarded Seed.
Onion,	40	1,183.82	88.7	11.3
Tobacco,	62	44.96	89.6	10.4
Lettuce,	13	323.45	74.4	25.6
Total,	115	1,552.23	-	-

No effort has been made on the part of the station as yet to establish and maintain a seed-control laboratory for the purpose of testing the purity of seed, and therefore in the past year the number of samples of seed sent in for examination as to their purity has been small. In all, some 30 samples have been examined; mostly clovers and grasses, but as this work takes considerable time, no grass mixtures have been examined for purity.

The station is always glad to receive samples of seed for germination, and it is believed that if the farmer would send his seed in for examination for purity also, he would very often save himself a great deal of trouble and expense, as much of the seed sold in this State is full of weed seeds. It is believed that there should be a seed-control act in Massachusetts, as has been stated in our previous reports, and the sooner this comes the better the farmer will be served by the seedsmen, since they are perfectly willing to handle good seed if it is what the farmer wants and demands.

All samples of seed to be germinated or separated should be addressed to G. E. Stone, Massachusetts Agricultural Experiment Station, Amherst, Mass., and the express or freight on these seeds should be prepaid.

AN OUTBREAK OF RUSTS.

BY G. E. STONE.

For the past three years certain rusts have increased materially in this State as well as in other sections of the United States. The rust on the apple, which has been scarcely noticeable for years, at least on our cultivated fruit trees, has become quite common the last three seasons. It was particularly prevalent three years ago, and quite a little of it has been noticed on apple leaves the past two years. The hawthorne (*Crataegus*), a plant closely related to the apple, has shown a much greater tendency to rust in the period above mentioned than formerly, and some anxiety has been felt by nurserymen who have had to contend with this in their nurseries.

The ash rust, which is supposed to have as one of its hosts the grass known as *Spartina*, has occurred much more commonly than usual during this period. It is to be found on young growths of ash trees, distorting the twigs. There have also been severe outbreaks of the bean rust lately, although this has given little trouble in former years; and the hollyhock, rose and quince rusts have been much more common than formerly.

SWEET PEA TROUBLES.

BY G. E. STONE.

One of the most unsatisfactory types of troubles with which the pathologist has to deal is that having no specific organism as its primary cause. It is especially difficult to diagnose such diseases where the conditions of growing the plants are almost entirely unknown, and this is the case with most of the miserable, sickly looking sweet pea plants sent into the laboratory for diagnosis. There may be well-defined troubles associated with sweet peas, but from 90 to 100 per cent. of them may be prevented if the grower has even an elementary knowledge of the conditions required by this plant.

When sweet peas are planted in poor soil, without care or preparation, unfavorable results may be looked for. That such is too often the case is evident from an examination of the material which is sent in for examination. To obtain a good crop of sweet peas unusual care should be given to preparation. A light soil is better than a heavy, compact soil. It is impossible to grow this crop without a good depth of garden loam, and, if this is not available, it must be secured by deep trenching and heavy manuring. Most skillful gardeners maintain that the best results are obtained by having a soil which the sweet pea roots can penetrate deeply, and in which they can develop luxuriantly.

A trench $1\frac{1}{2}$ to 2 feet deep and the same width, filled with manure and loam, is usually sufficient. If a good depth of root development is desired, it is best to sow the seeds in trenches 4 to 6 inches below the surface, and as the plants mature the soil can be gradually hoed around the stems. The many specimens which we receive from growers testify to the poor conditions in which the plants have been grown, there being little root or stem development, and often tubercles on the roots are lacking. Proper conditions count very much in growing sweet peas, and when these are given, many so-called "diseases" peculiar to this plant disappear.

A SPINACH DISEASE NEW TO MASSACHUSETTS.

BY HARRY M. JENNISON, B.S.

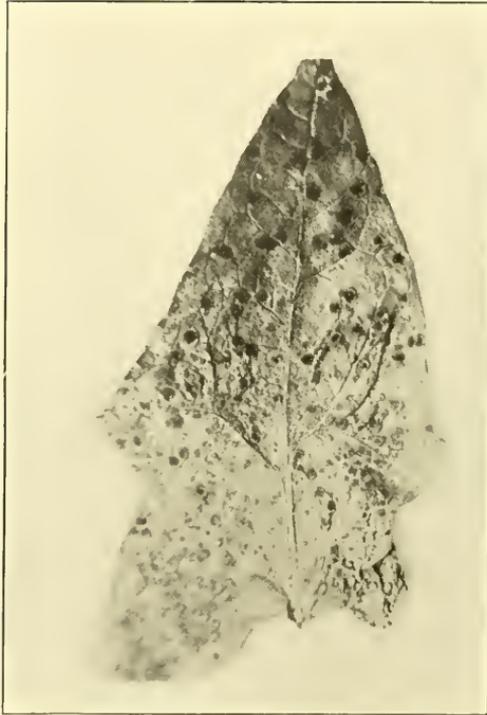
Early in the spring of 1910 the writer's attention was attracted to a plot of winter spinach growing on the college grounds which had been practically ruined by a fungus causing a spotting of the leaves. The olivaceous color of the spots on the diseased leaves suggested the possible presence of a *Cladospodium* as the causal organism, but upon microscopical examination the fungus was determined to be *Heterosporium variable*, Cke. This organism is closely related to that causing the *Heterosporium* disease of cultivated carnations, known as "fairy ring."

It was supposed that a disease which could so completely devastate this crop would have been extensively reported, but upon thorough search of the literature only a few references to this particular spotting of spinach could be found. In 1905 Clinton¹ reports having collected in the open market in New Haven, Conn., specimens of spinach leaves affected with the above-mentioned fungus, and he refers to it as "leaf mold." Halsted² in his investigations on the fungi attacking the spinach plant does not include *Heterosporium* in his list. Since 1908 Reed³ has been studying its occurrence and injurious effects in the truck crop regions of Virginia, where it causes large losses annually to the truck farmers of that State. At Amherst the disease was found infecting winter spinach, growing on two widely separated plots. Immediately adjacent to one of these was a considerable area set with young spinach

¹ Clinton, G. P., Connecticut Agricultural Experiment Station, report for 1905, Part V., p. 275.

² Halsted, B. D., New Jersey Agricultural Experiment Station Bulletin No. 70, 1890.

³ Reed, H. S., in Virginia Agricultural Experiment Station circular No. 7, revised edition, p. 80, 1910.



Showing *Heterosporium* Disease of Spinach.

plants for the late spring crop. Careful examination, however, failed to reveal any indications of this disease on the young plants. As has been suggested, this fact seems to indicate that the causal organism is not a true parasite, and that it cannot infect healthy, vigorous plants, being more probably one that is capable of infecting its host only after the latter has become weakened by adverse climatic conditions, or injuries produced by other causes.

Further observations upon this interesting phase unfortunately could not be made, but in a recent text-book on the "Diseases of Economic Plants"¹ the following statement is found:

"The disease does not seem capable of attacking healthy, vigorous plants, but usually follows injuries produced by other agencies."

The first indications of the presence of the disease are sub-circular areas of dead tissue from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in diameter and brownish in color. (See cut.) These spots soon become more noticeable by the development of a greenish-black felt of fungous mycelium, bearing conidiophores and conidia, on both the upper and lower sides of the leaf. The spots are frequently more numerous toward the apex of the leaf, and by the time the fungus felt is well developed, the intervening leaf tissue is yellowed and presents a sickly appearance. Often the leaf is so badly infected that the diseased areas coalesce, leaving very little of the leaf tissue visible.

The market value of the crop is lessened if the leaves are at all spotted, and when badly diseased it is not salable. Even if the whole plant does not collapse from the effects of the fungus, it is greatly injured, and trimming off the injured leaves necessitates extra labor and expense at harvest time.

Since the disease is new to this locality, and there have been such limited opportunities to study it and the factors responsible for it, it is impracticable to offer any remedies at present. If the disease is sporadic, and caused by adverse conditions, the proper remedy would be to find out what those conditions are and remedy them. On general lines, however, it would be well

¹ Reed, in Stevens & Hall's "Diseases of Economic Plants, — Heterosporiose," p. 288, 1910.

to employ sanitary methods in growing the crop, to use seed from healthy and vigorous plants, and try to prevent injuries from insects, etc.

ADDITIONAL REFERENCES.

Reed, *Science*, n. s., Vol. 31, p. 638, 1910.

Cooke, *Grevillea*, Vol. 5, p. 123, 1877.

Tubent & Smith, "Diseases of Plants," p. 516, 1897.

"Market Gardener's Journal" (Louisville, Ky.), Vol. 7, No. 5, 1910.

ABNORMALITIES OF STUMP GROWTHS.

BY GEORGE H. CHAPMAN.¹

For the past few years there have been called to our attention on stump land and burned-over wood lots various malformations and abnormalities of the leaves of sprouts growing from the stumps; and in connection with other physiological work being done in the laboratory,² these conditions were studied, with the idea of discovering, if possible, the cause and relationship to other physiological diseases, such as those arising from malnutrition; also mosaic disease, overfeeding and œdema.

These diseases are all different in character, but it might be well to give a brief description of them at this point.

Overfeeding, particularly with nitrates, may be recognized by a slight increase in size of leaf, the color being darker and the leaf stiffer in texture. The cells of the leaf, with the exception of the bundles, are normal in form and are larger, but the bundles are distorted, and this causes a distortion of the leaf, due to the form of the bundles. The leaf is usually somewhat larger than normal, and the distortion curves the edges of the leaf downward, *i.e.*, rolls them toward the under side.

All investigators agree that the mosaic disease is purely a physiological one, but there seems to be much doubt as to whether it is infectious or contagious in character, or both. There seems to be some difference in opinion, also, as to the direct cause of the disease. In tomatoes it is always produced when the vines are heavily pruned, and in the work here it has been shown that it is connected in no way with methods of transplanting the young plants, and only results from subsequent pruning.

It has been found that tobacco is much more susceptible un-

¹ Presented as part work for degree of M.Sc.

² Dept. of Veg. Phys. and Path., Mass. Agr. Exp. Sta.

der conditions which tend to produce the disease than is the tomato.

In the case of tobacco, A. F. Woods¹ found that when a plant was grown in soil containing small roots of diseased plants the disease occurred in a short or long period of time, as the case might be. In our observations on the tomato we have been unable to verify this statement, as in no case has the disease appeared when normal plants were grown in soil which contained roots of plants which had been badly diseased, and in the growing of tomatoes year after year in the station greenhouses there has never been the slightest evidence of infection arising from the soil.

In the case of the tomatoes grown under glass, the disease did not make its appearance when the plants were left normal, but occurred when the plants were pruned. These conditions held true for soils in which there were diseased roots as well as for those in which tomatoes had not previously been grown.

The appearance of mosaic disease has been described by many investigators, and nearly all have described it in a similar manner, but more particularly with reference to tobacco than to the tomato. The general characteristics of the disease are the same for both plants, but some difference is found in its appearance in extreme cases on the tomato, as will be noted from the following description.

In the first stages of the disease the leaf presents a mottled appearance, being divided into larger or smaller areas of light and dark green patches. At this point, however, no swelling of the areas is noticeable, but as the disease progresses the darker portions grow more rapidly, while the light-green areas do not grow so rapidly, and leaf distortion is brought about. In the case of tomato, the light-green areas become yellowish as the disease progresses, and in badly affected plants become finally a purplish red color. This purplish coloration is found principally on plants which are exposed to strong light, but does not always occur, as it has been found that sometimes, even in badly infested plants, the disease may reach its maximum without showing any reddish coloration whatever. The reddish

¹ U. S. Dept. Agr., Bur. of Plant Ind., Bul. No. 18.

appearance is noticeable only on the upper surface of the leaf, and appears to extend only through the palisade cells. As yet no investigation has been made with reference to its character, but from its appearance under the microscope it is thought that it may be due to the breaking down of the chlorophyll granules as a result of the diseased condition of the leaf.

Under all conditions of disease, however, the leaves are much distorted and stiff, and often very badly curled, usually with the edges rolled up over the leaf, and never possessing the flexibility of healthy, normal leaves.

Œdema is perhaps the least liable to be confounded with other physiological troubles as its appearance is more strongly characteristic. Only a brief description will be given here, as this trouble does not enter into the discussion in this paper. Usually the leaves, as a whole, hang pendent, but the leaflets curl strongly upward; on close examination it is found that the veins, midrib and surface of the leaf show elevated more or less frosty areas, somewhat resembling the masses of conidia of some of the *Erysiphæ*; although in mild cases this condition is not striking, but the leaves usually have a more or less pearly luster at some stage of its development. The epidermal cells are very much enlarged in these areas and turgid, and the chlorophyll-bearing cells are also greatly changed. For a detailed description and discussion of this trouble no better work can be found than that of G. F. Atkinson.¹

It can be seen from these brief descriptions that unless care were exercised it might be easy to confound these troubles, especially in the case of the first two. Keeping this in mind we will pass on to a more detailed description of the malformation of stump growth subsequent to the burning off or cutting down of large trees.

The malformation appears to be worst in the first two or three seasons' growth, the sprouts outgrowing the trouble as their age increases. From our observations this trouble appears to occur in two distinct forms: first, as an abnormal growth of stem and leaves, they sometimes reaching a size five to ten times that of normal young plants of the same species. This form of the

¹ N. Y. (Cornell Univ.) Agr. Exp. Sta., Bul. No. 53, "Œdema of Tomato."

leaf was especially noticeable in such sprouts as ash, poplar and plane tree, and sometimes occurred also on chestnut and oak, although it may be mentioned that they were occasionally very much distorted.

When the leaves were simply abnormally large it was found that the structure of the cells and their relative positions were analogous to a healthy, normal leaf, but that they were relatively much larger, and were of a stiffer texture than the normal specimens.

Very often it was found that the cell contents, especially the coloring matter, were brought into undue prominence, richly colored red leaves being of frequent occurrence. Occasionally, also, leaves having a decided yellow color, but otherwise appearing strong and healthy, were observed. This excessive coloration was evidently due to the abnormal deposition of pigment or activity of colored cell sap. When the leaves were green, the color seemed to be deeper than that of normal specimens.

The second form of the malformation has much the appearance of that caused by overfeeding, or excessive use of nitrates; *i.e.*, a severe distortion of leaves, but in this case accompanied by excessive production, usually smaller in size than the normal, but thickly clustered. Distorted leaves did not usually show much abnormal coloration, but occasionally a reddish or yellowish color was observable.

Usually the leaves were much more numerous and very badly distorted, the veins and ribs being especially twisted in various ways. The texture of the leaf was very stiff, much more so than in the case of the abnormally large leaves, the tissue having hardly any elasticity, and breaking easily, with a crackling sound. Plates I. and II. (Figs. 1, 2 and 3) show the two forms of this trouble better than mere description.

There is a remarkable dearth of literature bearing on this specific trouble, although much has been written in a general way on somewhat similar physiological troubles, but dealing principally with field crops and forced plants. In the reports of the various experiment stations will be found more or less literature on physiological troubles, and Woods,¹ Suzuke,² Stur-

¹ U. S. Dept. Agr., Bur. Plant Ind., Bul. No. 18.

² Bul. Col. Agr., Tokyo, Vol. IV., repts. for 1900.



FIG. 1.—Chestnut (*Castanea dentata*), showing Diseased (Left) and Healthy (Right) Shoots.



FIG. 2.—Red Oak (*Quercus rubra*), showing Diseased (Left) and Healthy (Right) Shoots.

PLATE I.



FIG. 3.—Poplar (*Populus grandidentata*), showing Diseased (Right) and Healthy (Left) Shoots.

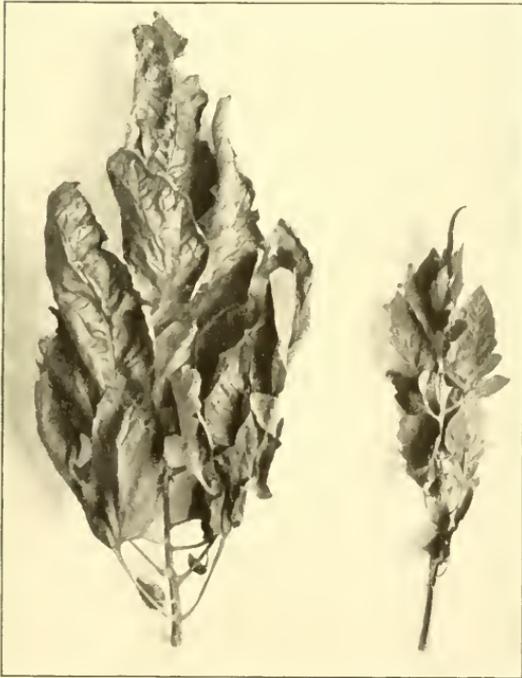


FIG. 4.—Mosaic Disease on Tomato.

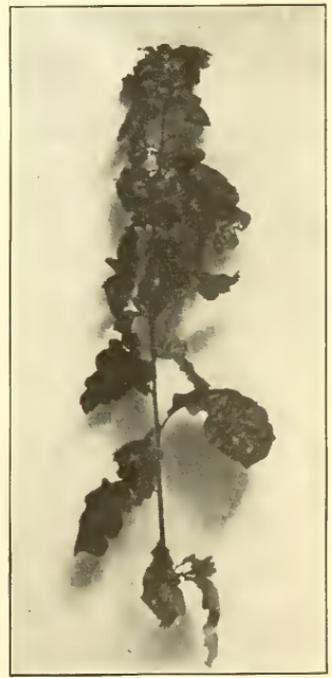


FIG. 5.—White Oak, showing Diseased Shoot.

PLATE III.

FIG. 1.—Mature pycnidia, showing a few unicellular hyaline spores and orifice from which they have been expelled.

FIG. 2.—Nearly mature pycnidia, with attached *Alternaria* spores.

FIG. 3.—Mycelium threads giving rise to *Alternaria* spores and an immature pycnidium.

FIG. 4.—Common type of *Alternaria*.

FIG. 5.—Conidial form of *Cladosporium* developed from microsclerotia found on gummy excretions.

All from camera lucida drawings.

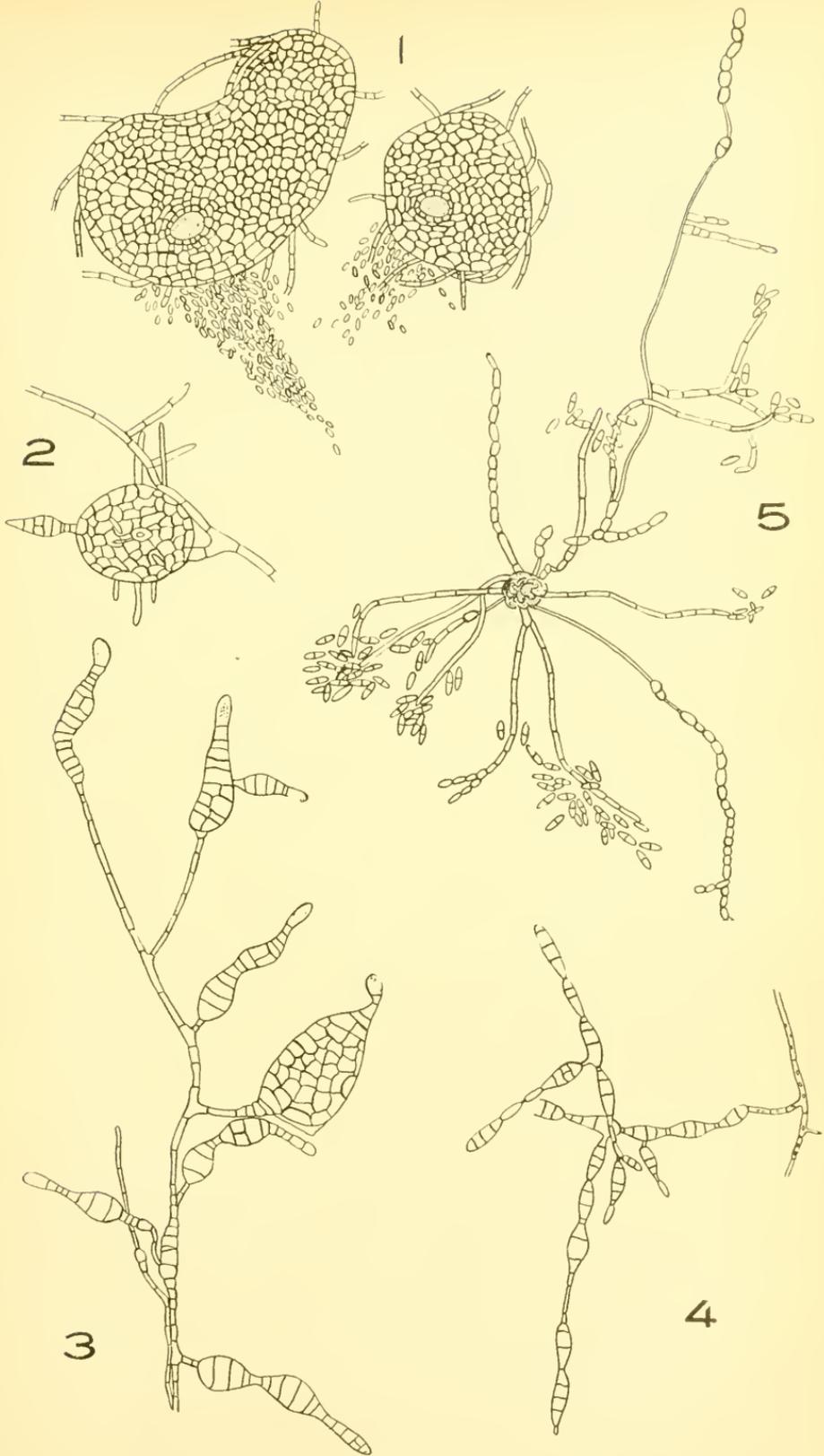


PLATE III.

gis,¹ Czapek,² Stone,³ Atkinson⁴ and others have dealt with various physiological troubles more in detail.

From our observations and experiments in the field and greenhouse we have come to the conclusion that it is a well-developed form of malnutrition, using malnutrition in its broadest meaning, *i.e.*, to include any physiological trouble which is caused by an excess or lack of any one or more nutritive substances necessary for the normal metabolism of a plant, and is allied to the phenomena exhibited in a severe case of overfeeding.

Logically it is what one would expect when a large tree is suddenly cut off or the top killed, and practically all transpiration, respiration, or, in short, all photosynthesis and leaf metabolism, is suddenly arrested. We have a violent disruption of the normal metabolism of the tree. The balance between root absorption, photosynthesis, etc., and the metabolic processes of the leaves is suddenly broken, and we have the roots, which are still alive, attempting to do their normal work without the aid of the leaves; starch formation is arrested and carbon assimilation cannot take place. In the roots there remains a great reserve store of food and during the winter no root pressure. As most woods are cut in the fall and winter, the trees are dormant, and forest fires also occur largely in fall and spring during this dormant period. Now, when spring comes and circulation starts, the adventitious buds are called upon to produce new shoots for the utilization of the reserve food in the roots. This they try to do in the manner we have described, by producing abnormally large leaves or a great number of small and distorted leaves. This distortion will be discussed later.

Of the trees which have come under our observation, maples, oaks and chestnuts seem to be the most susceptible to leaf distortion, while such trees as the ash, poplar and plane usually have abnormally large leaves with very little distortion. However, in some cases both conditions are observable.

The theory which has been advanced above as to the cause of the disease has been borne out by experiments carried on in the

¹ Conn. Agr. Exp. Sta., 1898, and others.

² Biochemie der Pflanzen (general).

³ Mass. Agr. Exp. Sta. reports.

⁴ N. Y. (Cornell Univ.) Agr. Exp. Sta., Bul. No. 53.

field and laboratory. The results of these experiments will be discussed later in the paper.

RELATION TO MOSAIC DISEASE.

It was at first thought that there might be some relation between the so-called "mosaic disease" and this, but from our observations we have been able to find only a superficial relationship, *i.e.*, as regards the distortion of the leaf in its first stages. Other investigators,¹ as has been previously mentioned, have proved that the "mosaic disease" can be communicated from one plant to another by inoculating a healthy plant with the juice of a diseased plant, and that the new growth subsequent to the inoculation will come diseased in nearly every case. This is not so in the case of sprout growth, however, as in no instance were we able to bring about a diseased condition of normal plants by inoculating them with juice taken from diseased leaves. As it was impossible to carry on these inoculation experiments in the laboratory, the work was done in the field, and observations taken from time to time.

EXPERIMENTS IN INOCULATION.

In order to prove that, unlike mosaic disease, this malformation could not be communicated from a diseased sprout to a healthy one, the following experiments were made. Two series of ten inoculations each were made; in one case diseased tissue was inserted at the base of the terminal bud of normal, healthy sprouts; in the second series the terminal buds of healthy sprouts were inoculated with the filtered juice from diseased plants. In all cases a healthy plant was inoculated with the tissue or juice of a malformed plant of the same kind, *i.e.*, a maple was inoculated with juice from a diseased maple shoot, etc. In not one case could we find that the trouble was either contagious or infectious in character. The results of these inoculations are given in Table I., and from these results it is evident that the disease cannot be communicated from one plant to another.

¹ A. F. Woods, U. S. Dept. Agr., Bur. Plant Ind., Bul. No. 18.

TABLE I.

SERIES A. — *Showing Results of Inoculation of Healthy Young Growth with Tissues from Malformed Plants.*

PLANT.	Number inoculated.	Number diseased.	Remarks.
Maple (<i>Acer rubrum</i>),	10	None.	The terminal bud died in two cases, but this was due to mechanical injury.
Chestnut (<i>Castanea dentata</i>),	10	None.	
Oak (<i>Quercus alba</i>),	8	None.	
Poplar (<i>Populus tremuloides</i>),	10	None.	
			The terminal bud died in three cases, but this was due to mechanical injury.

SERIES B. — *Filtered Juice used for Inoculation.*

PLANT.	Number inoculated.	Number diseased.	Remarks.
Maple (<i>Acer rubrum</i>),	14	None.	Inoculated twice two weeks apart with juice.
Chestnut (<i>Castanea dentata</i> , Borkh.),	11	None.	
Oak (<i>Quercus alba</i>),	10	None.	
Poplar (<i>Populus tremuloides</i>),	10	None.	
Ash (<i>Fraxinus Americana</i>),	5	None.	

The appearance of the leaves of "mosaic" plants is usually different from that of diseased shoots in the case under discussion. In mosaic these are flattened areas of cells which are lighter in color than the normal areas, and which are also smaller in size, growing more slowly than the normal cells, this causing a general unevenness or distortion of the leaf.

On the other hand, in the trouble under discussion, where abnormality occurs, the tissue of the leaf itself is not so much distorted as the vessels and veins. These are usually curved more or less, and thus distort the leaf. The leaf, also, is always of a healthy dark-green color, and shows no division of color into light and dark areas. Plate II. (Figs. 4 and 5) shows a typical mosaic leaf and some from affected sprout growth.

The cause of mosaic is not exactly known, but it has been produced repeatedly by severe pruning in the case of tomatoes,

tobacco and other allied plants. It occurs on tobacco, also, without pruning in the field, due to some functional disarrangement in all probability; but in the case of tomato we have not been able to find a case in which the disease occurred on a plant which was allowed to grow normally, that is, without pruning. Plants in the field are also not so susceptible to it, and it is rather difficult to conceive just why it is that under similar conditions, but with different plants, we sometimes get the characteristic mosaic disease and sometimes only a condition such as the one under discussion.

RELATION OF ROOT AREA TO INTENSITY OF DISEASE.

In the course of our experiments it was observed that in the same locality, with the same kinds of trees, there was a marked difference in the intensity or severity of the malformation. It was thought that the size of the original tree and its corresponding root area might bear some relation to the severity of the disease. Rough estimates were made of several root systems from which first-year sprouts were growing which were diseased, and in general it was found that the larger the root area the more distortion of the leaves. This seemed to be the general rule, but from the limited number of observations we were able to make it would be unwise to make a positive statement as to the absolute truth of this observation.

When young trees had been cut down or killed by burning, there was not such severe distortion, but more of a tendency to produce abnormally large leaves. As a result of our observations it may be stated that there is a relationship existing between the amount of active root surface and the severity of the trouble along the lines we have pointed out.

It has been stated elsewhere in this article that the severity of the disease diminishes from year to year as the plant grows older, and it would be natural to expect such a recovery for two reasons: first, the shoot is larger the second year than the first, thus having more leaf surface to effect transpiration, respiration, carbon assimilation, etc.; and secondly, some part of the root system, owing to lack of food (available), which the first year's leaves have been unable to supply, has died from general

weakening; thus the second year, and so on from year to year, we have a general attempt to balance up the root system and the leaf system. It is believed that this view is in accordance with the truth, although no specific work has been done here to prove it other than general observations.

CHEMICAL TESTS OF ABNORMAL LEAVES.

In view of the fact that physiological diseases in general are principally caused by derangement of the function of some organ of a plant, as a result of poor nutrition (lack or excess of some necessary plant food), it was thought that it would be well to obtain, in a general way, an idea as to the presence and absence of certain substances in the leaves of diseased plants. Owing to pressure of other work it was necessary to use dried specimens for examination. The specimens, however, were not over one or two months old when the examinations were made, therefore no great change of constituents could have taken place, with the exception of loss of water, and this was not of any importance. A complete analysis was not made of the leaves, but comparative tests were made, comparing the substance in healthy leaves with the same amount of diseased leaves. The substances tested for were principally nitrates, enzymes and starch.

As Woods¹ in his bulletin on mosaic disease advances the theory that it is caused by an excessive amount and increased activity of oxidizing enzymes, such as oxidase and peroxidase, equal amounts of leaves from healthy and diseased leaves were tested to see if there was any increase or decrease in the relative amounts present. It was found that in general there was usually present in diseased leaves a slightly larger amount than in the healthy leaves, but it was not necessarily so, as in five cases out of eighteen there was less present; but this may possibly have been due to individual variation in the leaf itself, as the method of taking equal weights of leaves for examination has some drawbacks, but no better method has as yet suggested itself.

It was found that catalase, another enzyme which was discov-

¹ *Loc. cit.*

ered in connection with tobacco by Loew,¹ was present in both healthy and diseased leaves in comparatively small amounts, but that there was practically no difference in the amounts present. Twenty samples of healthy and diseased leaves were tested, and below will be found a table containing the averages of these tests. The comparative amounts present were represented by the oxygen developed from a standard solution of hydrogen peroxide, which contained 3 per cent. H_2O_2 .

TABLE II. — *Amount of Oxygen developed from Healthy and Abnormal Leaves.*

[Averages of twenty samples.]

	Number of Samples.	Amount of Oxygen developed.	Time.
Abnormal,	20	118.5	30 min.
Healthy,	20	114.0	30 min.

The samples were shaken during the test, as this has been found to increase the amount of oxygen developed.

Fifteen grams of leaves were used in each case.

Individual variations were found in most cases between leaves of different kinds, but not sufficient to warrant distinctive mention.

Thus, in respect to the amount of catalase present we find that there is a difference between this disease and mosaic, for in the case of mosaic disease there is less catalase present in the diseased leaves than in the healthy ones.²

Colorimetric tests of healthy and diseased leaves were made to determine the relative amounts of nitrates present, and it was found that in the case of diseased leaves a deeper color was obtained than in the case of healthy specimens. The test for nitrates used was the well-known diphenylamine reaction. Only approximate results were obtained, but sufficient to show that nitrates were more abundant in diseased leaves than in normal specimens. This tends to confirm the idea that this disease is more a form of malnutrition or overfeeding than a specific trouble, such as "mosaic."

Aside from the direct work on the disease it was observed in some few cases that diseased leaves were more liable to the

¹ U. S. Dept. Agr., Report No. 68.

² Mass. Agr. Exp. Sta. report, 1908.

attacks of leaf-sucking insects, such as aphids, etc., as in a few instances specimens of diseased shoots were obtained which showed the effects of these insects, and some aphides were found also. No insects were observed, however, on healthy shoots, or to so great an extent on shoots which had only a slight indication of the disease in question. It appears from our observations that the disease renders the shoot more liable to the attacks of insects on account of its weakened condition, in some respects it being far more normal; also, the attacks of insects intensify the disease by taking from the leaf a large amount of proteids and sugars. The effects of insects have been noted by various authorities, among which may be mentioned Woods¹ and Suzuki.² More specific and interesting facts on this point might be brought out by further observations and detailed study in conjunction with entomologists, but this is without the scope of the present paper. It is, however, true that insects seem to prefer a diseased leaf to a healthy one under these conditions.

More purely chemical work would undoubtedly be of great interest in connection with this interesting disease, and no doubt will find a place in a future report, but it is thought that enough has been done with the disease to bring out several new points in regard to it.

CONCLUSIONS.

(1) The abnormal condition of leaves, shown by severe distortion and increase in number, and also sometimes in size, may be classed under the malnutrition diseases, due to functional derangement, as no fungi or bacteria have been found associated with it. It must therefore be due to internal conditions, such as an abnormal metabolism.

(2) It is allied to those pathological conditions which may be brought about by excessive use of nitrates or overfeeding.

(3) It is not allied to mosaic disease, which it somewhat resembles, as this is capable of transmission from one plant to another, and in no case have we been able to bring this result about by inoculation with tissue of malformed leaves.

(4) From our observations it is not of a permanent character,

¹ U. S. Dept. Agr., Bur. Plant Ind., Bul. No. 18.

² Gen. Bul. Col. Agr., Tokyo, Vol. IV., No. 4.

as the shoot will outgrow it in from three to five years, and does not seem to suffer any serious ill effects from the trouble.

(5) It is caused by a sudden disruption of the metabolic processes of the tree, all leaf activity being suspended; and there being no normal relationship between root metabolism and leaf metabolism, the new shoot is unable to properly bring into available form the food supplied for the nourishment of the tree. In other words, there is an attempt on the part of the leaves to correlate their functions with a root area many times larger, and consequently a pathological condition is set up within the tissue, due, as has before been said, to imperfect metabolism.

PEACH AND PLUM TROUBLES.

BY RAYMOND DEAN WHITMARSH, B.S.

Many diseases of the plum and peach have been known and described for years. Standing probably first among the most serious of the fungi are "brown or fruit rot," or *Monilia* (*Sclerotinia fructigena* (Pers.) Schroet.), and scab (*Cladosporium carpophyllum*, Thiimen). These fungous troubles have been very noticeable in the peach and plum orchards at the college during the past year or two.

The writer began investigations early in January, 1909, mainly to determine the cause of so much gum flow on the peach, almost every tree being affected to a greater or less extent. In connection with this study nearly every phase of the above diseases as they are described by various writers was noted, and a brief résumé of their characteristics and methods of treatment is given here, with observations on "gummosis" of the peach.

This paper has been prepared under the supervision of Dr. G. E. Stone of the Massachusetts Agricultural College, and to him I wish to express my heartiest thanks for his many suggestions, criticism of manuscript and verification of observations.

BROWN ROT OR FRUIT ROT, MONILIA (*Sclerotinia fructigena* (Pers.) Schroet.).

Distribution and Host Plants. — This disease is reported by Saccardo as being found in Germany, France, Austria, Italy, Belgium, Great Britain and the United States, where it is known as *Monilia fructigena*, one of the "imperfect fungi." Tubeuf and Smith speak of the disease as being very common in the United States and Great Britain. It was first described in the United States by Dr. C. H. Peck in 1881; since that time

a great many investigators have been at work on it. Finally, Prof. J. B. S. Norton in 1902 succeeded in giving us its life history in full, having found the ascospore stage. Within the United States, at least, the greatest damage is caused to the stone fruits.

Symptoms (on Fruit). — The first indications of the disease on the fruit are brown spots of a leathery appearance, which enlarge rapidly, and after the mycelium has become mature, the conidiophores break through the epidermis and give to the spots a downy, dirty, grayish-brown color, due to the great quantity of conidia produced by the fungus. The fruit then shrinks and withers to a thin, tough pellicle. In this "mummied" condition it hangs on the trees over winter or falls to the ground, where the fungus remains dormant until the right conditions of moisture and temperature cause it to become active and attack its host the following spring. The dormant or sclerotium form of this fungus occurs where the "mummied" fruit has laid on the ground over winter, covered by a thin layer of soil. These sclerotia give rise to apothecia, which are funnel-shaped, resembling small toadstools. The asci line, the cup-shaped portion of the apothecia and each ascus, contains eight ascospores. So far as I know this has not been found by any of the Massachusetts Experiment Station staff. The fungus will attack the fruit at different stages of its growth, but it makes the greatest headway on fruit that is almost mature. If the fruit has been attacked by the curculio, or injured in any way, the fungus readily takes advantage of the injury to get in its deadly work. It might be said, however, that although it attacks the fruit most readily where it has been injured, it will also attack the perfect fruit should the humidity and the temperature of the atmosphere be right. In the case of plums the fungus may have been working for some time within the tissue without being outwardly noticeable. This fact has put many shippers to great disadvantage and caused them much loss.

On Flowers. — The fungus usually first attacks the flowers just after the petals fall, but it has been known to attack them previous to that time. The first indication that the fungus is present is a slight brown discoloration on some part of the

flowers. This rapidly spreads until it affects the whole flower, and frequently extends into the pedicles. These diseased flowers often remain on the tree several weeks, until a heavy rain or damp weather comes, when they begin to fall, and as they are very sticky, owing to their decaying condition, they adhere very effectively to leaves and fruit, and serve as a new place of infection. They may remain in these new locations for some time before they are washed to the ground. When the fungus from the flower penetrates the pedicle, we have what is commonly called "twig blight."

On the Twigs. — One form in which the fungus attacks the twigs is commonly known as twig blight, and it is apparently a result of the early attacks on the blossoms. I have noticed it attacking both the peach and plum, but more often the former. The fungus penetrates the pedicle and into the tissues of the twig, causing a flow of gum. This fungus often works around the entire stem, cutting off all source of nourishment from the distal portion of the twig, causing it to die. The gummy portions and girdling resemble quite closely the symptoms of another disease, known as canker. In summer and early fall, as well as in spring, we often find this blighting of twigs, the source of infection being the fungus from the decaying fruit. This bores through the pedicle and then ramifies through the stem, often girdling it, as in the case of the blight, where the source of infection was the flowers. The injury in both cases nearly always is confined to a point near the attachment of the fruit or flowers. When the girdling is complete the leaves beyond the point of attack dry up and die.

Another form in which I have noticed it might be called the "brown spotting of twigs." This phase of the disease has been described by Dr. G. E. Stone of the Massachusetts Agricultural College. The spotting occurs on the new shoots, and was not noticed except in the case of the peach. These spots may be single, or several may come together, forming a more or less irregular mass. In these spots we find *Monilia*, which presents similar characteristics to the one found on the fruit. The principal distinction between this and the common *Monilia* of the fruit consists in the smaller spores of the former. Numerous

cultures and comparisons made of the two types of *Monilia* — that on the fruit and on the stem, made by Dr. Stone — show that the spores of the one on the twig are always smaller when grown in any media than those of that on the fruit, and the two species react quite differently chemically when grown in solutions on different media.¹

On the Leaves. — In wet weather, especially, one often notices spots on the leaves. These are found on both the upper and lower surfaces, but are generally most conspicuous on the upper. During wet, warm weather, if one examines these spots carefully he will find here and there small grayish masses of powder, which are in reality the conidia of the “brown rot” fungus.

Spores. — The spores, more or less oval shaped, are one celled, and their contents are quite noticeably granular. These spores germinate readily in water, producing a mycelium whose contents are granular, as in the case of the spores. The mycelium is broken up here and there by cross walls. The spores are produced in chains by a sort of budding, the last one of the chain being the newest one. When grown on culture media (prune agar) these spores form much longer chains than on the fruits out of doors.

Means of Spore Dispersal. — The influencing factors in the spreading of this fungous disease are wind, rain, insects (especially plum curculio), etc. Many minor ways in which the spores are disseminated might be enumerated, but the three above-named methods are probably by far the most influencing.

Methods of Control. — I would suggest the following ways in which to lessen the attacks of this disease. Destroy all “mummied” fruit which hangs on the trees or has fallen to the ground. Cut off and burn all twigs that are infected with the fungus mycelium. Keep the trees pruned, so that there will be a free circulation of air and plenty of light, because a tree which is crowded with cross limbs and has in consequence too much foliage acts as a convenient forcing house for “brown

¹ Dr. Stone has observed this species on the twig for many years in Massachusetts, the twig sometimes being very badly spotted. *Monilia* is also sometimes associated with *Cladosporium*, but the *Monilia* by far predominates. Where lime and sulphur has been used as a spring spray these spots have been entirely absent, with a much better annual growth of the twig as a result. (See Nineteenth Annual Report, Massachusetts Agricultural Experiment Station, p. 166.)

rot." Thin the fruits so that they do not at least come in contact with one another. By using the above precautions and applying the following spray mixtures for "brown rot," "scab" and "plum curculio" I believe that the fungus can be almost entirely controlled. For the Elberta, Belle, Reeves, and other varieties of peaches of about the same ripening season, the following is advised: (1) about the time the calyces of shucks are shedding, spray with arsenate of lead at the rate of 2 pounds to 50 gallons of water. In order to reduce the caustic properties of the poison, add milk of lime made from slaking 2 pounds of stone lime. The date of this treatment is too early for scab, and ordinarily no serious outbreaks of brown rot occur so early, so that the lime sulphur may be omitted with reasonable safety; but during warm, rainy springs, especially in the south, the lime sulphur will doubtless be necessary in this application. (2) Two or three weeks later, or about one month after the petals drop, spray with self-boiled lime sulphur; 8 pounds of lime, 8 pounds of sulphur and 2 pounds of arsenate of lead to each 50 gallons of water. (3) About a month before the fruit ripens, spray with the self-boiled lime sulphur, omitting the poison.

For earlier maturing varieties, such as Waddell, Carmen and Hiley, the first two treatments outlined above would probably be sufficient ordinarily, but in very wet seasons varieties susceptible to rot would doubtless require three treatments. Late varieties, such as Smock and Salway, having a longer season, would not be thoroughly protected by three applications. In view of the results obtained on midseason varieties it seems likely that three treatments will ordinarily be sufficient for the late varieties.

BLACK SPOT OR SCAB (*Cladosporium carpophyllum*, Thüm.).

History and Distribution. — This fungus was first noticed in 1876 by Von Thümen of Austria, who was at that time botanist to the Austrian Experiment Station. In the year following, 1877, he described the fungus, giving it the above name. Since that time it has been met with quite commonly in this country. In Saccardo's "Sylloge Fungorum" we find a copy of Von

Thümen's description, which mentions only that it was found in the locality of Klosterneuburg, where the Austrian Experiment Station was located.

On the Fruit. — Small, round, blackish spots on the skin of the fruit are the first indications of the disease. These spots usually appear when the fruit is about two-thirds grown, most frequently on the upper side of the fruit, and if the spots are very numerous they will, as they grow, coalesce and form a large, irregular, diseased area. When the fruit is thus attacked it becomes one-sided, due to the fact that a corky layer of cells is formed by the fruit under the diseased area as a protective layer. This corky layer is incapable of further growth, and hence we get, as a result, the ill-formed fruit. The corky layers are often ruptured, leaving deep cracks, which furnish an ideal place for the growth of the spores of *Monilia*, which are always ready to take advantage of such injuries. Hence we often find both troubles on the same specimen. This disease attacks the fruit much in the same way as the scab of apple and pear. Its attacks are generally most noticeable on the late varieties of fruits, and it thrives most luxuriantly during damp weather.

On the Leaves. — This fungus causes a shot hole appearance of the leaves. The first indications one has of the disease upon the leaves are scattering brown spots. These spots, as a rule, spread over the leaf, and as the fungus matures the tissues dry up and the diseased portion falls out, leaving a circular opening. This fungus seems to prefer the part of the leaf between the veins. The spores of the fungus attacking the leaf agree with those growing on the fruit, with the possible exception that they are somewhat smaller, but no doubt this slight variation is due to the environment rather than being a specific character.

On the Twigs. — Sturgis gives an account of this fungus attacking the peach twigs. He states that the twigs are marked more or less abundantly with circular spots, somewhat resembling in appearance the "birds' eye rot" of grapes (*Spaceloma ampelimum*, DeBary). Frequently the spots join together and cover the twig so thoroughly as to destroy the pinkish-brown color of the bark. Although not having seen this phase of the

disease, it apparently resembles in outward appearance very much the spotting that I described as due to the brown rot fungus.¹

PEACH LEAF CURL (*Ectoascus deformans* (Berk.) Fuckel).

This disease is found commonly in Massachusetts, and, as a matter of fact, more inquiries are sent to the station in regard to this trouble than any other peach disease. It is found in almost all parts of the world where the peach is grown to any extent, and has been seen by the writer in great quantities in the large orchards along the shores of Lake Erie.

It attacks the leaf buds just as they begin to open in the spring, also the tender shoots, flowers and young fruit, but is not so noticeable as on the leaves. The leaves become very much swollen, wrinkled and curled, and a little later take on the appearance of a moldy gray covering. In the earlier stages of the disease the leaves often show red or pinkish blotches, but they turn a brownish color as they grow older and fall to the ground. Cold and damp, or rainy, weather in the spring greatly favors this disease, and in fact determines the degree of severity of the attack. It often defoliates the trees to such an extent that they are not able to lay up sufficient material for their needs, or ripen the wood properly, so that when winter comes the trees are often found to be much weakened. In some cases the disease has been so severe that the trees were not able to endure the cold of winter, and consequently were winter killed.

It was previously thought that infection took place only by perennial mycelia, but this theory has gradually been discarded. Infection may take place by perennial mycelia, but most writers and observers now agree that infection is due almost entirely to the spores, which live over winter on the bark of trees and in other places.

The Elberta peach is one of the most susceptible varieties to the attacks of this fungus, but all varieties seem to be more or

¹ For other points of interest in regard to the fungus not given in this paper see Arthur's and Chester's writings.

less subject to the disease. Trees injured by other agencies, and consequently weakened, seem to be more susceptible to attack than healthy, vigorous trees.

It will be readily seen that it is probably useless to spray the trees after the leaves become infected, but since the spores live over winter on the bark, the trees should be sprayed in the spring, while the spores are still dormant.

It is generally accepted by all the largest and best growers that the lime sulphur wash, used for the control of San José scale, is by far the best remedy for this trouble, although some prefer Bordeaux and others copper sulphate solution, where the scale is not present. Since there is nearly always danger from scale infestation, however, it seems wiser to use the lime and sulphur, which is undoubtedly of great fungicidal value, as well as one of the best remedies for the scale.

The spray should be applied to the trees from one to two weeks before the buds open, if possible on a quiet day when the atmosphere is free from moisture.

If the above directions are followed, this treatment should suffice for the leaf curl and the San José scale. For this spray mixture use 10 pounds of good fresh stone lime and 15 pounds of sulphur to each 50 gallons of water. Make up the above spray solution as recommended by Quaintance.

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot, add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray pump or tank. The wash may be cooked in large kettles, or, preferably, by steam in barrels or tanks.

PLUM POCKETS (*Erosascus Pruni*, Fuckel).

The organism causing the disease known as "plum pockets" is closely related to that causing peach leaf curl, although not occurring on the peach. It was previously thought that the source of infection was only through the hibernating mycelium in the twigs and branches, but from what can be learned in regard to this more investigation seems to be needed on this point. A short time after the young fruit forms, it becomes yellowish, much swollen and stoneless.

These hollow, dropsical-like plums are often streaked with red at first, but after a time they take on a moldy, grayish appearance, similar to the peach leaf curl, and soon fall to the ground. This moldy covering is composed of saes (asei) which contain the spores.

The attacks of this parasite are generally local, possibly only one tree in a large orchard being affected, and the treatment given for peach leaf curl would probably suffice here.

BLACK KNOT (*Plowrightia morbosa* (Schw.) Sacc.).

One often notices in small family orchards containing a variety of trees, where little care is given them, that some of the plum trees show signs of a disease known as black knot. The knots often extend entirely around the limbs, and as a consequence the more distal parts of the limbs receive but little nourishment, and finally die.

Black knot, if given no treatment, usually destroys the value of the tree within a year or two, even if it does not kill the tree in that time. Almost all varieties of plums are subject to this disease. The first noticeable indication of the disease in the spring is the enlargement of limbs and branches affected. The bark then breaks open, and this new surface soon becomes covered with a moldy, green-like substance which contains the spores. This is followed by black knots containing spores which become mature before the next spring. The spores evidently obtain a foothold on their host through cracks or injuries caused by various agencies. It is therefore essential in the care

of an orchard that one should be careful not to bruise or injure the trees.

The wind is probably the greatest agent for conveying the spores from tree to tree. Remedial measures consist in pruning off the knots and burning, and it has been advised that they be cut out when young, and the exposed area coated with paint. Observations and experiments have shown that early spring spraying materially lessens the infection.

PLUM LEAF SPOT OR SHOT HOLE (*Cylindrosporium Padi*, Karst).

This disease causes spots on the leaves somewhat circular in outline, which often become joined. These affected parts usually have a reddish outline, and finally the diseased tissue turns dark brown and falls out. The leaves turn a yellowish color and often begin to fall in July, but the most severe defoliation usually occurs in August and early in September. The great loss from this disease is caused by defoliation before the tree stores up sufficient starch and ripens its wood enough to enable it to stand the cold of winter. Continual attacks very much weaken the tree and eventually kill it, but if lime sulphur is used thoroughly, little trouble will be experienced from this disease. This same disease also affects the cherry.

PEACH SHOT HOLE (*Cercospora circumscissa*, Sacc.).

The effects of this disease resemble those caused by *Cylindrosporium* of the plum. The diseased spots fall out, and the small branches are also attacked, often causing a great number of the young shoots to die. Spray with lime sulphur, as for peach leaf curl.

Shot Hole Effect caused by improperly mixed Bordeaux.

When improperly mixed Bordeaux is used for a summer spray, we invariably find the leaves badly riddled with holes, due to the burning of the tissues. One can readily distinguish this type of shot hole from those previously described, for the leaves which come out on the new shoots remain unaffected,

whereas, if the trouble had been due to a fungus, the new leaves would also become affected. Bordeaux is not, therefore, always safe to use on mature foliage, even at reduced strengths, for it has often been known to cause trouble when used at only half strength.

GUMMOSIS OF THE PEACH.

For the past two years there has been an abundance of gum flow in the college peach orchard. This has been found to the greatest extent on the early varieties, and owing to the poor condition of many of the trees it has seemed best to destroy them. The following gum disease which I am about to describe resembles almost identically in most of its life history the gummosis of *Prunus Japonica*, described by Masecé as due to *Cladosporium epiphyllum*, Fr. In this case (gummosis of peach) I believe the species to be *Cladosporium carpophyllum*, Thüm. Masecé mentions in his paper a species of *Macrosporium* that is often found in connection with this gum flow, but he is unable to find any genetic connection between the two fungi. Instead of finding a *Macrosporium* fungus in connection with the gummosis of peach, I have, with very few exceptions, found a species of *Alternaria*¹ or *Alternaria* form, which is apparently something new, as the fungus, in addition to the ordinary alternaria spores, bears pyrenidia bodies containing many minute hyaline spores. These in turn give rise to *Alternaria* spores and more pyrenidia. I could not, however, establish any genetic connection between this form of *Alternaria* and the *Cladosporium*.

Probable Cause of Gummosis.

On the trunks and large branches the gum flow is evidently due to borers, frost cracks and sun scald, and a copious flow of gum at any place of injury is generally found. These places serve as a refuge for the spores of *Cladosporium* and *Alternaria*, and we find some form of *Penicillium* inhabiting the same mass. But whatever the original cause of the flow, it is certain that these forms of *Cladosporium* and *Alternaria* take a hand in

¹ The organism which we term *Alternaria* here may possibly be an undeveloped form of some other type, such as *Pleospora*, etc.

stimulating the host to a more abundant flow. The mycelium of these fungi penetrate every portion of the gum, and their fungous threads may be seen even penetrating the host itself.

On the Fruit-bearing Wood.

The gum flow is almost without exception found at the base of the pedicle bearing diseased fruit. These gummy masses may be confined to a small area in the region of the pedicle, or may extend some little distance below and above the pedicle, sometimes becoming so bad as to entirely girdle the branch, thus killing the entire distal portion. When this happens it is best to cut the diseased member off some two or three inches below the gummy area. I believe this gum flow is first caused on these small branches by the brown rot fungus, which is, without an exception, found on the fruit attached to the diseased pedicle. But as soon as this fungus causes the flow of gum the *Cladosporium* and *Alternaria* come in, as in the case of the injuries on the trunks and large branches. After the above fungi, *Cladosporium* and *Alternaria*, get a foothold, it would seem that the brown rot fungus is less noticeable. *Monilia* is often to be found in these gummy masses, but in masses containing *Cladosporium* and *Alternaria* this fungus has been found very sparingly. These masses become soft during the damp spring weather, and are usually washed to the ground by rains.

Appearance of Cladosporium and Alternaria under the Above Environment.

At first the gummy mass is light in color, but after it remains on the tree some time it becomes browned and blackened. On sectioning one of these masses it is found that the darkened area is near the surface, due to the formation of dark, thick-walled cells, while farther in the mycelium becomes gradually lighter in color, until nearly colorless at the center. On inoculating branches of peach trees with the conidial form of *Cladosporium* grown on prune agar it was found that some little time afterwards a greenish growth of *Cladosporium* appeared. After the spores had disappeared there soon appeared small, tear-like drops, which, as the season advanced, grew larger and darker



Showing a Cross-section of a Three-year-old Peach Twig affected with
"Gummosis."

in color. On examination in the fall these masses were found to contain mycelium and spores similar to those found in other gummy masses in the orchard. These chains of dark spores produce many thick-walled spores, or micro-sclerotia, as described by Masseé, and these thick-walled spores, or micro-sclerotia, in turn give rise to many small hyaline conidia, while another form of the micro-sclerotia gives rise to a mycelium which bears numerous conidia. In the gummy mass one finds present many pycnidia of a brown color, similar in color to the micro-sclerotia, and from their situation, color, etc., one would take them for different stages of the same fungus. However, on isolating these pycnidial bodies, which were filled with myriads of minute hyaline spores, and growing them on pure cultures, I was unable to get any connection between the two; but I found that the minute hyaline spores without exception gave rise to other pycnidia and *Alternaria* spores; the *Alternaria* spores, growing on the same mycelium as the pycnidia, in turn gave rise to pycnidia and *Alternaria* spores.

Histological Changes Accompanying Gummosis.

The cut facing this page represents a cross-section of a diseased twig of a peach tree, showing two well-developed annular rings and a third partly developed. This twig was probably attacked by the brown rot fungus, together with *Cladosporium* and a form of *Alternaria*.

This section, which is a typical one, shows that the disease did not destroy the cambium ring until the fall of the second year, but the disease may have made its appearance even a year earlier. The noticeable feature in this illustration is that the last layer of wood formed was very much thinner towards the uninjured side of the twig than the injured side, and this ring of wood is not complete near the area where gummosis had set in. There is also a noticeable thickening of the incomplete rings of wood near the point of injury, a fact due probably to the difference in tension occurring in the stem produced by the injury from gummosis. The cambium, at the margin of the diseased area where it has attempted to heal over, is also much

thicker than at the opposite side of the twig, where the tension is different.

Microscopical examinations of sections also showed that considerable healing of the wound caused by gummosis took place. The callus forming as a result of this healing developed ridges along the side of the wound. The cavity of the wound was entirely filled with gum, which contained *Cladosporium* and a form of *Alternaria*.

Suggestions in Regard to the Treatment of Gummosis.

In very bad cases of gummosis it would be best to destroy the tree, since it is of little value and may possibly furnish an ideal place for the development of undesirable organisms. Branches may be cut off a few inches below the affected areas. Since this disease undoubtedly originates from the practice of leaving "mummied" fruit attached to the tree, it is best to remove and destroy them. It is even a question whether "mummied" fruit should be left on the ground. Practically all cases of infection from gummosis have occurred where the "mummied" fruit was left on the tree, and came in contact with the limb or branch.

Care should also be exercised in pruning, and this should be done in winter or early spring. A clean, sloping cut should be made, and large wounds should be covered with paint or coal-tar. This treatment will prevent infection from the wounds.

The practice of good sanitation and systematic spraying of peach trees, together with cultivation and feeding, will undoubtedly hold this disease in check.

DIRECTIONS FOR MAKING SUMMER SPRAY MIXTURE.

Essentials.

In making the self-boiled lime sulphur plus arsenate of lead, as recommended for the summer sprayings, the first essentials are to have good stone lime, a perfect mixture of the ingredients, and two men to attend to the mixing. After being mixed it is necessary that the mixture be kept well agitated while in the tank, for if not it will settle, no matter how well made. To

accomplish this it is suggested that those using a power outfit employ an agitator of the propellor type, as most others will allow a little settling; and where this occurs an even mixture of the spraying materials is not obtained.

Directions.

The following method has been found to work out satisfactorily in making 250-gallon quantities. First, weigh out 40 pounds each of good stone lime and flour of sulphur. Take the above quantity of lime and place in the bottom of a barrel (one holding 50 gallons is a convenient size to use when not making over 300 gallons at a time); then pour on water slowly and evenly. A good way to do this is to use a fine spray from a nozzle. As soon as the lime begins to slake have the sulphur sifted over the lime, adding just enough water while doing this to keep the lime from burning. By the time the sulphur is added the lime has become very active, and requires one person's attention to stir the mixture while another adds the water just fast enough to keep the mixture from burning. Water should be added cautiously to obtain the best results in slaking.

If the above directions are followed there will first be a thick, pasty substance which gradually becomes thinner as more water is added. The lime ought to keep the mixture well heated for several minutes, but as soon as it becomes well slaked water should be added. If allowed to cook too long the sulphur will go into solution and combine with the lime to form sulphides, and this form is harmful to the foliage. Weigh out 10 pounds of arsenate of lead, add water, and stir until thoroughly mixed; then strain through a sieve (20 to 30 mesh to an inch is satisfactory) either into the spray tank or barrel containing the lime-sulphur mixture. On the addition of the arsenate of lead to the lime sulphur, a dark-colored mixture is obtained. If the mixture has been properly made there will be very few settlings, and very little, if any, sulphur floating on the surface. The ingredients of this mixture ought not to settle for nearly half an hour. The above mixture should be strained into the spray tank and the tank filled with water. The solution is then ready to be sprayed on the trees.

CONCENTRATED LIME-SULPHUR SOLUTION.

The inconvenience experienced in preparing the lime-sulphur wash by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Certain manufacturers have therefore put on the market concentrated solutions of lime-sulphur wash which have only to be diluted with water for use. These commercial washes have proved to be about as effective in controlling the scale as the well-cooked lime-sulphur wash, and, although somewhat more expensive, have been adopted by many commercial orchardists in preference to the home-prepared spray. They are especially useful for the smaller orchardist, whose interests do not warrant the construction of a cooking plant. In other ways, too, they possess advantages; for instance, those using the commercial washes may always have on hand a stock solution, so that the spray may be quickly prepared and advantage taken of favorable weather conditions. These preparations should usually be used at the rate of 1 gallon to 10 gallons of water.

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CLIMATIC ADAPTATIONS OF APPLE VARIETIES.

BY J. K. SHAW.

I. INTRODUCTION.

The conditions of soil, climate and culture under which our many varieties of fruit succeed are little understood. Most of the publications dealing with varieties concern themselves with histories and technical descriptions, and but very little with the conditions under which the planting of this or that variety is to be recommended. As a result of this lack of information a given variety is planted under widely varying conditions, under some of which it does well and under others it does poorly.

At the present time fruit growing, more especially the growing of apples, is entering a new era. The increased demand resulting from the lessened production during the past decade; improved methods of culture, especially a better understanding of the combating of insects and diseases, and better business methods have stirred up growers all over the apple regions to a renewed interest in the business. This movement has had its origin in the Pacific coast and intermountain regions, but will soon, if it has not already, become general over a large portion of North America.

This movement will result in more or less change in the relative importance of commercial varieties, some becoming less esteemed and others gaining in favor. The consumer will come to prefer varieties of better quality and those better suited to various purposes. The same is true within a variety, where specimens grown to more perfect development will receive preference.

To attain the highest degree of success it will be more necessary than in the past for each grower to choose those varieties which he can grow, under his conditions of soil and climate, to

their highest perfection. A mistaken choice will be a serious thing, and one that will require valuable time and much expense to correct.

The present paper is the result of a study, carried on for the past four years, of the effect of varying climatic conditions on varieties, and an attempt is here made to lay down certain principles as to the climatic adaptations of varieties. Questions of soil and culture are given only incidental consideration. For the former there has not been sufficient opportunity, and a consideration of the latter would lead into the whole field of orchard management. Many samples of different varieties, grown under widely varying conditions, have been examined pomologically, and some of them chemically, and a study made of the pomological and meteorological literature available.

This paper does not make specific recommendations of varieties for any section of the country or for the country in general. That is more or less a local problem into which enter questions not considered here. Among them are those of soil, market demands, methods of culture to be followed, the individual preferences of the grower and many others. If the conclusions of this paper are sound, they should aid in such choice, for many varieties that might otherwise be considered are excluded as not being suited to the climatic conditions of the locality under consideration, while from those that are adapted climatically, the ones best suited to soil and other conditions may be singled out.

The subject under consideration is a large one. To understand at all fully the relations of apple variation to climate will require prolonged study and experiment. This paper is, in a large degree, introductory, and may contain errors and omissions which should be corrected. The writer will greatly appreciate any suggestions as to corrections or additions that should be made.

The work has been done as Adams fund research, and at the same time in partial fulfillment of the requirements for the degree of Doctor of Philosophy from the Massachusetts Agricultural College. It has been done under the direction of Prof. F. C. Sears, to whom the thanks of the writer are extended for

advice and criticism, and to Prof. F. A. Waugh as well, who has given many helpful suggestions. The chemical work has been under the direction of Dr. Charles Wellington, and assistance in the analytical work has been rendered by Mr. E. L. Winn and Mr. B. Ostrolenk of the senior class in the college. Many experiment station horticulturists and fruit growers in many sections of the country have aided by giving information and by furnishing samples of apples. It is impossible to name them all here, but their many favors are here acknowledged and hearty appreciation extended.

II. THE CAUSES OF VARIETAL VARIATION.

The causes of the great differences in apple varieties may be grouped under three heads: those arising from (1) cultural conditions, (2) differences in soil types, (3) differences in climate.

CULTURAL VARIATIONS.

The methods pursued in the growing and in the care of the trees have great influence on the character of the fruit. It is affected in every way, in size, form, color, keeping quality, shipping quality and dessert quality. These variations have been given only incidental investigation of such phases as relate directly to the climatic differences that have been the special object of study. A few of these may, however, be given passing attention at this point.

Every orchardist growing any number of trees is aware that there are great differences in the individuality of the trees, even when grown in the same orchard and under apparently identical conditions of climate and soil. One tree may be very productive and its neighbor only moderately so. The apples may differ in many of their characters. Further along in this paper some data are presented bearing on this question (see page 194). These individual differences have been ascribed to various causes, the principal ones of which are, perhaps, those of bud variations or varietal "strains," and that of the influence of the stock.

The method of handling the soil has great influence on the fruit, especially whether the orchard is in sod or is cultivated.

This has been shown in various bulletins from different experiment stations. The Baldwin seems especially influenced by conditions of orchard culture, and other varieties more or less so.

Certain experiments at this station¹ have shown marked effects from the use of different fertilizers. This question has been little investigated, but no doubt great variation in fruit may be produced by the fertilizer used on the land. Differences in pruning also have their effects. A tree kept with an open top will admit an abundance of sunshine, resulting in a higher colored fruit; in many other ways the effect of pruning may be shown in the character of the fruit.

Many fruit growers have discovered, to their grief, that Bordeaux mixture has a decided effect on many varieties, by producing russeting. On the other hand, the lime-sulphur preparation has frequently been found to render the appearance of the fruit better than when not sprayed at all.

SOIL VARIATION.

It has been shown that the nature of the soil has great effect on the character of the fruit. Red apples are likely to be higher colored on sandy soils than on clayey soils. Not enough is known regarding this question to make any very definite generalizations on the subject. H. J. Wilder has determined the soil adaptations of various varieties, and shown that different varieties have decided preferences as to soils.² The question of the adaptation of varieties to soils is much complicated by the question of stocks already alluded to. No doubt varieties have soil preferences which are general to the variety, and not seriously modified by differences in stock. Nevertheless, the writer is satisfied that much greater uniformity would be found in the adaptation of varieties to soils were they grown on their own roots.

CLIMATIC VARIATION.

In a broad way, the limits of apple growing are governed by climatic conditions. The apple is a fruit of a temperate climate, and does not flourish in the far north nor in the warmer

¹ Report, Massachusetts Experiment Station, 22, Part II., p. 10.

² Proceedings American Pomological Society, 31, p. 138 (1909).

sections of the temperate zones. The apple adapts itself under cultivation to a considerable range of rainfall, and in districts of deficient precipitation irrigation is practiced. Therefore, the question of rainfall has comparatively little weight in the general cultivation of the apple. Sunshine has considerable effect, but it is not a limiting factor anywhere in the apple belt. The great climatic factor which limits the distribution of apples in general, and of the different varieties in particular, is temperature.

Over the greater part of the North American continent the northern limit of successful apple growing is fixed by the minimum winter temperature. Different varieties of the common apple vary greatly in their ability to withstand minimum winter temperatures, and the condition of the tree, particularly as regards moisture content at the time minimum temperatures occur, has great influence in determining whether the tree survives. Very few, if any, varieties will withstand a temperature much below -40° F. without being killed back more or less. In many cases a considerably less severe temperature is fatal to even the hardiest varieties. With the possible exception of the extreme northern Pacific coast, under conditions of a maritime climate, there is nowhere in North America a region where certain varieties will not produce fruit in summer, provided they can withstand the cold of winter. In other words, the summers are warm enough to mature fruit of short-season varieties, provided the winters do not kill the tree before it has reached the bearing age.

The apple does not succeed in the southern portions of North America, although fruit may be produced in every State of the Union, and probably in portions of Mexico. The difficulty in the way of the southern extension of apple growing seems to be largely the heat during the summer. The trees fail to grow during hot periods in the growing season, and fail to set, or at least to mature fruit. The latter is especially true of winter sorts, and many varieties grown in the south are short-season ones, which are able to mature fruit before the hot periods of July and August arrive.

The Mean Summer Temperature.

For this work we have used as a measure of the summer heat an average monthly mean for the growing season. This has been taken as comprising the months of March to September inclusive. The monthly means for these seven months, as given in publications of the United States Weather Bureau and Canadian Meteorological Service, are averaged. This gives, for points within the apple-growing regions of North America, temperatures varying from about 52° to about 70° or 72° . Summer means have been computed for a great number of stations, and from these the isotherms given in Fig. 16 are drawn. This map is intended principally for study in connection with the matter given later in this paper, but it may be proper to explain it at this point, and to discuss the variations in the summer mean that occur and the causes thereof. In common with other questions of temperature, the summer mean for a given section is determined by a number of considerations. Among these are the following: (1) latitude, (2) elevation, (3) site and aspect, (4) soil, (5) culture, (6) prevailing winds, (7) sunshine.

The first two require no explanation. Temperatures vary inversely with the latitude and altitude, but, owing to the influence of the other features mentioned, no ratio can be laid down that is of any value.

With regard to slope, little need be said. The summer mean on a north slope may be several degrees lower than that of a corresponding southerly slope, though we have been unable to find any data showing the amount of difference. Slope must be considered in estimating the probable temperature of an orchard site.

Soils containing a large proportion of sand will not only be warmer than clayey soils, but will also influence the air temperature in the orchard to a considerable degree.

Hedrick found that the soil in a tilled orchard was from 1.1° to 2.3° warmer than a corresponding plot in sod.¹ This must have an influence on the air temperature in the orchard.

Prevailing winds influence the summer mean. These are de-

¹ Bulletin 314, New York Experiment Station.

terminated by mountain ranges and other topographic features, by the temperatures of bodies of water over which the air may have passed, and perhaps by other considerations.

The prevalence of a large proportion of sunshine will operate to raise the temperature in the orchard. The effect on the protoplasm of the tree will, owing to the heat absorptive powers of the dark colored bark, be even greater. This has been shown by Whitten. He also found that in peaches the color of the bark modifies in a marked manner the thermal effect of the sun.¹ The temperatures on which this work is based were presumably all taken in the regulation shelters of the Weather Bureau, where this effect would be less than in the orchard. The probable amount of sunshine should be taken into consideration in estimating the summer mean of an orchard.

III. THE DEVELOPMENT OF THE APPLE.

For convenience in discussion, the life history of the apple (fruit) may be somewhat arbitrarily divided into four periods: (1) that of growth, which extends from the blossom to the attainment of full size; (2) that of ripening, which covers the period from the termination of the first until the apple is picked from the tree; (3) that of "after ripening," extending from picking until the apple is in perfect eating condition; and (4) that of decay, covering the subsequent deterioration and breaking down of the fruit. Various fungous diseases may enter in during these periods and terminate the life of the apple at any time. These are not considered in this discussion. The second and third periods are scarcely differentiated in summer apples, these being ordinarily fit for immediate consumption on picking. In winter apples, on the other hand, there is a distinct period of ripening following the picking of the fruit.

Inasmuch as the discussion of these periods of growth will be largely from a chemical standpoint, it may be well to consider briefly the chemical composition of apples before discussing their development.

Apples vary widely in chemical composition, according to variety, stage of development and conditions of growth. They

¹ Report American Pomological Society, 26, p. 47 (1900).

contain ordinarily from 80 to 88 per cent. of water, most winter varieties when maturing averaging perhaps about 84 per cent., the remainder of the fruit comprising the total solids. The solids consist of the following substances: first, starch, of which there may be 3 or 4 per cent., in growing apples; second, sugars, of which there may be from 5 to 12 per cent., averaging perhaps 8 or 10 per cent. The total sugars are made up of at least three distinct compounds: sucrose, of which we may find from none to 6 per cent.; and a mixture of dextrose and levulose, of which there may be from 5 to 10 per cent. These two latter sugars are separated in the laboratory with some difficulty, and comparatively few figures are available to show their relative proportions, but it is evident that the levulose in apples is in excess of the dextrose, a condition not usually found in plant substances where these two sugars occur together. Of organic acid we may find from .12 to 1.50 per cent., presumably as some form of malic acid.

The foregoing solids are all soluble in water. The insoluble solids are largely of a carbohydrate nature, and consist of cellulose and pentosans for the most part. In the chemical work reported in this paper determinations of the total insoluble dry matter have been made and given as insoluble solids, and consist of those portions of the apple not dissolved by hot water under the conditions prescribed in the method of the Official Association of Agricultural Chemists.¹

Apples, particularly in the green state, contain small amounts of tannin. In the work here reported no determinations of this have been made, but a few analyses are available from other sources, giving the percentage present. The characteristic flavor and aroma of apples are due for the most part to certain esters or flavoring oils. These exist in the apple in very minute quantities, and though they are of great importance in determining the value and quality of the fruit, no attempt to determine the amount has ever been made, so far as the knowledge of the writer goes. Indeed, it is probable that, owing to the minute quantities present, their determination would be extremely dif-

¹ United States Department of Agriculture, Bureau of Chemistry, Bulletin 107, revised.

fruit, if not absolutely impossible. We can judge of their presence and abundance only by the taste and the aroma of the fruit.

Returning now to a consideration of the changes in the fruit during the four periods of development already mentioned, we find them taking place somewhat as follows. During the period of growth the amount of total solids of course increases greatly. This increase may continue into the ripening period, but after that there is a relative loss of total solids. The percentage, also, of total solids increases during the period of growth and during at least a part of the ripening period, but after that its changes are much dependent upon conditions. The percentage of acid in the fruit is largest in the early stages of growth, and decreases more or less steadily during the entire history of the fruit. The percentage of starch increases during the early part of the growth, and at varying points, under different conditions, it begins to decrease, and disappears during the ripening process. The sucrose increases pretty steadily until the period of after ripening is complete, and then more or less rapidly decreases, and frequently entirely disappears in the process of decay. The point of maximum of sucrose content may be taken as the point of full maturity of the fruit, with a fair degree of accuracy in most cases. The reducing sugars, dextrose and levulose, increase during the period of growth, and may or may not increase slightly during ripening. In the later periods of ripening and decay they in most cases tend to increase, at least until the final stages of decay.

Comparatively little can be said regarding the behavior of the insoluble solids during the periods of growth and ripening. During the periods of after ripening and decay they pretty steadily decrease. Probably they are at their maximum during the early stages of ripening. The stage of development of the insoluble solids of the apple is of great account in determining the quality and condition of the fruit; they compose for the most part the cell walls of the fruit. During the later stages of development of the fruit the middle lamellæ of the cell walls seem to soften, perhaps through the action of some enzyme. This

results in a comparatively easy separation of the individual cells from each other and in the mealy taste found in the over-ripe apple.¹

Comparatively little is known of the behavior of the flavoring oils, but it is evident that they do not develop very noticeably until the period of ripening. It would seem, however, that they develop during the later stages of the ripening period and through the period of after ripening, and tend to disappear as the stage of decay progresses.

Little, also, is known regarding the behavior of the tannin of the fruit, but it is probably highest during the late stages of growth. It may be connected with the development of color in red apples, and inasmuch as it seems to disappear during the ripening stage, when the apple is taking on color, it may be that it contributes in some way to the formation of pigment in the epidermal cells of the fruit.

IV. THE PERFECTLY DEVELOPED APPLE.

In the course of investigation herein reported, the writer has made a somewhat careful study of some twenty varieties of apples, chosen from among the more prominent and widely distributed sorts. From five to fifty or more samples of each variety have been received from many different localities scattered over the entire apple-producing portions of North America. These apples have been carefully examined and their characteristics noted, and from two to twenty samples of each variety have been subjected to chemical examination. In the case of the Ben Davis variety, during the past four years nearly two hundred samples have been received, and fifty or more of these have been given a more or less complete chemical examination. These samples have varied widely in physical appearance and chemical composition. These variations are dealt with in a later division of this paper. The study of these varieties, added to other general observations, has enabled the writer to form a fairly definite conception of them, when developed to their highest perfection in appearance, quality and chemical composition. The point of perfect development is taken as that where

¹ Bureau of Chemistry, Bulletin 94, p. 92.

the after-ripening stage is complete and before any signs of deterioration appear. A variety in this condition is at the point of highest dessert quality. Especial consideration will be given in this discussion to the question of high quality in each variety.

Before entering into this discussion, it may be well to consider the relation between chemical composition and quality. In the first place, it may be said that quality is used with several different meanings. It may refer to the dessert quality of the fruit or to its value for kitchen purposes. The apple of high dessert quality is different from the apple of high kitchen quality. We also speak of the shipping quality of fruit, and high shipping quality is in a measure opposed to high kitchen, and even more to high dessert quality. The apple which ships well will usually be a fair keeper, but these two qualities are by no means coincident. The chemical determinations which throw the most light on quality are those of the sugars and acid and of the insoluble solids, the latter being of greater importance than is usually considered to be the case.

The apple of high dessert quality is low in its content of insoluble solids, this signifying a tender flesh and probably thin-walled cells. It is high in sugars, more particularly sucrose. The amount of acid is proportional to the quantity of sugars; the higher the content of sugars the higher must be the content of acid, in order to bring an agreeable blending of these two constituents. If a large proportion of the sugars is sucrose, the proportion of acid needs to be larger than if the proportion of sucrose is low, in order to give the same quality. The ratio of acid to total sugars most favorable to high dessert quality will vary greatly with individual tastes. Some prefer a sweet apple, and, on the other hand, many like a fairly acid fruit. If the sugars are in the proportion approximately of two-thirds reducing sugars to one-third sucrose, the following may be taken as a fair estimate of the varying ratio of total sugars to acid for different flavored fruits. These ratios will not hold for fruits that have entered into the stage of physiological decay.

	Total Sugars to Acid as Malic.
Sweet apples,	1 : .010 to .025
Mild sub-acid,	1 : .025 to .035
Sub-acid,	1 : .035 to .045
Acid,	1 : .045 to .060
Very acid,	1 : .060 to .085

It has been said that a low percentage of insoluble solids is necessary for high quality in dessert fruits. For cooking purposes this is of minor importance, and the ratio of sugars to acid is narrowed; that is, the relative amount of acid should be larger than in dessert fruits.

Apples of good shipping quality have invariably a high percentage of insoluble solids, and as this is opposed to high dessert quality, it follows that we should not expect to find the highest table quality and highest shipping quality in the same fruit. Most varieties that keep well have a relatively high proportion of their sugars in the form of sucrose. It appears that an apple in order to keep well must be well nourished, and have stored up a large amount of soluble solids, principally in the shape of sugars. Table 1 shows the averages of a number of analyses of most of the varieties that have been examined. In these averages only analyses of normal, well-grown and well-ripened fruit have been included.

TABLE 1. — *Average Analyses of Varieties (Per Cent).*

	Number of Analyses.	Total Solids.	Insoluble Solids.	Soluble Solids.	Reducing Sugars.	Sucrose.	Total Sugars.	Acid as Malic.	Ratio, Total Sugars to Acid.
Wealthy,	3	13.84	2.11	11.73	7.40	1.71	9.11	.50	1 : .055
Maiden Blush,	3	14.59	2.66	11.93	4.80	3.14	7.94	.63	1 : .079
Fameuse,	5	15.09	2.64	12.45	7.72	1.38	9.10	.39	1 : .043
McIntosh,	6	14.45	2.32	12.16	7.21	1.91	9.12	.38	1 : .042
Jonathan,	10	15.19	2.38	12.81	8.28	1.65	9.93	.42	1 : .042
Grimes,	11	17.88	2.70	15.18	8.77	4.30	13.60	.45	1 : .035
King,	2	16.48	2.45	14.03	8.43	2.39	10.82	.38	1 : .035
Rhode Island Greening,	4	15.82	2.89	12.93	6.10	3.27	9.37	.59	1 : .063
Northern Spy,	10	14.93	2.39	11.54	8.00	2.22	10.22	.44	1 : .043
Baldwin,	9	16.19	2.71	13.48	5.74	3.91	9.65	.55	1 : .057
Esopus,	2	17.79	2.67	15.12	7.00	3.66	10.66	.56	1 : .053
Yellow Newton,	2	16.48	2.75	13.73	7.39	3.07	10.66	.47	1 : .044
Winesap,	7	17.42	2.71	14.71	10.02	2.20	12.22	.47	1 : .038
Stayman Winesap,	3	15.83	2.78	13.05	8.11	3.44	11.55	.52	1 : .045
Rome Beauty,	3	15.72	2.89	12.83	6.77	3.16	9.93	.41	1 : .041
Smith Cider,	2	17.37	3.30	14.07	7.34	2.37	9.91	.51	1 : .051
Roxbury Russet,	4	18.73	2.82	15.91	7.43	4.85	12.28	.59	1 : .045
York Imperial,	7	14.69	2.69	12.00	7.96	3.04	11.00	.39	1 : .035
Ben Davis,	11	15.66	3.07	12.59	6.91	2.95	9.86	.44	1 : .045

We may now proceed to the discussion of each of these varieties, and will endeavor to set forth the appearance and quality of these varieties when grown to their highest perfection. The conditions under which perfection is attained, and the effect of unfavorable conditions, are discussed in detail in a later section of this paper. These descriptions are not intended to be complete descriptions of the variety, but should be read in connection with a technical description, if one is not already familiar with the general appearance of the variety.

Wealthy. — Well-grown Wealthies should be about 75 to 80 millimeters in diameter and well colored over the entire surface. The color should be a deep, rich red, distributed in the form of stripes and splashes, deepening to a blush on the sunny side. Poor color is a sign of imperfect development in this fruit. The apple should be very symmetrical in form and appearance. It is altogether a handsome fruit when well grown. The chemical analysis shows that the variety is low in total solids, a condition that we find in most summer and early fall varieties. It is low in all the constituent solids except acid. This high ratio of acid to sugar makes it a good cooking apple, but its low content of insoluble solids makes it acceptable for the table, in spite of its rather low content of sugars.

Maiden Blush. — The well-grown Maiden Blush is of about the same size as the Wealthy, of a clear waxen yellow color, with a generous bright red blush on the sunny side. It is fairly high in solids, and, for a fall apple, is especially high in sucrose. The total sugars are, however, rather low, and the insoluble solids and acid high. Its chemical analysis indicates it to be a good cooking apple and fairly good for table use for those preferring an acid fruit.

Fameuse. — Fameuse should attain a diameter of at least 70 millimeters, and a deep red, almost crimson color, over nearly its entire surface. Its chemical analysis shows its excellent table quality, although the percentage of insoluble solids is somewhat high. The relation of sugars to acid is good. It is remarkably low in sucrose and not particularly high in total sugars.

McIntosh. — The McIntosh should grow a little larger than

the Fameuse, reaching about 80 millimeters. The color should be a deep, rich crimson, a little lighter on the shady side and showing sometimes rather obscure splashes and stripes. This variety is one of the most highly esteemed as a dessert fruit. The low content of insoluble solids is in accordance with this estimate, though it does not express fully the excellent texture of this variety. Neither does the analysis give indication of its agreeable aroma and flavor. The content of sugars is good for a variety of its season and the ratio of acid is excellent. The analysis in many ways closely resembles that of the Fameuse, thus indicating the relationship considered to exist between the two varieties.

Jouathan.—This is a favorite table apple of high quality. It should attain a diameter of 70 to 75 millimeters and be of a deep rich straw yellow, almost completely covered with a deep, rich crimson blush. It is a very handsome apple when well grown. Its tender flesh is indicated by its low content of insoluble solids. It is only fairly high in sugars even for a variety of its season, and on this account lacks the richness of flavor of the Grimes and Roxbury Russet. Its ratio of sugars to acid places it among the sub-acid varieties.

Grimes.—Grimes when well grown should reach a size of 75 to 80 millimeters or more, and should be, when ripe, a clear waxen yellow, and may be covered with a slight russeting over the entire surface. When grown in dry climates this russeting may appear in only a slight degree or not at all, a condition which perhaps adds to the good appearance of the fruit. The Grimes is remarkable for its high content of total solids, largely in the form of sugars, and of these a large proportion is in the form of sucrose. The last fact, together with its rather low content of acid, accounts for the almost sweet taste of this variety.

King.—The King when well grown should be not less than 80 to 85 millimeters in diameter, and may be quite variable in form, but should be colored over its entire surface with a deep, rich red, somewhat splashed and mottled. Inasmuch as only two samples of this variety were analyzed, less dependence can be put on the figures given than could be if a larger number had

been examined. Its high quality is shown in its analysis, but it is due to no one constituent. The King is good in every respect. It is a more acid apple than the Grimes, although the ratio of sugars to acid is the same. This is due to the fact that a smaller proportion of the sugars is in the form of sucrose.

Rhode Island Greening.—The Rhode Island Greening should reach a size of about 85 millimeters and possess a clear, greenish-yellow skin. It may show a faint red blush on the sunny side, although this character may not appear in fruit that is otherwise well developed. It is generally considered a variety of excellent cooking quality, and this is shown in its high ratio of acid to sugars and in its relatively high sucrose content, while its high content of insoluble solids does not detract from its value for this purpose.

Northern Spy.—The Northern Spy is reputed to be one of the highest quality of winter varieties. It should reach a size of 80 to 85 millimeters, and be well covered with bright red stripes and splashes. Spies of poor color are frequently, though not always, of inferior quality, depending on the nature and cause of the inferiority. The low content of insoluble solids of the Spy is in accordance with its well-known tenderness of flesh and the readiness with which it bruises.

Baldwin.—The Baldwin should reach a size of 75 to 80 millimeters, and be of even deeper color and more evenly distributed. It is a better shipping apple than the Spy, but hardly as good for the table. This condition of affairs is indicated in its higher percentage of insoluble solids. It is also higher in sucrose and in the ratio of acids to sugar.

Esopus.—This variety should reach a diameter of 75 millimeters at least, and the skin should be a deep, rich straw yellow, almost completely covered with deep, rather dull red splashes and stripes. This, like the Jonathan, often appears with a poor color, indicative of imperfect development. The Esopus stands among the best as an all-round high quality variety, and its chemical analysis is in accord with this. It is about medium in its content of insoluble solids, indicating that it is sufficiently firm of flesh to ship and cook well, but not enough to seriously

injure its table quality. It is about medium in sugars and the relative amount of sucrose is fairly high. Its ratio of sugars to acid places it among the more acid table fruits and less acid cooking varieties.

Yellow Newtown. — The Yellow Newtown should be from 80 to 85 millimeters in diameter, of a clear, greenish-yellow color, sometimes slightly blushed on the sunny side, and may often show over a considerable portion of the surface a grayish scurf skin characteristic of the variety. Its analysis indicates it to be of somewhat firmer flesh than the Esopus and somewhat less acid; otherwise, it is very similar in its constitution.

Winesap. — The Winesap should be about 75 millimeters in diameter, and should be deeply colored, although the color is hardly as dark as that of Jonathan. It should, however, when well grown, show little or no signs of the ground color of the fruit. Its analysis places it in the highest class. It is rather high in insoluble solids, but very high in sugars, being exceeded only by the Roxbury and Grimes. However, a smaller portion of the sugar is in the form of sucrose than in either of the other two sorts.

Stayman Winesap. — This variety is quite similar to the Winesap. It should reach a little larger size and is not quite as red in color. The ratio of acid to sugars is somewhat higher, but this excess of acid is obscured by the higher amount of sucrose, so the acidity of the apple is about the same to the taste.

Rome Beauty. — As only three samples of this variety have been examined we do not feel like venturing on any very positive statements in regard to it. It would seem to reach a size of 80 millimeters and a color somewhat less marked than other red varieties. It shows a relatively high proportion of sucrose, but is only fair in the amount of total sugars. It is rather high in insoluble solids to be a good table fruit, and altogether the analysis is not indicative of very high quality.

Smith Cider. — The same remarks concerning the study of the Rome Beauty will apply to this variety. Very few samples have been examined, and how typical the analysis given is,

the writer does not feel confident. It is remarkably high in insoluble solids, but whether this characteristic is constant or not will require further study to determine.

Roxbury Russet. — The Roxbury Russet should reach a size of 75 to 80 millimeters. The amount of russeting is dependent on climate. A moist atmosphere during the early stages of growth seems to contribute to the increase of russeting. Its analysis shows a high content of sugar, a large proportion of which is in the form of sucrose. It is also high in acid, but in view of the amount and form of the sugars it is not particularly acid to the taste. It is high in insoluble solids, indicating firmness of flesh and good shipping qualities. Altogether, it is one of the high quality varieties, as indicated by its chemical composition.

York Imperial. — The York Imperial should reach a size of about 80 millimeters, and be of a clear waxen yellow, partially overlaid with a pinkish red. Sometimes this over color deepens to a moderately dark red, but this is not necessary to the attainment of high color and pleasing appearance. Its analysis indicates its sub-acid flavor, and it shows as low a ratio of acids to sugars as any of the varieties here reported.

Ben Davis. — The Ben Davis should attain a diameter of 75 millimeters, and fairly deep red color over almost its entire surface. Partial coloration in this variety is a sure sign of imperfect development. It enjoys the reputation of being one of the best varieties to ship and keep, and one of the poorest for both kitchen and table uses. This opinion is supported by its chemical analysis. It is especially high in insoluble solids and low in everything else, although the proportion of sugar in the form of sucrose is fairly high. The total sugars, however, are low for a winter variety. Its serious deficiency as a table fruit is its high insoluble solids content, and as a kitchen fruit its low ratio of acids to sugar.

V. THE INDIVIDUALITY OF THE TREE.

The question of the individuality of the tree has already been mentioned (see page 179). The careful measurements that have been made of the apples from several Ben Davis and Baldwin

trees for the past three years afford some interesting data on this point. The trees are on nearly level land at the top of a slope. The soil is a uniform gravelly, clay loam, and the trees are of the same age, and vary only a little in size. In the years 1908-10, every apple borne to maturity by these trees has been measured, as described in the last report of this station,¹ and the results for the individual trees are presented in Table 2.

¹ Report Massachusetts Experiment Station, 1910, p. 198.

TABLE 2. — Apples from Different Trees.

		SIZE.			FORM.			
		Number of Apples.	Mean.	Standard Deviation.	Coefficient of Variability.	Mean.	Standard Deviation.	Coefficient of Variability.
<i>Davis.</i>								
Tree 2:—								
1908,	.	864	71.02±.14	6.16±.10	8.67±.14	1.1422±.0014	.0576±.0009	3.04±.08
1909,	.	251	70.89±.22	5.40±.16	7.62±.18	1.1248±.0024	.0553±.0017	4.91±.15
1910,	.	425	73.15±.19	5.69±.13	7.78±.15	1.1159±.0016	.0516±.0012	4.62±.12
Tree 3:—								
1908,	.	567	68.80±.15	5.31±.11	7.72±.16	1.1399±.0016	.0543±.0011	4.73±.09
1909,	.	343	68.88±.10	5.24±.13	7.65±.22	1.1267±.0020	.0533±.0014	4.89±.19
1910,	.	449	72.27±.19	6.01±.13	8.32±.22	1.1322±.0015	.0488±.0011	4.31±.11
Tree 5:—								
1908,	.	469	68.35±.13	5.55±.08	8.12±.13	1.1666±.0019	.0626±.0013	3.76±.08
1909,	.	135	68.32±.27	4.96±.18	7.26±.33	1.1295±.0028	.0519±.0019	4.59±.19
1910,	.	369	75.53±.21	5.88±.15	8.00±.22	1.1151±.0018	.0512±.0013	4.59±.12
Tree 7:—								
1908,	.	423	72.80±.18	6.45±.13	8.86±.17	1.1716±.0019	.0578±.0013	3.37±.07
1909,	.	431	70.37±.17	5.12±.12	7.28±.19	1.1486±.0017	.0511±.0012	4.45±.11
1910,	.	587	75.12±.19	6.85±.14	9.12±.21	1.1333±.0014	.0516±.0010	4.55±.09
Tree 8:—								
1909,	.	686	70.45±.13	4.93±.09	7.00±.13	1.1310±.0013	.0494±.0010	4.37±.09
1910,	.	1,093	72.57±.09	6.16±.06	8.52±.10	1.1211±.0007	.0481±.0005	4.29±.05
<i>Badwin.</i>								
Tree 2:—								
1909,	.	321	78.62±.21	5.59±.15	7.11±.23	1.1615±.0022	.0579±.0015	4.98±.13
1910,	.	287	78.84±.23	5.86±.16	7.43±.27	1.1745±.0021	.0536±.0015	4.56±.15
Tree 4:—								
1909,	.	621	74.39±.14	5.01±.10	6.73±.15	1.1818±.0014	.0523±.0010	4.41±.10
1910,	.	189	76.90±.27	5.57±.10	7.24±.30	1.1831±.0027	.0553±.0019	4.67±.17
Tree 5:—								
1909,	.	319	77.66±.21	5.06±.15	7.29±.22	1.1790±.0024	.0644±.0017	5.46±.16
1910,	.	546	77.71±.15	5.20±.11	6.69±.15	1.1888±.0018	.0622±.0013	5.23±.12

A study of this table shows some positive signs of individuality in the trees in the characters of size, form and productiveness. Size is of course considerably affected by the number of apples borne, though not as much as usual in this case, as the trees have not matured a very heavy crop during the period of observation. The marked seasonal fluctuation in size will be considered later. We can say that Ben Davis trees 7 and 2 show a tendency to bear large apples and trees 3 and 5 a tendency to bear smaller fruit, though in 1910 tree 5 bore the largest fruit of any, but at the same time the crop was lightest of all. Among the three Baldwins, the rank has been the same each year, in spite of the fluctuations in productiveness. In variability there are no constant differences. In the Ben Davis there seems to be a relation between variability and number of apples produced, the greater the number of apples the greater the standard deviation and coefficient of variability, — a relation that is to be expected.

In form, the situation is much the same. Ben Davis tree 7, which produced the largest apples, has invariably borne the flattest ones, usually by a considerable margin. Tree 2 shows a fairly constant character of producing more elongated apples than its fellows. In the Baldwins, also, there are signs of slight differences between the trees.

The variation in number of apples borne by the different trees is great. Ben Davis tree 8 has averaged about three times as many apples as tree 5, and they have been larger. A part of this difference is due to the fact that tree 8 is somewhat larger than tree 5, but the difference in size is not enough to account for all the difference in productiveness.

Productiveness is one of the most important qualities of a variety or individual tree. If the tree does not produce at least a fair crop of fruit, all other valuable qualities it may possess lose their attractiveness to the commercial grower, while great productiveness covers a multitude of deficiencies. Other investigations, and common observations as well, have shown very marked differences in the bearing ability of different trees.¹ In our opinion, these differences, as well as any others which may occur, are generally due to one or more of four influences:

¹ See Macoun, Report Central Experiment Farm for 1903, p. 102.

(1) differences in soil, (2) differences in aspect or exposure, (3) some inherent quality of the tree, (4) the influence of stock.¹

That the first two of these cause difference no one will dispute, but there are many variations which can hardly be explained by differences in soil or site. It has been assumed by many that variations in productiveness arise from within the tree, and are transmissible. We know of no direct evidence to support this view. Inheritable variation in color and form has appeared in certain varieties. The Collamer, Banks and possibly Gano apples are instances of the former, and a probable case of the latter has been reported by the writer.² Whether the slight differences in form and size reported here are transmissible by bud is by no means certain. We are of the opinion that they are not, for it seems possible to explain these and the other variations in productiveness, not attributed to soil and site by reference to a different cause.

Wangh has shown that in plums different stocks produce marked modification in the trees grown on them.³ Apple stocks do not differ as widely as do the plum stocks, above referred to, but the observed differences are also less marked. Every apple tree of a named variety is growing on a stock of a different, unnamed variety, *i.e.*, a seedling. These seedlings differ to a considerable degree. May not the slight differences observed between individual trees of a variety, growing under apparently similar conditions, be largely due to the influence of the seedling root? We know of no direct evidence to support this view, but to us it seems a more promising theory than that of individuality of the different buds.

If this supposition is true, it is probable that the production of the most desirable trees of a given variety would be favored by growing on a particular known root; thus the Baldwin grown on roots of Spy, Wealthy or Siberian Crab might be an especially desirable tree, while if grown on Tolman or King⁴ it might be less desirable. Different soils and localities might be

¹ There are, of course, large seasonal fluctuations in productiveness due to conditions peculiar to the different years. These are not considered in this discussion.

² See Report Massachusetts Experiment Station, 22, Part II., p. 187.

³ Report Massachusetts Experiment Station, 21, Part II., p. 174.

⁴ The varieties mentioned are random selections for illustration. There is no reason to believe that they would influence the Baldwin as indicated.

suiting by different stocks. We know of no experiments to learn what are the preferences of different varieties or soils, but it appears to be a desirable and promising line of investigation.

VI. THE MODIFYING EFFECT OF CLIMATE ON THE DEVELOPMENT OF THE APPLE.

OX FORM.

In the last report of this station ¹ the question of the variation in form of the Ben Davis was dealt with to some extent, but without arriving at any very definite conclusion as to the cause, further than that it was climatic and closely related to the nearness of large bodies of water. Since this report was written, two years' further work have been completed, which serve to emphasize the conclusions mentioned above, and to show, further, that there are large seasonal fluctuations in the index of form. The following figures from a few selected stations will illustrate this:—

TABLE 3. — *Seasonal Variation in Form.*

	Number of Apples.	Mean Index of Form.	Standard Deviation.	Coefficient of Variability.
Charlottetown, P. E. I.: —				
1907,	74	1.0511±.0049	.0619±.0034	5.88±.31
1908,	122	1.1250±.0052	.0858±.0037	7.63±.33
1910,	135	1.0557±.0043	.0744±.0031	7.05±.29
Abbotsford, Quebec: —				
1907,	151	1.1788±.0039	.0735±.0028	6.23±.24
1908,	129	1.1739±.0041	.0683±.0029	5.82±.23
1909,	184	1.1986±.0031	.0628±.0022	5.24±.21
1910,	115	1.1356±.0029	.0455±.0021	4.01±.18
Ile la Motte, Vt.: —				
1907,	203	1.1547±.0024	.0735±.0024	6.28±.27
1908,	170	1.1406±.0027	.0526±.0020	3.74±.15
1909,	148	1.1475±.0033	.0590±.0023	5.14±.24
Amherst, Mass.: —				
1907,	284	1.1656±.0023	.0581±.0017	4.98±.14
1908,	2,321	1.1515±.0008	.0589±.0006	5.29±.05
1909,	1,866	1.1338±.0009	.0527±.0006	4.65±.06
1910,	2,914	1.1238±.0007	.0504±.0004	4.48±.04
Storrs, Conn.: —				
1907,	147	1.1557±.0030	.0534±.0021	4.62±.18
1908,	131	1.1423±.0041	.0689±.0029	6.03±.21
1909,	146	1.1330±.0035	.0622±.0025	5.49±.24
Marblehead, Mass.: —				
1908,	192	1.1021±.0029	.0598±.0021	5.42±.18
1910,	176	1.0982±.0033	.0651±.0023	5.93±.22
Sandwich, Mass.: —				
1908,	162	1.1281±.0021	.0407±.0015	3.67±.14
1909,	143	1.1167±.0036	.0654±.0025	5.86±.24

¹ Report Massachusetts Experiment Station, 22, p. 194 (1909). The reader is referred to this paper for the methods used in measuring and studying this variation in form.

This has led to a study of the differences in the climatic conditions in the different years. The apple during its early stages of growth, following blossoming, is relatively more elongated than is the mature fruit. During the later periods of growth it enlarges in cross diameter relatively more. A study of the temperature during the latter part of the summer failed to show any differences corresponding to the variations in form. An examination of the daily mean temperatures for a period at and following the blossoming period gave more positive re-

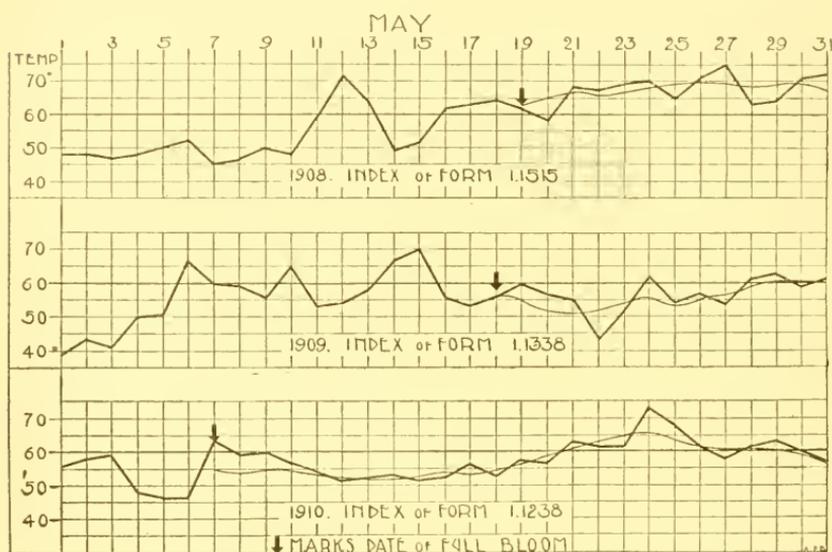


FIG. 1.

sults. At Amherst the apples measured in the last four years have been successively more and more elongated. The temperatures during the blossoming season for the last three years are shown in Fig. 1. The date of full bloom and index of form are also shown. We do not know the date of full bloom in 1907. An examination of this chart shows that the temperature for a period of two or three weeks following blossoming has been lower each year, in agreement with the greater elongation of the fruit.

We have data for a number of other stations, and all show a similar correspondence of temperature and form. Fig. 2 shows

conditions in the Lake Champlain valley, the apples being from Isle la Motte, Vt., and temperature data from Burlington. We

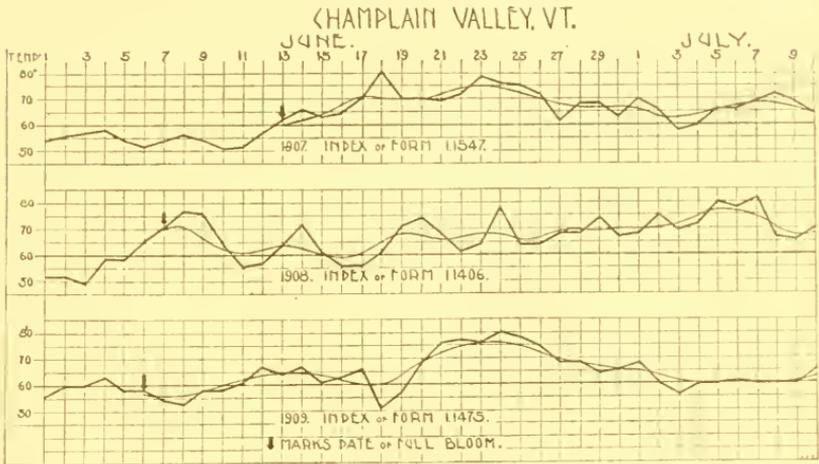


FIG. 2.

do not know the date of bloom in 1908, but it was probably not far from June 8. In Fig. 3 the temperature data are from

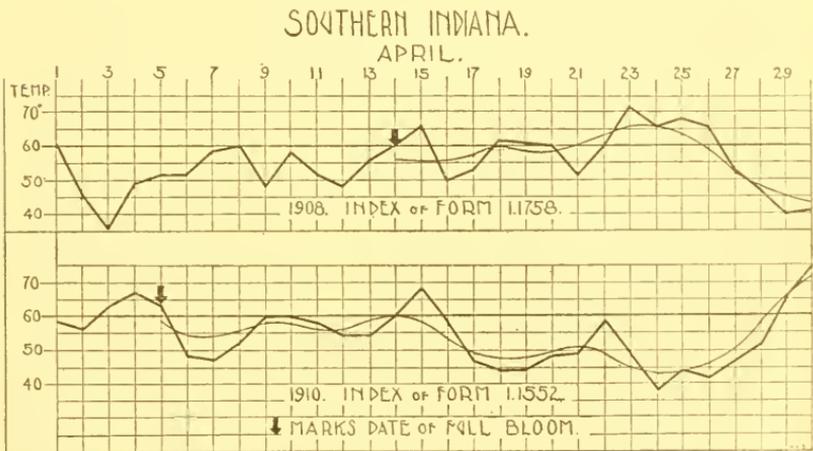


FIG. 3.

Salem, Ind., and the apples from Mitchell; in Fig. 4 both apples and temperature data are from Bentonville, Ark.

An examination of these charts shows a reasonably close agreement with that for Amherst. A period of cool weather,

probably during a space of two or three weeks, results in greater elongation of the fruit, presumably through a prolongation of the period of relatively greater axial elongation before referred to.

This theory explains not only the seasonal variations but the greater elongation in the vicinity of large bodies of water, for the fact that in such locations the weather is relatively cool during the spring needs no discussion. In this connection we have observed that the seasonal fluctuation in form is less near

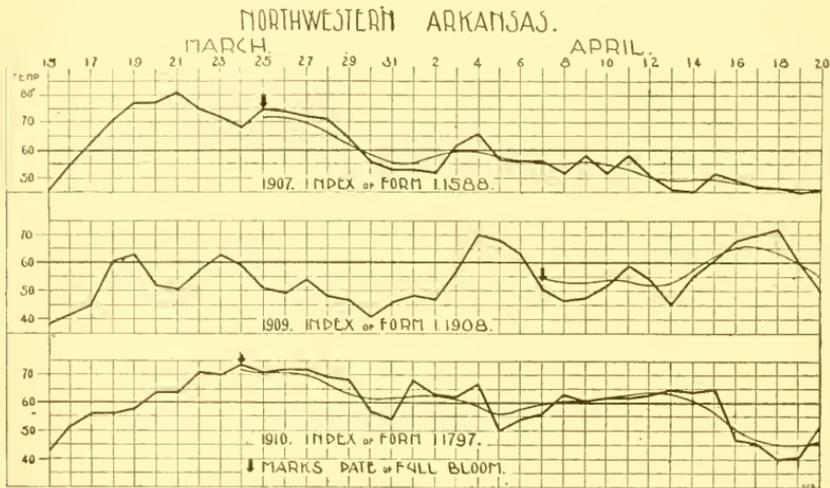


FIG. 4.

the great lakes and the ocean than at a distance from them, this showing the influence on the form of the apple of the equalizing effect on the temperature of the large bodies of water.

In gathering the apples from the trees under observation in Amherst, they have been divided into four lots, by bisecting the tree with a perpendicular plane running east and west, and again with a horizontal plane about midway of the head of the tree. This divides the tree into quarters designated upper south, lower south, upper north and lower north. The sections of each tree have approximately equal amounts of bearing wood. From the first these different portions of the tree have shown differences in form which have been meaningless and confusing until the theory of the temperature following blossoming was

proposed. If this is the correct solution we ought to expect the upper south portions of the tree, owing largely to its exposure to the warmth of the sun, to give the flattest apples, and the lower north to give the most elongated ones, with the other two portions intermediate. The calculations for the three years 1908-10 are shown in Table 4.

TABLE 4.—Variation in Form in Different Parts of the Tree.

	Number of Apples.	Mean Index of Form.	Standard Deviation.	Coefficient of Variability.
<i>Ben Davis.</i>				
Upper south:—				
1908,	518	1.1643 ± .0017	.0593 ± .0012	3.61 ± .07
1909,	552	1.1390 ± .0015	.0520 ± .0011	4.57 ± .10
1910,	707	1.1299 ± .0013	.0500 ± .0009	4.43 ± .09
Lower south:—				
1908,	714	1.1512 ± .0015	.0619 ± .0011	4.19 ± .07
1909,	379	1.1302 ± .0018	.0516 ± .0012	4.57 ± .12
1910,	893	1.1249 ± .0011	.0489 ± .0009	4.35 ± .08
Upper north:—				
1908,	414	1.1553 ± .0020	.0607 ± .0014	3.91 ± .08
1909,	305	1.1333 ± .0020	.0509 ± .0014	4.40 ± .14
1910,	576	1.1216 ± .0016	.0544 ± .0010	4.85 ± .10
Lower north:—				
1908,	676	1.1406 ± .0016	.0644 ± .0011	4.58 ± .07
1909,	287	1.1338 ± .0021	.0529 ± .0015	4.67 ± .14
1910,	869	1.1171 ± .0012	.0505 ± .0008	4.52 ± .08
<i>Baldwin.</i>				
Upper south:—				
1909,	467	1.1877 ± .0019	.0606 ± .0013	5.10 ± .13
1910,	235	1.1955 ± .0024	.0537 ± .0016	4.49 ± .16
Lower south:—				
1909,	290	1.1688 ± .0020	.0500 ± .0014	4.28 ± .14
1910,	137	1.1792 ± .0031	.0536 ± .0022	4.57 ± .20
Upper north:—				
1909,	327	1.1809 ± .0020	.0548 ± .0014	4.64 ± .13
1910,	168	1.1792 ± .0030	.0575 ± .0021	4.88 ± .18
Lower north:—				
1909,	177	1.1586 ± .0026	.0522 ± .0019	4.51 ± .18
1910,	86	1.1717 ± .0044	.0602 ± .0031	5.14 ± .31

The relative rank of the different parts of the trees of the Ben Davis is as follows:—

	1908.	1909.	1910.
1. Most flattened,	Upper south.	Upper south.	Upper south.
2,	Upper north.	Lower north.	Lower south.
3,	Lower south.	Upper north.	Upper north.
4. Most elongated,	Lower north.	Lower south.	Lower north.

It is seen that the upper south quarter of the tree yielded the flattest apples each year, and usually by a considerable margin, while the most elongated fruit comes from the lower portion of the tree, and, in two of the years under consideration, on the north side. On the whole the figures for the different parts of the tree support the theory already presented that the elongation is due to relatively cold weather, and gives support to the idea that the heat of the sun has much to do with the temperature of the tree itself and probably the development of the fruit.

In the Baldwins the relative rank is as follows for both years: upper south, upper north, lower south, lower north.

ON SIZE.

The size of an apple is determined by several factors. Each variety has its individuality in this respect. Culture is important, an abundance of nitrogenous fertilizers and an abundant supply of moisture being favorable to the attainment of large size. An excessively heavy crop prevents the development of full size of the individuals, but a light crop does not seem favorable to any larger fruit than a moderate one. Young trees usually bear larger fruit than mature ones, while in very old trees the fruit is commonly inferior in size. The differences due to age are probably in considerable degree at least due to the influences already mentioned.

Aside from these influences the summer temperature seems to have considerable influence. Some evidence on this point was presented in an earlier paper.¹ Table 4 (page 203) gives further data on this point.

The mean summer temperatures at Amherst were as follows: 1908, 58.8°; 1909, 56.7°; 1910, 58.9°.

The size of the apples is in a general way in accordance with these temperatures.

In 1910 the apples were much larger than in 1908, while the temperature was practically the same. This may be due to increased amounts of fertilizer which have been applied. The orchard was lined in the spring of 1909, and this may have had

¹ Report Massachusetts Experiment Station, 22, pp. 204, 211 (1909).

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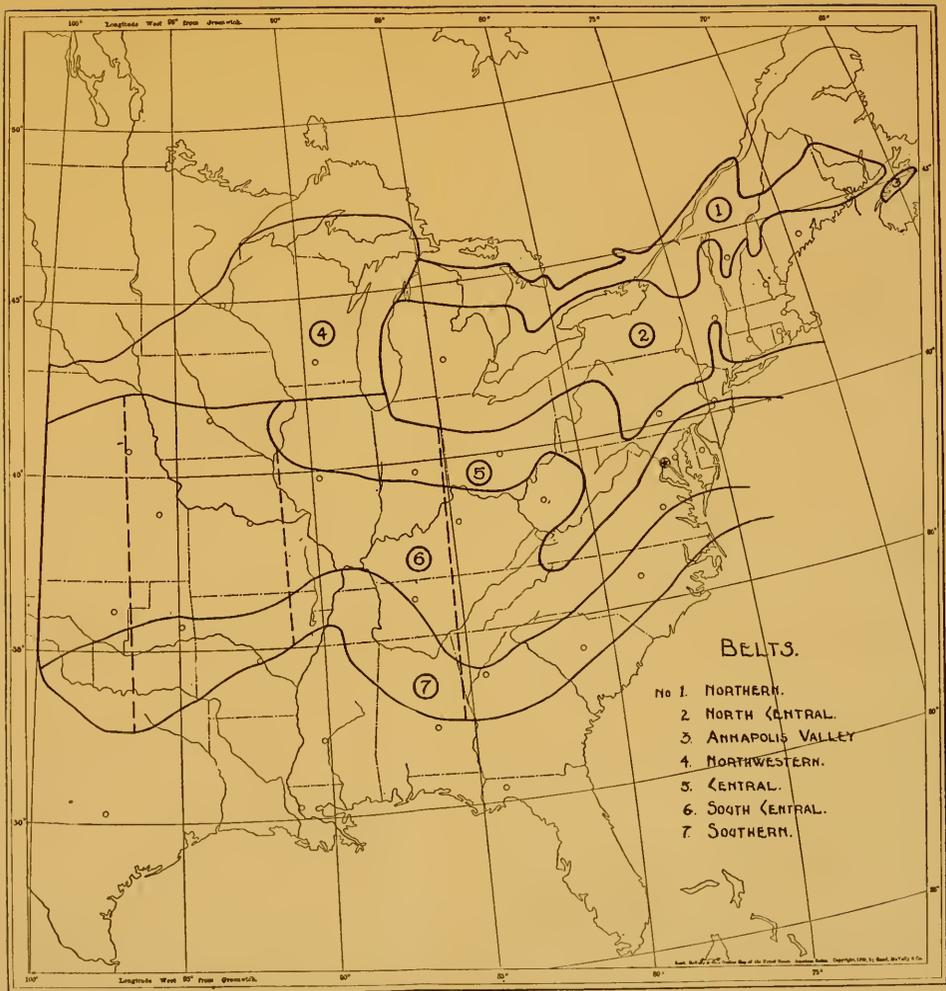


FIG. 5.—APPLE BELTS OF NORTH AMERICA.

an effect by liberating increased amounts of plant food. It does not seem possible to account for the increased size by temperature conditions.

Data from other localities similar to that previously published might be presented, but inasmuch as they show no new features, it is deemed unnecessary to do so.

ON GENERAL DEVELOPMENT.

The question of variation in form and size having been especially considered, we may now proceed to a consideration of the differences in the general development of different varieties, with more particular reference to color, keeping quality and table quality. These are the characters of paramount importance in determining the commercial value of a lot of apples. In order to discuss these questions we have found it convenient to divide the country into belts.

Apple Belts of North America.

We find in pomological writings frequent mention of different apple "belts," such as the Baldwin belt or the Ben Davis belt. This term is understood to designate a certain area over which the variety named is the leading one grown. We find many other varieties referred to a given belt, as the Northern Spy and Rhode Island Greening, which are referred to the Baldwin belt. In connection with the work herein reported, and for convenience in the discussions, the writer presents the division of North America into apple belts, shown in Fig. 5.

1. The northern belt, in which the Fameuse is the most characteristic sort.

2. The north central belt, perhaps the most recognized of any. It is characterized by the Baldwin, Northern Spy, Rhode Island Greening, Hubbardston and many others. It comprises the oldest and in some ways best understood portion of the apple region of North America.

3. The Annapolis valley, in which we find varieties similar to the second belt, but where the season is shorter and many of the varieties of the second belt do not mature well.

4. The northwestern belt, comprising the States of Minnesota and Wisconsin and adjacent territory; somewhat like the Baldwin belt to the east, but having winters too severe for many of the varieties of that belt. It is characterized by the Oldenburg, Wealthy, Hibernia, Northwestern Greening and many others.

5. The central belt, which is of less importance. There is no one variety that predominates over the whole of this territory. In eastern sections we find the Yellow Newtown, Smith Cider and Fallawater, and west of the mountains the Rome Beauty.

6. The south central belt, one of the largest and most important. There are three varieties that are quite generally spread over this belt, the Ben Davis, Winesap and York Imperial. The Grimes is quite general and important in the western part, also the Jonathan.

7. The southern belt, which extends to the southern limit of apple growing, and is characterized by the Yates, Terry, Shockley and Horse as leading varieties.

The figure shows these belts somewhat roughly. They depend on latitude and altitude more than anything else. Inasmuch as the altitude along the Appalachian Mountains is variable, it is impossible to show the belts with entire accuracy. Each belt will dip further south than is indicated in the higher elevations of this region. Some varieties are found generally distributed through the entire range of its belt from east to west. Others do not extend the entire length. The western portion of the territory covered has a smaller precipitation, and this may affect some varieties. More important than this, however, are the higher summer temperatures which prevail, and which cannot be successfully withstood by some varieties grown in the east. Other varieties succeed even better in this warmer summer climate than they do in the cooler and more humid east. The dotted lines in the figure show a possible division of the belts, but such division is not very definite nor of great value. No attempt is made to map the Rocky Mountain and Pacific Coast apple region, owing to the fact that the distribution of varieties there is governed largely by elevation, and would be very difficult to map, especially on so small a scale as the figure shows.

Distribution of Varieties.

A few varieties, most of them well known and of rather general distribution, have been selected for a special study in connection with this work. We may now proceed to a discussion of the distribution and some of the characteristics of these varieties.

Oldenburg. — This variety extends over almost the entire apple-growing region of North America. We find it recom-

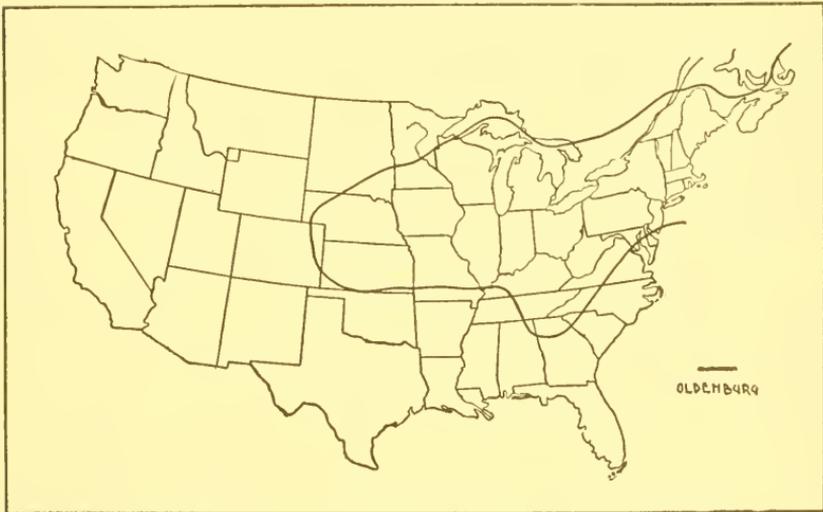


FIG. 6.¹

mended as a commercial variety in some region of every apple belt shown in Fig. 5, with the possible exception of the southern. The two principal reasons for the wide distribution of this variety are its extreme hardiness, which enables it to withstand the severe winters of the far north, and the short season of maturity, which enables it in the south to ripen before the hot periods of July and August. In addition to this it is an early, regular and fairly abundant bearer, and not particularly subject to disease and insect injuries, and the fruit stands handling quite well.

¹ Figs. 6 to 14 are intended to show the territory over which the various varieties have been recommended as desirable commercial sorts. The places of origin of each variety, so far as known, is indicated by a cross.

Wealthy. — The Wealthy is a fall apple of rather wide distribution. It is growing in favor, especially as a filler in new orchards, and its territory of cultivation is spreading. It originated in Minnesota, and finds its highest favor in the northwestern belt. It also succeeds perfectly over a greater part at least of the north central belt. It is cultivated somewhat in New Jersey, but does not find favor south of there. It will mature a little farther north than the Baldwin, and is not subject to winter-killing as is the Baldwin in severe winter temper-

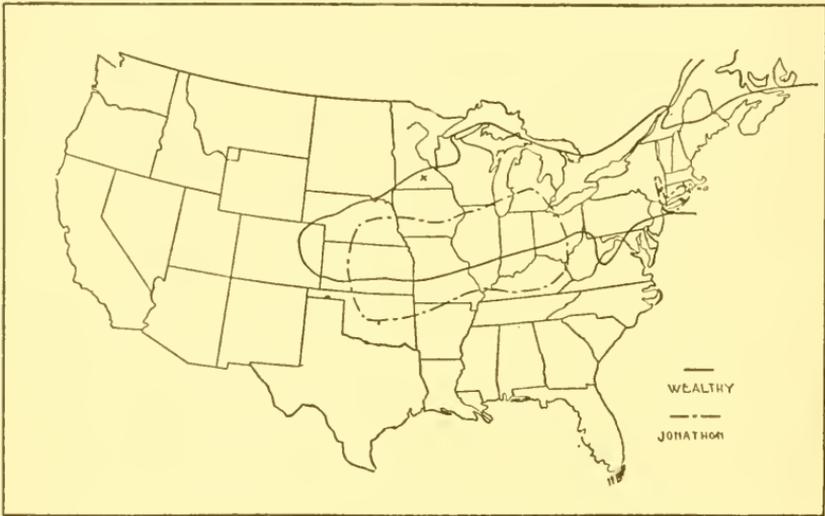


FIG. 7.

atures. It is found in greatest perfection through southern New Hampshire and Massachusetts, and along a line passing west just south of Lake Ontario and through the Province of Ontario, south central Michigan and southern Wisconsin.

Wolf River. — The Wolf River is reputed to be a seedling of the Alexander, one of the Russian varieties, and it may serve as a type of this class of apples. It is of Wisconsin origin and has attained high favor in that State. It appears to succeed best in the central and northern parts of the northwestern belt, in the northern part of the north central belt and the southern part of the northern belt. When grown too far south it does not keep well, is apt to become mealy and tasteless and is of general

inferior quality. The Russian varieties as a class are reputed to be of poor quality. They are not of the highest quality, but much of their reputation for inferiority results, in our opinion, from their being grown too far south. As a class they belong to the northern frontier of apple growing, and when grown there, many of them are equal to the better varieties of the more southern apple regions.

Maiden Blush.—This variety is a fall sort, originating in Burlington, N. J., in which State it has attained its highest

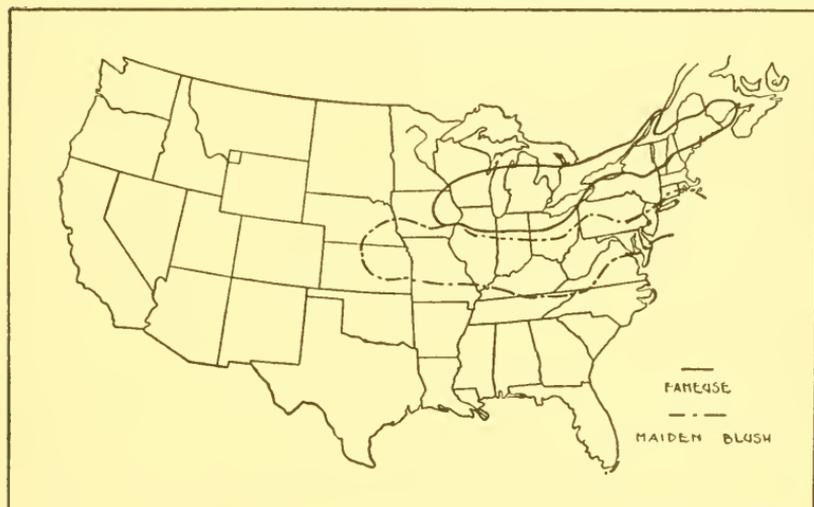


FIG. 8.

favor. It is grown with success as far north as Long Island and southern Connecticut, and west through southern Indiana and central and southern Illinois. It does not withstand the dry climate of the plains as well as some others, but reaches as far west as eastern Nebraska and Kansas. It is cultivated successfully south into the mountains of Virginia. Gould says:—

On Cecil sandy loam, at 900 to 1,000 feet elevation, it is inclined to rot severely, but on the more clayey soil of the Piedmont regions it does well. Its season of ripening varies considerably, ranging from summer to early fall. In the middle Piedmont orchards it would probably ripen in August or early September. At one point in North Carolina having an altitude of 3,500 to 4,000 feet, with rather less friable loam, some very fine specimens have been seen the middle of October.¹

¹ Bureau of Plant Industry Bulletin 135, p. 38.

It will be seen that the Maiden's Blush belongs to the central belt and the northern part of the south central belt.

Fameuse. — The Fameuse is one of the most northern of commercial apples. It is grown in most parts of the northern belt, also in northern Indiana and Illinois and in southern Michigan, though in these regions the variety does not attain the quality of the St. Lawrence and Champlain valleys. It becomes a fall apple, and is of poor color and inferior flavor. Specimens received from Prince Edward Island were dull red and green, and small in size, while those from southern Quebec were very good specimens of the variety.

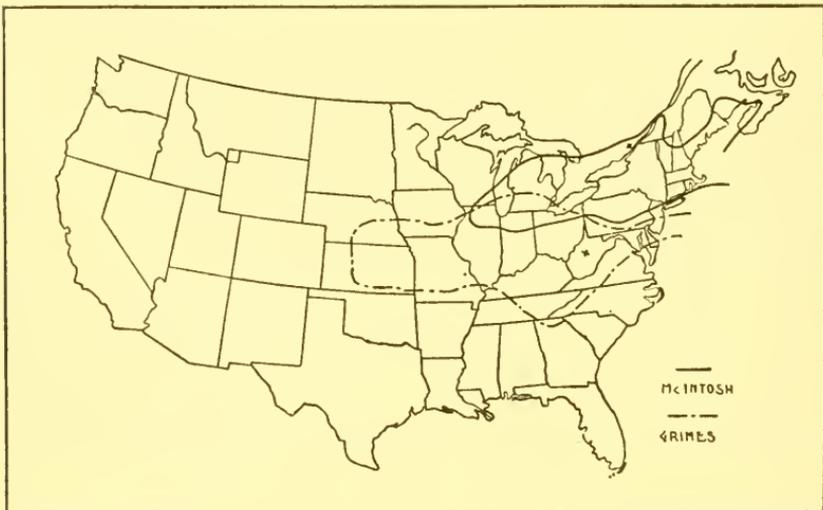


FIG. 9.

McIntosh. — The McIntosh is similar to the Fameuse and succeeds in similar territory. It does well further south, however, being at its best in south central New England and western New York. While it has been known a long time, it has not attained great favor as a commercial variety until recently, probably on account of its susceptibility to the apple scab, which has heretofore been difficult to control in a satisfactory manner. It is now gaining rapidly in popularity, and the territory of its culture is spreading. It is not grown to any extent west of Michigan, excepting in the far northwest. Throughout the Baldwin belt it is a fall apple, and south of this it becomes a

late summer or early fall variety, and is inferior in flavor and color to those grown farther north. Beach says:—

It is adapted to a wider range of localities than is the Fameuse. . . . In western New York it cannot be expected to keep much later than October in ordinary storage without considerable loss, but in cold storage it may be held until December or January. When grown in more northern or elevated regions it is often held in good condition until mid-winter or later.¹

Jonathan. — This variety had its origin in the Hudson valley, where it is now grown to a considerable extent, as well as in Long Island and southern Connecticut. It is a favorite in the south central belt west of the mountains and in favored portions of southwestern Michigan. It is at its best in central Illinois, northern Missouri and eastern Kansas and Nebraska. In Virginia and North Carolina it seems to succeed best at elevations of 1,200 to 1,500 feet or more. It has received considerable favor in the intermountain and pacific northwest apple regions, where conditions are similar to those in the regions already mentioned. It requires good care and a fairly rich soil in order to develop to its best. It should receive more attention from growers in regions where it succeeds well. It loses its sucrose in storage more readily than most varieties, after which, while still of good desert quality, it lacks the richness possessed by apples high in sucrose. It is necessary to harvest this variety at the proper time of maturity. If allowed to hang too long on the tree, especially if the weather is warm, it develops the defects of overripe apples, and will not keep well.

Grimes. — Grimes is an old Virginia apple which has spread very generally over the south central belt. It is well known over nearly all of this territory, especially in the western portion of it. Its culture extends west to central Nebraska and eastern Kansas. In the northern portion of this belt it is a late fall and early winter apple; in the southern portion it is more strictly a fall variety. It is grown to some degree north of the territory indicated, being found frequently in southern Michigan. In its more northern locations it is smaller than in

¹ Apples of New York, Vol. 1, p. 133.

the south and more acid, the latter being a quality that is appreciated by some, inasmuch as in the south the variety has a mild subacid flavor. Gould says:—

An orchard twelve to fifteen years old in Bedford County, Va., on Porters clay, at 1,500 feet elevation, with southeast exposure, produces fruit of unusual excellence, notable for its good size, fine yellow color, crispness of texture, and rich, spicy flavor. This orchard has had hardly fair care. The fruit of this variety from it reaches edible maturity early in October, but possesses good keeping qualities for the variety. On the same farm, at a point having somewhat lower elevation and a looser type of soil, it matures considerably earlier, and is not of such excellent flavor as from the location above mentioned. Produced at elevations of 2,000 feet in the upper sections of the Blue Ridge region, it may be kept under fairly favorable conditions until early winter. . . . At points south of Virginia, at the elevations of the Piedmont region, it is inclined to drop prematurely, but when grown at points having not less than 1,500 feet altitude it is highly prized in its season. One grower in the southwestern part of North Carolina has this variety at 2,500 to 2,800 feet elevation, and also at an altitude 400 to 600 feet higher. It is his experience that the fruit grown at the latter elevation will keep two months longer than that from the lower level. The fruit is also finer in appearance and more satisfactory in every way at the greater elevation. For best keeping qualities it should not be allowed to become too mature before picking.¹

Favorable reports on it have been received from certain localities in New York, but in general as grown in this State it does not develop in size, color or quality as well as it does in more southern latitudes, and there is a high percentage of loss from drops and culls.²

Tompkins King.—The King is a variety found over a limited portion of the north central belt. It is a standard apple in western New York, and is grown in southern Ontario and to some extent in Michigan. It is also a favorite variety in Annapolis valley in Nova Scotia, where it succeeds to a high degree. The tree is weak, and requires high cultivation and good care. It is scarcely known west of Lake Michigan, and is met with scatteringly as far as Virginia, where it is found in the higher levels of the Blue Ridge. The tree is

¹ Bureau of Plant Industry, Bulletin 135, p. 36.

² Beach, Apples of New York, Vol. 1, p. 154.

evidently not able to withstand the hot dry summers of the middle west.

Esopus. — This is an old variety, but one that has never been very largely cultivated. This may be partially accounted for by the fact that the tree is not particularly vigorous nor especially productive, and is somewhat susceptible to diseases. The apple is of superior quality, being much better than the Baldwin, which it considerably resembles. It has been grown somewhat in the Champlain and Mohawk valleys. It is an apple of limited cultivation for the Baldwin belt. Gould says, regarding its behavior in Virginia and North Carolina: —

At lower levels it usually drops prematurely, and even on Porters black loam at 2,000 feet elevation it often rots and drops seriously. At 3,000 to 3,500 feet altitude in North Carolina, on a rather loose loamy soil with porous subsoil containing more or less red clay, it develops more satisfactorily, keeps well into the winter, and does not manifest in any marked degree the defects observed at the lower levels.¹

It has recently attained high favor with the growers in certain portions of the Pacific northwest. In our opinion this variety is deserving of wider cultivation inasmuch as it is an excellent variety for all purposes. In fact, so far as the fruit goes we believe that none of the better known varieties of commercial apples answers so well the requirements of a general purpose market apple. When well grown it is of good size and attractive appearance, and is adapted for both dessert use and cooking. It is also a reasonably good shipping apple. It requires the better care and higher cultivation which orchards are destined to receive in the near future.

Rhode Island Greening. — The distribution of the Rhode Island Greening is very similar to that of the Baldwin, but is perhaps adapted to somewhat wider range of conditions; being a green apple it does not call for conditions adapted to the production of good color necessary for the Baldwin. It attains better size and appearance than the Baldwin when grown towards the northern limit of its culture. It is possibly somewhat hardier in tree. It is grown all through the north central

¹ Bureau of Plant Industry, Bulletin 135, p. 34.

belt, and extends somewhat further south in the higher elevations. In the south it becomes a fall apple, and is apt to ripen prematurely and drop and sometimes to decay on the trees.

Northern Spy. — This is a variety of the Baldwin belt, and its distribution is very similar to that variety, although less general. It is at its best in the Champlain valley and in western New York. Some excellent specimens have been seen from southern New England, but they do not keep as well as those from farther north. It seems to be somewhat capricious as to soils and culture, and in localities of ill success it is not always possible to determine the cause of the difficulty. When grown

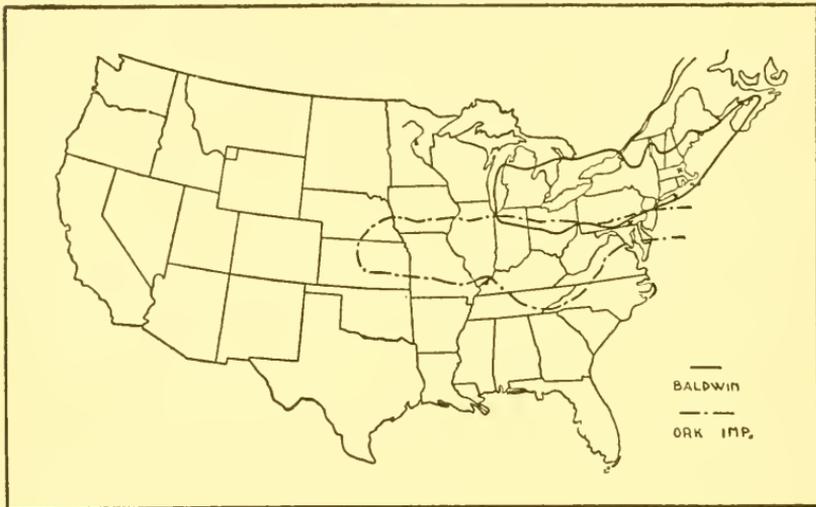


FIG. 10.

in the south it rots badly and drops, nor does it attain the high color and quality that characterize it in its more northern home.

Baldwin. — The Baldwin is the standard winter apple of the northeastern United States. It is distributed all over the north central belt, and is so nearly confined to it as to lend its name to that zone. It is also grown to a considerable extent in the Annapolis valley and very sparingly in the central belt, although it rarely attains any commercial standing in this region. It is not grown west of Lake Michigan, owing to the extremes of maximum and minimum temperatures which there

prevail. In the northwestern belt the winters are too severe and the trees winter-kill; while south of this region the summers are so warm that the variety ripens prematurely and is apt to rot and drop. These same remarks will apply to many other varieties of the Baldwin belt, most of them being too tender to withstand the winters west of Lake Michigan. The Wealthy, which is very well adapted to the Baldwin belt, is an exception to this, and grows to perfection in both regions. We have observed the Baldwin for several years in an orchard growing on the higher elevations of the Green Mountains. Here it occasionally matures pretty well. In other years it is small, dull

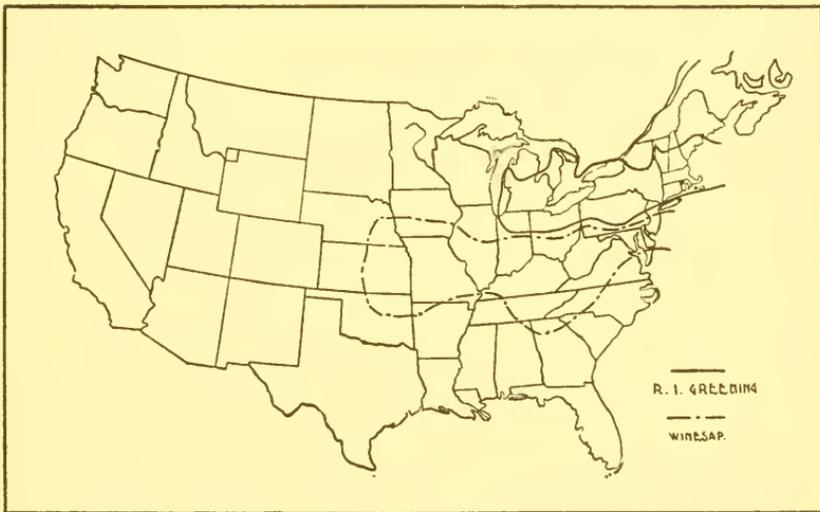


FIG. 11.

green and red in color, and of acid, astringent flavor, indicating that the variety has not had sufficient heat to mature properly. In the Champlain valley, while a standard market apple, it in most seasons fails to reach the size, color and quality that it does in western New York and south central New England. The same applies to its growth in Maine. One may observe in traveling northward through that State increasing signs of immaturity. In Massachusetts 1,000 to 1,200 feet is about the limit of certain full maturity.

Winesap. — The Winesap is a variety that has been known for a long time and has been tested over a wide area. It be-

longs to the south central belt, being grown from southern New Jersey, Virginia and North Carolina west through the Ohio valley to southern Nebraska. It reaches as far south as Georgia on the higher elevations. It reaches the highest favor in the eastern section of this belt, being of secondary importance west of the Allegheny Mountains. When grown in southern New England it is somewhat inferior in size, of doubtful color and flavor, although it keeps better than when grown in many places in its native region. It has found very little favor north of Pennsylvania and New Jersey. Specimens from Arkansas

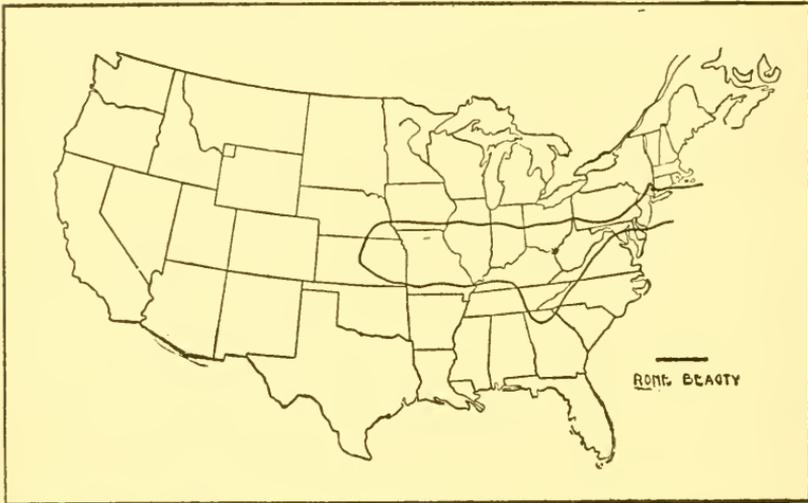


FIG. 12.

and Alabama were of medium size, though somewhat inferior in color and of only moderately good quality. Summarizing his observations regarding its behavior in Virginia and North Carolina Gould says:—

It is apparent that the conditions in the northern portion of the Piedmont region at 1,000 to 1,200 feet elevation do not produce the best results, and that in the more southern counties of Virginia which have been referred to the conditions produce very excellent fruit, but less satisfactory results are secured at points having elevations which much exceed that of the Piedmont region, while still farther south this variety can be grown at higher altitudes than is possible in the northern portion of the Piedmont. Its behavior thus indicates in an interesting way the

corresponding relationship between altitude and latitude in their influence upon the behavior of this variety.¹

Rome Beauty. — The Rome Beauty is an apple grown principally in southern Ohio, although it is found quite generally over the entire middle portion of the central belt. It is mentioned as a valuable commercial apple for Maryland, Delaware, southern Ohio, southern Indiana and southern Illinois. Specimens from Arkansas were of poor quality, but were of good size and color.

In Virginia, on Cecil sandy loam, at 900 feet, it is especially satisfactory, particularly in view of the fact that these conditions are unfavorable to most varieties. So grown, it is said to keep until the holidays. Cecil clay and Porters clay at elevations of 1,000 to 1,500 feet, in the northern Piedmont and Blue Ridge regions, usually combine conditions which are favorable to this variety. At 1,500 feet altitude on Porters clay it becomes an early winter variety of very fine appearance and good dessert quality. As a rule, it is considered especially well adapted to sandy soil. On Porters black loam, at 2,300 feet, it is considered of more than usual value. It is highly prized in western North Carolina, where it occurs at an altitude of 3,000 feet, on a deep porous mountain loam. It is, however, somewhat inclined to drop.²

York Imperial. — While the York Imperial is believed to have originated fully one hundred years ago, its period of commercial development extends over a much shorter time. It came from southeastern Pennsylvania, and there it has attained its greatest commercial value. It has spread, however, over nearly the whole of the south central belt. It is recommended as a valuable commercial variety in New Jersey, through southern Ohio to southern Iowa and Nebraska. To the south it is much valued as far as North Carolina on the higher elevations and west through Missouri and eastern Kansas. Its distribution is therefore very similar to the Ben Davis, although it has not spread into northern localities as has that variety, nor does it extend quite as far west. As to its behavior in the southern Appalachian Mountains Gould says: —

It appears to be less influenced by soil conditions than by elevation. In the Piedmont orchards having less than 1,000 to 1,200 feet elevation

¹ Bureau of Plant Industry, Bulletin 135, p. 46.

² Gould, Bureau of Plant Industry, Bulletin 135, p. 43.

serious rotting and premature dropping are apt to occur, and while frequent exceptions to this have been observed, it is sufficiently constant to suggest that extensive plantings of it in this region should be made cautiously, if at all, except in the northern portion, where it appears to be more nearly free from serious faults than almost any other commercial variety that is being grown, and is considered one of the most profitable sorts. This applies specially to locations in Rappahannock County, in close proximity to the mountains. In the Blue Ridge region above an elevation of 1,200 to 1,500 feet premature dropping is generally less severe than it is at lower points. Especially satisfactory results have usually been obtained on Porters clay at these middle elevations, where very heavy crops are expected, at least in alternate years. If heavy dropping occurs in such cases, a sufficient quantity of fruit

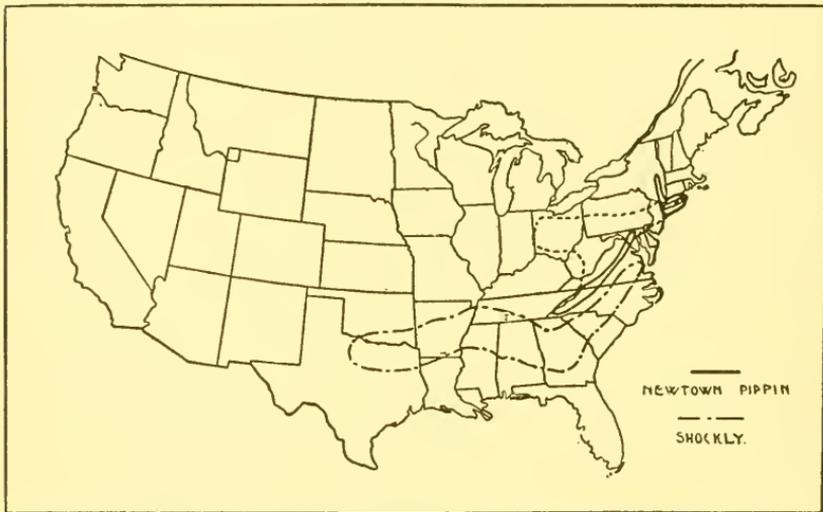


FIG. 13.

usually remains to result in a heavy crop. At the higher altitudes this is considered a valuable variety, especially in North Carolina, where it has grown at 2,500 to 3,500 feet altitude. . . . The contrast between this variety and Winesap in the manner in which they respond to the influence of elevation is of interest. The elevation at which Winesap begins to deteriorate and above which it becomes more inferior as the elevation increases appears to be about the point below which York Imperial is inclined to manifest certain faults which tend to disappear at higher altitudes.¹

Yellow Newtown. — This variety is one of restricted cultivation. The only region in the east where it can be said to have

¹ Bureau of Plant Industry, Bulletin 135, p. 49.

commercial standing is in the Hudson Valley and Long Island, and in the Upper Piedmont and Blue Ridge sections of Virginia and North Carolina. It has also attained favor in certain sections of the Pacific northwest. It is therefore an apple of the central belt. The climatic conditions, particularly the mean summer temperature, of the several regions where this variety is cultivated are even more alike than is indicated by the temperature map. The tree makes a slow growth and is rather late in coming into bearing. The variety requires better care than do many of the leading commercial sorts. The tree is evidently unable to withstand the conditions of the western plains, and apparently does not succeed west of Indiana. We are confident, however, that if given good care it will do well in many places in Pennsylvania and central Ohio, provided, also, that the soil conditions are right. Gould devotes considerable space to a discussion of the behavior of this variety in the southern Appalachians, mostly with reference to its soil preferences. He concludes that it requires a soil of high fertility and of a loose, friable texture; and a subsoil comparatively open and porous. Bearing on climatic conditions he says:—

This apple is found principally in the mountains, at various altitudes and in coves where Porters black loam abounds, often at elevations not exceeding the general level of the Piedmont. Even these lower points, where the drainage is good, are favorable places for this variety, though the higher altitudes are to be preferred.¹

In Nelson County, Va., the slopes of the mountains and hills at elevations of 1,000 to 1,500 feet are considered desirable locations. In northeastern Georgia premature dropping was observed. In Fig. 13 the solid line shows where the variety is generally recommended, and the dotted line includes additional territory where we believe it would do well in favorable locations and with good care.

Ben Davis. — This variety has been quite fully dealt with in a previous publication.² We have little to add to the statements made at that time. Many other samples of the variety have

¹ Bureau of Plant Industry, Bulletin 135, p. 48.

² Massachusetts Experiment Station Report, 1910, p. 197.

been studied and additional data as to variation in form and size have been secured, and these are set forth in an earlier portion of this paper. It cannot be grown to its full development north of southern Pennsylvania, central Ohio and Indiana, north central Illinois and central Iowa, although it is often a profitable commercial variety further north than this. It is, however, inferior in most respects to the variety grown south of that line. It is apt to be hard and astringent and poorly colored, and undersized unless grown under relatively high cultural conditions. The map given in Fig. 14 shows the

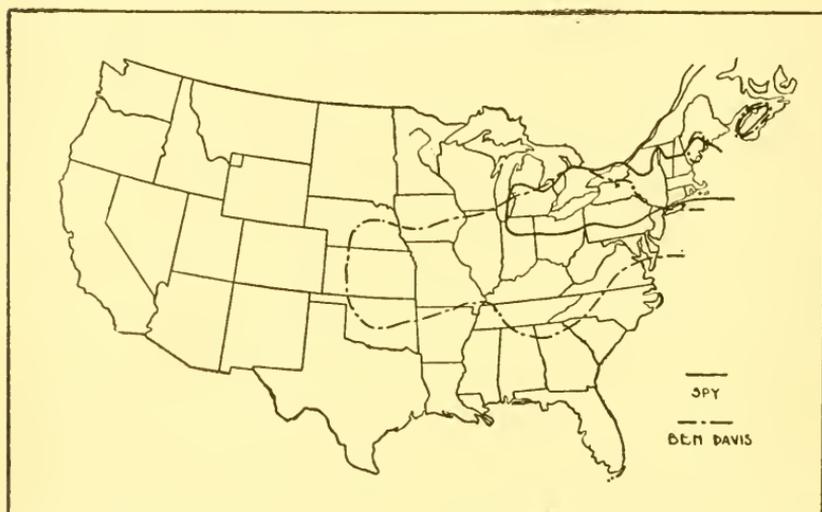


FIG. 14.

distribution of this variety. This shows it extending farther north than the map given in a previous report. It should be borne in mind that the previous map shows the area over which it is the leading commercial variety and the present map the area where it may be said to rank as a valuable commercial sort.

Shockley. — Shockley is a variety belonging almost exclusively to the southern belt. It flourishes in regions where the summer heat is greater than that favorable to most commercial varieties. It is recommended for cultivation in the hill and pine belt regions of South Carolina, and west through northern and central Alabama to northeastern Texas. Gould gives the

following concerning its behavior in the southern Appalachian Mountains: —

At 1,500 feet altitude in Albemarle County, Va., on Porters clay, this variety is not considered of special value, but at the same elevation in Georgia on a soil containing rather more sand than Porters clay does, with good culture it comes to a high degree of perfection, and when held until midwinter it generally brings very satisfactory prices in local markets. In the southwestern part of North Carolina, at 1,700 feet elevation, on a friable, porous loam, with good culture it bears annual crops of highly colored fruits, which develop to a larger size than under most conditions. In North Carolina at 3,500 to 3,800 feet, while the Shockley bears heavily and colors well, it is usually too small to be of much value, especially as other more desirable sorts succeed at these elevations. The clay and clay loam soils of the Piedmont region, with the usual elevations of those soils, may be expected, as a rule, to produce this variety in a fair degree of perfection.¹

The Relation of Temperature to Development.

The Mean Summer Temperature. — There is a close relation between the mean summer temperature and the development of the fruit. For every variety there can be determined a mean summer temperature at which it reaches its highest and most satisfactory development. Any departure from this mean results in greater or less inferiority of the fruit, the degree of inferiority depending on the amount of the departure, and the variety. For the successful growth of the tree the mean summer temperature is of little significance, but the major controlling factors are the minimum winter temperature and the mean of the hottest part of the summer. Other factors enter in, but we believe that these are the principal ones and must first be complied with if a variety is to succeed.

The Winter Minimum. — The temperature which a tree of a given variety can withstand cannot be stated with definiteness. It depends not only on the degree of cold, but also on the condition of the tree and the rapidity and amount of the fall and subsequent rise of the temperature. In the northwestern belt this is the great problem of apple culture, and much study has been given to it. The Minnesota Horticultural Society men-

¹ Bureau of Plant Industry, Bulletin 135, p. 43.

tions the following varieties as of sufficient hardiness to endure the severe winters of that State: ¹—

Of the first degree of hardiness, Oldenburg, Hibernial, Charlamoff, Patten, Okabena.

Of the second degree of hardiness, Wealthy, Tetofski, Malinda, Peerless, Northwestern Greening.

Many other sorts thrive in the more favorable parts of this belt, but the great bulk of the varieties grown in localities of similar summer temperatures in the east perish from winter-killing. The minimum winter temperatures in this territory, according to the records of the Weather Bureau,² are around -40° F., which may be considered a degree of cold which any tree of *Pyrus malus* can rarely endure without injury (see Fig. 15). It should be borne in mind that this temperature must be taken in accordance with the methods of the Weather Bureau and with correct instruments, else the figures obtained are likely not to be comparable.

The Heat of Summer.—A glance at the figures (Figs. 6–14) giving the distribution of varieties shows that some extend the entire length of its belt, while others succeed well only through the eastern portion. There are three differences between the eastern and western portions of these belts. In the west we find (1) lower humidity, (2) less precipitation, (3) more severe heat during the summer. Probably all these have their influence in limiting the western spread of certain varieties, for their effects on the plant are similar, in that they tend to dry it out. In relative importance the greater heat is probably of the greatest significance followed by rainfall and humidity.

The Effects of Low and High Mean Summer Temperatures.—The effects on the fruit of a low summer heat, as indicated by the mean summer temperature, are as follows:—

1. *Greater Acidity.*—It is shown that the acidity of the fruit steadily decreases all through the stages of growth, ripening and decay. It naturally follows that if the fruit does not have time to mature properly it will be acid, and this is clearly shown in the table of analyses.

¹ Report, 1907, p. 34.

² United States Weather Bureau, Bulletin Q.

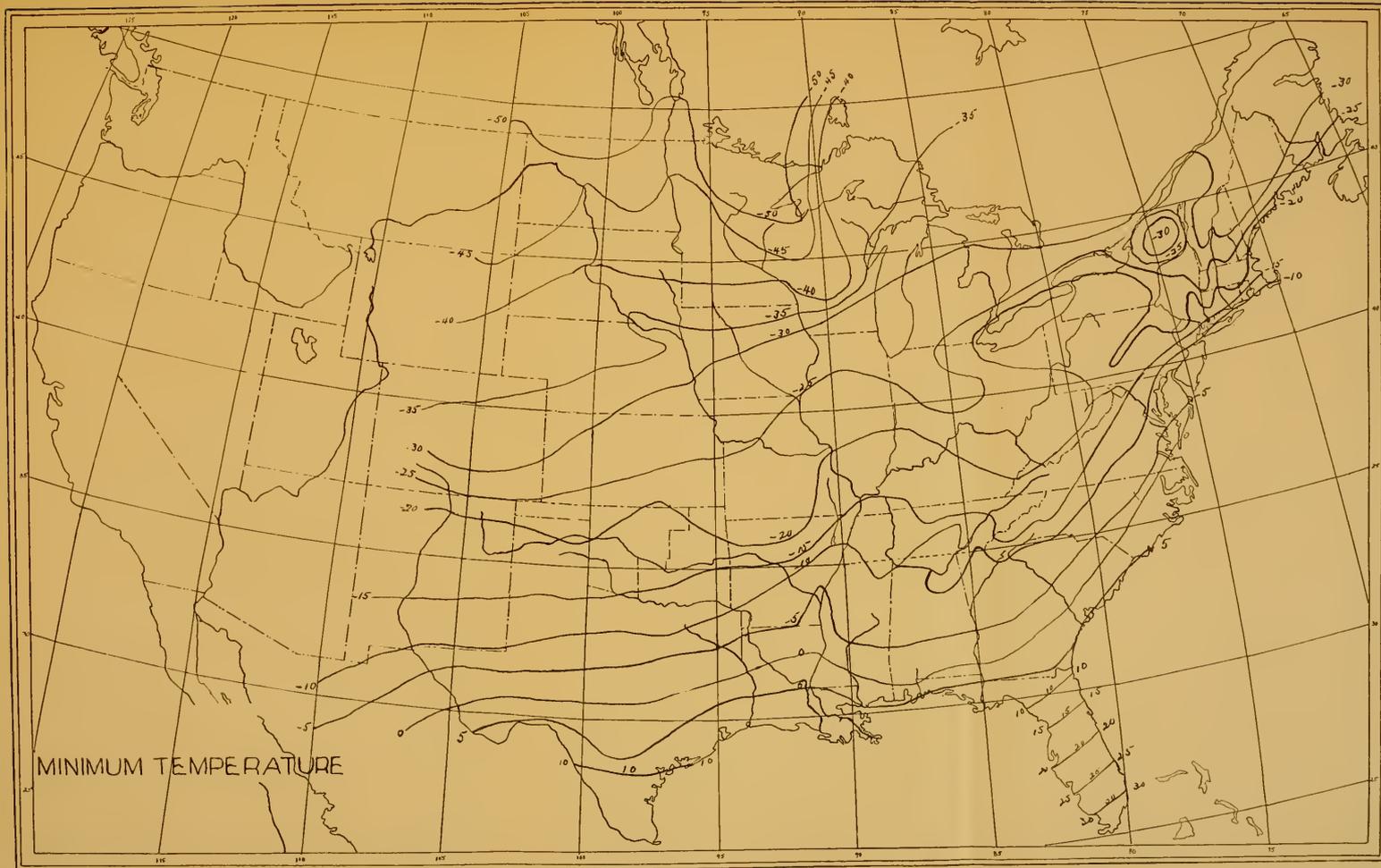


FIG. 15.—ISOTHERMS OF MINIMUM WINTER TEMPERATURE.

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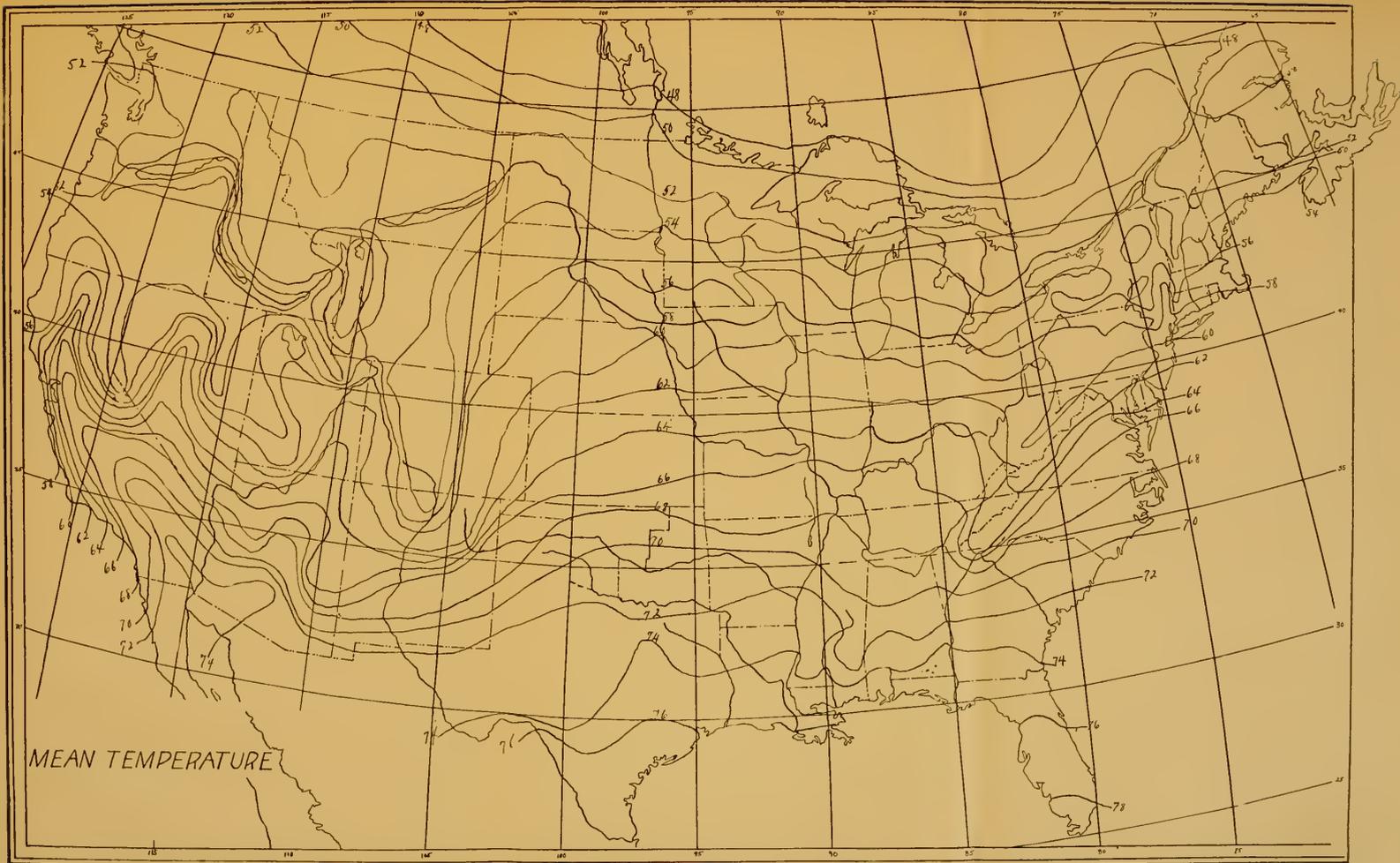


FIG. 16. — ISOTHERMS OF MEAN SUMMER TEMPERATURE.

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2. *Higher Content of Insoluble Solids.* — The analyses show that there is a decided tendency for the insoluble solids to decrease during the stage after ripening. The figures do not show just when the content of insoluble solids is highest, but it must be at or before the time of picking. The analyses also give clear indication of the immaturity of the fruit when grown too far north. This is especially marked in the case of the Ben Davis, doubtless owing to the fact that some lots of this variety came from the far north of the region in which it matures properly, and it falls far short of full maturity. It shows an average content of 2.97 per cent. for the Ben Davis belt and 3.60 per cent. for the specimens from north of this region. Other sorts show similar differences.

3. *Greater Astringency.* — All apples in an immature state doubtless contain small amounts of tannin. No determinations of tannin have been made in connection with this work, nor have we discovered any report that shows conclusively just what changes in tannin content go on in the growing and ripening fruit. Nevertheless, it is evident to the taste that green apples have greater astringency than do ripe specimens, and we have repeatedly observed a markedly greater astringency in northern-grown apples than in the same sort grown farther south.

4. *Less Coloration.* — It is well known that plants exhibit brighter, more intense coloration when grown in high latitudes and altitudes. This is true of the coloration of red apples. In the north we find bright intense reds, which become duller towards the south, with a tendency toward a pinkish red towards the southern limit. The proportion of the fruit covered, however, behaves in a different way. We find the greatest proportion of color near the middle of a distribution, with a decrease to both the north and south. We find then, near the center of a distribution of most varieties of red apples, fruit well covered with fairly bright color, which is brighter and more intense in northern varieties than in those of the south.

5. *Decreased Size.* — When the season is short or cool it is natural that a variety should not reach the maximum size. It is somewhat difficult to determine, in lots of varying size, how much of the difference is due to climatic causes and how much

to cultural methods and conditions. However, in the case of the Ben Davis a study of the table on page 199 shows clearly not only the general influence of the different regions on size, but also that of different seasons, and almost invariably a lower summer mean is accompanied by decreased size.

6. *Scalding in Storage.* — It has been shown by Powell¹ and Beach² that immature apples are more likely to scald in storage than are those that have been well matured on the trees. In order to keep longest in storage an apple should have fully completed the stages of growth and ripening on the tree, and been picked and without delay placed and kept in a temperature barely above the freezing point of the fruit. In practice it is necessary to allow a margin for safety, owing to possible lack of uniformity of the temperature at different times and in different parts of the storage rooms, but the better the control of the temperature the closer may the ideal conditions be approached. It is probable that scalding may also appear on fruit that has been poorly grown, but still has reached full maturity. The chemical work here reported indicates that fruit matured on poor soil or under unfavorable cultural conditions may be in some respects similar to immature fruit. The poorly grown fruit is lower in most of the soluble solids.

When a variety is grown where the summer mean temperature is excessively high we note the following effects: —

1. *Uneven Ripening.* — Summer and fall varieties always show a tendency to ripen unevenly, making it desirable to make two or more pickings as the different specimens reach maturity. Late fall and winter sorts show less evidence of this, though a difference in the maturity of specimens in a lot of winter fruit may be detected without difficulty. Inasmuch as the result of growing a variety south of its natural range is to cause earlier maturity, and fall varieties tend to become summer varieties, it is to be expected that the uneven ripening characteristic of summer sorts should follow. This is not marked with winter varieties unless they are grown a considerable distance south of their most favorable localities.

¹ Bureau of Plant Industry, Bulletin 48.

² New York Experiment Station, Bulletin 248; Iowa Experiment Station, Bulletin 108.

2. *Premature Dropping.* — It is but natural that dropping of ripened fruit should follow uneven ripening, and this is commonly observed to be the case. We find, also, that apples may drop even at immature stages when the summer heat is too great for the liking of the variety, particularly when the heated period closely follows the period of blossoming.

3. *Rotting on the Tree.* — This is another sign of summer heat too great for the variety, which is right along the line of those already mentioned. It occurs with most varieties only when the heat is excessive. The Jonathan is especially subject to this trouble, because the margin between temperature that will give the maximum size, color and quality and one that will cause rotting seems to be narrow, and perhaps within the range of seasonal fluctuations. Therefore there is great danger that the apples will become overripe and decay before being picked.

4. *Poor Keeping Quality.* — This defect of southern-grown specimens is also along the same lines of those already dealt with. The apples mature to the end of the ripening or after-ripening stages, and being still subject to high temperature, continue rapidly on the road to decay. It is probable that in many cases this difficulty might be largely overcome by picking the apples at the proper stage and placing them at once in cold storage. I am informed by Mr. W. A. Taylor of the Department of Agriculture that Baldwins grown in West Virginia kept in a satisfactory manner when handled in this way. The chemical work here reported shows no material difference in the chemico-physiological processes of the growth and maturing of the fruit of a given variety, whether grown in the north or in the south, but only in the degree of completeness with which they are achieved.

The converse of this proposition is that northern-grown fruit, if well matured, will keep better than that variety grown farther south, and this indicates that any variety should be grown as far north as possible to fully mature it in the coolest seasons that are likely to occur. The progress of the stage of after ripening may be easily controlled if the proper facilities are at hand, but it is an advantage to have the air temperature low at this time unless it is desired to hasten instead of retard this stage.

5. *Lack of Flavor.* — The basis of flavor in apples has already been discussed. The leading element of flavor for discussion here is that of the flavoring oils. It appears that for high development of these a relatively cool atmosphere is desirable. Summer and early fall varieties do not, as a rule, possess high flavors, and any late fall or winter variety grown so far south that it ripens before the cool weather of autumn comes is likely to be inferior in the development of flavoring oils.

6. "*Mealiness.*" — This is another sign of overripeness that is an indication that the variety is grown in too great summer heat. Mention has already been made of the softening of the middle lamella, which is the cause of this mealiness (see page 186). The result is that when eaten the cells separate from each other without breaking open and releasing the juices contained therein, and the apple is said to be "dry," whereas it probably contains a normal amount of water. Some varieties, the Jonathan, for example, do not show this characteristic in marked degree, but most varieties do if they can be kept long enough without parasitic decay, and the warmer they are the shorter the time necessary to bring about this result.

7. *Less Intense Color.* — A red variety grown to the south of its normal range is apt to show a less intense color, though it may be pretty well spread over the fruit. There is often a decided tendency toward a pinkish red, which may appear pale or faded in extreme cases.

Bright sunlight during the ripening period of the fruit has much to do with the attainment of high color, especially if at this time the nights are cool and frosty. But in order for these influences to have their full effect the apple must have been brought to the proper stage of development by a sufficient amount of heat during the period of growth. Underdeveloped apples do not take on a satisfactory color, no matter how favorable the conditions may be during the ripening period.

8. *Smaller Size.* — This effect does not manifest itself unless the variety is grown far to the south of its most favorable region. The signs of overripeness show themselves much sooner as one goes south over the distribution of a variety. Nevertheless, in some cases, at least, it is evident that a variety may fail

to reach its normal size on account of too severe summer heat. It is probable that this occurs most noticeably in the extreme south of the apple region. We have seen evidences of it in the Ben Davis and Winesap that were grown about as far south as these varieties are much cultivated.

The Optimum Mean Summer Temperature. — It is evident from the foregoing discussion that the development of the highest perfection in any given variety is closely related to most favorable mean summer temperatures. In Table 5 is given a list of varieties, with an estimate of the optimum temperature for each sort, and in some cases of their possible range and hardiness with respect to the cold of winter. The list of varieties includes all those that are given the double star, indicating highly successful varieties, in the list of the American Pomological Society, with a number of additions of varieties that, for various reasons, seemed worthy of consideration. Inasmuch as we consider keeping quality of considerable account with most sorts, the policy has been to prescribe about as low a temperature as will suffice to thoroughly mature a variety, leaving a margin of about 2° for seasonal fluctuations; that is, we believe that any variety may be matured when the summer mean is 2° lower than the one given. This applies more particularly to the fall and winter varieties. We believe, on the other hand, that any increase in the summer mean for any variety, unless it be the earliest ones, will be a disadvantage, though a very slight one, if the rise is not more than 1° or 2° . Up to a certain degree the overmaturity of the fruit in a too warm climate may be overcome if the grower will pick at the time of full maturity and put the fruit at once in cold storage. If the heat is too great, however, even with this method the fruit will be inferior in flavor and color, and, in very extreme cases, in size. We believe that a departure of more than 2° in either direction from the temperatures given will be a noticeable disadvantage with any of the winter varieties. This remark will apply less to the fall sorts and still less to the summer varieties; or, to put it in other words, the earlier the variety the greater may be its range of temperature without marked deterioration of the fruit. There are doubtless errors in the case of some varieties, concerning which we have limited infor-

mation. It is hoped that these may, in time, be corrected, as we are able to learn more concerning the behavior of these varieties under different conditions.

In Table 6 these same varieties are grouped under their optimum temperatures for convenience in reference.

In Table 5 there is also given for some varieties the range of temperature which they can stand without serious deterioration. This is, as already stated, closely connected with the season of the variety, being wide with early sorts and relatively narrow with most winter sorts. Just how much difference there is between the ranges of varieties of the same season is difficult to say. It is complicated with a variety of related questions.

In the case of a few of the varieties given in Table 5 an attempt is made to give their hardiness with respect to the winter cold. Inasmuch as the ability of the tree to withstand cold depends on a variety of factors other than the temperature, it is of no use to attempt to state this in degrees. The designation Ex. H. is used for the varieties equal in hardiness to those classified as of the first degree of hardiness; the designation V. H. for those of the second degree of hardiness (by the Minnesota Horticultural Society); and the designation H., M. and T. for various degrees of hardiness below these two classes. Many of the more southern sorts are not grown far enough north on account of a lack of summer heat to test their winter hardiness in a satisfactory manner. Therefore it is impossible to make any statements regarding them, nor would there be any practical value in such statements were they possible.

TABLE 5. — *Mean Summer Temperatures.*

	Optimum Temperature (Degrees).	Range.	Hardiness.		Optimum Temperature (Degrees).	Range.	Hardiness.
Akin,	52			Holland Winter,	57		
Alexander,	54		H.	Horse,	66		
Arctic,	53		H.	Hubbardston,	57		
Arkansas,	65			Huntsman,	62	N.	N.
Arkansas Black,	63			Hyde King,	60		
Babbit,	57			Ingraham,	62		
Bailey Sweet,	58						
Baldwin,	56	N.	M.	Jefferis,	57		
Baxter,	53		H.	Jewett,	54		
Beach,	65			Jonathan,	59	N.	N.
Ben Davis,	64	M.	H.	July,	59		
Benoni,	59						
Bethel,	53		H.	Kent Beauty,	58		
Bietigheimer,	53			Keswick,	58		
Bismark,	53			King David,	59		
Black Gilliflower,	55			Kinnaird,	59		
Blenheim,	55						
Blue Pearmain,	54		H.	Lady,	58		
Boiken,	57			Lady Sweet,	57		
Bonum,	65			Lankford,	61		
Borovinka,	53			Lawyer,	64		
Bough,	57			Limbirtwig,	66		
Buckingham,	66			Longfield,	57		
Buncombe,	66			Lowell,	58		
				Lowland Raspberry,	58		
Cabashea,	58						
Cannon Pearmain,	65			Maiden Blush,	61	M.	V. H.
Charlamoff,	53		Ex. H.	Malinda,	54	N.	H.
Chenango,	57			Mann,	55	M.	
Collins,	65			McAfee,	60		H.
Cooper Market,	60			McIntosh,	56	W.	H.
Cox Orange,	35			McMahon,	55		
				Melon,	57		
Delicious,	59			Milden,	58		H.
Dominie,	60			Milwaukee,	54		H.
Dudley,	53			Minkler,	60		
				Missouri Pippin,	64		
Early Harvest,	56	V. W.		Monmouth,	57		
Early Joe,	56			Mother,	58		
Early Pennock,	56						
Early Strawberry,	58			Newell,	55		
English Russet,	56			Newtown Spitzenburg,	60		
Esopus,	59	N.		Northern Spy,	56	M.	H.
Ewalt,	58			Northwestern Greening,	55		V. H.
Fallwater,	60			Okabena,	52		Ex. H.
Fall Harvey,	57			Oldenburg,	52	V. W.	Ex. H.
Fall Orange,	57			Oliver,	64		
Fall Pippin,	58			Ontario,	56		H.
Fameuse,	54	M.	II.	Ortley,	61		
Fanny,	63						
Flushing Spitzenburg,	58			Paragon,	64		
Foundling,	54		II.	Patten,	55		Ex. H.
				Payne,	62		
Gano,	64	M.		Peck Pleasant,	58		
Gideon,	54		H.	Peerless,	56		
Golden Russet,	56			Pewaukee,	53		V. H.
Golden Sweet,	58			Plumb Cider,	57		V. H.
Gravenstein,	55	M.	M.	Pomme Gris,	55	N.	
Green Sweet,	58			Porter,	57	W.	
Grimes,	62	M.	H.	Primate,	57		
				Pumpkin Sweet,	57		
Haas,	59		II.				
Hagloe,	60			Ralls,	62		
Hibernal,	52	N.	Ex. H.	Rambo,	60		
Holland Pippin,	57			Red Astrachan,	54	W.	H.

TABLE 5. — *Mean Summer Temperatures* — Concluded.

	Optimum Temperature (Degrees).	Range.	Hardiness.		Optimum Temperature (Degrees).	Range.	Hardiness.
Red Canada,	59	M.		Tolman,	56	M.	H.
Red June,	58	M.		Tompkins King,	56	M.	M.
Rhode Island Greening,	56	M.	H.	Twenty Ounce,	58		M.
Ribston,	55	N.		Twenty Ounce Pippin,	58		
Rolfe,	56		H.	Wagener,	59		
Roman Stem,	61			Walbridge,	54		H.
Rome Beauty,	60			Washington Royal,	56		
Roxbury Russet,	57	W.	H.	Wealthy,	56	W.	V. H.
				Westfield,	56		
Salome,	55		H.	White Astrachan,	54		
Scott Winter,	55		V. H.	White Pearmain,	62		
Shiawasse,	55		H.	White Pippin,	61		
Shockley,	65	N.		Williams,	57	W.	
Smith Cider,	61			Willow,	64		
Smokehouse,	60			Windsor,	55		H.
Stark,	62	M.	H.	Winesap,	64	M.	
Stayman Winesap,	63			Winter Banana,	58		
St. Lawrence,	54			Wolf River,	54	M.	V. H.
Sutton,	56						
Swarr,	58			Yates,	67		
Swazie,	55	N.		Yellow Belleflower,	61	W.	
Switzer,	58			Yellow Newtown,	60	V. N.	
				Yellow Transparent,	53	W.	V. H.
Terry,	67	N.		York Imperial,	62	M.	
Tetofski,	53	V. W.	V. H.				
Titovka,	56		H.				

TABLE 6. — *Optimum Temperatures by Groups.*

52°.	53°.	54°.	55°.
Hibernal Okabena Oldenburg	Aretic Baxter Bethel Bietsigheimer Bismark Borovinka Charlamoff Dudley Pewaukee Tetofski Yellow Transparent	Alexander Blue Pearmain Fameuse Foundling Gideon Jewett Malinda Milwaukee Red Astrachan St. Lawrence Walbridge White Astrachan Wolf River	Black Gilliflower Blenheim Cox Orange Gravenstein Mann McMahon Newell Northwestern Greening Patten Pomme Gris Ribston Salome Scott Winter Shiawasse Swazie Windsor
56°.	57°.	58°.	59°.
Baldwin Early Harvest Early Pennock English Russet Golden Russet Lowland Raspberry McIntosh Milden Northern Spy Ontario Peerless Rhode Island Greening Rolfe Sutton Titovka Tolman Tompkins King Washington Royal Wealthy Westfield	Babbit Boiken Bough Chenango Fall Harvey Fall Orange Holland Pippin Holland Winter Hubbardston Jefferis Lady Sweet Longfield Melon Monmouth Plumb Cider Porter Primate Roxbury Russet Williams	Bailey Sweet Cabashea Early Joe Early Strawberry Ewalt Fall Pippin Flushing Spitzenburg Golden Sweet Green Sweet Kent Beauty Keswick Lady Lowell Mother Peck Pleasant Red June Switzer Twenty Ounce Twenty Ounce Pippin Winter Banana	Benoni Delicious Esopus Haas Jonathan July King David Kinnaird Red Canada Wagner
60°.	61°.	62°.	63°.
Cooper Market Dominie Fallawater Hagloe Hyde King McAfee Minkler Newtown Spitzenburg Rambo Rome Beauty Smokehouse Yellow Newtown	Lankford Maiden Blush Ortley Roman Stem Smith Cider White Pippin Yellow Bellflower	Akin Grimes Huntsman Ingram Payne Ralls Stark White Pearmain York Imperial	Arkansas Black Fanny Stayman Winesap
64°.	65°.	66°.	67°.
Ben Davis Gano Lawver Missouri Pippin Oliver Paragon Willowtwig Winesap	Arkansas Beach Bonum Cannon Pearmain Collins	Buckingham Buncombe Horse Limbertywig Shockley	Terry Yates

Chemical Determinations.

The work here reported is based in considerable degree on chemical work done in the laboratory of the college. During the past two years over 150 samples of apples have been subjected to partial analysis, the results of which, so far as they are deemed worthy of publication, are presented in Table 7. The names and locations of the growers are as follows:—

NAME.	Post-office Address.	NAME.	Post-office Address.
F. Boyer, . . .	Charlottetown, P.E.I.	Slaymaker & Son, . .	Wyoming, Del.
C. E. Hardy, . . .	Hollis, N. H.	Dr. S. S. Guerrant, . .	Callaway, Va.
Edw. Lefavour, . . .	Marblehead, Mass.	G. C. Sheible, . . .	Tiptop, Ky.
Massachusetts Agricultural College, . . .	Amherst, Mass.	G. H. & S. G. Ellis, . .	Dayton, Tenn.
J. M. Fisk, . . .	Abbottsford, Que.	J. O. Kelley & Sons, . .	Jeff, Ala.
T. L. Kinney, . . .	South Hero, Vt.	Joe H. Burton, . . .	Mitchell, Ind.
G. H. Wright, . . .	Middlebury, Vt.	J. C. B. Heaton, . . .	New Burnside, Ill.
Wilfred Wheeler, . . .	Concord, Mass.	Geo. T. Lincoln, . . .	Bentonville, Ark.
F. S. Wallbridge, . . .	Belleville, Ont.	Geo. L. Sipes, . . .	West Fork, Ark.
Connecticut Agricultural College, . . .	Storrs, Conn.	C. S. Bouton, . . .	Springfield, Ark.
New York Experiment Station, . . .	Geneva, N. Y.	G. S. Christy, . . .	Lincoln, Neb.
Wm. Miller, . . .	Gypsum, O.	Kansas State Agricultural College, . . .	Manhattan, Kan.
U. T. Cox, . . .	Proctorville, O.	Ira Townsend, . . .	Iola, Kan.
Wm. Stewart, . . .	Landisburg, Pa.	J. B. Fergus, . . .	Kincaid, Kan.
F. H. Fasset, . . .	Meshoppen, Pa.	G. B. Prince, . . .	Santa Fé, N. M.
S. H. Derby, . . .	Woodside, Del.	E. F. Cadwallader, . . .	Mountain Park, N. M.
A. J. Norman, . . .	Harris' Wharf, Md.	Stirling & Pitcairn, . . .	Kelowna, B. C.

As a rule the samples represent about the best type of the various varieties grown in the different localities. The samples received varied from a half dozen to a barrel, and from these from six to twelve good specimens were selected for analysis. They were ground in a food chopper, and after weighing a sample for sugar determinations, were preserved in a glass jar with formaldehyde. The methods of analysis followed were those of Bulletins 66 and 107 of the Bureau of Chemistry.

The determination of total solids was made by drying 25 grams on pumice in a water oven at 95° to 98° for twenty

to twenty-two hours. This probably gives results too low, but this method seemed the best with the facilities at hand. Insoluble solids were determined by washing 25 grams with 500 cubic centimeters hot water on muslin filters, and drying on pumice fourteen hours at 95° to 98°. The reducing sugars were determined by reducing Fehling's solution and weighing the precipitate as cuprous oxide; the sucrose, by means of the polariscope; and malic acid, by titrating with N/10 alkali with phenolphthalein as an indicator.

Most of the analyses were made during the winter of 1910-11. All samples, save those from Amherst, were shipped direct to cold storage in Holyoke, Mass., and transferred to Amherst a few samples at a time, as needed, where they were held as cool as possible. The Amherst samples, as well as all those of 1910, were kept in an excellent cellar storage at the college. The laboratory numbers were given in order of analysis, work being begun with No. 1 in November, 1910, and completed about March 1, 1911. The samples of 1910 were analyzed in March, and while no notes of their condition were taken, it can be said that they were in excellent condition, most of them eating ripe.

These analyses form the basis for the chemical side of the discussions of the different varieties in this paper. There are, however, certain questions not dealt with elsewhere which may receive consideration at this point.

Nearly all the differences in analyses between the different samples, aside from those fairly attributable to the unavoidable errors of sampling and analysis, can be traced to one of two causes: (1) varietal differences; these are brought out in Table 1; (2) those attributable to different stages of maturity of the fruit. The chemical changes occurring in the growth and ripening of the apple are clearly brought out in the work of the Bureau of Chemistry, reported in Bulletin 94 of the Bureau, and the reader is referred to that publication for a discussion of this question. During the past winter analyses were made of four samples in November and again in February. These were: —

	November.	February.		November.	February.
Greening, . . .	No. 4	No. 93	Baldwin, . . .	No. 2	No. 97
Baldwin, . . .	No. 1	No. 98	McIntosh, . . .	No. 27	No. 102

Reference to the analyses of these samples will show that they are in entire accordance with the results reported in the above-mentioned publication. A study of the figures given shows that, as a rule, varieties grown to the north of their natural range exhibit the characteristics of immature fruits. The analysis of the Ben Davis, sample 91, indicates an apple that failed to mature on the tree, and has gone down in storage after the manner of immature fruit. In general, the analysis of this variety shows that the more northern-grown specimens are low in solids and sugars and high in insoluble solids and acid, and the same is generally true of the other varieties.

TABLE 7. — *Chemical Determinations.*

VARIETY AND SOURCE.	Laboratory Number.	Total Solids (Per Cent.).	Insoluble Solids (Per Cent.).	Soluble Solids (Per Cent.).	Reducing Sugars (Per Cent.).	Sucrose (Per Cent.).	Total Sugars (Per Cent.).	Malic Acid (Per Cent.).	Size (Millimeters).	Color.	Quality.
<i>Wealthy.</i>											
Charlottetown, P. E. I., . . .	19	14.97	1.74	13.23	8.81	1.78	10.59	.60	75×60	40 to 60 per cent. striped and splashed; some blush on sunny side.	Rather poor; lacks Wealthy flavor; very slightly astringent.
Amherst, Mass., . . .	28	13.38	2.20	11.18	6.91	1.98	8.89	.44	Medium and below	Fair.	Ripe, or a little past; flavoring oils deficient; slightly mealy.
Storrs, Conn., . . .	6	12.97	2.29	10.68	6.47	1.36	7.83	.46	65×52	Fair; well covered, but not intense.	Rather flat; lacks flavor; may be over-ripe.
<i>Wolf River.</i>											
Charlottetown, P. E. I., . . .	16	14.81	3.05	11.76	5.84	6.61	12.45	.72	85×65	Poor to good.	Poor; lacks flavor; astringent; immature and overripe.
Kineaid, Kan., . . .	72	14.24	2.49	11.75	8.93	.85	9.78	.44	87×66	Pale; poorly covered; pale stripes.	Fair; slightly acid; somewhat mealy.
Mountain Park, N. M., . . .	14	12.59	2.49	10.10	6.22	3.82	10.04	.74	Medium	Good; nearly blushed; slightly pinkish.	Not equal to those of north; lacks flavoring oils; slight musty flavor.
<i>Maiden Blush.</i>											
Storrs, Conn., . . .	5	13.23	2.10	11.13	3.95	2.43	6.38	.50	70×53	Good; one-third blushed.	A little flat; perhaps a little overripe; slightly astringent; lacks flavor.
Callaway, Va., . . .	12	15.39	3.06	12.33	5.05	4.14	9.19	.72	Medium	Greenish; dull red.	Good; better than No. 10; not mealy.
Tip Top, Ky., . . .	10	15.15	2.83	12.32	5.39	2.85	8.24	.67	Medium	Good; one-third blushed.	Slightly overripe; better than No. 5.
Springdale, Ark., . . .	11	13.34	2.74	10.60	5.73	1.29	7.02	.35	Medium	Dull; poorer than No. 10.	Overripe; somewhat astringent; mealy; lacks acid.

TABLE 7. — *Chemical Determinations* — Continued.

VARIETY AND SOURCE.	Laboratory Number.	Total Solids (Per Cent.).	Insoluble Solids (Per Cent.).	Soluble Solids (Per Cent.).	Reducing Sugars (Per Cent.).	Sucrose (Per Cent.).	Total Sugars (Per Cent.).	Malle Acid (Per Cent.).	Size (Millimeters).	Color.	Quality.	
<i>Fameuse.</i>												
Charlottetown, P. E. I.,	13	15.76	2.85	12.91	7.88	.99	8.87	.47	Small	Green; one third dull red.	Fair; rather acid and lacks oils; very thick skin.	
Abbotsford, Que.,	44	14.36	2.50	11.86	7.81	1.72	9.53	.19	64×53	Fair to good.	Good.	
Storrs, Conn.,	7	14.87	2.32	12.55	6.06	1.64	7.70	.41	68×58	Fair to good; deep dull red.	Fair; somewhat flat; not equal to more northern grown; a little past.	
Landisburg, Pa.,	71	15.21	2.33	12.88	9.63	.40	10.12	.23	68×64	Fair; not intense.	Were fair; now overripe; not acid.	
Gypsum, O.,	46	15.80	2.79	13.01	8.84	1.34	10.18	.45	Small	Fair.	Good, ripe, or a little past.	
Santa Fé, N. M.,	18	14.65	2.75	11.90	8.00	.91	8.91	.43	68×53	Rather pale, blushed and striped.	Fair; lacks Fameuse flavor; not much acid.	
<i>McIntosh.</i>												
Charlottetown, P. E. I.,	15	15.40	2.21	13.19	6.80	1.19	7.99	.43	Small; roundish	Green and dull red.	Poor; lacks oils; good texture; slightly astrigent.	
Abbotsford, Que.,	45	14.26	2.38	11.88	7.09	3.44	10.51	.45	68×60	Very good; deep, rich bluish.	Good; ripe; possibly a trifle astrigent.	
Amherst, Mass.,	27	14.77	2.38	12.39	8.17	2.74	10.91	.38	Medium or above	Fair.	Very good; flavoring oils a little low.	
Amherst, Mass.,	102	13.59	2.30	11.29	8.26	1.07	9.33	.31	76×57	Fair.	Much overripe; lacks flavor and body; still juicy.	
Geneva, N. Y.,	9	15.05	2.21	12.84	9.90	2.68	12.58	.35	66×54	Striped and blushed; good.	More aromatic and tender than No. 8.	
Storrs, Conn.,	8	14.10	2.42	11.68	5.50	2.14	7.64	.39	76×66	Fair to good.	Fair; perhaps a little overripe.	
Bitter Root Valley, Mont.,	103	13.30	2.42	10.88	7.41	1.61	9.02	.29	Below medium	Very good.	Not equal to No. 27; seems astrigent; perhaps picked immature.	
<i>Jonathan.</i>												
Ghent, N. Y.,	105	15.60	2.68	12.92	9.39	.31	9.81	.40	67×56	Fair though not equal to best.	Good; lacks body; barely ripe.	
Wyoming, Del.,	49	15.71	2.35	13.36	8.05	2.60	10.65	.42	72×62	Fair.	—	

Proctorville, O.,	24	14.42	2.21	12.21	8.43	1.52	9.95	.42	70X58	Fair; 40 per cent. over color.	Good, but not as rich as No. 23; less mature.	
Moran, Kan.,	73	15.88	2.20	13.68	9.88	.90	9.88	.34	68X62	Very good.	Good; prime condition.	
Kincaid, Kan.,	80	14.35	2.23	12.12	9.66	.61	10.27	.31	71X58	Fair, not very deep.	Good; fully ripe or a little past.	
Tip Top, Ky.,	29	16.18	2.70	13.48	9.00	1.98	10.98	.60	Small	Deep, dull red.	Fair to good.	
Mountain Park, N. M.,	23	15.68	2.30	13.38	8.35	3.42	11.77	.55	73X64	Very good; waxy yellow and deep red.	Good; slightly acid; eating ripe.	
Hood River, Ore.,	106	13.83	2.23	11.60	8.16	1.34	9.50	.36	73X61	Good, about like No. 105.	Very good; more tender than No. 105; variable.	
Ghent, N. Y.,	1910	13.97	2.35	11.62	5.36	2.40	7.76	.39	-	-	-	
Kelowna, B. C.,	1910	16.24	2.58	13.66	6.48	2.40	8.88	.50	-	-	-	
<i>Esopus Spitzenburg.</i>												
Cornwall, Conn.,	1910	16.51	2.54	13.97	6.81	3.10	9.91	.49	-	-	-	
Hood River, Ore.,	1910	19.07	2.79	16.28	7.18	4.22	11.40	.62	-	-	-	
<i>Grimes.</i>												
Storrs, Conn.,	109	14.97	2.55	12.42	6.71	2.98	9.69	.39	69X64	Good; considerable russet.	Good, but not equal to No. 108; ripe.	
Cypsaun, O.,	48	18.66	3.04	15.62	5.36	5.43	16.79	.47	67X56	Fair to good; some russet.	-	
Proctorville, O.,	22	17.84	2.52	15.32	8.40	3.34	11.74	.34	71X58	Good; yellow; some russet.	Good, better than No. 21; very slightly acid.	
Landisburg, Pa.,	70	14.33	2.24	12.09	7.08	3.50	10.58	.31	75X66	Fair to good; not clear and bright.	Good; more acid and not as rich as No. 68 and No. 69.	
Wyoming, Del.,	50	17.58	2.81	14.77	5.81	4.71	10.52	.64	89X65	Good, slightly russeting.	Excellent; prime condition.	
Mitchell, Ind.,	68	15.95	2.50	13.45	8.35	4.24	12.59	.24	76X67	Excellent; clear, rich yellow.	Excellent; fully ripe; sweetish.	
Tip Top, Ky.,	21	19.87	3.07	16.70	8.35	5.54	13.89	.50	66X54	Good; very slightly russet.	Fair; lacks flavoring oils; slightly overripe.	
Moran, Kan.,	69	16.62	2.48	14.14	8.39	3.46	11.85	.28	74X62	Very good.	Good; slightly wilted; a little overripe.	
Kelowna, B. C.,	108	15.40	2.42	12.98	6.86	2.98	9.84	.34	71X65	Excellent; clear straw-yellow.	Excellent; crisp; mild subacid; just ripe.	
Storrs, Conn.,	1910	16.00	2.84	13.16	6.53	2.97	9.50	.39	-	-	-	
Kelowna, B. C.,	1910	16.68	2.65	14.03	7.82	3.38	11.20	.29	-	-	-	

TABLE 7. — *Chemical Determinations* — Continued.

VARIETY AND SOURCE.	Laboratory Number.	Total Solids (Per Cent.).	Insoluble Solids (Per Cent.).	Soluble Solids (Per Cent.).	Reducing Sugars (Per Cent.).	Sucrose (Per Cent.).	Total Sugars (Per Cent.).	Millic Acid (Per Cent.).	Size (Millimeters).	Color.	Quality.
<i>King.</i>											
Amherst, Mass.,	26	15.20	2.53	12.67	8.61	2.06	10.67	.35	Medium	Rich, yellow, fair over-color.	Good; ripe, or a little past.
Gypsum, O.,	35	17.75	2.36	15.39	8.25	2.71	10.96	.41	82×72	Good, somewhat russeting.	Very good; clear, mild subacid; somewhat mealy; a little overripe.
<i>Rhode Island Greening.</i>											
Amherst, Mass.,	4	15.29	2.68	12.61	3.91	4.07	8.01	.62	Large	Good, yellow-green.	Good, though not very rich.
Amherst, Mass.,	93	14.23	2.91	11.32	6.04	1.42	7.46	.52	81×65	Good, yellow-green.	Very good; slightly past time.
Gypsum, O.,	53	16.25	3.12	13.13	6.45	3.88	10.33	.75	80×58	Good, greenish.	Very good; not very acid; eating, ripe.
Landsburg, Pa.,	75	17.51	2.86	14.65	7.98	3.71	11.69	.48	80×64	Good, deeper yellow than No. 74.	Good, better than No. 74; richer and sweeter.
Kincaid, Kan.,	74	15.05	2.68	12.37	7.48	1.77	9.25	.38	85×65	Good, clear yellowish-green.	Fair; not up to best; possibly a little overripe.
<i>Northern Spy.</i>											
Port Williams, N. S.,	1910	16.80	2.62	14.18	6.91	3.42	10.33	.43	-	-	-
Charlotteville, P. E. I.,	86	14.22	2.98	11.24	8.48	1.42	9.90	.59	75×62	Fair; 20 per cent. striped and splashed.	Poor; lacks Spy flavor; slightly as-tringent.
Middlebury, Vt.,	101	14.47	2.25	12.19	7.88	2.30	10.18	.44	80×74	Very good.	Good; more crisp than No. 100; a little better flavor.
Concord, Mass.,	87	14.51	2.14	12.37	9.14	1.53	10.67	.32	81×69	Good; 30 to 40 per cent. covered.	Very good; perhaps a trifle past prime.
Amherst, Mass.,	95	13.94	2.46	11.48	8.04	.00	8.04	.38	78×67	Rich yellow; over-color not best.	Fair to good; full ripe.
Meshoppen, Pa.,	54	15.80	2.21	13.59	7.84	2.86	10.70	.46	96×76	Good, but not brightest.	Good; lacks oils; not up to best.
Johnson, Neb.,	30	14.37	2.34	12.03	8.47	1.98	10.45	.44	Above medium	Good; yellow; over-color pale and scant.	Poor; lacks oils, sugars and acid; flat.

Kelowna, B. C.,	100	14.63	2.21	12.42	8.12	1.99	10.11	.44	83X72	Very good; well covered; bright.	Fair and crisp; lacks flavor, though good.	
Grand Isle, Vt.,	1910	15.55	2.45	13.10	7.39	3.21	10.60	.48	-	-	-	
Kelowna, B. C.,	1910	15.18	2.17	13.01	7.71	3.10	10.81	.41	-	-	-	
<i>Baldwin.</i>												
Amherst, Mass.,	1	11.32	2.60	11.72	4.49	3.41	7.90	.86	Medium	Dull green and red.	Sour; not yet ripe.	
Amherst, Mass.,	98	11.15	2.11	9.04	5.84	2.41	8.25	.73	71X56	Dull green and red.	Good; acid; probably lacks sugars.	
Amherst, Mass.,	2	17.08	2.98	14.10	4.49	6.15	10.64	.63	Medium and above	Good; bright yellow and red.	Good; hardly ripe, but much ripier than No. 1.	
Amherst, Mass.,	97	13.77	2.74	13.03	6.19	2.75	8.94	.43	72X62	Very good; clear, rich, bright.	Very good; a bit overripe.	
Amherst, Mass.,	3	16.10	2.76	13.34	3.74	5.53	9.27	.64	Medium and above	Clear, bright yellow; fairly well covered.	Fairly good; a little ripier than No. 2; not as good.	
Gypsum, O.,	51	17.01	2.83	14.18	6.25	4.75	11.00	.71	78X65	Fair, considerable russet.	Good; no signs of too much heat.	
Mechoppen, Pa.,	52	16.59	2.86	14.73	6.23	3.06	9.89	.68	81X63	Good; more intense than No. 31.	Good; nearly ripe.	
Kelowna, B. C.,	107	14.41	2.44	11.97	5.90	2.45	8.35	.41	84X68	Very good; bright.	Good; slight astringency; lacks flavor.	
Kincaid, Kan.,	78	16.92	2.53	14.39	7.63	4.16	11.79	.43	77X64	Good, well covered; fairly bright.	Good, mild, subacid; almost sweetish; firm texture.	
Hollis, N. H.,	1910	16.68	2.80	13.88	5.93	3.23	9.16	.53	-	-	-	
Kelowna, B. C.,	1910	15.18	2.43	12.75	5.31	2.55	7.86	.52	-	-	-	
<i>Winesap.</i>												
Amherst, Mass.,	94	14.88	3.18	11.70	7.46	1.31	8.80	.52	76X61	Dull, somewhat rusty.	Poor; acid; slightly astringent; not ripe.	
Wyoming, Del.,	58	16.65	2.53	14.12	8.85	2.87	11.72	.35	78X64	Excellent; dark, rich red.	Very good; crisp and juicy; not very ripe.	
Woodside, Del.,	60	14.55	2.63	11.92	8.97	.45	9.42	.49	68X56	Fairly deep, but dull.	Good; lacks richness; a bit acid.	
New Burnside, Ill.,	34	18.89	2.83	16.06	10.88	2.24	13.12	.43	76X57	Good.	Rather poor; mealy; overripe.	
Dayton, Tenn.,	32	17.07	2.74	14.33	11.02	.75	11.77	.38	62X49	Good.	Good, but not up to best; ripe, firm, crisp.	
Johnson, Neb.,	33	19.05	2.70	16.35	10.35	2.84	13.19	.51	72X58	Good.	Fairly good; full ripe.	
Kincaid, Kan.,	76	18.24	2.81	15.43	11.06	2.92	13.98	.48	60X56	Good, fairly rich red.	Fair; lacks richness.	

TABLE 7. — *Chemical Determinations* — Continued.

VARIETY AND SOURCE.	Laboratory Number.	Total Solids (Per Cent.).	Insoluble Solids (Per Cent.).	Soluble Solids (Per Cent.).	Reducing Sugars (Per Cent.).	Sucrose (Per Cent.).	Total Sugars (Per Cent.).	Malic Acid (Per Cent.).	Size (Millimeters).	Color.	Quality.
<i>Winesap</i> — Con.											
Manhattan, Kan.,	31	17.51	2.85	14.66	9.02	3.35	12.37	.63	Small	Deep; not very bright.	Good; ripe.
Jeff, Ala.,	59	15.70	2.61	13.09	9.75	.08	9.83	.42	68×57	Fair, pale.	Poor; lacks flavor; much overripe.
<i>Stayman Winesap</i> .											
Wyoming, Del.,	62	16.14	2.39	13.75	7.11	4.52	11.63	.43	80×70	Well covered, but dull.	Extremely good; tender, juicy, sub-acid.
Woodside, Del.,	63	16.39	3.05	13.34	8.98	2.56	11.54	.70	68×58	Fair, not intense.	Fair to good; not so rich as No. 62; more acid.
Harris Wharf, Md.,	99	14.97	2.42	12.55	8.25	3.25	11.50	.42	79×69	Fair to good; some russet.	Very good; crisp, tender, juicy.
<i>Rome Beauty</i> .											
Gypsum, O.,	56	15.51	2.87	12.64	6.32	3.29	9.61	.43	80×69	Good; yellow, green and bright red (one-third to two-thirds).	Fair; seems undeveloped but ripe.
Iola, Kan.,	77	13.90	2.63	11.27	6.69	2.72	9.41	.30	85×66	Rich straw-yellow and pale red (30 to 40 per cent.).	Overripe; mealy; not good.
West Fork, Ark.,	90	17.75	3.18	14.57	7.30	3.48	10.78	.51	Medium	Good; well covered; fairly bright.	Not good; lacks flavor; mealy; probably overripe, though firm.
<i>Smith Cider</i> .											
Landisburg, Pa.,	89	17.96	3.56	14.40	7.02	2.37	9.39	.57	81×71	Good; 50 to 60 per cent. covered; fairly bright.	Pretty good; a little overripe.
Kincaid, Kan.,	88	16.78	3.05	13.73	8.05	2.37	10.42	.44	84×68	Fair, a little pale.	Extremely poor; far overripe; very dry and mealy.

<i>Roxbury Russet.</i>											
Amherst, Mass.,	104	18.42	2.94	15.48	7.42	.84	8.28	.66	77×39	Good.	Very good; prime condition.
Proctorville, O.,	43	19.55	2.72	16.83	9.65	4.19	13.84	.40	73×57	Good; well russeted.	Good, somewhat wilted; ripe, or a little past.
Wyoming, Del.,	61	17.33	2.49	15.44	6.52	7.64	14.16	.70	77×58	Good, deep, even russet.	Fair to good.
Amherst, Mass.,	1910	19.03	3.14	15.89	6.96	5.93	12.89	.60	-	-	-
<i>York Imperial.</i>											
Amherst, Mass.,	96	14.38	2.89	11.49	7.67	.46	8.13	.41	78×62	Good, yellow, overcolor pale and scant.	Fair; just about ripe.
Landsburg, Pa.,	81	15.13	2.62	12.51	8.57	1.65	10.22	.37	81×65	Excellent; rich; fairly deep red.	Good, firm and crisp; just ripe; sweetish.
Wyoming, Del.,	25	15.60	2.84	12.76	7.78	2.66	10.44	.39	78×68	Good; straw-yellow; overcolor scanty.	Fair, firm and crisp; very nearly ripe.
Woodside, Del.,	57	16.02	2.70	13.32	7.28	4.01	11.29	.28	88×78	Good; fairly bright; not intense.	Good; very juicy; sweetish; barely ripe; crisp.
Dayton, Tenn.,	35	16.47	2.76	13.71	7.61	3.22	10.83	.42	79×58	Good.	Very good; just ripe.
Johnson, Neb.,	36	17.62	2.85	14.77	7.45	3.78	11.23	.49	78×68	Good.	Very good; just ripe.
Manhattan, Kan.,	37	16.20	2.45	13.75	8.68	3.40	12.08	.41	74×63	Good; a little rusty.	Very good; ripe; crisp.
Kincaid, Kan.,	79	15.81	2.59	13.22	8.55	2.53	11.08	.38	80×66	Very good; nearly covered; rich red.	Good; prime condition; not as crisp as some.
<i>Yellow Newtown.</i>											
Milton-on-Hudson, N. Y.,	1910	17.25	2.66	14.59	7.38	3.13	10.51	.42	-	-	-
Hood River, Ore.,	1910	15.70	2.83	12.87	7.79	3.00	10.79	.51	-	-	-
<i>Ben Davis.</i>											
Charlottetown, P. E. I.,	91	15.78	4.28	11.50	7.07	.46	7.53	.54	63×58	Poor; 25 to 40 per cent. covered.	Very poor; green; astringent; hard.
Abbotsford, Que.,	67	14.38	3.34	11.04	6.28	2.26	8.69	.39	66×55	Poor; not well covered.	Not ripe; about like No. 66.
Marblehead, Mass.,	66	14.21	3.61	10.60	7.24	2.41	9.50	.42	63×58	Poor; not well covered.	Not yet ripe; poor; slightly astringent; acid; tough.
Amherst, Mass.,	92	15.08	4.02	11.06	5.64	1.87	7.51	.61	75×66	Good.	Fair to good; perhaps not quite ripe.
Belleville, Ont.,	39	17.51	3.60	13.91	7.65	3.23	10.88	.42	70×58	Good.	Fair to good; not ripe; flesh greenish.

TABLE 7. — *Chemical Determinations* — Concluded.

VARIETY AND SOURCE.	Laboratory Number.	Total Solids (Per Cent.).	Insoluble Solids (Per Cent.).	Soluble Solids (Per Cent.).	Reducing Sugars (Per Cent.).	Sucrose (Per Cent.).	Total Sugars (Per Cent.).	Malic Acid (Per Cent.).	Size (Millimeters).	Color.	Quality.
<i>Ben Davis</i> — Con.											
South Haven, Mich.,	82	15.21	3.39	11.82	6.25	2.98	9.23	.44	70×65	Fair; 25 to 40 per cent. covered.	Fair; ripe.
Gypsum, O.,	65	16.53	3.28	13.25	7.46	3.32	10.78	.51	67×57	Fair; not well covered.	A little riper than No. 64; hardly as acid.
Mitchell, Ind.,	83	13.88	2.77	11.11	5.75	1.53	7.28	.45	80×68	Very good; all covered, striped.	Very good; prime condition.
Wyoming, Del.,	64	15.57	3.20	12.37	6.77	3.35	10.02	.52	78×62	Very good; not well covered.	Not quite ripe; promises good.
Johnson, Neb.,	38	15.31	2.68	12.63	6.53	3.46	9.99	.51	81×65	Excellent.	Excellent; just ripe; flesh white.
Manhattan, Kan.,	42	15.42	2.89	12.53	6.98	3.34	10.32	.39	74×61	Good.	Good; a little more acid than No. 41.
Kincaid, Kan.,	84	15.17	2.88	12.29	6.88	3.59	10.47	.41	81×70	Very good; like No. 83.	Very good; equal or better than No. 63.
Springdale, Ark.,	40	15.46	3.06	12.40	7.29	1.97	8.96	.43	77×66	Fair; slightly pinkish.	Good; ripe, lacks flavoring oils; flesh white.
Bentonville, Ark.,	41	15.64	2.86	12.78	7.44	2.35	9.79	.29	75×65	Good.	Very good; flesh white.
West Fork, Ark.,	85	16.53	3.13	13.40	6.95	3.71	10.66	.47	Above medium	Good; dark but dull.	Mealy and dry; overripe.

VII. SUMMARY.

Some of the more important results of this work may be summarized as follows: —

1. The many variations in apple varieties arise from many causes, which may be grouped as (1) cultural, using the word in a broad sense; (2) soil; and (3) climatic. Of climatic influences, temperature is the most potent.

2. The life history of the apple may for convenience in discussion be divided into four periods: (1) growth, extending from the blossom to the attainment of full size; (2) ripening, extending to the time of harvest; (3) after ripening, extending to complete edible maturity; and (4) decay, covering the period of physiological breaking down.

3. The apple of superior table quality is high in sugars, especially sucrose, and low in insoluble solids, indicating a tender flesh and fine texture. The acid is proportionate to sugars; the ratio may vary somewhat to accord with different tastes. Good kitchen apples are wider in ratio of sugars to acid, and the proportion of insoluble solids is of little significance. Good shipping apples are high in insoluble solids.

4. In any variety of apples, high development at full maturity is marked by the attainment of full normal size for the variety, high color, well spread over the apple, and a high development of sugars, especially sucrose.

5. Each variety has a characteristic chemical composition, fairly constant when perfect maturity is attained. Most of the differences found in different samples of a variety are due to a difference in the stage of development reached.

6. The fruit of individual trees shows slight differences in size, color, form and abundance that are characteristic and not due to environmental conditions. Some of this may be due to bud variation, but it is believed that most of it is due to the interrelation of stock and scion.

7. Variation in form in the Ben Davis, and probably in other sorts as well, is due principally to the temperature during a period of about two or three weeks following blossoming. The lower the temperature the more elongated the apple. This elon-

gation is seen in apples grown near large bodies of water, which lower the temperature at this season of the year, and in seasons when the temperature is low owing to seasonal fluctuations. This influence is also seen in the form of apples in different parts of the tree. Those in the lower north portion are more elongated than those from the warmer, upper south portion.

8. Seasonal temperature affects the size of apples, a cool season resulting in smaller fruit. This is marked only in full-season varieties, and is especially noticeable in the more northerly portions of their distribution. On the other hand, in the extreme south a variety is apt to be smaller than when grown in a somewhat cooler climate.

9. For convenience in discussion, North America may be divided into seven apple belts, each having a fairly characteristic list of varieties. These are named and illustrated in the text.

10. Some varieties are of wide distribution; others more or less limited. Varietal qualities favoring a wide distribution are (1) great hardiness of tree, (2) a short season of development, (3) great vigor and ability to thrive under generally unfavorable conditions, (4) productiveness and good market qualities.

11. The northern limit of apple growing is fixed by the minimum winter temperature, and the southern limit by the heat of the hottest part of the summer, occurring usually in July or August.

12. The attainment of the highest quality, appearance and keeping quality is very largely dependent on the warmth and length of the growing season. This may be measured with fair satisfaction for the apple-growing regions of North America by an average of the mean temperatures for the months of March to September inclusive. This is called the mean summer temperature, and give temperatures ranging from 52° to 72°.

13. Factors determining the mean summer temperature in a given orchard are (1) latitude, (2) elevation, (3) site and aspect, (4) soil, (5) culture, (6) prevailing winds, (7) sunshine.

14. The optimum mean summer temperature for different varieties may be determined with fair satisfaction, and some deter-

minations are shown in Table 5. A departure of over 2° from this mean will result in less desirable fruit, though this may not be marked in short-season varieties.

15. A summer mean too low for a variety results in (1) greater acidity, (2) increased insoluble solids, (3) greater astringency, (4) less coloration, (5) decreased size, (6) scalding in storage.

16. A summer mean too high for a variety results in (1) uneven ripening, (2) premature dropping, (3) rotting on the trees, (4) poor keeping quality, (5) lack of flavor, (6) "mealiness," (7) less intense color (8) decreased size.

COMPILATIONS.

INTRODUCTION.

BY J. B. LINDSEY.

A compilation of the chemical composition of fodder articles, agricultural chemicals and manurial residues was first made by Prof. C. A. Goessmann and his assistants in 1887, and published in the fifth report of the Massachusetts State Agricultural Experiment Station, pages 181-227. This compilation included all analyses made by Goessmann and his co-workers since 1868. It was later enlarged to include compilations of the analyses made at this station of dairy products, fruits, garden crops and insecticides. The parties largely responsible for the details of the several compilations were W. H. Beal, C. S. Crocker, J. B. Lindsey, H. D. Haskins, E. B. Holland and P. H. Smith. In 1896 the classification of fodder articles was considerably modified and improved; the present compilation of agricultural chemicals and manurial residues has undergone a similar re-arrangement, and the available analyses have been added to the compilation of fruits and garden crops. Naturally a few materials, being no longer of interest, have been omitted.

The tables of compilations are as follows:—

- Table I. Composition and Digestibility of Fodder Articles, pp. 247-265.
Table II. Fertilizer Ingredients of Fodder Articles, pp. 266-271.
Table III. Analyses of Dairy Products, p. 272.
Table IV. Coefficients of Digestibility of American Fodder Articles, pp. 273-303.
Table V. Analyses of Agricultural Chemicals, etc., pp. 304-323.
Table VI. Analyses of Fruit and Garden Crops, pp. 324-338.

COMPILATION OF ANALYSES OF FODDER ARTICLES AND DAIRY PRODUCTS, MADE AT AMHERST, MASS., 1868-1910.¹

P. H. SMITH AND J. B. LINDSEY.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES.

- I. Green fodders.
 - (a) Meadow grasses and millets.
 - (b) Cereal fodders.
 - (c) Legumes.
 - (d) Mixed and miscellaneous.
- II. Silage.
- III. Hay and dry, coarse fodders.
 - (a) Meadow grasses and millets.
 - (b) Cereal fodders.
 - (c) Legumes.
 - (d) Straw.
 - (e) Mixed and miscellaneous.
- IV. Vegetables, fruits, etc.
- V. Concentrated feeds.
 - (a) Protein.
 - (b) Starchy.
 - (c) Poultry.

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES.

TABLE III. — ANALYSES OF DAIRY PRODUCTS.

EXPLANATION OF TABLE I.

Under *composition* the figures mean that each 100 pounds of the fodder contains so many pounds of water, protein, fiber, etc.

Water. — The approximate average which is likely to occur in the material is stated.

Ash refers to the residue which is left behind when the material is burned, and consists of lime, potash, soda, magnesia, iron, phosphoric and sulfuric acids.

Protein is a collective name for all of the nitrogenous matter; it corresponds to the 'lean meat' in the animal, and may be termed

¹ Part III. of the report of Department of Plant and Animal Chemistry.

“vegetable meat.” It serves as the exclusive source of flesh, as well as a source of heat or energy, and fat.

Fiber is the coarse or woody part of the plant. It may be called the plant's framework. It is a source of heat or energy and fat.

Nitrogen-free extract represents the sugars, starches and gums. It is the principal source of heat or energy and fat.

Fat includes not only the various oils and fats in all grains and coarse fodders, but also waxes, resins and coloring matters. It is also termed ether extract because it is that portion of the plant soluble in ether. It serves as a source of heat or energy and body fat.

Under *digestibility* the figures mean that so many pounds of protein, fiber, nitrogen-free extract and fat in 100 pounds of the fodder are actually digested and made use of by the animal. No feed is entirely digestible; concentrates are more digestible than coarse fodders. The data under digestibility have been worked out by actual experiment. In cases where no figures appear, data as a result of experiments are lacking.

Net Energy Value. — The entire amount of heat or energy contained in a feeding stuff is termed its total heat or energy value. All of this heat or energy cannot be utilized by the animal for the purposes of maintaining its body in a state of equilibrium, or for aiding in the production of growth and milk. The several losses may be enumerated as follows: (a) the undigested material, *i.e.*, the faeces; (b) the incompletely used material of the urine; (c) the work required in the processes of digestion and assimilation in preparing the nutrients so that they can be used for maintenance and for the production of growth and milk. These several sources of loss expressed as energy, deducted from the total energy, leaves the real or *net energy value*.

The calorie is the unit of energy measurement.

The small calorie represents the amount of heat required to raise 1 gram of water 1° C.

The large calorie represents the amount of heat necessary to raise 1 kilogram (1,000 grams) of water 1° C.

The therm, a name proposed by Armsby, represents the amount of heat required to raise 1,000 kilograms of water 1° C. It is to be preferred to the small or large calorie as a unit of measurement because it can be expressed in fewer figures.

In the last column of the following table, headed net energy value, is given the number of therms contained in 100 pounds of the different feeding stuffs, based on the results of very carefully conducted experiments by Kellner, a German investigator.¹

¹ For a full explanation of the components of the animal body, the composition of feeds, the different ways in which the food is used in the animal body and the explanation for using the therm in the calculation of rations for farm animals, see Farmers' Bulletin 346, United States Department of Agriculture, prepared by H. P. Armsby.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES.

[Figures equal percentages of pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
I. GREEN FODDERS.													
<i>(a) Meadow Grasses and Millets.</i>													
Johnson grass (<i>Andropogon halepensis</i>),	1	75	1.4	1.2	8.9	13.2	0.3	-	-	-	-	-	-
Orchard grass (<i>Dactylis glomerata</i>),	7	70	2.1	2.9	10.4	13.7	0.9	-	-	-	-	-	-
Tall oat grass (<i>Arrhenatherum elatius</i>),	4	70	1.6	2.3	10.8	14.7	0.6	-	-	-	-	-	-
Common millet (<i>Chenopodium italicum</i>),	16	80	1.0	1.5	6.5	10.5	0.5	0.9	4.6	7.0	0.3 ¹	9.9	
Canary bird seed millet (<i>C. Italica</i>),	1	80	1.6	1.0	7.1	10.0	0.3	-	-	-	-	-	
Early harvest millet (<i>C. Italica</i>),	1	80	1.4	1.1	7.4	9.7	0.4	-	-	-	-	-	
Golden millet (<i>C. Italica</i>),	1	80	1.2	0.8	7.0	10.7	0.3	-	-	-	-	-	
Hungarian grass (<i>C. Italica</i>),	3	80	1.4	1.9	5.8	10.5	0.4	1.2	4.1	7.0	0.2	9.9	
Japanese millet (<i>C. Italica</i>),	12	80	1.2	1.7	6.2	10.5	0.4	0.9	3.8	7.0	0.3	9.4	
Broom-corn millets.													
Millet (<i>Panicum miliaceum</i>),	1	80	1.1	1.1	5.3	11.7	0.8	-	-	-	-	-	
Broom-corn millet (<i>P. miliaceum</i>),	1	80	1.2	1.3	6.4	10.7	0.4	-	-	-	-	-	
Hog millet (<i>P. miliaceum</i>),	1	80	1.4	1.5	6.5	10.2	0.4	-	-	-	-	-	
Japanese broom-corn millet (<i>P. miliaceum</i>),	2	80	1.2	0.9	6.2	11.4	0.3	-	-	-	-	-	
Barnyard millet (<i>Panicum crus-galli</i>),	8	80	1.7	1.9	6.6	9.4	0.4	1.2	4.8	6.7	0.2	9.9	

¹ Same coefficients used as for Hungarian grass.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — *Continued.*
 [Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
I. GREEN FODDERS — <i>Con.</i>													
(a) <i>Meadow Grasses and Millets — Con.</i>													
Pearl millet (<i>Pennisetum spicatum</i>),	1	80	1.4	1.4	6.9	10.1	0.2	-	-	-	-	-	-
Japanese millet (variety uncertain),	3	80	1.1	1.2	7.1	10.2	0.4	0.6	4.4	6.8	0.3	8.8	8.8
(b) <i>Cereal Fodders.</i>													
Barley,	1	75	2.1	3.2	9.4	9.6	0.7	2.3	5.7	6.8	0.4	10.7	10.7
Barley in milk,	1	75	1.2	2.6	7.3	13.2	0.7	1.8	4.1	9.8	0.3	12.9	12.9
Corn ears (as harvested),	4	70	0.7	2.9	4.0	21.5	0.9	-	-	-	-	-	-
Corn husks (as harvested),	6	80	0.7	1.2	6.0	11.8	0.3	-	-	-	-	-	-
Corn leaves (as harvested),	4	75	2.4	3.6	6.2	12.0	0.8	-	-	-	-	-	-
Corn stalks (as harvested),	4	80	1.0	0.8	6.5	11.5	0.2	-	-	-	-	-	-
Corn fodder, Brewers Dent,	2	80	1.0	2.0	5.0	11.7	0.3	1.4	3.4	9.0	0.2	12.0	12.0
Corn fodder Early Mastodon Dent,	3	80	0.9	1.7	4.6	12.4	0.4	1.0	2.8	9.8	0.3	12.3	12.3
Corn fodder, Klondike,	1	80	1.2	1.1	5.7	11.7	0.3	-	-	-	-	-	-
Corn fodder, Leaming,	5	80	1.0	1.6	4.9	12.1	0.4	1.0	3.0	9.3	0.3	11.8	11.8
Corn fodder, Longfellow,	1	80	1.1	1.8	4.0	12.8	0.3	-	-	-	-	-	-
Corn fodder, Pride of the North,	6	80	0.9	1.7	4.3	12.6	0.5	1.1	2.8	10.2	0.4	13.2	13.2

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — Continued.
 [Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	
I. GREEN FODDERS — Con.												
(c) Legumes — Con.												
Soy bean (medium green),	18	80	2.3	4.1	5.2	7.8	0.6	3.2	2.4	6.0	0.3 ¹	9.7
Soy bean (medium green), in bud,	1	80	2.5	4.2	5.5	7.3	0.5	3.3	2.8	5.3	0.3	9.2
Soy bean (medium green), in blossom,	5	80	2.3	4.0	5.5	7.7	0.5	3.1	2.6	5.5	0.3	9.0
Soy bean (medium green), in pod,	9	78	2.3	4.5	5.9	8.6	0.7	3.5	2.7	6.6	0.4	10.7
Soy bean (medium black),	2	80	2.5	3.8	4.7	8.0	1.0	3.0	2.1	6.2	0.6 ¹	10.3
Soy bean (late),	4	80	2.6	4.6	4.2	8.0	0.6	3.6	1.9	6.2	0.3 ¹	10.4
Clover, alsike (<i>Trifolium hybridum</i>),	8	80	2.3	3.3	5.4	8.5	0.5	-	-	-	-	-
Clover, crimson (<i>T. incarnatum</i>),	2	80	2.8	3.1	6.0	7.6	0.5	2.4	3.4	5.6	0.3	9.0
Clover, mammoth red (<i>T. medium</i>),	4	80	1.9	3.0	5.8	8.9	0.4	-	-	-	-	-
Clover, medium red (<i>T. pratense</i>),	13	80	1.8	3.1	5.7	8.8	0.6	2.0	3.0	6.3	0.4	9.3
Clover, medium red, in bud,	2	80	2.1	3.6	4.7	9.0	0.6	2.4	2.5	6.6	0.4 ²	10.1
Clover, medium red, in blossom,	3	79	1.9	3.5	6.0	9.0	0.6	2.3	3.2	6.5	0.4	9.9
Clover, medium red, seeding,	2	75	2.3	3.8	7.2	11.0	0.7	2.5	3.8	7.9	0.4	10.2
Sweet clover (<i>Melilotus alba</i>),	4	80	1.9	3.8	6.3	7.4	0.6	-	-	-	-	-
Cow pea (<i>Vigna catjang</i>),	12	85	2.0	2.8	3.5	6.3	0.4	2.1	2.1	5.1	0.2 ³	8.1

Cow pea, black,	6	85	2.2	2.8	3.6	6.1	0.3	2.1	2.2	4.9	0.2 ³	8.0
Cow pea, New Era,	1	85	1.9	2.6	3.6	6.4	0.5	2.0	2.2	5.2	0.3 ²	8.3
Cow pea, Whip-poor-will,	7	85	1.9	2.6	3.7	6.5	0.3	2.0	2.2	5.3	0.2 ³	8.9
Canada beauty pea (<i>Pisum arvense</i>),	1	85	1.2	2.4	4.4	6.6	0.4	-	-	-	-	-
Canada field pea (<i>P. arvense</i>),	8	85	1.3	3.2	4.3	5.8	0.4	2.6	2.1	4.4	0.2	8.0
Canada field pea (<i>P. arvense</i>), in bud,	2	85	1.1	3.2	4.1	6.1	0.5	2.6	2.5	4.3	0.3 ⁴	8.0
Canada field pea (<i>P. arvense</i>), in blossom,	3	87	1.2	2.8	3.8	4.8	0.4	2.3	1.7	3.6	0.2	6.1
Canada field pea (<i>P. arvense</i>), in pod,	2	84	1.2	2.3	4.8	6.3	0.4	1.9	2.2	4.8	0.2	6.9
English gray pea (<i>P. arvense</i>),	1	85	1.4	3.1	4.5	5.5	0.5	-	-	-	-	-
Prussian blue pea (<i>P. arvense</i>),	1	85	1.3	2.8	4.5	5.9	0.5	-	-	-	-	-
Flat pea (<i>Lathyrus sylvestris wagneri</i>),	2	85	1.3	4.4	3.7	5.0	0.6	-	-	-	-	-
Sainfoin (<i>Onobrychis sativa</i>),	1	75	2.1	4.4	6.0	11.6	0.9	-	-	-	-	-
Serradella (<i>Ornithopus sativus</i>),	3	85	1.6	2.2	4.4	6.5	0.3	-	-	-	-	-
Sulla (<i>Hedysarum coronarium</i>),	2	75	2.3	4.3	5.2	12.5	0.7	-	-	-	-	-
Spring vetch (<i>Vicia sativa</i>),	4	85	1.4	2.7	4.5	6.1	0.4	1.9	2.0	4.6	0.2	7.8
Winter or sand vetch (<i>Vicia villosa</i>),	7	85	2.1	3.4	4.4	4.7	0.4	2.8	2.8	3.6	0.3	7.5
Winter or sand vetch (<i>V. villosa</i>), in bud,	2	86	2.4	3.3	3.5	4.4	0.4	-	-	-	-	-
Winter or sand vetch (<i>V. villosa</i>), in blossom,	4	82	2.5	4.2	5.5	5.4	0.4	3.5	3.5	4.2	0.3	9.1
Kidney vetch (<i>Anthyllis vulneraria</i>),	1	85	2.0	2.8	2.3	7.4	0.5	-	-	-	-	-
(d) Mixed and Miscellaneous.												
Barley and peas,	1	80	1.6	2.8	6.8	8.2	0.6	2.1	3.5	5.6	0.4	8.5
Barley and vetch,	2	80	1.2	2.8	6.5	9.0	0.5	2.1	3.4	6.1	0.3 ⁵	8.9

¹ Same coefficients applied to all soy beans except to medium green varieties in different stages of growth.

² Coefficients taken from the German.

³ Same coefficients applied to all cow peas. ⁴ Same coefficients applied to Canada field peas in blossom and in pod. ⁵ Same coefficients used as for barley and peas.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — Continued.

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therm.).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
I. GREEN FODDERS — Con.													
(d) Mixed and Miscellaneous — Con.													
Corn and soy bean,	3	80	1.5	2.6	5.0	10.4	0.5	-	-	-	-	-	-
Corn and cow peas,	1	80	1.8	2.1	5.3	10.4	0.4	-	-	-	-	-	-
Sweet corn and cow peas,	4	80	1.7	1.7	5.2	10.9	0.5	-	-	-	-	-	-
Millet and peas,	1	80	1.8	2.4	7.5	8.0	3.0	-	-	-	-	-	-
Tall oat grass and alsike clover,	2	80	1.5	2.7	5.8	9.5	0.5	-	-	-	-	-	-
Orchard grass and alsike clover,	1	80	1.5	2.4	6.5	9.0	0.7	-	-	-	-	-	-
Peas and oats,	4	80	1.7	2.9	6.0	8.8	0.6	2.1	3.8	6.3	0.4	10.0	-
Sorghum and cow peas,	1	80	1.6	1.6	6.5	9.9	0.4	-	-	-	-	-	-
Vetch and oats (1-1),	3	80	1.8	3.0	6.3	8.4	0.5	2.3	4.3	5.7	0.2	9.6	-
Vetch and oats (1-4),	1	80	1.8	2.7	6.0	8.8	0.7	-	-	-	-	-	-
Wheat and vetch,	4	80	1.6	3.4	6.4	8.1	0.5	2.6	4.4	5.9	0.3	10.4	-
Apple pomace,	6	83	9.6	1.0	2.9	11.6	0.9	-	1.9	9.9	0.4	11.7	-
Sugar beet pulp,	1	90	0.1	1.4	2.5	5.9	0.1	0.9	2.1	5.0	-	-	-
Cabbage waste,	1	82	4.9	3.6	2.6	6.6	0.3	-	-	-	-	-	-

Carrot tops,	1	80	2.8	4.2	2.7	9.9	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Prickley comfrey (<i>Symphytum aspernum</i>),	1	87	2.8	2.3	1.5	6.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-
Purslane (<i>Portulaca oleracea</i>),	1	91	1.5	2.3	1.6	3.4	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Dwarf Essex rape (<i>Brassica napus</i>),	1	85	2.4	1.9	2.9	7.2	0.6	1.7	2.5	6.6	0.31	10.3	-	-	-	-	-	-	-
Summer rape (<i>B. napus</i>),	1	85	2.8	2.1	2.7	6.9	0.5	1.9	2.3	6.3	0.2	9.9	-	-	-	-	-	-	-
Winter rape (<i>B. napus</i>),	1	85	3.3	2.3	1.8	7.1	0.5	2.0	1.6	6.5	0.2	9.1	-	-	-	-	-	-	-
Sorghum (<i>Andropogon sorghum</i>),	7	80	1.3	1.7	5.5	11.1	0.4	0.8	3.4	8.3	0.3	10.6	-	-	-	-	-	-	-
Spurry (<i>Spergula arvensis</i>),	1	72	2.6	2.9	7.0	15.4	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Teosinte (<i>Euchlana Mexicana</i>),	2	70	2.3	2.3	9.4	15.6	0.4	-	-	-	-	-	-	-	-	-	-	-	-
II. SILAGE.																			
Apple pomace,	1	85	0.6	1.2	3.3	8.8	1.1	-	2.2	7.5	0.5 ¹	9.4	-	-	-	-	-	-	-
Corn,	49	80	1.1	1.7	5.4	11.1	0.7	0.9	3.5	7.7	0.5	10.6	-	-	-	-	-	-	-
Corn and soy bean,	6	76	2.3	2.7	7.3	10.9	0.8	1.7	4.5	8.5	0.7	12.6	-	-	-	-	-	-	-
Millet,	3	74	2.4	1.7	7.5	13.6	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Millet and soy bean,	9	79	2.8	2.8	7.2	7.2	1.0	1.6	5.0	4.2	0.7	8.4	-	-	-	-	-	-	-
III. HAY AND DRY COARSE FODDERS.																			
(a) Meadow Grasses and Millets.																			
Canada blue grass (<i>Poa compressa</i>),	1	14	4.8	5.9	31.3	42.1	0.9	2.5	22.2	26.5	0.3	36.0	-	-	-	-	-	-	-
Kentucky blue grass (<i>Poa pratensis</i>),	3	14	6.4	7.7	30.5	39.7	1.7	4.4	20.1	24.2	0.9	35.0	-	-	-	-	-	-	-
Canada hay,	4	14	4.6	6.1	28.1	45.1	2.1	-	-	-	-	-	-	-	-	-	-	-	-
English hay (mixed grasses),	122	14	5.3	7.9	27.8	42.8	2.2	4.5	17.2	26.5	1.1	36.9	-	-	-	-	-	-	-
Fermented hay,	1	14	6.3	8.4	25.4	43.7	2.2	-	-	-	-	-	-	-	-	-	-	-	-

¹ Same coefficients applied to all varieties of rape.² Same coefficients used as for fresh apple pomace.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — Continued.

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Thermals).
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	
III. HAY AND DRY COARSE FODDERS — Con.												
(a) Meadow Grasses and Millets — Con.												
Meadow fescue (<i>Festuca elatior pratensis</i>),	7	14	7.1	5.8	32.2	39.3	1.6	3.0	21.6	23.2	0.9	30.3
{ Barnyard grass (<i>Panicum crus-galli</i>),	1	14	8.6	13.1	29.0	33.6	1.7	-	-	-	-	-
{ Barnyard millet (<i>P. crus-galli</i>),	8	14	7.3	8.2	28.4	40.4	1.7	5.2	17.6	21.0	0.8	30.7
{ Hungarian grass (<i>Chaetochloa Italica</i>),	3	14	6.3	8.4	24.6	45.0	1.7	5.0	16.7	30.2	1.1	42.4
Orchard grass (<i>Dactylis glomerata</i>),	7	14	5.9	8.3	29.9	39.3	2.6	5.0	18.2	21.6	1.4	32.1
Tall oat grass (<i>Arrhenatherum elaius</i>),	4	14	4.6	6.4	30.9	42.1	1.9	3.3	17.0	24.4	1.1	30.8
Red top (<i>Agrostis alba vulgaris</i>),	6	14	4.6	6.5	28.5	44.9	1.5	4.0	17.4	27.8	0.8	36.6
Red top (<i>A. alba vulgaris</i>), early cut,	1	14	4.3	5.8	30.9	43.3	1.7	-	-	-	-	-
Red top (<i>A. alba vulgaris</i>), late cut,	1	14	4.1	6.0	31.0	43.2	1.7	-	-	-	-	-
Rowen,	32	14	6.5	11.4	24.1	41.0	3.0	7.9	15.9	26.2	1.4	41.1
Italian rye grass (<i>Lolium Italicum</i>),	4	14	6.4	7.1	28.6	42.2	1.6	-	-	-	-	-
Perennial rye grass (<i>Lolium perenne</i>),	4	14	7.9	10.1	25.4	40.5	2.1	-	-	-	-	-
{ Black grass (<i>Juncus Gerardi</i>),	3	16	7.4	7.0	24.3	43.1	2.2	4.1	14.3	22.4	1.0	28.7
{ Branch grass (<i>Distichlis spicata</i>),	2	16	7.6	6.8	22.4	45.1	2.1	3.8	12.1	22.1	0.7	28.1
{ Flat sage (<i>Spartina stricta maritima</i> var.),	1	16	8.2	6.6	25.0	41.8	2.4	3.4	15.0	23.0	0.9	30.6

Salt hay's	Fox grass (<i>Sparina patens</i>),	2	16	5.8	6.7	22.5	46.9	2.1	4.0	11.9	24.9	0.8	31.3	
	High-grown salt hay (largely <i>Sparina patens</i>),	1	16	7.0	6.3	22.2	46.4	2.1	3.8	11.8	24.6	0.8	30.8	
	Cove mixture (black grass and red top),	1	16	6.0	7.4	23.2	45.6	1.8	3.6	13.9	24.2	0.7	31.6	
	Mixed salt hay (largely fox grass and branch grass),	1	16	8.4	5.5	22.5	45.5	2.1	2.3	13.1	23.7	0.6	29.1	
	Salt hay (variety uncertain),	2	16	4.3	3.4	24.0	49.8	2.5	-	-	-	-	-	
	Swamp or swale hay,	2	14	5.8	7.1	26.7	44.5	1.9	2.4	8.8	20.5	0.8	19.6	
	Timothy (<i>Phleum pratense</i>),	9	14	4.1	8.0	28.3	43.7	1.9	3.8	14.2	27.1	1.0	30.8	
	Timothy (<i>P. pratense</i>), early cut,	1	14	4.0	5.7	31.0	43.5	1.8	3.2	17.7	27.4	0.9	34.3	
	Timothy (<i>P. pratense</i>), late cut,	1	14	3.9	5.2	29.7	45.2	2.0	2.2	13.7	26.7	1.0	29.2	
	White top (<i>Agrostis vulgaris</i> var.),	1	14	6.0	11.2	24.4	41.5	2.9	-	-	-	-	-	
	(b) Cereal Fodders.													
	Corn stover, from field,	46	40	3.9	4.6	20.6	30.1	0.8	1.7	13.2	17.8	0.6	23.4	
	Corn stover, very dry,	46	20	5.2	6.1	27.5	40.2	1.0	2.3	17.6	23.7	0.7	31.0	
	Oats,	6	15	6.9	11.7	25.5	38.3	2.6	6.2	13.0	21.1	1.6	30.4	
	(c) Legumes.													
Alfalfa, first cutting,	3	15	6.6	14.3	27.2	35.3	1.5	10.3	13.6	24.4	0.5	35.4		
Alfalfa, second cutting,	1	15	5.7	13.0	32.3	32.9	1.1	10.0	14.9	24.3	0.5	33.3		
Alsike clover,	8	15	9.7	14.0	23.1	36.1	2.1	9.2	11.6	23.8	0.8	34.6		
Mammoth red clover,	4	15	8.2	13.1	24.4	37.6	1.7	-	-	-	-	-		
Medium red clover, bud to early blossom,	1	15	9.5	15.1	24.1	34.6	1.7	9.7	14.2	23.5	0.9	37.2		
Medium red clover, full blossom,	1	15	7.6	13.0	25.4	37.4	1.6	7.8	11.7	25.8	0.9	34.2		
Medium red clover,	15	15	7.7	13.3	24.3	37.2	2.5	7.7	13.1	24.2	1.4	35.6		

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — Continued.

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Thermals).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
III. HAY AND DRY COARSE FODDERS — Con.													
(d) Straw.													
Barley,	2	15	4.8	6.5	32.2	39.0	2.5	1.3	18.0	21.1	1.11	25.5	
Horse bean,	1	15	8.1	8.3	35.2	32.1	1.3	-	-	-	-	-	
Soy bean,	3	15	6.1	4.7	36.1	36.3	1.8	2.4	13.7	24.0	1.11	31.2	
Millet (<i>Chatochloa Italica</i>),	1	15	5.3	3.6	35.2	39.5	1.4	-	-	-	-	-	
Millet (<i>Panicum crus-galli</i>),	1	15	4.6	5.2	30.4	42.7	2.1	-	-	-	-	-	
Millet (<i>P. miliaceum</i>),	1	15	5.2	3.3	35.9	38.1	2.5	-	-	-	-	-	
Millet (variety uncertain),	1	15	5.8	4.2	35.5	38.3	1.2	-	-	-	-	-	
Wheat,	1	15	4.1	6.2	30.5	42.8	1.4	0.7	15.9	16.3	0.44	17.2	
(e) Mixed and Miscellaneous.													
Hairy lotus,	2	15	7.0	12.6	16.8	46.1	2.5	-	-	-	-	-	
Oat grass and alsike clover,	2	15	6.5	11.6	24.5	40.1	2.3	-	-	-	-	-	
Orchard grass and alsike clover,	1	15	6.6	10.1	27.6	38.3	2.4	-	-	-	-	-	
Peas and oats,	4	15	7.2	12.2	25.5	37.5	2.6	8.9	14.8	22.9	1.5	36.7	
Vetch and oats (1-1),	3	15	7.4	12.8	26.7	35.8	2.3	8.3	13.1	21.1	1.4	31.4	
Wheat and vetch,	4	15	6.8	14.5	27.2	34.4	2.1	10.7	17.7	23.4	1.3	40.7	
White daisy,	1	15	6.0	6.6	30.7	39.7	2.0	-	-	-	-	-	

IV. VEGETABLES, FRUITS, ETC.

Apples,	2	78	0.7	1.0	1.5	18.3	0.5	-	-	-	-	-	-	-	-	-	-	-	-	
Artichokes,	1	78	1.1	2.9	0.9	16.9	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Beets, red,	7	88	1.1	1.5	0.7	8.6	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Sugar beets,	13	86	0.9	1.6	0.9	10.5	0.1	1.5	0.9	10.5	0.1	10.5	0.1	10.5	0.1	10.5	0.1	10.5	0.1	10.5
Yellow fodder beets,	4	89	1.0	1.3	1.0	7.5	0.2	1.0	-	4.2	-	4.2	-	4.2	-	4.2	-	4.2	-	4.2
Cabbages,	1	90	0.8	2.6	0.9	5.5	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Carrots,	5	89	0.9	1.0	1.1	7.8	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cranberries,	1	89	0.2	0.5	1.2	8.5	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Mangolds,	5	88	1.2	1.4	0.8	8.5	0.1	1.0	0.3	7.7	0.1	7.7	0.1	7.7	0.1	7.7	0.1	7.7	0.1	7.7
Parsnips,	1	80	1.5	1.3	1.5	15.0	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Potatoes,	54	80	0.8	2.1	0.5	16.5	0.1	1.0	-	14.8	-	14.8	-	14.8	-	14.8	-	14.8	-	14.8
Potatoes,	125	80	-	-	-	14.3 ²	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruta-bagas,	3	89	1.1	1.2	1.3	7.2	0.2	1.0	1.0	6.8	0.2	6.8	0.2	6.8	0.2	6.8	0.2	6.8	0.2	6.8
Japanese radish,	1	93	0.7	0.5	0.7	5.0	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Turnips,	5	90	0.9	1.5	1.2	6.6	0.2	1.4	1.2	6.3	0.2	6.3	0.2	6.3	0.2	6.3	0.2	6.3	0.2	6.3
Alfalfa meal,	1	9	8.0	13.2	32.7	35.8	1.3	9.8	15.0	25.8	0.5 ³	25.8	0.5^{3}	25.8	0.5^{3}	25.8	0.5^{3}	25.8	0.5^{3}	25.8
Horse beans,	1	14	3.8	25.8	7.0	48.6	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-
Red adzinki beans,	2	14	3.6	21.0	4.0	56.7	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Saddle beans,	1	14	5.3	13.0	4.1	49.4	14.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Soy bean,	5	14	5.0	31.2	4.7	28.4	16.7	28.4	-	23.0	15.5	23.0	15.5	23.0	15.5	23.0	15.5	23.0	15.5	23.0

¹ Digestion coefficients taken from the German.² Starch.³ Same coefficients used as for alfalfa hay.

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — Continued.

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
V. CONCENTRATED FEEDS — Con.													
(a) <i>Protein</i> — Con.													
Soy bean (medium green),	3	14	4.6	35.3	4.0	24.3	17.8	32.1	-	19.7	16.6	94.7	
Soy bean cake,	1	8	5.4	41.6	4.8	31.6	8.6	-	-	-	-	-	
Blood meal, Armour's edible,	3	11	3.1	84.3	-	1.2	0.4	70.8	-	-	-	-	
Brewers' dried grains,	19	10	3.6	24.0	13.4	42.8	6.2	19.4	6.6	24.4	5.5	56.4	
Brewers' wet grains,	1	77	0.7	6.7	3.8	9.8	2.0	5.3	2.0	5.7	1.8	15.2	
Buckwheat feed,	2	10	3.2	15.9	22.0	44.8	4.1	-	-	-	-	-	
Buckwheat middlings,	3	10	4.7	26.7	6.8	44.6	7.2	22.7	1.1	37.0	6.4	76.8	
Calf meal (Schumachers),	2	9	2.2	18.7	2.0	60.2	7.9	-	-	-	-	-	
Cocconut meal,	3	9	4.7	20.4	11.0	40.6	4.3	-	-	-	-	-	
Cottonseed meal,	404	7	6.7	44.6	6.5	25.2	10.0	37.5	2.3	19.7	9.4	80.8	
Cottonseed meal (low grade),	33	8	4.6	24.9	18.0	37.0	7.5	18.9	7.0	27.0	7.1	62.2	
Dairy feed, Union Grains,	1	7	6.2	25.2	9.9	44.1	7.6	19.2	9.2	37.9	7.4	-	
Dairy feed Buffalo Creamery,	1	9	4.3	19.9	12.4	50.2	4.2	16.1	6.8	35.6	3.7	-	
Dairy feed, Unicorn,	1	8	3.3	27.3	9.0	46.1	6.3	21.3	6.5	41.0	6.0	-	
Distillers' dried grains, largely from corn,	81	8	1.7	31.7	12.3	34.1	12.2	23.1	11.7	27.6	11.6	80.2	

Gluten feed,	278	8.5	1.9	25.9	7.2	53.3	3.2	22.0	6.3	48.0	2.6	77.8
Gluten flour, wheat,	1	5.5	0.4	84.8	0.2	8.1	1.0	-	-	-	-	-
Gluten meal, wheat,	2	8.0	0.9	39.8	0.8	48.9	1.6	-	-	-	-	-
Gluten meal,	139	9.5	1.0	36.0	2.1	49.1	2.3	31.7	-	43.2	2.1	74.9
Germ oil meal,	13	9.0	2.7	22.7	9.3	45.9	10.4	15.7	-	37.2	10.1	79.4
Flax screenings,	2	8.0	6.0	16.8	13.7	40.9	14.6	-	-	-	-	-
Flaxseed meal,	2	7.0	3.5	23.5	5.5	23.3	37.2	-	-	-	-	-
Linseed meal (new process),	58	9.0	5.6	37.4	8.9	36.4	2.7	31.5	6.6	29.1	2.4	72.7
Linseed meal (old process),	138	8.5	5.2	34.3	8.5	36.4	7.1	30.5	4.8	28.4	6.3	80.3
Malt sprouts,	32	11.0	5.9	26.4	12.3	43.1	1.3	20.1	12.2	36.6	1.1	56.4
Bibby's dairy cake,	4	10.0	7.7	19.7	8.6	44.9	9.1	13.0	4.0	36.4	8.4	-
Holstein sugar feed,	1	8.0	6.7	12.6	10.0	60.0	2.7	8.3	4.4	48.6	2.4	-
Sucrene dairy feed,	9	9.0	6.4	16.9	11.4	52.0	3.3	10.3	8.2	38.0	3.1	-
Oat middlings, fine,	4	9.0	2.3	15.8	2.4	64.3	6.2	12.8	1.2	61.7	5.8	92.2
Pea meal,	1	10.0	2.6	18.9	17.5	49.4	1.6	15.7	4.6	46.4	0.9	70.4
Peanut bran,	2	5.0	4.8	19.2	9.1	33.6	28.3	-	-	-	-	-
Peanut germ,	2	3.0	3.4	28.5	3.3	18.4	43.4	-	-	-	-	-
Peanut meal,	1	8.0	4.0	49.0	3.5	24.7	10.8	44.6	0.8	22.7	9.6	94.1
Rye feed,	20	11.0	3.3	14.8	3.8	64.4	2.7	11.8	-	56.7	2.4	78.2
Sun flower seed cake,	1	10.0	4.2	34.8	10.9	21.8	18.3	-	-	-	-	-
Wheat middlings (flour),	140	10.0	3.2	18.8	3.3	59.9	4.8	16.5	1.2	52.7	4.1	83.8
Wheat middlings (standard),	371	10.0	4.3	17.8	7.0	55.9	5.0	13.8	2.1	43.5	4.4	57.6
Wheat mixed feed, bran and middlings,	859	10.0	5.3	16.9	8.1	55.2	4.5	13.2	5.0	42.5	3.9	-

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — *Continued.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
V. CONCENTRATED FEEDS — <i>Con.</i>													
(a) <i>Protein</i> — <i>Con.</i>													
Wheat mixed feed, adulterated,	7	10.0	4.3	12.3	15.5	54.6	3.3	7.7	4.3	38.8	3.0	-	
Wheat bran,	452	10.0	6.2	16.1	10.0	53.3	4.4	12.4	3.9	37.8	2.8	49.0	
Wheat bran (spring),	4	10.0	5.8	16.1	10.5	52.6	5.0	12.2	4.6	38.9	3.2	-	
Wheat bran (winter),	3	10.0	6.2	15.3	8.6	57.0	2.9	11.8	2.3	37.1	1.9	-	
Wheat screenings,	1	8.0	4.9	15.6	9.1	54.7	7.7	11.7	5.9	40.5	7.2	-	
(b) <i>Starchy.</i>													
Bakery refuse,	1	13.0	10.1	8.0	0.3	63.0	5.6	-	-	-	-	-	
Barley,	7	12.0	2.5	11.4	5.7	66.6	1.8	10.0	4.0	61.9	1.5	82.3	
Dried beet pulp,	2	16.0	3.3	9.1	18.6	58.3	0.7	-	-	-	-	-	
Dried molasses beet pulp,	4	8.0	5.8	9.9	14.1	61.7	0.5	6.3	11.8	56.1	-	72.1	
Broom corn seed,	3	12.0	2.7	10.4	7.4	64.2	3.3	-	-	-	-	-	
Buckwheat,	1	12.0	1.9	9.9	10.3	63.5	2.4	-	-	-	-	-	
Cassava starch refuse,	1	12.0	1.6	0.8	6.1	78.8	0.7	-	-	-	-	-	
Cocoa dust,	1	7.0	6.3	14.4	5.5	42.7	24.1	-	-	-	-	-	
Cocoa shells,	1	5.0	8.4	18.0	15.9	50.9	1.8	-	-	-	-	-	

TABLE I. — COMPOSITION AND DIGESTIBILITY OF FODDER ARTICLES — *Concluded.*

[Figures equal percentages or pounds in 100]

NAME.	Number of Analyses.	COMPOSITION.						DIGESTIBILITY.				Net Energy Values (Therms).	
		Water.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.		
CONCENTRATED FEEDS — <i>Con.</i>													
<i>(b) Starchy — <i>Con.</i></i>													
Oat kernels,	10	11.0	3.0	12.5	8.5	60.4	4.6	10.7	2.6	47.7	3.81	69.7	
Oats, ground,	10	12.0	3.0	12.3	8.4	59.7	4.6	10.1	1.2	51.3	3.71	71.2	
Oat feed,	122	7.0	5.5	7.9	21.8	55.0	2.8	5.1	7.0	23.1	2.5	40.9	
Oat feed (low grade),	17	7.0	5.5	5.1	26.4	54.4	1.6	3.2	8.4	18.0	1.5	33.2	
Oat feed, Canada,	2	7.0	5.4	13.2	24.8	44.7	4.9	9.1	8.2	22.8	4.3	49.5	
Pea bran,	2	11.0	2.7	10.0	39.7	35.6	1.0	-	-	-	-	-	
Peanut shells, ground, ²	5	9.4	2.4	7.4	60.6	16.9	3.3	-	-	-	-	-	
Rice, cleaned,	1	11.0	0.3	8.5	0.1	79.8	0.3	-	-	-	-	-	
Rice, bran,	2	11.0	12.7	6.8	20.6	42.8	6.1	4.3	6.0	33.4	5.4	-	
Rice meal,	2	11.0	8.2	11.8	5.3	50.8	12.9	7.3	-	46.7	11.7	87.7	
Rye middlings,	1	11.0	3.6	11.7	3.3	65.4	5.0	-	-	-	-	-	
Speltz,	1	8.0	3.9	11.5	11.1	62.9	2.2	9.2	6.7	56.0	1.9	-	
Starch refuse,	2	12.0	1.8	4.8	3.8	76.3	1.3	-	-	-	-	-	
Red wheat kernels,	1	12.0	1.7	8.8	2.6	72.4	2.5	5.9	1.0	66.6	2.0	78.9	
White winter wheat kernels,	1	12.0	1.7	11.5	2.1	70.8	1.9	9.4	1.6	65.8	1.2	80.3	

Wheat kernels,	13	12.0	1.8	12.0	2.6	69.7	1.9	9.0	1.5	64.8	1.4	78.9
Wheat flour,	2	12.0	0.4	9.9	0.1	76.8	0.8	-	-	-	-	-
<i>(c) Poultry.</i>												
Green cut bone,	2	27.0	19.2	18.6	-	5.8	29.4	-	-	-	-	-
Raw ground bone,	1	8.0	64.4	23.9	-	3.4	0.3	-	-	-	-	-
Cut clover,	2	10.0	6.8	17.9	20.5	41.8	3.0	-	-	-	-	-
Meat and bone meal,	38	6.0	37.3	39.6	-	6.3	10.8	-	-	-	-	-
Meat scrap,	12	9.0	18.4	50.6	-	4.2	17.8	-	-	-	-	-
Rava meat meal,	1	10.0	1.7	83.2	-	-	5.1	-	-	-	-	-
Mutton scrap,	1	7.0	33.1	39.9	-	5.3	14.7	-	-	-	-	-
Fish glue waste,	1	14.0	34.9	39.1	-	4.1	7.9	-	-	-	-	-
Milk albumen,	1	11.0	31.4	42.4	-	14.4	0.8	-	-	-	-	-
Granulated milk,	1	10.0	26.5	35.9	-	18.1	9.6	-	-	-	-	-

¹ Coefficients obtained from digestion experiments with horses.

² Valueless for feeding.

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES.¹

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
I. GREEN FODDERS.					
<i>(a) Meadow Grasses and Millets.</i>					
Orchard grass,	4	70	0.43	0.56	0.13
Millet,	1	80	0.29	0.43	0.11
Barnyard millet,	3	80	0.30	0.67	0.10
Hungarian grass,	1	80	0.30	0.42	0.12
Japanese millet,	3	80	0.33	0.22	0.10
<i>(b) Cereal Fodders.</i>					
Corn fodder,	22	80	0.39	0.30	0.13
Oats,	3	75	0.72	0.56	0.19
Rye,	2	75	0.27	0.57	0.11
<i>(c) Legumes.</i>					
Alfalfa,	4	80	0.44	0.31	0.11
Horse bean,	1	85	0.41	0.21	0.05
Soy bean (early white),	1	80	0.57	0.55	0.13
Soy bean (medium green), average,	14	80	0.64	0.53	0.14
Soy bean (medium green), in bud,	1	80	0.66	0.58	0.15
Soy bean (medium green), in blossom,	5	80	0.64	0.60	0.13
Soy bean (medium green) in pod,	7	78	0.72	0.52	0.17
Soy bean (medium black),	1	80	0.70	0.50	0.16
Soy bean (late),	1	80	0.60	0.68	0.14
Alsike clover,	6	80	0.53	0.50	0.15
Mammoth red clover,	3	80	0.50	0.27 ²	0.12
Medium red clover, average,	10	80	0.52	0.57	0.11
Medium red clover, in bud,	2	80	0.58	0.71	0.13
Medium red clover, in blossom,	3	79	0.51	0.58	0.12
Medium red clover, seeding,	2	75	0.61	0.65	0.13
Sweet clover,	1	80	0.43	0.40	0.12
White lupine,	1	85	0.45	0.26	0.05
Yellow lupine,	1	85	0.40	0.44	0.09
Canada field peas, average,	6	85	0.50	3.08	0.12

¹ Many of these analyses were made in earlier years by the Massachusetts State Experiment Station. The percentages of the several ingredients will vary considerably depending upon the fertility of the soil, and especially upon the stage of growth of the plant. In the majority of cases the number of samples analyzed is too few to give a fair average. The figures, therefore, must be regarded as close approximations rather than as representing absolutely the exact fertilizing ingredients of the different materials. (J. B. L.)

² Evidently below normal.

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES — *Continued.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
I. GREEN FODDERS— <i>Con.</i>					
<i>(c) Legumes — Con.</i>					
Canada field peas, in bud,	2	85	0.50	0.44	0.11
Canada field peas, in blossom,	2	87	0.45	0.32	0.11
Canada field peas, in pod,	2	84	0.52	0.37	0.13
Cow pea, average,	9	85	0.45	0.47	0.12
Black cow peas,	4	85	0.40	0.47	0.12
Whip-poor-will cow peas,	5	85	0.49	0.47	0.12
Flat pea,	1	85	0.75	0.32	0.10
Small pea,	1	85	0.40	0.31	0.09
Sainfoin,	1	75	0.68	0.57	0.20
Serradella,	2	85	0.36	0.37	0.12
Sulla,	2	75	0.68	0.58	0.12
Spring vetch,	1	85	0.36	0.45	0.10
Hairy or sand vetch, average,	5	85	0.55	0.51	0.13
Hairy or sand vetch, in bud,	2	86	0.52	0.54	0.12
Hairy or sand vetch, in blossom,	3	82	0.65	0.57	0.16
Kidney vetch,	1	85	0.44	0.28	0.08
Average for legumes,	-	-	0.53	0.44	0.12
<i>(d) Mixed and Miscellaneous.</i>					
Vetch and oats,	4	80	0.30 ¹	0.30	0.14
Apple pomace,	2	83	0.21	0.12	0.02
Carrot tops,	1	80	0.69	1.08	0.13
Prickley comfrey,	1	87	0.37	0.76	0.12
Common buckwheat,	1	85	6.44	0.54	0.09
Japanese buckwheat,	1	85	0.26	0.53	0.14
Silver-hull buckwheat,	1	85	0.29	0.39	0.14
Summer rape,	1	85	0.34	0.78	0.10
Sorghum,	8	80	0.26	0.29	0.11
Teosinte,	1	70	0.47	1.18	0.90
II. SILAGE.					
Corn,	7	80	0.42	0.39	0.13
Corn and soy bean,	1	76	0.65	0.36	0.35 ²
Millet,	3	74	0.26	0.62	0.14
Millet and soy bean,	5	79	0.42	0.44	0.11

¹ Too low; 0.43 nearer correct.² Evidently too high.

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES — *Continued.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
III. HAY AND DRY COARSE FODDERS.					
<i>(a) Meadow Grasses and Millets.</i>					
Barnyard millet,	3	14	1.29	2.88	0.43
Hungarian grass,	1	14	1.29	1.79	0.52
Italian rye grass,	4	14	1.12	1.19	0.53
Kentucky blue grass,	2	14	1.20	1.54	0.39
Meadow fescue,	6	14	0.93	1.98	0.37
Orchard grass,	4	14	1.23	1.60	0.38
Perennial rye grass,	2	14	1.16	1.47	0.53
Red-top,	4	14	1.07	0.95	0.33
Timothy,	3	14	1.20	1.42	0.33
English hay (mixed grasses),	13	14	1.34	1.61	0.32
Rowen,	13	14	1.72	1.58	0.48
Branch grass,	1	16	1.06	0.87	0.19
Fox grass,	1	16	1.18	0.95	0.18
Salt hay (variety uncertain),	1	16	1.05	0.64	0.23
<i>(b) Cereal Fodders.</i>					
Corn stover, from field,	17	40	0.69	0.92	0.20
Corn stover, very dry,	17	20	0.92	1.22	0.26
Oats,	3	15	2.45 ¹	1.90	0.65
<i>(c) Legumes.</i>					
Alsike clover,	6	15	2.26	2.10	0.63
Mammoth red clover,	3	15	2.14	1.16 ²	0.52
Medium red clover,	10	15	2.21	2.42	0.47
<i>(d) Straw.</i>					
Barley,	2	15	0.95	2.03	0.19
Soy bean,	1	15	0.69	1.04	0.25
Millet,	1	15	0.68	1.73	0.18
<i>(e) Mixed and Miscellaneous.</i>					
Vetch and oats,	4	15	1.29 ³	1.27	0.60
Broom corn waste (stalks),	1	10	0.87	1.87	0.47
Palmetto root,	1	12	0.54	1.37	0.16
Spanish moss,	1	15	0.61	0.56	0.07
White daisy,	1	15	0.26	1.18	0.41

¹ Too high; 1.90 nearer correct.² Evidently below normal.³ Too low; 1.80 nearer correct.

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES — *Continued.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
IV. VEGETABLES, FRUITS, ETC.					
Apples,	2	78	0.12	0.17	0.01
Artichokes,	1	78	0.46	0.48	0.17
Beets, red,	8	88	0.24	0.44	0.09
Sugar beets,	4	86	0.24	0.52	0.11
Yellow fodder beets,	1	89	0.23	0.56	0.11
Mangolds,	3	88	0.15	0.34	0.14
Carrots,	3	89	0.16	0.46	0.09
Cranberries,	1	89	0.08	0.10	0.03
Parsnips,	1	80	0.22	0.62	0.19
Potatoes,	5	80	0.29	0.51	0.08
Japanese radish,	1	93	0.08	0.40	0.05
Turnips,	4	90	0.17	0.38	0.12
Ruta-bagas,	3	89	0.19	0.49	0.12
V. CONCENTRATED FEEDS.					
(a) Protein.					
Red adzinki bean,	1	14	3.27	1.55	0.95
White adzinki bean,	1	14	3.45	1.53	1.00
Saddle bean,	1	14	2.08	2.09	1.49
Soy bean,	3	14	5.61	2.12	1.82
Blood meal (Armour's),	1	11	13.55	0.18	0.26
Brewers' dried grains,	2	8	3.68	0.86	1.06
Cottonseed meal,	167	7	7.08	2.05	2.90
Distillers' dried grains,	20	8	4.50	0.31	0.61
Gluten feed,	106	8.5	4.13	0.40	0.77
Gluten meal,	46	9.5	5.87	0.21	0.55
Linseed meal (new process),	21	9	5.97	1.42	1.79
Linseed meal (old process),	56	8.5	5.35	1.30	1.66
Malt sprouts,	12	11	4.32	2.00	1.56
Bibby's dairy cake,	1	10	2.94	1.67	2.07
Sucrene feed,	1	10	2.62	2.08	0.55
Pea meal,	1	10	3.04	0.98	1.81
Peanut meal,	1	8	7.84	1.54	1.27
Proteina,	1	8	3.04	0.58	1.02

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES — *Continued.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
V. CONCENTRATED FEEDS — <i>Con.</i>					
<i>(a) Protein — <i>Con.</i></i>					
Rye feed,	11	11	2.36	1.08	1.60
Wheat middlings (flour),	44	10	3.06	1.01	1.65
Wheat middlings (standard),	103	10	2.88	1.28	2.06
Wheat mixed feed,	282	10	2.72	1.44	2.57
Wheat bran,	116	10	2.59	1.45	2.79
<i>(b) Starchy.</i>					
Ground barley,	1	13	1.56	0.34	0.66
Buckwheat hulls,	1	12	0.49	0.52	0.07
Cocoa dust,	1	7	2.30	0.63	1.34
Corn cobs,	8	8	0.52	0.63	0.06
Corn and cob meal,	29	11	1.38	0.46	0.56
Corn kernels,	13	11	1.82	0.40	0.70
Corn meal,	3	14	1.92	0.34	0.71
Corn and oat feed (Victor),	2	10	1.38	0.61	0.59
Corn, oat and barley feed (Schumachers),	1	8	1.80	0.63	0.83
Cotton hulls,	3	11	0.75	1.08	0.18
Hominy meal,	125	11	1.65	0.76	1.27
Common millet seed,	2	12	2.00	0.45	0.95
Japanese millet seed,	1	12	1.58	0.35	0.63
Molasses (Porto Rico),	1	24	0.51	3.68	0.12
Dried molasses beet pulp,	1	8	1.60	1.47	0.16 ^k
Oat kernels,	1	11	2.05	-	-
Oat feed,	14	7	1.26	0.75	0.48
Oat feed (low grade),	15	7	0.88	0.70	0.35
Peanut feed,	2	10	1.46	0.79	0.23 ⁱ
Peanut husks,	1	13	0.80	0.48	0.13 ^j
Louisiana rice bran,	1	11	1.42	0.83	1.70
Rye middlings,	1	11	1.87	0.82	1.28
Damaged wheat,	1	13	2.26	0.51	0.83
Wheat flour,	2	12	2.02	0.36	0.35
<i>(c) Poultry.</i>					
American poultry food,	1	8	2.22	0.52	0.98
Meat and bone meal,	10	6	5.92	-	14.68
Meat scraps,	4	9	7.63	-	8.11

TABLE II. — FERTILIZER INGREDIENTS OF FODDER ARTICLES — *Concluded.*

[Figures equal percentages or pounds in 100.]

NAME.	Number of Analyses.	Water.	Nitrogen.	Potash.	Phosphoric Acid.
VI. DAIRY PRODUCTS.					
Whole milk,	297	86.4	0.57	0.19 ¹	0.16
Human milk,	3	88.1	0.24	-	-
Skim milk,	22	90.3	0.59	0.18 ²	0.20
Butter milk,	1	91.1	0.51	0.05	0.04
Whey,	1	93.7	0.10	0.07	0.17
Butter,	117	12.5	0.19	-	-

¹ From Farrington and Woll.² From Woll's Handbook.

TABLE III. — ANALYSES OF DAIRY PRODUCTS.

[Per Cent.]

NAME.	Number of Analyses.	Solids.			Fat.			Proteids (N. X 6.25).	Salt.	Ash.
		Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.			
Whole milk,	6,399 ¹	19.55	10.02	13.55	10.70	1.50	4.49	3.52 ²	—	0.73 ³
Human milk,	3	13.59	10.50	11.87	3.77	1.66	2.52	1.48	—	0.24
Colostrum,	2	24.75	21.25	23.00	3.00	3.00	3.00	2.84 ⁴	—	1.00
Skim milk (largely from Cooley process),	359	10.48	7.68	9.20	1.80	0.05	0.32	—	—	—
Buttermilk,	31	9.86	6.83	8.33	0.38	0.11	0.27	—	—	—
Cream (from Cooley process),	203	32.78	18.12	26.10	25.00	10.53	17.60	—	—	—
Butter (salted),	189	94.84	82.55	86.95	89.33	75.94	82.65	1.11 ⁵	3.21	—
Butter (fresh),	14	85.36	72.49	82.24	85.05	72.21	81.48	0.76	—	—

¹ Largely station herd, Jersey blood predominating.² Average of 961 samples.³ Average of 388 samples.⁴ Nitrogen.⁵ Curd and natural ash.

TABLE IV.—COEFFICIENTS OF DIGESTIBILITY OF
AMERICAN FODDER ARTICLES. EXPERIMENTS
MADE IN THE UNITED STATES.¹

J. B. LINDSEY AND P. H. SMITH.

EXPERIMENTS WITH RUMINANTS.
EXPERIMENTS WITH SWINE.
EXPERIMENTS WITH HORSES.
EXPERIMENTS WITH POULTRY.
EXPERIMENTS WITH CALVES.

Complete through Aug. 1, 1910.

EXPLANATION OF TABLE IV.

The first compilation of all digestion coefficients resulting from experiments made in the United States was made and published by J. B. Lindsey in 1896.² Jordon and Hall also published very complete data in 1900.³ Since then the writer and his co-workers have revised and published similar tables in 1902⁴ and 1906.⁵ The present publication is intended to be complete to December, 1910.

By *coefficient of digestibility* is meant the percentage of the ingredients which the animal can actually digest. Thus, of the 6.3 pounds of total protein in 100 pounds of Timothy hay, experiments have shown that 48 per cent., or 3 pounds, are digestible. The figure 48 is the digestion coefficient. The average coefficients determined have been applied to the average fodder analyses in Table I., and have enabled us to calculate the average amount of each fodder constituent digestible.

¹ Being a portion of the report of the Department of Plant and Animal Chemistry.

² Ninth report of the Hatch Experiment Station, pp. 157-170.

³ Bulletin 77, United States Department of Agriculture, Office of Experiment Stations.

⁴ Fourteenth report of the Hatch Experiment Station, pp. 195-216.

⁵ Eighteenth report of the Hatch Experiment Station, pp. 224-248.

EXPERIMENTS WITH RUMINANTS.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
I. GREEN FODDERS.									
(a) Meadow Grasses and Millets.									
Grass, native blue, Nevada (<i>Poa Sandbergii</i>),	1	2	52-53 53	-	20-25 23	64-64 64	44-45 45	60-61 60	48-51 50
Grass, meadow, young,	1	1	69	-	-	65	74	72	55
Grass, meadow, young, dried,	1	1	71	-	-	71	77	73	60
Grass, timothy,	1	3	63-65 64	-	31-33 32	48-48 48	51-58 56	65-67 66	52-54 52
Grass, timothy, rowen,	1	2	-	65-67 66	-	72-72 72	60-68 64	67-68 68	51-55 52
Grass, Western brome (<i>Bromus marginatus</i>),	1	2	60-60 60	-	42-42 42	68-68 68	53-53 53	67-67 67	15-16 16
Barnyard millet in blossom (Massachusetts) (<i>Panicum crus-galli</i>),	3	6	67-76 70	-	45-67 56	58-70 65	71-77 73	65-77 71	54-67 58
Japanese millet, bloom to early seed (Storrs),	2	3	-	62-66 64	52-58 55	45-57 50	59-63 62	64-68 67	60-72 68
Hungarian grass, early to late bloom,	3	8	61-71 66	61-74 68	-	59-72 63	65-76 70	64-71 67	48-85 62
(b) Cereal Fodders.									
Barley fodder, bloom,	2	4	-	62-71 67	-	69-73 72	40-66 61	69-76 71	59-63 60
Barley fodder, seeds forming,	2	2	-	66-71 68	40-44 42	67-71 69	47-65 56	- 74	48-50 49
Corn fodder, dent, immature,	5	14	64-74 68	-	42-43 42	56-80 66	50-76 65	64-79 71	37-83 86

Corn fodder, dent, milk, average,	7	17	70	-	391	62	64	77	76
Corn fodder, dent, mature, average,	12	23	69	72 ²	34	54	59	75	75
Corn fodder, dent, mature, B. & W., coarse,	1	2 {	51-54 52	-	-	20-28 24	46-47 40	57-61 59	74-82 78
Corn fodder, dent, brewers, milk,	1	2 {	71-73 72	-	44-49 46	68-69 69	67-71 69	76-77 77	67-70 68
Corn fodder, dent, early Mastodon, milk,	1	2 {	72-72 72	-	33-38 36	56-58 57	60-60 60	79-79 79	80-81 81
Corn fodder, Eureka silage, ears just forming,	1	3 {	64-69 67	-	42-43 42	67-68 67	56-61 60	70-74 72	65-67 66
Corn fodder, dent, Leaming, milk,	1	2 {	69-71 70	-	34-40 36	60-60 60	60-63 61	75-77 77	75-77 76
Corn fodder, dent, Pride of the North, mature,	2	4 {	69-81 74	-	29-40 35	59-68 63	58-74 66	76-86 81	74-78 80
Corn fodder, dent, Rustler's white, mature,	1	2 {	69-70 70	-	25-30 28	40-45 43	57-61 59	77-79 78	75-78 76
Corn fodder, dent, Wing's improved white cap, milk,	1	2 {	70-71 70	-	38-40 39	62-64 63	62-68 65	76-76 76	69-71 70
Corn fodder, flint, Sanford, mature,	2	4 {	63-73 69	67-75 71	14-50 34	46-57 52	67-80 75	67-75 71	53-74 66
Corn fodder, sweet, milk stage,	1	2 {	77-78 77	-	-	77-78 77	74-76 75	80-81 81	73-74 74
Corn fodder, sweet, roasting stage,	9	12 {	-	67-70 72	22-61 48	52-69 62	54-72 60	73-82 77	62-82 74
Oat fodder, bloom to early seeding,	3	5 {	-	56-65 62	49-68 60	68-76 73	43-63 55	66-67 62	67-72 69
Rye fodder, heading,	1	2 {	73-74 74	-	-	79-80 79	80-80 80	70-71 71	74-74 74
Sorghum fodder, blossom,	1	2 {	73-73 73	-	-	51-56 53	74-75 75	78-78 78	81-82 81

1 Average eight trials.

2 Average seventeen trials.

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
I. GREEN FODDERS — Con.									
(a) <i>Cereal Fodders</i> — Con.									
Sorghum fodder, Early Amber, past blossom,	2	4 {	61-69 65	-	40-43 42	38-51 44	42-72 55	70-74 73	60-67 64
Sorghum fodder, average,	3	6	68	-	42	47	62	75	70
(c) <i>Legumes</i> .									
Alfalfa, fodder,	1	2 {	61-61 61	-	40-40 40	73-75 74	42-43 43	71-72 72	38-39 39
Soy beans, variety uncertain, before bloom,	1	2 {	-	64-67 66	-	77-80 79	45-55 50	71-73 72	50-58 54
Soy beans, variety uncertain, seeding,	1	2 {	-	61-63 62	-	68-71 69	38-43 41	72-75 73	49-50 54
Soy beans, medium green, full blossom,	1	2 {	-	62-63 63	22-28 25	70-78 77	45-40 47	60-73 71	46-54 50
Soy beans, medium green, seeding,	4	12 {	62-69 65	65-69 67	16-45 28	74-84 78	31-53 45	71-81 77	31-69 55
Clover, crimson, late blossom,	1	3 {	-	68-70 69	-	77-77 77	54-58 56	74-75 74	68-69 66
Clover, red, late blossom,	1	2 {	65-67 66	-	-	66-68 67	52-53 53	76-79 78	68-66 65
Clover, rowen, late blossom,	1	2 {	-	60-62 61	-	61-62 62	51-54 52	64-68 65	60-61 61
Clover, average two samples,	2	4 {	65-67 66	60-62 61	-	61-68 65	51-51 53	64-79 72	60-60 63
Cow peas, ready for soiling,	2	4 {	66-77 68	72-76 74	19-28 23	73-77 76	57-62 60	76-84 81	56-62 59

Little Lupine (<i>Lupinus Sp.</i>),	1	{	2	{	62-74 68	-	65-69 67	73-77 75	40-65 56	67-84 76	42-72 57
Canada field peas, before bloom,	1	{	2	{	68	71-72 71	-	81-83 82	62-62 62	71-71 71	50-55 52
Canada field peas, bloom to seeding,	2	{	6	{	60-67 64	-	20-45 37	79-83 81	40-52 45	72-80 76	45-64 55
Spring vetch (<i>Vicia sativa</i>),	1	{	2	{	62-62 62	-	17	71-72 72	42-46 44	75-77 76	57-60 59
Winter or hairy vetch (<i>Vicia villosa</i>), bloom,	4	{	14	{	66-78 71	-	29-55 42	79-88 83	52-73 63	68-84 77	63-82 71
(d) Mixed and Miscellaneous.											
Apple pomaee,	2	{	6	{	66-80 72	-	24-63 49	-	36-85 65	80-90 85	39-82 46
Balsam root or big sunflower (<i>Balsamorhiza sagittata</i>),	1	{	2	{	66-66 66	-	34-42 38	76-79 78	57-61 59	74-76 75	74-75 74
Barley and peas, bloom,	3	{	4	{	-	55-71 65	52-55 54	73-81 75	38-61 52	56-76 68	54-65 59
Bitter brush (<i>Kunzia tridentata</i>),	1	{	2	{	75-79 77	-	48-69 59	79-85 82	56-83 70	86-87 87	70-73 71
Wild carrot (<i>Septoclasia multifida</i>),	1	{	2	{	68-69 69	-	52-54 53	70-72 71	43-52 47	82-84 83	81-82 82
Wild dandelion (<i>Orepis vinternedia</i>),	1	{	2	{	62-63 63	-	58-60 59	61-65 63	34-37 36	77-78 78	31-35 33
Thousand headed kale (<i>Brassica oleracea</i>),	2	{	4	{	66-71 68	-	37-45 39	78-83 81	55-64 59	74-77 76	61-72 66
Oats and spring vetch, bloom,	1	{	3	{	65-69 67	-	49-55 53	73-76 75	65-72 68	66-70 68	42-52 47
Oats and peas, bloom,	2	{	5	{	69-72 70	67-69 68	45-52 49	68-82 74	54-70 64	66-77 72	51-74 64
Oats and peas, partly seeded,	3	{	5	{	-	58-70 62	36-63 47	68-83 74	48-67 55	56-67 63	55-74 64

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
I. GREEN FODDERS — Con.									
(d) Mixed and Miscellaneous — Con.									
Prickly pear (<i>Opuntia lindheimeri</i>),	1	2	{ 65—67 66	71—77 74	34—37 36	57—59 58	41—41 41	82—83 83	67—68 68
Prickly pear (<i>Opuntia leavis</i>),	1	2	{ 62—65 64	70—73 71	33—38 36	39—42 41	51—56 54	78—80 79	69—69 69
Prickly pear (<i>Opuntia engelmannii cycloides</i>),	2	4	{ 57—70 65	63—75 71	39—44 42	-	30—45 39	77—83 81	74—88 83
Mountain Indian Pink or Painted Cup (<i>Casilleja miniata</i> var.),	1	2	{ 66—68 67	-	46—47 47	63—66 65	48—50 49	79—81 80	75—78 77
Indian potato (<i>Atenia Gairdnei</i>),	1	2	{ 66—67 67	-	50—50 50	54—59 57	73—75 74	64—66 65	76—78 77
Dwarf Essex rape, first growth,	1	2	{ 88—88 88	-	76—77 76	90—91 90	90—90 90	94—94 94	54—55 54
Dwarf Essex rape, second growth,	1	2	{ 81— -	-	47—51 49	86—89 87	84—84 84	90—91 90	42—44 43
Dwarf Essex rape, average,	2	4	85	-	63	89	87	92	48
Common sunflower, Nevada (<i>Wyethia mollis</i>),	1	2	{ 60—62 61	-	53—53 53	69—70 69	54—55 54	50—63 61	62—64 63
Winter wheat and hairy vetch,	2	5	{ 68—71 69	-	40—46 44	69—78 75	66—71 68	71—76 73	54—61 57
II. SILAGE.									
Soy bean silage, goats,	1	2	{ 52—66 59	-	-	71—80 76	47—62 55	46—58 52	66—77 72
Soy bean silage, steers,	1	2	{ 50—50 50	-	-	54—56 55	42—44 43	61—61 61	47—52 49

Soy bean silage, mammoth yellow, bloom,	1	3	52-65 58	63-73 67	-	57-69 61	51-67 59	74-80 76	48-60 52
Soy bean silage, average,	3	7	56	67	-	66	53	65	57
Soy bean and barnyard millet silage,	1	4	54-65 59	-	-	55-62 57	61-73 69	54-63 59	69-75 72
Soy bean and corn silage (9 pints beans, 14 pints corn),	4	8	62-73 69	71-75 72	39-48 42	54-68 63	51-73 63	73-81 78	67-91 83
Clover silage,	2	5	32-52 44	36-54 45	26-51 36	22-40 35	41-55 48	31-56 45	36-60 45
Corn silage, dent, immature, average all trials,	7	17	59-68 64	60-68 64	31-35 33	42-65 53	54-78 68	60-70 66	61-85 71
Corn silage, dent, mature, average all trials,	10	27	57-76 66	60-77 70	24-54 38	21-69 51	45-80 65	63-83 71	65-90 82
Corn silage, dent, Leaming, immature,	2	4	59-66 62	60-68 64	31-35 33	46-51 49	54-71 63	62-66 65	61-77 72
Corn silage, dent, Leaming, mature,	1	2	68-72 70	-	46-54 50	59-69 64	68-74 71	71-74 73	83-86 85
Corn silage, dent, Pride of the North, mature,	1	2	72-76 74	-	24-28 26	-	72-73 73	81-83 82	72-82 77
Corn silage, dent, Virginia, mature,	1	4	57-74 64	60-75 66	-	21-55 39	51-69 58	66-79 72	65-84 77
Corn silage, Sanford, ears glazing,	1	2	74-76 75	76-77 77	47-48 48	54-54 54	77-78 78	78-80 79	76-78 77
Corn silage, dent, average all trials,	17	48	64	70	38	50	65	69	77
Corn silage, flint, mature, small varieties,	4	11	68-78 75	66-80 77	-	48-73 65	75-79 77	71-83 70	-
Corn silage, flint, large white, partly eared,	1	2	69-70 70	72-73 72	31-37 34	56-56 56	72-72 72	75-76 76	72-74 73
Corn silage, fine crushed, steers,	1	2	60-68 64	-	-	32-44 38	72-78 75	60-70 65	75-77 76

¹ Average twenty-five trials.

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
II. SILAGE — Con.									
Corn silage, fine crushed, sheep,	1	2 {	51—56 54	—	—	21—22 21	59—68 64	53—57 55	67—69 68
Corn silage, mature, fed raw,	1	1	—	—	—	45	59	71	86
Corn silage, mature, cooked,	1	1	—	—	—	39	70	75	87
Corn silage, steamed,	1	2 {	73—74 73	75—76 76	46—50 48	53—57 56	75—76 76	75—77 76	90—90 90
Corn silage, variety unknown,	1	2 {	—	—	—	55—58 57	68—68 68	78—78 78	66—67 66
Corn silage, variety unknown, raw,	1	2 {	71—73 72	—	40—45 43	54—63 59	72—75 74	74—76 75	90—90 90
Corn silage, variety unknown, steamed,	1	2 {	60—62 61	—	5—13 9	5—6 5	62—64 63	70—72 71	79—80 79
Corn silage, sweet, mature,	1	2 {	67—70 68	68—72 70	—	53—55 54	68—74 71	71—73 72	82—85 83
Kafir corn silage, well matured,	1	3 {	54—56 55	56—59 57	—	22—23 28	57—59 57	59—62 62	47—54 50
Oat and pea silage,	1	2 {	63—68 65	63—70 67	59—53 52	74—75 75	58—65 61	64—70 67	73—77 75
Cow pea silage,	1	4 {	59—60 60	—	—	57—58 57	50—54 52	72—73 72	62—64 63
Sorghum silage, well matured,	1	3 {	51—60 57	53—62 59	—	6—13 9	51—63 58	59—67 64	53—60 56
Silage, mixture of corn, sunflower heads and horse beans, ¹	1	2 {	64—68 66	66—70 68	40—41 41	60—65 63	56—64 60	71—74 72	75—78 77

Silage, mixture of corn, sunflowers (whole plant) and horse beans, ¹	1	3	64-67 65	68-71 60	20-31 26	57-59 58	63-68 65	72-75 74	72-76 74	
Vetch silage, raw,	1	2	62-64 63	-	46-48 47	56-57 56	61-64 63	66-68 67	76-79 77	
Vetch silage, steamed,	1	2	50-53 51	-	35-40 38	13-16 15	50-53 51	61-64 63	63-63 63	
<p>III. HAY AND DRY COARSE FODDERS.</p> <p>(a) <i>Meadow Grasses and Millets.</i></p>										
Kentucky blue grass (<i>Poa pratensis</i>),	2	7	50 ² -	-	9-42 23	47-63 57	63-74 66	53-69 61	43-62 52	
Canada blue grass (<i>Poa compressa</i>), bloom,	1	2	62-63 62	-	42-42 42	43-44 43	70-71 71	63-63 63	36-39 37	
Blue-joint, bloom,	1	2	67-70 69	68-71 70	-	68-72 70	71-73 72	66-71 69	51-53 52	
Blue-joint, past bloom,	1	1	40	42	-	57	37	43	37	
Bromus inermis hay,	2	4	-	-	-	45-52 50	55-61 59	66-70 68	17-31 24	
Buffalo grass (<i>Bulbitis Dactyloides</i>),	1	1	55	-	6	54	65	62	62	
Cheese or cheat (<i>Bromus secatinus</i>),	1	1	45	-	23	42	46	49	32	
Colorado upland hay (largely <i>Agropyrum tenerum</i>),	2	6	47-63 56	45-59 52	40-48 43	58-67 62	54-63 59	49-66 57	16-63 34	
Cord grass (<i>Spartina Cynosuroides</i> L.),	1	6	-	-	16-38 23	34-42 39	54-58 56	46-52 49	47-55 50	
Crab grass (<i>Eragrostis Neo Mexicana</i>), ripe,	3	8	47-57 53	-	29-32 43	30-56 58	50-66 60	50-59 53	30-52 43	
Dakota lowland prairie hay,	1	2	-	-	-	41-44 43	59-61 60	56-57 57	40-40 40	
Dakota upland prairie hay,	1	6	-	-	5-17 11	28-40 32	45-61 53	44-55 51	25-64 32	

¹ Proportion of one acre corn, one-fourth acre sunflower heads and one-half acre horse beans. 2 One trial.

EXPERIMENTS WITH RUMINANTS — Continued.

Kind of Fodder.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
III. HAY AND DRY COARSE FODDERS — Con.									
(a) <i>Meadow Grasses and Millets</i> — Con.									
Meadow fescue (<i>Festuca elatior pratensis</i>), bloom,	1	2	{ 60-61 61	-	46	51-53 52	67	58-60 59	53-54 54
Johnson grass (<i>Andropogon halepensis</i>),	2	3	57	-	-	40	68	57	38
Barnyard millet, well headed,	1	3	{ 57-58 57	-	63-64 63	63-64 64	60-64 62	50-52 52	44-50 46
Barnyard millet, just heading out,	1	2	{ 59-62 61	-	51-52 52	50-59 58	60-71 69	55-59 57	47-49 48
Cat-tail millet (<i>Pennisetum spicatum</i>),	1	2	{ 61-64 62	-	-	61-65 63	65-68 67	58-60 59	45-48 46
Golden millet,	1	1	54	-	31	23	56	58	49
Hungarian,	1	2	{ 64-65 65	66-67 66	-	-	67-68 68	67-67 67	- 64
Millet (<i>Chatochloa Italica</i>),	1	2	{ 52-58 56	-	16-32 24	30-32 31	60-66 63	52-59 56	48-52 50
Mixed grasses, rich in protein (8 to 10 per cent.),	21	73	{ 54-69 61	60-66 62	37-53 47	34-65 57	49-78 62	56-68 62	26-58 50
Mixed grasses, timothy predominating,	5	10	{ 49-59 55	51-61 58	16-36 30	37-54 47	46-50 65	56-66 59	30-57 45
Meadow, swale or swamp hay,	1	2	{ 38-40 39	-	-	31-37 34	30-36 33	- 46	- 44
Nevada native hay, second growth, mixed grasses,	1	2	{ 75-77 76	-	62-63 63	71-72 71	77-79 78	76-79 77	78-80 79

Millets.

Nevada native hay, half clover,	1	{	65-67 66	-	44-44 41	51-53 52	66-67 66	70-72 71	61-62 62
Nevada native hay, largely Buckley's blue grass,	1	{	64-65 65	-	44-45 45	40-47 47	-66 66	68-69 69	68-71 70
Nevada native hay, largely timothy and tickle grass,	1	{	73-75 74	-	57-61 59	64-64 64	71-77 74	78-79 79	70-74 72
Nevada native hay, largely wire grass and brown top sedge,	1	{	64-67 66	-	50-52 51	48-49 49	75-77 76	58-64 61	70-71 71
Tall oat grass (<i>Arrhenatherum elatius</i>), late bloom,	1	{	54-57 55	-	30-43 41	-	53-57 55	50-59 58	54-58 56
Wild oat grass (<i>Danthonia spicata</i>),	2	{	60-68 64	61-69 65	-	49-68 58	65-71 68	62-69 65	36-63 50
Orchard grass, ten days after bloom,	1	{	54	56	-	59	58	54	54
Orchard grass, stage not given,	1	{	57-60 59	-	-	60-60 60	60-67 64	55-57 56	55-57 56
Orchard grass, average both samples,	2	{	56	56	-	60	61	55	55
Pasture grass,	1	{	73	73	52	73	76	74	67
Prairie grass (<i>Sporobolus Asper</i>),	1	{	56	-	25	18	61	61	57
Iced top,	2	{	58-62 60	59-64 61	-	60-62 61	61-62 61	59-65 62	44-50 51
Rowen, mixed grasses,	3	{	-	63-68 65	-	70	62-72 66	60-69 65	44-51 47
Rowen, chiefly timothy,	1	{	-	62-67 64	-	66-69 68	62-73 66	60-65 63	48-51 49
Rowen, average all trials,	4	{	-	65	-	69	66	64	47

¹ Average sixty trials.

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
III. HAY AND DRY COARSE FODDERS — Con.									
(a) Meadow Grasses and Millets — Con.									
{ Black grass (<i>Juncus Gerardi</i>),	2	{ 5	{ 50-62 56	-	{ 67-71 69	{ 53-63 58	{ 50-66 59	{ 46-59 52	{ 37-51 44
{ Branch grass (<i>Dactylis spicata</i>),	2	{ 5	{ 49-57 52	-	{ 58	{ 56	{ 48-57 54	{ 45-55 49	{ 27-42 35
{ Flat sage (<i>Spartina stricta maritima</i> var.),	1	{ 3	{ 55-58 57	-	{ 61-62 62	{ 50-55 52	{ 60-61 60	{ 54-57 55	{ 33-40 36
{ Fox grass (<i>Spartina patens</i>),	3	{ 7	{ 51-56 54	-	{ 57-59 58	{ 56-63 60	{ 46-60 53	{ 51-55 53	{ 17-51 36
{ Salt hay mixture, fox and branch grasses, etc.,	1	{ 2	{ 52-56 54	-	{ 68-70 69	{ 41-43 42	{ 54-61 58	{ 51-54 52	{ 26-30 28
{ Slough grass hay, Dakota,	1	{ 6	{ -	-	{ 20-31 24	{ 36-46 42	{ 54-68 59	{ 49-65 55	{ 44-68 54
{ Timothy, in bloom,	4	{ 8	{ 54-66 59	{ 51-67 58	{ 33-34 34	{ 50-60 57	{ 50-62 57	{ 57-72 63	{ 26-62 48
{ Timothy, past bloom,	8	{ 17	{ 47-61 52	{ 43-62 52	{ 30-68 59	{ 32-50 43	{ 32-57 46	{ 53-70 59	{ 23-70 51
{ Timothy, stage unknown,	1	{ 4	{ 57-62 59	{ 57-62 59	{ 47-54 50	{ 38-41 40	{ -	{ -	{ -
{ Timothy, average all trials,	24	{ 58	{ 55	{ 56	{ 39	{ 48	{ 50	{ 62	{ 50
{ Timothy fed with cottonseed meal (16 hay, 1 meal),	1	{ 2	{ 52-56 54	-	{ 17-28 22	{ 24-32 28	{ 46-52 49	{ 61-63 62	{ 36-37 36
{ Timothy fed with cottonseed meal (12 hay, 1 meal),	1	{ 2	{ 49-55 52	-	{ 9-30 20	{ 27-38 32	{ 43-51 47	{ 58-62 60	{ 52-54 53

Salt hays.

Timothy fed with cottonseed meal (8 hay, 1 meal),	1	2 {	44—48 46	—	3—10 6	18—23 21	40—44 42	53—56 54	42—45 44	
Timothy fed with cottonseed meal (4 hay, 1 meal),	1	2 {	45—46 46	—	—	4—4 4	42—43 43	56—75 67	44—66 55	
Timothy fed with cottonseed meal (2 hay, 1 meal),	1	2 {	48—56 52	—	13	—	34—44 39	65—71 68	72—74 73	
Timothy fed with cottonseed meal (1 hay, 1 meal),	1	2 {	47—52 49	—	19—23 21	—	24—26 25	68—78 73	79—87 83	
Timothy fed with cottonseed meal, average all trials,	6	12	50	—	16	20	41	62	57	
Timothy and clover, poorly cured,	1	2 {	54—55 55	—	—	37—38 38	52—54 53	—	—	
Timothy and red top, late bloom,	1	7 {	48—60 54	—	11—24 19	35—43 39	49—63 55	55—66 60	28—51 42	
Western wheat grass (<i>agropyrum glaucum occidentale</i>),	1	6 {	—	—	2—30 14	42—61 51	62—74 68	55—69 61	31—49 39	
Wyoming native hay, wire grass,	2	5 {	51—64 57	—	31—55 42	33—60 47	56—66 61	53—65 56	53—63 58	
Wyoming native hay, wheat grass,	4	9 {	61—67 64	—	28—64 40	53—62 57	63—74 68	63—70 66	38—54 47	
Witch grass (<i>Triticum repens</i>),	2	4 {	60—63 61	61—64 62	—	49—64 58	56—68 62	62—70 66	54—60 57	
(b) Cereal Fodders.										
Barley hay,	1	4	59	62	—	65	62	63	41	
Corn fodder, dent, immature, average all trials,	6	15 {	51—70 62	51—71 63	39—47 43	20—67 50	45—77 67	55—70 62	44—84 65	
Corn fodder, dent, immature, B. & W.,	1	4 {	51—64 57	—	—	20—36 27	45—74 59	57—66 61	66—84 76	
Corn fodder, dent, in milk,	5	11 {	59—66 63	—	—	44—51 50	50—71 64	61—69 66	67—79 75	
Corn fodder, dent, mature,	10	30 {	57—70 66	—	16—30 23	30—61 45	43—73 63	61—81 73	56—82 70	

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).	
III. HAY DRY AND COARSE FODDERS — Con.										
(b) <i>Cereal Fodders</i> — Con.										
Corn fodder, flint, ears forming,	1	3	69-72 70	71-73 71	-	69-73 70	72-73 72	71-73 71	63-71 67	
Corn fodder, flint, mature,	5	11	63-73 70	-	-	56-79 64	69-80 76	63-78 71	59-79 71	
Corn fodder, sweet, mature,	3	6	60-71 67	62-74 70	-	54-73 64	70-77 74	57-73 68	63-71 74	
Corn stover, dent, Pride of the North,	1	2	53-55 54	-	29-33 31	45-45 45	58-63 61	53-55 54	63-66 65	
Corn stover, Eureka silage, ears just forming,	2	4	54-64 59	-	40-46 43	57-58 53	56-72 65	53-64 59	62-67 65	
Corn stover, average all trials,	12	33	53-64 57	49-58 55	29-46 41	11-58 37	52-74 64	53-64 59	36-77 69	
Corn stover, below ear,	1	2	64-69 67	-	-	15-27 21	71-75 74	65-73 69	79-80 80	
Corn stover, above ear,	1	2	52-58 55	-	-	17-27 22	69-72 71	50-57 54	62-65 64	
Corn stover, minus pith (by hand),	1	3	54-57 55	55-59 57	-	19-28 20	60-65 63	55-58 57	70-75 72	
Corn stover, minus pith, ground (Marsden's process),	1	3	63-64 63	-	46-55 49	57-62 60	60-61 61	65-66 66	82-83 83	
Corn stover minus pith, ground (Marsden's process), steamed,	1	3	51-59 59	-	47-55 50	59-60 60	37-54 48	57-62 59	70-85 80	
Corn stover, minus pith, average,	3	9	51-64 58	55-59 57	46-55 50	16-62 47	37-65 57	55-66 61	70-85 78	

Corn stover, blades and husks,	1	4	{	60-68 65	-	15-35 23	41-55 48	67-76 73	64-71 66	53-64 58
Corn stover, tops and blades,	1	2	{	59-60 60	-	-	54-57 55	71-72 71	62-63 62	71-72 71
Corn stover, leaves,	1	2	{	55-56 56	-	-	43-60 56	54-67 61	57-61 59	61-65 63
Corn stover, leaves,	1	2	{	62-67 65	-	-	28-41 35	75-80 78	66-70 68	52-59 56
Corn stover, leaves, average both trials,	2	4	{	55-67 61	-	-	28-69 46	54-80 70	57-70 64	52-65 60
Corn stover, husks,	1	2	{	71-73 72	-	-	24-35 30	78-81 80	- 75	23-42 33
Kafir corn fodder,	1	4	{	59-62 61	-	5-11 8	34-42 38	56-63 60	64-68 66	57-67 61
Kafir corn stover, shredded,	1	4	{	54-58 56	-	13-26 19	29-34 30	65-69 67	56-60 58	77-81 79
Kafir corn stover,	1	1	{	63	-	43	50	67	67	60
Kafir corn stover, average both trials,	2	5	{	57	-	24	34	67	60	75
Oat hay, bloom to milk,	2	6	{	51-59 55	50-61 55	35-64 45	47-66 57	54-71 58	47-58 53	44-65 53
Oat hay, milk to dough,	4	14	{	48-60 54	48-61 54	20-54 37	34-60 52	39-62 48	49-62 56	52-72 64
Oat hay, average all trials,	6	20	{	54	54	39	53	51	55	60
Oat straw,	4	12	{	42-61 54	51-53 52	21-62 38	3-36 21	34-76 61	43-64 55	24-58 42
Sorghum fodder, Minnesota Early Amber,	1	3	{	58-60 58	54-55 54	41-49 44	40-47 43	42-56 49	57-67 61	62-67 65
Sorghum fodder, variety unknown,	1	6	{	-	-	9-55 23	30-74 53	57-84 71	49-82 64	66-87 77

EXPERIMENTS WITH RUMINANTS — Continued.

Kind of Fodder.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
III. HAY AND DRY COARSE FODDERS — Con.									
<i>(b) Cereal Fodders — Con.</i>									
Sorghum fodder, leaves,	1	{ 2	{ 60—66 63	—	—	59—62 61	65—76 70	62—67 65	40—47 47
Sorghum fodder, bagasse,	1	{ 1	{ 61	—	—	14	64	65	46
<i>(c) Legumes.</i>									
Alfalfa, first crop,	19	{ 33	{ 55—72 63	—	34—67 34	61—85 75	19—65 47	61—79 72	23—65 43
Alfalfa, second crop,	13	{ 27	{ 54—67 63	—	35—59 52	64—81 77	40—53 46	65—80 74	14—51 42
Alfalfa, third crop,	1	{ 2	{ 56—60 58	—	40—49 44	68—70 69	28—40 34	71—71 71	38—45 42
Alfalfa, poor quality,	1	{ 2	{ 56—56 56	58—58 58	35—44 39	66—66 66	38—43 40	68—72 70	31—45 38
Alfalfa, stage of cutting unknown,	1	{ 2	{ 54—55 55	—	24—25 25	67—70 69	40—42 41	68—70 69	13—19 16
Alfalfa, stage of cutting unknown,	1	{ 6	{ —	—	31—40 35	74—80 78	40—50 44	65—77 72	33—42 37
Alfalfa, average all trials,	42	{ 80	{ 62	—	50	74	46	72	40
Soy bean,	1	{ 2	{ 62—63 62	—	—	70—72 71	59—62 61	66—71 69	19—40 29
Clover, alsike, full to late bloom,	4	{ 9	{ 55—64 59	56—65 60	42	64—71 66	40—59 50	59—74 66	21—69 38
Clover, crimson,	3	{ 9	{ 57—65 62	52—58 56	—	64—73 69	32—58 45	52—74 62	29—54 44

Clover, red, bud to early blossom,	1	{	63-64 64	-	59-61 60	64-64 64	57-62 59	67-68 68	52-52 52	
Clover, red, full blossom,	1	{	58-61 60	-	54-58 56	59-61 60	43-49 46	68-71 69	55-56 55	
Clover, red, stage of cutting not given,	10	{	49-67 58	51-66 55	0-44 32	47-69 57	42-70 54	56-72 65	40-70 56	
Clover, red, average all trials,	12		58	55	36	58	54	65	56	
Clover, white,	1		66	67	-	73	61	70	51	
Clover, rowen,	2	{	-	58-60 59	42-50 46	60-69 65	45-51 47	62-64 63	58-60 60	
Sweet clover,	1	{	58-62 61	-	65-67 66	75-76 75	27-37 34	71-73 72	28-33 31	
Pea straw,	1	{	65-69 67	-	27-37 33	76-80 78	48-54 51	78-80 79	47-51 50	
Cow pea,	1	{	-	-	-	64-65 65	41-45 43	-	46-51 50	
Peanut vine,	1	{	59-60 60	-	-	63-64 63	51-53 52	69-70 70	62-70 66	
French pea (<i>Lathyrus</i> —),	1	{	67-68 68	-	65-69 67	81-82 82	49-50 49	75-76 75	58-60 59	
Spring vetch (<i>Vicia sativa</i>),	2	{	64-67 66	66-68 67	52-60 56	61-71 66	54-61 58	70-72 72	68-72 70	
Winter or hairy vetch (<i>Vicia villosa</i>),	2	{	59-71 67	-	34-67 47	68-83 82	51-63 58	62-75 67	53-74 67	
(d) Mixed and Miscellaneous.										
Buttercups (<i>Ranunculus acris</i>),	1		56	57	-	56	41	67	70	
Cottonseed feed (4-1), ¹ sheep,	2	{	54-60 56	-	23-25 28	36-45 41	51-60 56	57-60 59	86-94 91	
Cottonseed feed (1-1), steers,	1		54	-	46	54	45	58	85	

¹ Four hulls to one meal.

-EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
III. HAY AND DRY COARSE FODDERS — Con.									
<i>(d) Mixed and Miscellaneous — Con.</i>									
Cottonseed feed, average both (4-1) trials,	3	8	56	-	33	44	53	59	90
Cottonseed feed (5-1) steers,	2	5 {	42-60 49	-	20-46 31	32-54 42	28-54 50	50-67 60	83-94 88
Cottonseed feed (7-1) and (6-1), steers,	1	3 {	45-46 46	-	-	44-46 45	34-40 37	50-51 50	81-82 82
Cottonseed feed (3-1) to (2-1), steers,	2	9	54	-	32	64	47	54	85
Cottonseed feed, average all trials,	8	25	53	-	31	51	47	56	87
Cottonseed hulls,	4	13 {	35-47 41	-	-	0-25 6	.5-58 47	13-46 34	58-89 79
Oats and peas,	2	7 {	56-67 61	56-67 60	54-65 58	69-78 73	50-64 58	54-66 61	51-69 59
Oats and sand vetch,	1	2 {	55-55 55	56-56 56	43-46 44	61-66 65	48-50 49	58-59 59	58-67 63
Oats and spring vetch,	2	5 {	57-63 59	60	60	60-71 65	47-67 57	34-65 59	17-76 52
Oats and vetch, average,	3	7	58	58	56	65	55	59	55
Salt bush (<i>Atriplex Argentea</i>),	1	3 {	46-47 46	31-32 31	71-72 72	65-68 66	3-15 8	46-51 49	50-55 52
Wheat and sand vetch, blossom,	2	6 {	64-69 66	-	33-60 47	70-77 74	63-66 65	67-71 68	62-67 64
White weed (<i>Leucanthemum vulgare</i>),	1	2	58	58	-	58	46	67	62
Willows (<i>Salix erigina</i>),	1	2 {	50-58 51	-	24-40 32	20-38 29	40-44 42	63-70 67	73-67 70

IV. ROOTS AND TUBERS.

Sugar beets,	1	{	94-95 95	98-100 99	-	90-93 91	88-113 100	100-100 100	40-53 50	
Mangolds,	1	{	77-80 79	83-87 85	-	70-80 75	27-59 43	91-92 91	-	
Potatoes,	1	{	73-80 77	75-81 78	-	43-45 44	-	87-93 91	13	
Ruta-bagas,	1	{	84-90 87	89-93 91	-	75-86 80	61-87 74	94-95 95	77-92 84	
English flat turnips,	1	{	91-95 93	93-99 96	-	84-95 90	89-117 100	96-97 97	82-92 88	
V. CONCENTRATED FEEDSTUFFS.										
(a) Protein.										
Soy bean meal, variety unknown,	2	{	75-79 78	-	-	89-91 90	0-73 33	68-73 71	81-98 89	
Soy bean meal, medium green, coarse ground,	2	{	81-98 90	-	42-77 57	88-95 91	-	61-100 81	89-97 93	
Bibby's dairy cake,	2	{	61-81 70	-	18-44 33	58-76 66	1-68 46	71-88 81	84-99 92	
Bile's Union Grains,	2	{	72-94 81	-	22-70 39	69-86 76	78-118 93	75-98 86	95-102 98	
Blood meal, Armour's,	1	{	-	-	-	80-88 84	-	-	-	
Brewers' dried grains,	2	{	56-62 62	-	-	78-84 81	28-62 49	51-60 57	87-93 89	
Buckwheat middlings,	1	{	71-79 75	-	26-41 36	83-86 85	8-26 17	79-87 83	87-92 89	
Buffalo Creamery Feed,	1	{	68-71 69	-	20-25 23	80-82 81	52-57 55	70-72 71	83-91 87	
Chapins Alfalfa Meal, a dairy feed,	1	{	52-67 59	-	13-40 26	67-75 71	31-58 45	56-70 63	76-92 84	

EXPERIMENTS WITH RUMINANTS — Continued.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).	
V. CONCENTRATED FEEDSTUFFS — Con.										
(a) <i>Proteins</i> — Con.										
Cottonseed, raw,	1	2	63-80 66	-	-	66-70 68	65-86 76	49-50 50	- 87	
Cottonseed, roasted,	1	2	53-55 56	-	-	44-50 47	62-69 66	50-53 51	68-75 72	
Cottonseed meal,	4	12	67-90 79	81-95 88	84	76-96 84	26-55 35	66-96 78	87-100 94	
Cottonseed meal, high grade (Maine),	1	2	90	95	-	83	-	96	100	
Cottonseed meal, medium grade (Maine),	1	2	67-79 73	73-83 78	-	81-86 84	40-47 44	73-91 82	95-95 95	
Cottonseed meal, low grade (Maine),	1	2	60-63 62	62-67 65	-	72-73 73	30-45 38	66-70 68	87-93 90	
Cottonseed meal, low grade (Massachusetts),	1	2	60-76 68	-	80-89 85	77-80 78	- 40	73-83 75	100-100 100	
Cottonseed meal, high grade, dark colored, slightly fermented (Maine),	1	2	81-91 86	85-95 90	-	82-83 83	-	90-100 95	95-100 98	
Dairy feed, H-O,	2	4	65-65 65	-	-	68-80 76	14-43 35	67-75 72	83-88 84	
Distillers' dried grains, largely from rye,	1	2	56-59 58	-	-	56-63 59	-	61-73 67	80-88 84	
Distillers' dried grains, largely from corn,	8	17	70-89 79	-	-	66-80 73	59-100+ 95	69-97 81	88-98 95	
Germ oil meal,	2	5	72-83 76	-	-	65-77 73	-	68-82 76	95-98 96	

Gluten feed,	10	18 {	85-98 88	92-93 93 ²	78-99 88 ³	69-93 85	64-100 ⁺ 87	83-97 90	60-83 81
Gluten meal,	4	8 {	75-95 87	-	-	86-93 88	-	78-94 88	91-99 93
Linseed meal, old process,	1	3 {	75-82 79	-	-	86-93 89	38-71 57	76-79 75	85-92 89
Linseed meal, new process,	1	3 {	73-83 78	-	-	82-88 85	49-100 74	82-87 84	90-98 93
Linseed meal, new process, Cleveland flax,	3	9 {	76-88 83	79	-	-	-	-	-
Linseed meal, new process, average,	4	12	82	79	-	84	74	80	89
Malt sprouts,	1	1	67	68	-	80	34	69	100
Malt sprouts (Massachusetts),	1	3 {	75-89 82	-	3-33 19	74-77 76	98-100 99	76-91 85	74-100 87
Maize feed (Chicago),	1	2 {	83-85 84	-	-	83-84 84	68-76 72	84-87 85	90-90 90
Oat middlings, fine,	1	2 {	88-91 90	-	31-40 36	80-81 81	21-77 49	94-97 96	93-94 94
Pea meal,	1	2 {	85-88 87	86-80 88	-	80-86 83	25-26 26	93-94 94	52-57 55
Protena Dairy Feed,	1	2 {	63-66 65	-	33-37 35	70-73 72	33-45 39	72-76 74	97-99 98
Cow pea meal,	1	2 {	85-88 87	-	22-45 33	80-85 82	62-66 64	92-94 93	74-74 74
Rye feed, bran and middlings,	1	3 {	77-83 82	-	25-48 35	78-82 80	-	86-89 88	79-99 90
Unicorn Dairy Ration,	2	3 {	81-87 83	-	6-40 25	73-77 76	62-84 72	86-94 89	95-96 96

1 One trial.

2 Average thirteen trials.

3 Average two trials.

EXPERIMENTS WITH RUMINANTS — *Continued.*

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
V. CONCENTRATED FEEDSTUFFS — <i>Con.</i>									
(a) Protein — <i>Con.</i>									
Wheat bran, spring,	3	{ 7	{ 62-70 67	{ 69-74 71	{ 20-32 25	{ 74-82 76	{ 22-76 44	{ 70-80 74	{ 38-83 63
Wheat bran, winter,	1	{ 3	{ 57-60 62	{ -	{ -	{ 75-79 77	{ -	{ 62-76 65	{ 51-80 64
Wheat bran, average all trials,	4	{ 10	{ 66	{ -	{ -	{ 77	{ 39	{ 71	{ 63
Wheat feed flour,	1	{ 2	{ 67-67 67	{ 70-70 70	{ -	{ 78-80 79	{ -	{ 73-78 76	{ -
Wheat middlings, flour,	2	{ 4	{ 78-86 82	{ 81-84 83	{ -	{ 82-91 88	{ 33-40 36	{ 84-91 88	{ 82-88 86
Wheat middlings, standard,	2	{ 6	{ -	{ 73	{ 25	{ 77	{ 30	{ 78	{ 88
Wheat mixed feed, bran and middlings,	2	{ 4	{ 71-78 73	{ 73-81 76	{ 34-43 37	{ 77-79 78	{ 47-79 62	{ 74-79 77	{ 81-92 87
Wheat mixed feed, adulterated with corn cobs,	1	{ 3	{ 59-65 62	{ 61-67 64	{ 28-34 31	{ 62-63 63	{ 17-36 28	{ 68-74 71	{ 91-93 92
Wheat screenings,	1	{ 2	{ 70-87 79	{ -	{ -	{ 68-81 75	{ 45-85 65	{ 81-89 85	{ 92-95 94
(b) Starchy.									
Feed barley meal,	1	{ 2	{ 87-91 89	{ -	{ 28-47 38	{ 86-90 88	{ 45-96 70	{ 92-94 93	{ 86-87 86
Hanna barley,	3	{ 13	{ -	{ -	{ -	{ 63-90 77	{ 15-98 56	{ 87-96 92	{ 55-99 78
Manchuria barley,	1	{ 2	{ -	{ -	{ -	{ 84-84 84	{ -	{ 89-93 91	{ 78-82 80

Cerealine feed,	1	3 {	89-92 90	-	-	79-81 80	72-92 82	93-97 95	78-83 81
Chop feed, corn bran and germs,	2	6 {	71-92 80	-	-	56-77 67	54-70 62	64-92 84	61-86 82
Corn bran,	2	4 {	70-71 70	-	-	53-55 54	50-65 59	74-80 77	60-85 77
Corn cobs,	1	2 {	50-60 59	-	-	13-22 17	65-66 65	60-60 60	44-56 50
Corn meal, coarse,	2	4 {	74-93 84	75-94 86	-	45-54 48	-	79-91 86	-
Corn meal, fine,	5	8 {	84-90 87	89-90 90 ¹	-	48-81 65	-	87-98 93	75-95 89 ²
Corn meal, average all trials,	12	26 {	74-98 88	75-94 90	-	40-87 67	-	79-100 92	71-99 90
Corn and cob meal,	1	3 {	74-83 79	-	-	43-55 52	2-86 45	86-91 88	82-85 84
Corn and oat feed, Victor,	1	3 {	74-76 75	-	-	60-75 71	30-53 48	81-85 83	84-88 87
Kaffir corn kernels,	2	6 {	29-58 43	-	-	28-54 41	-	34-62 45	-
Kaffir corn meal,	3	7 {	54-81 70	-	-	36-65 56	61 ³ -	67-88 79	25-81 55
White Kaffir corn heads,	1	4 {	14-35 24	-	-	7-23 12	0-46 27	14-40 31	5-65 31
Dairy feed, Quaker,	3	8 {	58-64 62	52	-	62-72 70	54-56 55	55-71 59	72-80 74
Hominy meal,	3	8 {	71-91 82	-	-	54-74 65	2-100+ 67	82-94 89	88-95 92
Horse feed, H-O,	3	5 {	70-77 74	78	-	62-81 70	52-59 56	79-85 83	74-87 80

¹ Average three trials.² Average five trials.³ One trial.

EXPERIMENTS WITH RUMINANTS — *Concluded.*

Kind of Fodder.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen- free Extract (Per Cent.).	Crude Fat (Per Cent.).
V. CONCENTRATED FEEDSTUFFS—<i>Con.</i>									
<i>(b) Starchy — <i>Con.</i></i>									
Milo maize meal,	1	2 {	77-91 84	-	84-100 927	61-71 66	-	83-86 85	87-94 90
Alma dried molasses beet pulp,	1	2 {	82-87 85	-	55-69 62	59-69 64	83-84 84	89-93 91	-
Blomo feed,	1	2 {	64-69 67	-	31-32 32	61-64 63	51-72 61	73-79 76	14-17 16
Green Diamond sugar feed,	1	2 {	61-70 66	-	36-39 38	68-72 70	36-52 44	70-78 74	75-92 84
Holstein sugar feed,	1	3 {	70-74 71	-	24-43 33	61-71 66	26-62 44	79-82 81	86-89 88
Macon sugar feed,	1	2 {	69-72 71	-	20-21 20	57-61 59	36-51 44	81-83 82	74-91 82
Sucrene dairy feed,	1	2 {	67-72 69	-	28-47 38	57-64 61	70-73 72	71-75 73	93-96 95
Molasses feeds, average last four,	4	9	69	-	32	64	50	79	87
Red Orenburg millet,	2	4 {	-	-	-	39-64 55	24	84-95 88	86-91 88
Black Voronezh millet,	4	8 {	-	-	-	54-63 70	14-65 30	76-95 88	68-91 81
Sixty day oats,	1	1	-	-	-	86	50	86	79
Swedish select oats,	4	11 {	-	-	-	67-85 77	16-55 36	76-87 81	82-97 89
Oats, unground,	2	6 {	66-74 70	68-74 71	2-61 25	72-81 77	15-40 31	74-79 77	87-92 89

Oat feed, Royal, many hulls,	1	3	{ 42-51 47	42-53 48	33-40 37	64-72 69	20-43 33	50-54 51	86-92 88
Oat feed, excessive hulls,	1	3	{ 29-38 34	-	8-21 13	51-69 62	25-37 32	29-36 33	89-97 92
Oat feed, average last two,	2	6	{ 40	-	25	65	32	42	90
Parson's "Six-dollar" feed, mill sweepings,	1	2	{ 55-56 56	-	10-14 12	56-62 59	45-50 47	63-65 64	80-81 81
Peanut feed, largely husks,	1	2	{ 32-32 32	-	-	70-71 71	10-13 12	41-58 49	90-90 90
Rice meal,	1	2	{ 71-76 74	-	-	62	7	89-95 92	91-92 91
Rice bran,	1	2	{ 56-66 62	-	1-34 18	58-68 64	13-42 21	76-81 78	52-92 72
Rye meal,	1	2	{ 85-90 87	-	-	83-85 84	-	89-94 92	63-65 64
Rice polish,	1	2	{ 82-83 83	-	27-36 31	65-66 66	22-23 22	92-93 93	66-81 74
Speltz or emmer, unground (Minnesota),	1	2	{ 93-94 94	-	51-56 53	85-88 87	82-85 84	96-97 97	90-94 92
Speltz or emmer (South Dakota),	3	9	{ -	-	-	68-85 78	42-60 50	81-95 87	74-90 87
Speltz or emmer, average,	4	11	{ -	-	-	80	60	89	88
Schumacher's stock feed (corn, oat and barley),	1	2	{ 70-72 71	-	-	68-72 70	46-59 52	70-79 79	87-89 88
Durum wheat,	1	2	{ -	-	-	76-80 78	40	92-92 92	61-69 65
Red wheat meal,	1	2	{ 83-88 86	-	26-29 28	66-68 67	40	91-94 92	79-81 80
White Winter wheat meal,	1	2	{ 86-91 88	-	10-49 30	81-83 82	77	92-95 93	62-66 64

EXPERIMENTS WITH SWINE.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
Barley meal,	1	1	80	80	-	81	40	87	57
Linseed meal, old process,	1	4 {	76-79 77	-	8-12 10	83-90 86	10-14 12	82-87 85	78-82 80
Maize kernels,	1	1	83	83	-	69	38	89	46
Maize meal,	2	2 {	89-90 90	91-92 92	-	86-90 88	29-49 30	94-94 94	78-82 80
Maize meal with cobs,	1	1	76	77	-	76	29	84	82
Hog millet seed (<i>Panicum mitia ceum</i>),	1	1	73	-	19	68	33	92	59
Pea meal,	1	1	90	92	-	89	78	95	50
Potatoes,	1	4	97	-	-	84	-	98	-
Wheat, whole,	1	?	72	-	-	70	30	74	60
Wheat, cracked,	1	?	82	-	-	80	60	83	70
Wheat shorts (middlings),	1	2 {	74-79 77	-	-	71-75 73	25-48 37	85-88 87	-
Wheat bran,	1	2 {	54-78 66	-	-	74-76 75	30-39 30	50-75 66	65-78 72

EXPERIMENTS WITH HORSES.

Kind of Fodder.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Crude Fat (Per Cent.).
Corn kernels,	1	2 {	71-78 74	-	20-32 26	40-76 58	-	85-92 88	43-52 48
Corn meal, same as above,	1	2 {	84-93 88	-	-	74-77 76	-	93-99 96	70-76 73
Corn stover minus pith, ground (Marsden's process),	1	2 {	40-59 50	-	6-37 22	65-70 68	38-71 55	39-54 47	48-72 60
Oat kernels,	1	2 {	67-77 72	-	31-36 33	84-87 86	13-49 31	75-83 79	80-85 82
Oats, ground, same as above,	1	2 {	73-78 76	-	9-49 20	81-83 82	.6-2.8 1.4	85-87 86	79-81 80
Oats, average,	2	4	74	-	31	84	22	82	81
Timothy hay,	1	2 {	39-48 44	-	29-39 34	18-24 21	37-48 43	44-50 47	44-51 47

EXPERIMENTS WITH POULTRY.

KIND OF FODDER.	Number of Different Lots.	Single Trials.	Dry Matter (Per Cent.).	Organic Matter (Per Cent.).	Crude Ash (Per Cent.).	Crude Protein (Per Cent.).	Crude Fiber (Per Cent.).	Nitrogen-free Extract (Per Cent.).	(Crude Fat (Per Cent.).
Clover, second crop, just beginning to blossom,	1	3	-	28	-	71	10	14	36
Corn kernels,	1	3	-	86	-	44-35 50	-	90-96 92	88-95 92
Corn kernels,	2	6	-	86-87 87	-	68-87 81	1-25 15	88-92 90	81-87 85
Corn, cracked,	1	2	-	83-84 83	-	72-73 72	-	87-89 88	87-88 87
Corn meal,	1	3	-	85	-	41-55 48	-	91-92 91	92-94 93
Corn meal,	1	2	-	82-84 83	-	72-77 75	-	84-88 86	87-88 88
Kaffir corn kernels,	1	3	-	88	-	50-55 53	17-22 20	94-98 96	71-73 74
Kaffir corn meal,	1	3	-	87	-	42-44 43	30-42 35	95-97 96	82-84 83
Meat,	1	2	-	87-87 87	-	90-91 91	-	-	86-87 87
Beef scrap,	1	2	-	80	-	93	-	-	96
Oats, whole,	2	12	-	59-68 63	-	68-84 75	4-11 81	62-75 69	77-80 83
Oats, rolled,	1	2	-	79-84 82	-	78-81 80	-	85-87 86	86-102 94
Cow peas,	1	3	-	71	-	32-48 40	2-43 18	86-88 87	87-90 89

Cow pea meal,	1	3	—	—	—	72	—	40—49 44	8—11 10	84—91 88	75—98 89
Wheat,	1	1	—	—	—	84	—	77	—	89	59
Wheat, hard,	1	1	—	—	—	82	—	71	—	81	57
Wheat, soft,	1	5	—	—	—	81—85 82	—	57—79 74	—	87—90 89	45—69 54
Wheat bran, coarse,	1	3	—	—	—	46—47 47	—	69—74 72	13—14 14	46—46 46	35—38 37
India wheat,	1	3	—	—	—	67—76 73	—	71—80 75	5—20 21	79—86 83	79—87 84

EXPERIMENTS WITH CALVES.

Whole milk,	2	8	—	—	—	—	—	90—98 95	—	—	93—99 97
Pasteurized whole milk,	2	9	—	—	—	—	—	88—95 93	—	—	91—99 95
Cooked whole milk,	1	3	—	—	—	—	—	80—94 87	—	—	92—99 95
Raw skim milk,	1	3	—	—	—	—	—	94—95 95	—	—	—
Skim milk, with sheep,	1	3	96—102 97	—	—	—	—	46—74 62	—	—	—
			100	—	—	—	—	94	—	—	100

¹ Eight trials.

AVERAGE DIGESTION COEFFICIENTS OBTAINED WITH POULTRY.¹

[German and American Experiments.]

KIND OF FODDER.	Number of Experiments.	Organic Matter.	Crude Protein.	Nitrogen-free Extract.	Fat.
Bran, wheat,	3	46.70	71.70	46.00	37.00
Beef scrap,	2	80.20	92.60	-	95.00
Beef (lean meat),	2	87.65	90.20	-	86.30
Barley,	3	77.17	77.32	85.09	67.86
Buckwheat,	2	69.38	59.40	86.99	89.22
Corn, whole,	16	86.87	81.58	91.32	88.11
Corn, cracked,	2	83.30	72.20	88.10	87.60
Corn meal,	2	83.10	74.60	86.00	87.60
Clover,	3	27.70	70.60	14.30	35.50
India wheat,	3	72.70	75.00	83.40	83.80
Millet,	2	-	62.40	98.39	85.71
Oats,	13	62.69	71.31	90.10	87.89
Peas,	3	77.07	87.00	84.80	80.01
Wheat,	10	82.26	75.05	87.04	53.00
Rye,	2	79.20	66.90	86.70	22.60
Potatoes,	6	78.33	46.94	84.46	-

¹ Compiled by J. M. Bartlett, Bulletin 184, Maine Agricultural Experiment Station.

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TABLE V.—COMPILATION OF ANALYSES OF AGRICULTURAL CHEMICALS, REFUSE SALTS, PHOSPHATES, GUANOS, ASHES, LIME COMPOUNDS, MARLS, BY-PRODUCTS, REFUSE SUBSTANCES AND ANIMAL EXCREMENTS.

H. D. HASKINS AND L. S. WALKER.

- A. CHEMICALS AND REFUSE SALTS.
 - (a) Nitrogen chemicals.
 - (b) Potash chemicals.
 - (c) Refuse salts.
- B. PHOSPHATES AND GUANOS.
 - (a) Natural phosphates.
 - (b) Dissolved phosphates.
 - (c) Guanos.
- C. ASHES, LIME COMPOUNDS AND MARLS.
 - (a) Ashes.
 - (b) Lime compounds.
 - (c) Marls.
- D. BY-PRODUCTS AND REFUSE SUBSTANCES.
 - (a) Abattoir products.
 - (b) Fish products.
 - (c) Seaweeds.
 - (d) Vegetable products.
 - (e) Wool products.
 - (f) Miscellaneous substances unclassified.
- E. ANIMAL EXCREMENTS.
- F. INSECTICIDES.

As a rule, the analyses reported in the following compilation were made at this laboratory.¹ Some of them were made many years ago. Refuse products from various manufacturing industries are likely to vary more or less in composition, due to frequent changes in the parent industry. The revision of the

¹ In the compilation of analyses of seaweeds, five of said analyses were taken from Bulletin No. 21 of the Rhode Island Agricultural Experiment Station.

compilation every five years, however, insures quite reliable figures in most instances. In case of the agricultural chemicals and by-products which are commonly known to the fertilizer trade, the present compilation includes the samples collected by our inspectors during the last five years, as well as those samples sent by farmers and farmer organizations. In all cases where samples are forwarded for analysis, they are taken according to printed directions furnished from this office, which is a reasonable assurance that the analyses are representative of the materials sampled. In many instances extremely wide variations occur in different analyses of the same product. This emphasizes the importance of careful sampling as well as the purchase of such materials on a specific guarantee of plant food which they furnish.

In the majority of instances only the highest, lowest and average percentage of nitrogen, potash and phosphoric acid are given in the tables, but it should be remembered that blanks do not imply the absence of the other ingredients.

A. CHEMICALS AND REFUSE SALTS.

[Figures equal percentages or pounds in 100.]

FERTILIZER MATERIALS.	Analyses.	Moisture.	Ash.	NITROGEN.			POTASH.			TOTAL PHOSPHORIC ACID.			Soluble Phos-phoric Acid.	Reverted Phos-phoric Acid.	Insoluble Phos-phoric Acid.	Sodium Oxide.	Calcium Oxide (Lime).	Magnesium Oxide	Ferric and Alu-minic Oxides.	Sulphuric Acid.	Carbonic Acid.	Chlorine.	Insoluble Matter.	
				Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.												
<i>(a) Nitrogen Chemicals.</i>																								
Calcium cyanide,	3	.71	-	-	-	19.06	-	-	-	-	-	-	-	-	-	-	63.19	-	-	2.10	-	-	-	1.00
Carbonate of ammonia,	1	-	-	-	-	22.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.74	-	-
Nitrate of potash,	10	1.58	-	14.58	11.42	12.57	45.62	43.48	44.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate of soda,	186	1.76	-	16.57	14.14	15.38	-	-	-	-	-	-	35.50	-	-	-	-	-	-	-	-	.50	.50	-
Nitrate of lime,	1	5.88	-	-	-	12.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrogenous chalk,	4	.78	-	9.88	8.42	9.11	-	-	-	-	-	-	-	-	-	29.30	-	-	-	-	-	-	2.28	-
Phosphate of ammonia,	1	6.05	-	-	-	10.87	-	-	-	-	-	-	43.86	-	-	-	-	-	-	12.46	-	-	.82	-
Sulfate of ammonia,	35	1.01	-	22.72	19.44	20.91	-	-	-	-	-	-	-	-	-	-	-	-	-	60.00	-	-	-	-
<i>(b) Potash Chemicals.</i>																								
Carbonate of potash, high grade,	26	2.25	-	-	-	-	67.20	55.68	63.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbonate of potash and magnesia,	2	18.22	-	-	-	-	20.00	18.48	19.24	-	-	-	-	-	-	-	-	-	-	-	-	-	.39	-
Carnallite,	1	-	-	-	-	-	-	-	-	13.68	-	-	7.66	-	-	-	-	-	-	-	.56	-	41.56	-
Hard salts,	1	.45	-	-	-	-	-	-	-	17.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kainit,	24	3.04	-	-	-	-	16.50	10.90	13.07	-	-	-	-	-	-	-	-	-	-	20.25	-	-	20.61	2.13
Krugite,	1	4.82	-	-	-	-	-	-	-	8.42	-	-	-	-	-	-	-	-	-	31.94	-	-	6.63	14.96

C. ASHES, LIME COMPOUNDS AND MARLS — Concluded.

[Figures equal percentages or pounds in 100.]

FERTILIZER MATERIALS.	Analyses.	Moisture.	Ash.	NITROGEN.			POTASH.			TOTAL PHOSPHORIC ACID.			Soluble Phosphoric Acid.	Reverted Phosphoric Acid.	Insoluble Phosphoric Acid.	Sodium Oxide.	Calcium Oxide (Lime).	Magnesium Oxide.	Ferric and Aluminic Oxides.	Sulphuric Acid.	Carbonic Acid.	Chlorine.	Insoluble Matter.	
				Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.												
<i>(b) Lime Compounds — Con.</i>																								
Boiler cleanings,	1	3.44	-	-	-	.28	-	-	4.15	-	-	1.14	-	-	-	-	21.92	-	-	-	-	-	-	24.32
Burned lump lime,	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93.63	-	-	-	-	-	-	-	1.33
Carbonate of lime,	4	.56	-	-	-	-	-	-	-	-	-	-	-	-	-	52.33	-	-	-	-	40.75	-	.42	-
Carbonate of lime (coral),	2	19.76	-	-	-	.28	.14	.13	.13	.21	.16	.18	-	-	-	.32	38.18	.93	.62	-	43.39	-	9.49	
Gas-house lime,	5	11.16	-	-	-	-	-	-	-	-	-	-	-	-	-	48.19	8.30	-	19.66	-	30.56	-	8.99	
Ground lime none (unburned),	1	.28	-	-	-	-	-	-	-	-	-	-	-	-	-	42.56	-	-	-	-	-	-	19.66	
Gypsum,	3	8.01	-	-	-	-	-	-	-	-	-	-	-	-	-	36.00	-	-	51.43	-	-	-	-	-
Lime waste from tannery,	2	.88	-	-	-	.65	-	-	-	-	-	-	-	-	-	54.78	-	-	-	-	-	-	2.83	
Lime waste from sugar factory,	1	36.30	-	-	-	-	-	.22	-	-	2.25	-	-	-	-	27.51	-	-	-	-	-	-	.26	
Lime waste from soda factory,	1	24.07	-	-	-	-	-	-	-	-	-	-	-	-	-	14.86	1.36	-	23.14	-	-	-	1.33	
Lime sludge from glue factory,	1	37.20	-	-	-	.63	-	-	-	-	.15	-	-	-	-	19.62	-	-	-	-	14.51	-	-	
Magnesia lime,	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	47.55	32.75	-	-	-	1.35	-	-	
Nova Scotia plaster (gypsum),	17	6.45	-	-	-	-	-	-	-	-	-	-	-	-	-	33.74	.75	-	44.87	-	-	-	5.79	
Onondaga plaster, New York, gypsum,	4	13.27	-	-	-	-	-	-	-	-	-	-	-	-	-	30.00	4.66	-	32.50	-	8.20	-	9.83	
Oyster shell lime, partially burned,	7	5.13	-	-	.17	-	-	-	-	-	.36	-	-	-	-	45.87	-	-	-	-	20.73	-	10.08	

D. BY-PRODUCTS AND REFUSE SUBSTANCES — Continued.

[Figures equal percentages or pounds in 100.]

FERTILIZER MATERIALS.	Analys's.	Moisture.	Ash.	NITROGEN.			POTASH.			TOTAL PHOS- PHORIC ACID.			Soluble Phos- phoric Acid.	Reverted Phos- phoric Acid.	Insoluble Phos- phoric Acid.	Sodium Oxide.	Calcium Oxide (Lime).	Magnesium Oxide.	Ferric and Alu- minic Oxides.	Sulphuric Acid.	Carbonic Acid.	Chlorine.	Insoluble Matter.		
				Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.													
(c) Sea Weeds — Con.																									
Irish or Carotegen moss (<i>Chondrus Crispus</i>),	3	76.13	-	.81	.34	.57	1.46	.66	1.02	.20	.10	.13	-	-	-	-	.49	.33	-	-	-	-	-	.09	
Kelp or ribbon weed (<i>Laminaria Sacchar- ina</i>),	3	87.99	-	.22	.12	.17	.17	.14	.16	.06	.03	.05	-	-	-	-	.38	.17	-	-	-	-	-	.04	
Rockweed (green),	1	68.50	23.70	-	-	.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rockweed (dry),	2	13.73	35.75	1.45	1.07	1.26	4.89	1.56	3.22	2.75	.14	1.44	-	-	-	-	5.97	4.88	.96	1.22	-	-	.16	-	-
Round stalked rockweed (<i>Ascophyllum nodosum</i>),	3	77.26	-	.32	.18	.24	.75	.55	.64	.08	.08	.08	-	-	-	-	.48	.35	-	-	-	-	-	.03	
Sea weed (decomposed),	1	78.33	-	-	-	.55	-	-	.15	-	-	.04	-	-	-	-	.24	-	-	-	-	-	-	13.37	
(d) Vegetable Products.																									
Banana skins,	1	13.99	-	-	-	.24	-	-	5.46	-	-	1.80	-	-	-	-	-	-	-	-	-	-	-	-	-
Blue-green alge (<i>Langbia Majusculas</i>),	1	16.26	-	-	-	4.25	-	-	.79	-	-	.19	-	-	-	-	3.53	2.06	1.18	-	-	-	-	5.53	
Brewers' grains (rotten),	1	78.77	-	-	-	.72	-	-	.04	-	-	.43	-	-	-	-	.26	.15	-	-	-	-	-	.59	
Brewery, kiln dust from,	1	9.72	-	-	-	4.32	-	-	2.16	-	-	.96	-	-	-	-	.78	-	-	-	-	-	-	7.11	
Broom corn seed,	1	7.40	-	-	-	1.51	-	-	.50	-	-	.57	-	-	-	-	-	-	-	-	-	-	-	-	
Calico works, refuse from,	1	4.07	-	-	-	4.28	-	-	-	-	-	11.95	-	-	-	-	-	-	-	-	-	-	-	-	
Castor bean pomace,	24	8.20	5.70	6.17	4.65	5.22	3.40	.64	1.21	2.26	1.57	2.07	-	-	-	-	.92	.29	.82	-	-	-	-	1.75	
Cassava waste,	1	9.03	-	-	-	.33	-	-	.28	-	-	.06	-	-	-	-	.61	-	-	-	-	-	-	-	

F. ANALYSES OF INSECTICIDES.

[Figures equal percentages or pounds in 100.]

	Analyses.	Moisture.	Arsenous Oxide As ₂ O ₃ .	Copper Oxide.	Arsenous Oxide As ₂ O ₃ .	Water Soluble Arsenic.	Lead Oxide.	Zinc Oxide.	Barium Oxide.	Acetic Acid.	Nicotine.	Mercury.	Sulfur.	Sulfuric Acid.	Chlorine.	Calcium Oxide.	Potassium Oxide.	Ferric and Alu- minic Oxide.	Insoluble Matter in Hydrochloric Acid.
Barium arsenate (white arsenoid),	1	2.35	31.30	-	-	-	.96	-	48.31	-	-	-	-	-	3.19	-	-	-	-
Copper arsenite,	2	5.21	51.52	36.82	-	8.08	-	-	-	-	-	-	-	-	-	-	-	-	.09
Lead arsenate (dry neutral), . . .	3	2.49	-	-	25.92	.25	68.19	-	-	-	-	-	-	-	-	-	-	-	.22
Lead arsenate (dry acid),	2	.50	-	-	30.21	.09	64.50	-	-	-	-	-	-	-	-	-	-	-	.04
Lead arsenate (waste from),	8	44.53	-	-	15.58	-	33.21	-	-	6.76	-	-	-	-	-	-	-	-	.06
Laurel green,	1	7.64	7.34	13.50	-	-	-	-	-	-	-	-	-	-	-	26.31	-	-	-
Lime arsenite,	1	.80	76.31	-	-	40.88	-	-	-	-	-	-	-	-	-	21.63	-	-	.02
Nicotina,	1	10.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.12
Paris green,	27	.85	58.44	30.96	-	4.41	-	-	-	-	-	-	-	-	-	4.45	9.15	-	.21
Paris green (aceto copper arsenite, .	2	1.12	56.65	31.34	-	1.46	-	-	-	11.95	-	-	-	-	-	-	-	-	.03
Paris green (collected during 1901),	14	.81	57.73	29.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyrox,	1	58.09	-	4.21	6.79	-	16.35	-	-	-	-	-	-	-	-	-	-	-	-
Tobacco liquor,	1	37.71	-	-	-	-	-	-	-	-	2.12	-	-	-	-	5.27	-	-	.23
Tobacco liquor,	1	40.89	-	-	-	-	-	-	-	-	.53	-	-	-	-	1.47	16.34	-	.01

TABLE VI. — COMPILATION OF ANALYSES OF FRUITS
AND GARDEN CROPS.

H. D. HASKINS.

- A. Analyses of fruits.
- B. Analyses of garden crops.
- C. Relative proportions of phosphoric acid, potassium oxide and nitrogen found in fruits and garden crops.

The figures in A and B are in parts per 1,000. To convert into percentages or pounds in 100, move the decimal point one place to the left.

Some of the following analyses were taken from the compilation of E. Wolff. Those marked with an asterisk (*) were made at the laboratory of the Massachusetts Agricultural Experiment Station.

The tables will be found suggestive when one is preparing fertilizer formulas for various fruit and garden crops. One has also to consider, however, in making such fertilizer mixtures, the influence of cultivation and crop rotation as well as the plant food in the soil.

Members of the clover family are not dependent wholly upon supplied nitrogen, they having the power, after a vigorous start, to acquire atmospheric nitrogen when plenty of potash phosphoric acid and lime are supplied. An excess of phosphoric acid may be used in formulas without danger of loss from leaching. The same is true, to a certain extent, in case of potash, although this element is more often found in a water-soluble form in soils than is phosphoric acid. The well-known system of crop fertilization advocated originally by Wagner is based upon the necessity of an abundant supply of potash and phosphoric acid in the soil, while the nitrogen is added in such limited amounts and at such times as will provide for the maximum growth of the crop and the minimum loss through leaching.

A. ANALYSES OF FRUITS.
Fertilizer Constituents of Fruits.

[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulfuric Acid.	Chlorine.
Ericaceae: —										
*Cranberries,	996	—	1.8	.9	.1	.3	.1	.3	—	—
*Cranberries,	894	.8	—	1.0	—	.2	.1	.3	—	—
Rosaceae: —										
Apples,	831	.6	2.2	.8	.6	.1	.2	.3	.1	—
*Apples,	799	1.3	4.1	1.9	.3	.3	.3	.1	—	—
Cherries,	825	—	3.9	2.0	.1	.3	.2	.6	.2	.1
*Peaches,	884	—	3.4	2.5	—	.1	.2	.5	—	—
Pears,	831	.6	3.3	1.8	.3	.3	.2	.5	.2	—

Fertilizer Constituents of Fruits — Concluded.

[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulfuric Acid.	Chlorine.
Rosaceæ — <i>Con.</i>										
Plums,	S38	—	2.9	1.7	—	.3	.2	.4	.1	—
Strawberries,	902	—	3.3	.7	.9	.5	—	.5	.1	.1
*Strawberries,	—	—	5.2	2.6	.2	.7	.4	1.0	—	—
*Strawberry vines,	—	—	33.4	3.5	4.5	12.2	1.3	4.8	—	—
Saxifragaceæ: —										
*Currants, red,	S71	—	4.1	1.9	.2	.8	.3	.9	—	—
*Currants, white,	—	—	5.9	3.1	.2	1.0	.3	1.1	—	—
Gooseberries,	903	—	3.3	1.3	.3	.4	.2	.7	.2	—
Viticeæ: —										
Grapes,	S30	1.7	8.8	5.0	.1	.7	.4	1.4	.5	.1
Grape seed,	110	19.0	22.7	6.9	.5	5.6	1.4	7.0	.8	.1

B. ANALYSES OF GARDEN CROPS.
Fertilizer Constituents of Garden Crops.

[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulfuric Acid.	Chlorine.
Chenopodiaceæ: —										
*Beets, red,	877	2.4	11.3	4.4	.9	.5	.3	.9	—	—
Beets, sugar,	750	1.4	6.0	2.3	1.4	.6	.5	.8	.2	.2
*Beets, sugar,	869	2.2	10.4	4.8	.8	.6	.4	1.0	.1	—
Beets, sugar, leaves,	800	3.0	15.0	3.0	3.0	1.5	1.1	.7	.5	1.0
Beets, sugar, seed,	146	—	45.3	11.1	4.2	10.2	7.3	7.5	2.0	1.9
Beets, sugar, tops,	840	2.0	9.6	2.8	2.3	.9	1.1	1.2	.2	.3
Mangolds,	900	1.2	6.5	2.8	1.5	.3	.4	.6	.3	.9
*Mangolds,	873	1.9	12.2	3.8	1.3	.6	.4	.9	—	—

Fertilizer Constituents of Garden Crops — Continued.

[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.
Chenopodiaceæ — <i>Con.</i>										
Mangold leaves,	905	3.0	14.6	5.0	2.8	1.6	1.4	.8	.8	2.3
Spinach,	903	4.9	16.0	2.7	5.7	1.9	1.0	1.6	1.1	1.0
*Spinach,	922	3.4	9.6	9.6	2.1	.6	.5	.5	—	—
Composite: —										
Artichoke,	811	—	10.1	2.4	.7	1.0	.4	3.9	.5	.2
*Artichoke, Jerusalem,	775	4.6	—	4.8	—	—	—	1.7	—	—
Lettuce, common,	940	—	8.1	3.7	.8	.5	.2	.7	.3	.4
Lettuce, head,	943	2.2	10.3	3.9	.8	1.5	.6	1.0	1.1	.8
*Lettuce, head,	970	1.2	—	2.3	.2	.3	.1	.3	—	—
Lettuce, Roman,	925	2.0	9.8	2.5	3.5	1.2	.4	1.1	.4	.4

Convolvulaceae:—											
Sweet potato,	. . . . .	758	2.4	7.4	3.7	.5	.7	.3	.8	.4	.9
Cruciferae:—											
Cabbage, Savoy,	. . . . .	871	5.3	14.0	3.9	1.4	3.0	.5	2.1	1.2	1.1
Cabbage leaves,	. . . . .	890	2.4	15.6	5.8	1.5	2.8	.6	1.4	2.4	1.3
Cabbage, white,	. . . . .	900	3.0	9.6	4.3	.8	1.2	.4	1.1	1.3	.5
*Cabbage, white,	. . . . .	984	2.3	—	3.4	.3	.2	.1	.2	—	—
Cauliflower,	. . . . .	904	4.0	8.0	3.6	.5	.5	.3	1.6	1.0	.3
Horse-radish,	. . . . .	767	4.3	19.7	7.7	.4	2.0	.4	2.0	4.9	.3
Kohlrabi,	. . . . .	850	4.8	12.3	4.3	.8	1.4	.8	2.7	1.1	.6
Radishes,	. . . . .	933	1.9	4.9	1.6	1.0	.7	.2	.5	.3	.5
*Ruta-bagas,	. . . . .	891	1.9	10.6	4.9	.7	.9	.3	1.2	—	—
Turnips, white,	. . . . .	920	1.8	6.4	2.9	.6	.7	.2	.8	.7	.3
*Turnips, white,	. . . . .	895	1.8	10.1	3.9	.8	.9	.3	1.0	1.0	—
Turnips, white, leaves, .	. . . . .	898	3.0	11.9	2.8	1.1	3.9	.5	.9	1.1	1.2

Fertilizer Constituents of Garden Crops — Continued.

[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulfuric Acid.	Chlorine.
Cucurbitaceæ: —										
Cucumbers,	956	1.6	5.8	2.4	.6	.4	.2	1.2	.4	.4
Pumpkins,	900	1.1	4.4	.9	.9	.3	.2	1.6	.1	—
Gramineæ: —										
Barley, grains,	108	19.2	—	4.8	—	—	—	7.9	—	—
Buckwheat, grain,	134	17.3	—	3.0	—	—	—	6.9	—	—
Corn, kernels,	144	16.0	12.8	3.7	.1	.3	1.9	5.7	.1	.2
*Corn, kernels,	100	18.2	—	4.0	.3	.3	2.1	7.0	—	—
*Corn, whole ears,	90	14.1	—	4.7	.6	.2	1.8	5.7	—	—
*Corn, stover,	282	11.2	37.4	13.2	7.9	5.2	2.6	3.0	—	—
Corn, whole plant, green,	829	1.9	10.4	3.7	.5	1.4	1.1	1.0	.3	.5

*Corn, whole plant, green,	786	4.1	-	3.8	.5	1.5	.9	1.5	-
Hay, English,	140	12.6	-	16.1	-	3.2	-	3.2	-
Millet seed,	140	18.5	29.5	3.3	.4	6.5	2.8	.1	.1
Oats, grain,	143	17.6	27.4	4.8	.4	7.4	1.9	.5	.3
Rye, grain,	87	18.1	-	5.8	-	8.6	-	-	-
Wheat, grain,	144	20.0	-	5.2	-	8.0	-	-	-
Leguminosæ: —									
Alfalfa hay,	68	24.7	-	17.9	-	6.1	-	-	-
Bean straw,	160	-	40.2	12.8	3.2	3.9	2.5	1.7	3.1
Clover, hay,	153	19.7	-	18.7	-	5.5	-	-	-
*Cow pea, green,	788	2.9	-	3.1	.6	1.0	1.0	-	-
Garden beans, seed,	150	39.8	27.4	12.1	.4	9.7	2.1	1.1	.3
Hay of peas cut green,	167	22.9	62.4	23.2	2.3	6.8	6.3	5.1	2.0
*Leaves and stems of velvet beans,	58.8	28.6	-	-	-	-	-	-	-
Peas, straw,	160	10.4	43.1	9.9	1.8	3.5	3.5	2.7	2.3
Peas, seed,	143	36.5	27.5	12.5	.2	10.0	1.9	.8	.4

Fertilizer Constituents of Garden Crops — Concluded.
[Parts per 1,000.]

	Moisture.	Nitrogen.	Ash.	Potassium Oxide.	Sodium Oxide.	Calcium Oxide.	Magnesium Oxide.	Phosphoric Acid.	Sulfuric Acid.	Chlorine.
Leguminosæ: —										
*Small pea, dry (<i>Lathyrus Sylvestris</i>), . . .	90	38.5	—	25.7	4.7	17.9	5.0	9.0	—	—
Soy bean, seed,	100	53.4	28.3	12.6	.3	1.7	2.5	10.4	.8	.1
*Velvet beans, kernel,	111.6	31.1	—	13.2	—	—	—	7.7	—	—
*Velvet beans, with pod,	115.2	19.6	—	13.1	—	—	—	8.4	—	—
Liliacæ: —										
*Asparagus,	942	3.3	—	3.29	—	—	—	1.08	—	—
Asparagus,	933	3.2	5.0	1.2	.9	.6	.2	.9	.3	.3
*Asparagus roots, ¹	81.7	16.2	58.8	21.6	1.8	2.8	1.4	4.7	4.0	—
Onions,	860	2.7	7.4	2.5	.2	1.6	.3	1.3	.4	.2
*Onions,	892	—	4.9	1.8	.1	.4	.2	.7	—	—
Solanacæ: —										
Potatoes,	750	3.4	9.5	4.0	.3	.3	.5	1.6	.6	.3
*Potatoes,	798	2.1	9.9	2.9	.1	.1	.2	.7	—	—

Potato tops, nearly ripe,	770	4.9	19.7	4.3	.4	6.4	3.3	1.6	1.3	1.1
Potato tops, unripe,	825	6.3	16.5	4.4	.3	5.1	2.4	1.2	.8	.9
Tobacco leaves,	180	24.5	150.7	50.9	4.5	50.7	10.4	6.6	8.5	9.4
*Tomatoes,	940	1.7	-	3.6	-	.3	.2	.4	-	-
*Tobacco, whole leaf,	103.1	24.3	-	57.9	24.7	45.8	13.8	4.3	16.3	1.59
Tobacco stalks,	180	16.4	74.7	38.2	6.6	12.4	.5	9.2	2.2	2.4
*Tobacco stems,	106	22.9	140.7	64.6	3.4	38.9	12.3	6.0	-	-
Umbellifera: —										
Carrots,	850	2.2	8.2	3.0	1.7	.9	.4	1.1	.2	.4
*Carrots, *	898	1.5	9.2	5.1	.6	.7	.2	.9	-	-
Carrot tops,	822	5.1	23.9	2.9	4.7	7.9	.8	1.0	1.8	2.4
Carrot tops, dry,	98	31.3	125.2	48.8	40.3	20.9	6.7	6.1	-	-
Celery,	841	2.4	17.6	7.6	-	2.3	1.0	2.2	1.0	2.8
Parsnips,	793	5.4	10.0	5.4	.2	1.1	.6	1.9	.5	.4
*Parsnips,	803	2.2	-	6.2	.1	.9	.5	1.9	-	-

: Twenty-four analyses.

C. RELATIVE PROPORTIONS OF PHOSPHORIC ACID, POTASSIUM OXIDE
AND NITROGEN IN FRUITS AND GARDEN CROPS.

	Phosphoric Acid.	Potassium Oxide.	Nitrogen.
FRUITS.			
Ericaceæ: —			
*Cranberries,	1	3.0	—
*Cranberries,	1	3.33	2.66
Rosaceæ: —			
Apples,	1	2.7	2.0
*Apples,	1	1.9	1.3
Cherries,	1	3.3	—
*Peaches,	1	1.3	—
Pears,	1	3.6	1.2
Plums,	1	4.3	—
Strawberries,	1	1.4	—
*Strawberries,	1	2.6	—
*Strawberry vines,	1	.7	—
Saxifragaceæ: —			
*Currants, red,	1	2.1	—
*Currants, white,	1	2.8	—
Gooseberries,	1	1.9	—
Viticeæ: —			
Grapes,	1	3.6	1.2
Grape seed,	1	1.0	2.7
GARDEN CROPS.			
Chenopodiaceæ: —			
*Beets, red,	1	4.1	3.3
Beets, sugar,	1	2.88	1.75

C. RELATIVE PROPORTIONS OF PHOSPHORIC ACID, ETC., IN FRUITS
AND GARDEN CROPS — *Continued.*

	Phosphoric Acid.	Potassium Oxide.	Nitrogen.
Chenopodiaceæ — <i>Con.</i>			
*Beets, sugar,	1	4.8	2.2
Beets, sugar, leaves,	1	4.28	4.28
Beets, sugar, tops,	1	2.3	1.7
Beets, sugar, seed,	1	1.5	—
Mangolds,	1	4.66	2.0
*Mangolds,	1	4.2	2.1
Mangold leaves,	1	6.25	3.75
Spinach,	1	1.7	3.06
*Spinach,	1	19.2	6.8
Compositæ: —			
Artichoke,	1	.63	—
*Artichoke, Jerusalem,	1	2.8	2.7
Lettuce, common,	1	5.3	—
Lettuce, head,	1	3.9	2.2
*Lettuce, head,	1	7.7	4.0
Lettuce, Roman,	1	2.3	1.8
Convolvulaceæ: —			
Potato, sweet,	1	4.6	3.0
Cruciferæ: —			
Cauliflower,	1	2.3	2.5
Cabbage, leaves,	1	4.1	1.7
Cabbage, Savoy,	1	1.9	2.5
Cabbage, white,	1	4.1	1.7
*Cabbage, white,	1	11.0	7.6

C. RELATIVE PROPORTIONS OF PHOSPHORIC ACID, ETC., IN FRUITS
AND GARDEN CROPS — *Continued.*

	Phosphoric Acid.	Potassium Oxide.	Nitrogen.
Cruciferæ — <i>Con.</i>			
Kohlrabi,	1	1.6	1.8
Radishes,	1	3.2	3.8
Radish, horse,	1	3.9	2.2
*Ruta-bagas,	1	4.1	1.6
Turnips, white,	1	3.6	2.3
*Turnips, white,	1	3.9	1.8
Turnips, white, leaves,	1	3.1	3.3
Cucurbitacæ: —			
Cucumbers,	1	2.0	1.3
Pumpkins,	1	.56	.69
Gramineæ: —			
Barley, grain,	1	.61	2.43
Buckwheat, grain,	1	.43	2.51
Corn, whole plant, green,	1	3.7	1.9
*Corn, whole plant, green,	1	2.2	2.8
Corn, kernels,	1	.6	2.8
*Corn, kernels,	1	.6	2.6
*Corn, stover,	1	4.4	3.7
*Corn, whole ears,	1	.8	2.5
Hay, English,	1	5.03	3.93
Millet, seed,	1	.51	2.84
Oats, grain,	1	.65	2.38
Rye, grain,	1	.67	2.10
Wheat, grain,	1	.65	2.50

C. RELATIVE PROPORTIONS OF PHOSPHORIC ACID, ETC., IN FRUITS
AND GARDEN CROPS—*Continued.*

	Phosphoric Acid.	Potassium Oxide.	Nitrogen.
Leguminosæ:—			
Alfalfa, hay,	1	2.93	4.05
Bean straw,	1	3.3	—
Clover, hay,	1	3.4	3.58
*Cow pea, green (<i>Dolichos</i>),	1	3.1	2.9
Garden beans, seed,	1	1.2	4.0
Hay of peas, cut green,	1	3.4	3.4
Peas, seed,	1	1.2	3.65
Pea straw,	1	2.8	4.0
Soy bean seed,	1	1.21	5.12
*Small pea, dry (<i>Lathyrus sylvestris</i>),	1	3.4	4.2
*Velvet beans, kernel,	1	1.7	4.0
*Velvet beans, with pod,	1	1.56	2.3
Liliacæ:—			
*Asparagus,	1	3.05	3.06
Asparagus,	1	1.3	3.6
*Asparagus roots, ¹	1	4.60	3.45
Onions,	1	1.9	2.1
*Onions,	1	2.6	—
Solanacæ:—			
Potatoes,	1	2.5	2.1
*Potatoes,	1	4.1	3.0
Potato tops, nearly ripe,	1	2.7	3.1
Potato tops, unripe,	1	3.7	5.3

¹ Twenty-four analyses.

C. RELATIVE PROPORTIONS OF PHOSPHORIC ACID, ETC., IN FRUITS
AND GARDEN CROPS — *Concluded.*

	Phosphoric Acid.	Potassium Oxide.	Nitrogen.
Solanaceæ — <i>Con.</i>			
Tobacco leaves,	1	7.71	3.71
*Tobacco, whole leaf,	1	13.46	5.65
Tobacco stalks,	1	4.15	1.78
*Tobacco stems,	1	10.7	3.8
*Tomatoes,	1	8.7	4.5
Umbelliferæ: —			
Carrots,	1	2.7	2.0
*Carrots,	1	5.7	1.7
Carrot tops,	1	2.9	5.1
Carrot tops, dry,	1	8.0	5.1
Celery,	1	3.5	1.1
Parsnips,	1	2.8	2.8
*Parsnips,	1	3.3	1.2

COMPOSITION OF SOME MASSACHUSETTS SOILS.

BY J. B. LINDSEY.

In the year 1892 samples of typical soils were taken from different parts of the State under the general supervision of Prof. William P. Brooks. Prof. Benjamin K. Emerson, the geologist of Amherst College, advised as to the most suitable location to secure some of the soils, in order that they might be representative. The soils were carefully analyzed under the direct supervision of the late Prof. C. A. Goessmann, and the completed results of each soil are here presented for the first time.

DESCRIPTION OF TYPES.

- Soil No. 1.* — Ten inches surface soil taken on the grounds of the Massachusetts agricultural experiment station, north of Hatch barn.
- Soil No. 2.* — Ten inches surface soil taken on Agawam Plains, not cultivated for ten years.
- Soil No. 3.* — Twelve inches surface soil taken from hill pasture in Agawam. The soil known as Agawam red sandstone.
- Soil No. 4.* — Granite till from Dedham, locality of Fox Hill; 12 inches surface soil.
- Soil No. 5.* — Cranberry bog from Colony Stock Farm; 6 inches surface soil.
- Soil No. 6.* — Diked Salt Marsh, Marshfield; tide shut off twenty years ago; soil cultivated.
- Soil No. 7.* — Soil of alluvial formation from Hadley meadows; overflowed in 1862 and 1872, and a deposit of sand was left which injured it materially.
- Soil No. 8.* — Virgin soil, taken from South River salt marsh, Marshfield, Mass.
- Soil No. 9.* — Natural fresh-water meadow from Sudbury, Mass.; very wet.
- Soil No. 10.* — Gneiss till from Shutesbury, Mass.; very barren.
- Soil No. 11.* — Mica schist from Deerfield, Mass.; taken from base of hill. Virgin soil, good pasture land, never cultivated.
- Soil No. 12.* — Limestone till from Pittsfield, Mass.
- Soil No. 13.* — Copperas rock from Hubbardston. Virgin soil, very strong.

Analysis of Types of Massachusetts Soils.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.
Coarse materials (.5 mm.),	1.42	14.48	45.81	23.63	-	6.13	.05	-	-	26.26	14.92	18.03	44.36
Fine earth,	98.58	85.52	54.19	76.37	100.00	93.87	99.95	100.00	100.00	73.74	85.08	81.97	55.64
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
ANALYSIS OF FINE EARTH.													
Insoluble matter,	80.38	86.68	73.89	76.48	9.25	72.45	82.42	78.31	9.40	82.68	77.83	81.05	70.39
Soluble silica,	2.41	1.73	7.57	3.88	-	1.15	1.78	2.11	.96	1.20	1.82	.78	.92
Potash (K ₂ O), . . . . .	.38	.18	.30	.19	.16	.24	.22	.33	.53	.13	.40	.25	.46
Soda (Na ₂ O), . . . . .	.29	.38	.46	.42	.34	.19	.21	1.63	1.78	.38	1.96	.96	.90
Lime (CaO), . . . . .	.70	.68	.47	.41	.01	.68	.99	.36	1.71	.92	1.15	1.58	.50
Magnesia (MgO), . . . . .	.26	.81	.90	.49	-	.72	.93	.19	.66	.19	.79	.34	.22
Manganese oxide (Mn ₂ O ₄), . . . . .	.06	.17	.13	.09	-	.05	.07	.06	.09	.06	.07	.07	.01
Iron oxide (Fe ₂ O ₃),	3.76	3.49	4.59	3.86	39	4.47	5.09	3.54	1.71	3.79	5.93	5.39	12.26
Alumina (Al ₂ O ₃),	6.22	4.27	6.24	4.69	.04	5.37	3.15	2.57	2.09	3.01	5.86	4.32	4.98
Phosphoric acid (P ₂ O ₅), . . . . .	.31	.10	.22	.05	-	.24	.32	.13	.20	.20	.29	.29	.36
Sulfur trioxide (S ₂ O ₃), . . . . .	.15	.12	.12	.21	.38	.64	.27	.33	.71	.03	.05	.08	.05
Volatile matter,	4.88	2.68	4.37	9.81	89.76	14.42	3.83	9.89	80.13	6.89	4.45	4.92	8.72
Total,	99.80	100.69	99.66	100.59	100.33	100.62	99.28	99.45	99.36	99.48	100.20	100.03	99.85
Humus,	1.72	.46	.54	1.89	41.23	6.56	1.97	1.30	26.86	1.80	1.05	.87	1.46
Ash, . . . . .	.406	.026	.199	.249	1.90	.943	.64	.226	.56	.275	.28	.23	.31
Phosphoric acid, . . . . .	.079	.012	.032	.036	.027	.063	.045	.11	.11	.036	.053	.029	.026
Silica, . . . . .	.107	.006	.084	.12	-	.228	.320	.144	.124	.124	.11	.12	.17
Nitrogen, . . . . .	.20	.07	.09	.30	.27	.50	.11	.28	.43	.18	.12	.18	.15
Hygroscopic moisture,	5.38	3.69	10.69	7.40	26.29	14.85	3.81	20.66	36.78	5.200	4.25	8.88	14.34

According to Hilgard¹ "Virgin soils with high plant food percentages are always productive, provided, only, that extreme physical characters do not interfere with normal plant growth." By high plant food percentages is meant 1 per cent. of acid soluble potash, 1 of lime, the same or less of magnesia and .15 per cent. of phosphoric acid. In case there is a low percentage of one of the above elements, it is an indication that this will be the first to fail, and will have to be supplied in the form of farm-yard manures or chemical fertilizers. The total percentage of nitrogen in the soil is of less importance than the nitrogen percentage in the humus, of which there should be at least 4 per cent. to insure satisfactory production.

It will be seen that none of the above soils could be classed as highly productive, yet by comparing the analyses with the standards for average soils as given further on, it will be seen that, in so far as their chemical analysis is concerned, most of them would be capable of producing satisfactory crops.

MISCELLANEOUS SOIL ANALYSES.

From time to time during the last ten or fifteen years the station has had occasion to examine soils sent from different sections of the State. The following tabulation shows the percentages of the more important fertilizer constituents which they contained. The data concerning the history of each soil are not at present available. From our present knowledge of the value of chemical analysis in determining soil fertility it is doubtful if such data would have proved particularly helpful, so much depending upon the physical character of the soil and subsoil, drainage and the character of the crops to be grown. This matter is briefly referred to further on. In general it may be said that the soils were taken from the cultivated fields of Massachusetts farms.

¹ Soils, by E. W. Hilgard, p. 343.

Table of Miscellaneous Soil Analyses (Per Cent.).¹

SOURCE.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potassium Oxide.	Calcium Oxide.
Abington (garden?),	-	.85	.78	.44	-
Amesbury (reclaimed marsh),	6.21	1.41	.24	.36	-
Amherst (Massachusetts Agricultural College, productive),	-	.23	.26	.112	.06
Amherst (Massachusetts Agricultural College, unproductive).	-	.23	.16	.114	.07
Amherst (Massachusetts Agricultural College, experiment station).	-	.20	.16	.253	1.64
Amherst (Massachusetts Agricultural College, south acre),	-	.16	.13	.271	1.33
Amherst,	-	.48	.11	.36	.54
Amherst,	-	.18	.24	.17	.34
Amherst,	-	.08	.15	.07	.24
Amherst,	-	.11	.20	.15	.24
Amherst,	7.38	.21	.10	.21	.17
Amherst,	-	.16	.11	.28	1.04
Amherst,	-	.22	.07	.29	.73
Amherst,	-	.24	.11	.23	.67
Arlington (average of 3 samples),	-	.14	.15	.23	.80
Athol,	8.79	.27	.13	.11	.23
Barre (average of 3 samples),	-	.20	.25	.29	.65
Belmont,	8.57	.27	.21	.15	.12
Berlin,	-	.26	.14	.30	.46
Bernardston,	-	.12	.25	.20	.95
Bernardston,	-	.08	.15	.11	.15
Beverly,	-	.37	.30	.56	.56
Beverly,	-	.02	.22	.56	.50
Bisbees,	-	.21	.13	.25	.32
Boston,	6.02	.16	.205	.401	trace
Boston,	-	.35	.387	.26	1.17
Boston,	-	.13	.04	.09	.11
Boston,	-	.25	.26	.19	.13
Boston,	-	.11	.04	.11	.16
Boston,	4.25	.11	.04	.07	.55
Boston,	6.69	.20	.06	.01	.33
Boston,	6.04	.14	.06	.07	.21
Boston (near seacoast),	8.53	.47	.17	1.02	1.08

¹ Analyses made by H. D. Haskins and assistants.

Table of Miscellaneous Soil Analyses (Per Cent.) — Continued.

SOURCE.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potassium Oxide.	Calcium Oxide.
Brockton (greenhouse?),	-	.42	.19	.11	.69
Brookfield,	-	.47	.36	.29	.20
Brookline (greenhouse?),	-	.93	.23	.21	1.42
Brookline (greenhouse?),	-	.51	.07	.25	1.48
Cambridge,	-	.18	.29	.18	.77
Canton,	-	.30	.19	.23	.78
Clinton,	-	.22	.13	.15	1.52
Clinton,	-	.22	.24	.81	.65
Concord,	9.88	.48	.21	-	trace
Concord (asparagus),	4.30	.13	.24	.09	.22
Conway,	-	.24	.07	.17	-
Conway,	-	.44	.09	.21	-
East Holliston,	-	.19	.14	.14	1.00
East Whately,	-	.14	.25	.24	.16
East Whately,	-	.11	.34	.18	.19
East Whately,	-	.19	.09	.18	.10
East Whately,	-	.12	.32	.49	.69
East Whately,	-	.08	.18	.53	.85
Florence (tobacco),	2.24	.81	.98	-	1.79
Florence (tobacco),	-	.96	.37	-	1.12
Foxborough,	9.47	.28	.08	.10	.63
Foxborough (average of 7 samples),	-	.21	.25	.16	1.19
Framingham,	-	.17	.34	.23	.56
Framingham,	-	.13	.13	.13	.24
Gloucester (low and swampy; reclaimed),	-	.86	.60	.74	1.00
Greenfield,	-	2.42	.30	.30	3.57
Hadley,	-	.15	.49	.24	.49
Hadley (mill pond basin),	-	.17	.08	.56	.82
Halifax (average of 6 samples),	12.18	.28	.03	.09	.26
Halifax (average of 2 samples),	-	.66	.31	.22	2.88
Halifax,	-	.10	.09	.26	.75
Hampden,	-	.20	.23	.13	.39
Hampden,	-	.41	.30	.08	.46
Harding,	-	.14	trace	.12	.30

Table of Miscellaneous Soil Analyses (Per Cent.) — Continued.

SOURCE.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potassium Oxide.	Calcium Oxide.
Harding,	-	.12	trace	.11	.41
Harding,	-	.17	.04	.13	.24
Harding,	-	.14	trace	.17	.33
Haverhill,	-	.17	.45	.20	1.30
Haverhill (meadow, 3½ feet),	72.60	1.61	.09	.12	1.01
Haverhill (bank of river),	-	.51	.21	.13	.32
Holliston,	-	.20	.22	.25	1.00
Hubbardston,	-	.26	.12	.39	1.88
Lenox,	-	.07	.39	.28	1.41
Lenox,	9.18	.29	.23	.32	.10
Lenox,	-	.28	.34	.33	.85
Lenox,	-	.30	.17	.26	1.20
Lynn,	-	.39	.40	.32	1.51
Longmeadow,	-	.34	.20	.21	.54
Malden (garden soil),	12.57	.64	-	.49	.79
Mansfield (average of 3 samples),	-	.16	.15	.13	1.28
Mattapoisett,	-	.19	.20	.11	.73
Merrick,	-	.13	.35	.29	.79
Monson,	8.46	.24	.03	.21	.10
Montague (corn experiment plat),	-	.16	.13	.37	1.41
Newbury,	-	.26	trace	.16	.15
Newbury,	-	.28	.13	.15	.29
Newbury,	-	.28	.16	.23	.17
Newbury,	-	.28	.29	.15	.11
Newbury,	-	.29	.17	.15	.15
Newton,	-	.18	.01	.23	.59
Newton,	-	.18	.01	.23	.59
Newton,	-	.23	.07	.13	.76
Newton,	-	.22	.01	.14	.42
Newton,	-	.26	.08	.14	.82
Newton,	-	.22	.01	.14	.42
Newton,	-	.38	.23	.22	.85
Newton,	-	.10	.15	.22	1.19
Newton Highlands,	7.42	.31	.18	.16	-

Table of Miscellaneous Soil Analyses (Per Cent.) — Continued.

SOURCE.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potassium Oxide.	Calcium Oxide.
Newton Highlands,	-	.34	.07	.50	.65
New Bedford (average of 6 samples),	-	.24	.14	.25	.53
Northampton (average of 3 samples),	-	.14	.19	.39	1.00
North Adams,	-	.60	.36	.89	2.41
North Adams,	-	.23	.14	.62	.40
North Adams,	-	.25	.10	.55	.30
North Eastham (asparagus farm),	-	.22	.05	.07	.58
North Easton,	-	.12	.09	.21	-
North Easton,	-	.19	.24	.20	-
North Weymouth,	-	.35	.10	.34	.67
North Weymouth,	-	.32	.32	.25	.71
Norton,	-	.18	.05	.09	.75
Norton (average of 3 samples),	-	.14	.15	.09	.84
Orange,	-	.20	.11	.28	.38
Orange,	-	.44	.20	.20	.49
Plymouth,	-	.15	.10	.18	.50
Rutland (sanatorium),	-	.20	.16	.25	.09
Scituate,	-	.33	.13	.10	.16
South Carver,	-	.06	.08	.19	.23
South Carver,	-	.10	.29	.59	.48
South Carver,	-	.11	.31	.39	.27
South Framingham (average of 6 samples),	6.89	.22	.14	.19	.47
Springfield,	-	.16	.18	.22	.57
Springfield,	-	.15	.16	.16	.55
Springfield,	-	.39	.14	.48	1.32
Sunderland,	14.09	.64	.70	.49	.54
Swift River,	-	.23	.09	.23	.17
Taunton,	-	.34	.23	.22	trace
Tewksbury (average of 2 samples),	6.93	.36	-	.29	.64
Truro,	-	.19	.24	.27	.81
Upton (carnation soil),	-	.41	.44	.20	.64
Upton (carnation soil),	-	.23	.60	.23	.83
Upton (carnation soil),	-	.50	.81	.46	.60
Waltham (greenhouse?),	-	.76	.40	.47	.83

Table of Miscellaneous Soil Analyses (Per Cent.)—Concluded.

SOURCE.	Organic Matter.	Nitrogen.	Phosphoric Acid.	Potassium Oxide.	Calcium Oxide.
Webster,	1.25	-	.03	-	-
Wellesley,	-	.28	.66	.28	1.77
Westfield,	-	.29	.25	.31	.95
Westminster,	-	.32	.13	.30	.28
West Newton,	-	.14	.25	.16	1.14
West Springfield (average 14 samples),	-	.25	.51	.36	.97
Weymouth,	5.69	.24	.11	.24	.31
Whately,	-	.12	.02	.58	1.07
Whately,	-	.13	.20	.36	.94
Williamstown,	-	.27	.21	.37	.18
Winter Hill,	6.39	.27	.18	.23	.92
Worcester,	-	.29	.07	.45	1.23
Worcester,	-	.14	.05	.20	1.57

EUROPEAN STANDARDS FOR COMPARISON (HILGARD).¹*Practical Rating of Soils by Plant Food Percentages.*²

GRADE OF SOIL.	Potash.	Phosphoric Acid.	LIME.		Total Nitrogen.
			Clay Soil.	Sandy Soil.	
Poor,	Below 0.05	Below 0.05	Below 0.10	Below 0.05	Below 0.05
Medium,	0.05-0.15	0.05-0.10	0.10-0.25	0.10-0.15	0.05-0.10
Normal,	0.15-0.25	0.10-0.15	0.25-0.50	0.15-0.20	0.10-0.15
Good,	0.25-0.40	0.15-0.25	0.50-1.00	0.20-0.30	0.15-0.25
Rich,	Above 0.40	Above 0.25	Above 1.00	Above 0.30	Above 0.25

In case of the above analyses of Massachusetts soils, the potash percentage varies from .01 to 1.02, with an average of .26; the phosphoric acid from .01 to .98, with an average of .21; the lime from .06 to 3.57, with an average of .71, and the nitrogen from .02 to 2.42, averaging .30.

¹ Soils, p. 343.² According to the late Prof. Max. Maercker of the Halle Station, Germany.

Judging from such results most of the soils can at least be classed as normal from a chemical standpoint, some of them good and a few rich. Practically all of them are quite suitable for crop production if properly handled. One, however, would not care to say, from a chemical analysis alone, whether any one of them was suited to a particular crop, so many other conditions entering into the problem. Brooks, in Circular No. 29 of this station, has made this matter clear, as follows:—

1. *The Crop Adaptation.*—While the chemical condition of a soil is not altogether without influence in determining the crops to which it is suited, this, as a rule, at least within such range of soil variation as exists in this State, plays a much less important part than mechanical and physical peculiarities. The crops to which a soil is suited are determined chiefly by its drainage, its capacity to hold and to conduct water, its temperature and its aëration, and these in turn are determined by the mechanical structure of the soil and sub-soil. Variations in the proportions of gravel, sand, silt and clay, and not in chemical composition, cause the usual differences in these respects. The varying proportions of these, therefore, usually determine the crops to which a soil is suited.

2. *Fertilizer Requirements.*—The results of a chemical analysis of a soil do not, as a rule, afford a satisfactory basis for determining manurial requirements. The chemist, it is true, can determine what the soil contains, but no ordinary analysis determines with exactness what proportion of the several elements present is in available form for the crop. Indeed, there is no such thing as a constant ratio of availability. While one crop finds in a given soil all the plant food it requires, another may find a shortage of one or more elements. Further, on the very same field one crop may find an insufficient amount of potash; another may find enough potash for normal growth, but insufficient phosphoric acid; while a third may suffer only from an insufficient supply of nitrogen.

Most of our soils are of mixed rock origin, and, as a rule, possess similar general chemical characteristics, providing they have been farmed under usual conditions. The manurial and fertilizer requirements are determined more largely in most soils by the crop than by peculiarities in the chemical condition of the soil.

3. *Crop Diseases.*—The chemical composition of the soil may in some instances exercise a controlling influence in determining a condition of health or disease, and is never unimportant from the standpoint of vigorous, normal and healthy growth; but in the case of most diseases, the immediately active cause is the presence of a parasitic fungus, and this fungus is usually capable of fixing itself upon the

plant, whatever may be the composition of the soil. A knowledge of the chemical composition of soils, therefore, will not make it possible to advise such manurial or fertilizer treatment as will insure immunity from disease.

CONDITIONS UNDER WHICH ANALYSES WILL BE MADE.

For the reasons which have been briefly outlined, the chemical analysis of soils does not, as a rule, afford results which have a value commensurate with the cost; and this station, therefore, will not make such analysis unless the soil differs widely from the normal in natural characteristics, or has been subjected to unusual treatment of such a nature as to probably greatly influence its chemical condition. In order that we may decide whether analysis seems called for, correspondents are urged to write before taking samples, and when doing so to state all the conditions as fully as possible. This statement should include a full description of the soil and as full a report as possible as to the manures and fertilizers applied and crops raised for a number of years previous to the date of writing. In all cases in which, on the basis of the information given, it appears that a chemical analysis promises results of value, such an analysis will be made, and for the present free of charge; but, as explained in the preceding paragraphs, such analyses appear to be only rarely worth while. It will usually be possible to give helpful advice in relation to the use of manures and fertilizers on receipt of a full statement as to the character and history of the soil and the crop which is to be raised, and such advice will always be gladly given.

In case analysis is regarded as desirable, full directions for taking and forwarding samples will be sent.

INDEX.

INDEX.

	PAGE
Agricultural chemicals, etc., compilation of analyses of,	304
Agriculturist, report of,	34
Alfalfa, co-operative experiments with,	22
<i>Alternaria</i> in connection with gummosis,	172
Ammonia, sulfate of, quality of,	65
Analyses, tables of,	246
Tabulation of,	53
Animal excrements, compilation of analyses of,	322
Animal nutrition, research work in,	53
Apiaries, inspection of,	30
Apple, acidity as affected by temperature,	222
Approximate composition of varieties,	235
Astringency as affected by temperature,	223
Average analyses of varieties,	189
Belts of North America,	205
Characteristics of varieties:—	
Baldwin,	192
Ben Davis,	194
Esopus,	192
Fameuse,	190
Grimes,	191
Jonathan,	191
King,	191
Maiden Blush,	190
McIntosh,	190
Northern Spy,	192
Rhode Island Greening,	192
Rome Beauty,	193
Roxbury Russet,	194
Stayman Winesap,	193
Smith Cider,	193
Wealthy,	190
Winesap,	193
Yellow Newtown,	193
York Imperial,	194
Chemical examination of,	232
Color as related to temperature,	226
Coloration as affected by temperature,	223
Color of,	226
Distribution of varieties:—	
Baldwin,	214
Ben Davis,	210
Esopus,	213
Fameuse,	210
Grimes,	211
Jonathan,	211
Maiden Blush,	209
McIntosh,	210
Northern Spy,	214

	PAGE
Apple, distribution of varieties -- <i>Concluded.</i>	
Oldenburg,	207
Rhode Island Greening,	213
Rome Beauty,	217
Shockley,	220
Tompkins King,	212
Wealthy,	208
Winesap,	215
Wolf River,	208
Yellow Newtown,	218
York Imperial,	217
Influence of heat of summer on,	221
Insoluble solids as affected by temperature,	223
Keeping quality,	225
Lack of flavor in,	226
Mealiness of,	226
Mean summer temperature for varieties,	229
Mean summer temperature in relation to development,	221
Modifying effect of climate on development of,	199
Modifying effect of climate on form,	199
Modifying effect of climate on general development,	205
Modifying effect of climate on size,	204
Optimum mean summer temperature,	227
Optimum temperatures by groups,	231
Premature dropping,	225
Relation of temperature to development,	221
Rotting on the tree,	225
Scalding in storage as related to climate,	224
Seasonal variation in form,	199
Size as affected by temperature,	223
Size as related to temperature,	226
The development of the,	183
The perfectly developed,	186
Uneven ripening as related to climate,	224
Varieties, climatic adaptations of,	177
Varieties, climatic adaptations of summarized,	243
Variation in form in different parts of the tree,	203
Winter minimum temperature in relation to development,	221
Apples, causes of varietal variation,	179
Climatic variation,	180
Cultural variations,	179
Individuality of the tree,	194
Soil variation,	180
Arsenates, iodine method for,	129
Arsenic, determination in insecticides,	122
Iodine method for determining,	124
New processes for determining in insecticides,	125
Practice in determining at Massachusetts station,	127
Ashes, lime compounds and marls, compilation of analyses of,	310
Ashes, wood, quality of,	64
Asparagus, breeding experiments in substitution,	24
Fertilizer experiments, Concord,	25
Nitrogen fertilizers and potash salts for,	39
Substation, Concord,	24
Asparagus roots, chemical work on,	25
Soluble carbohydrates in,	135
Basic slag phosphate, quality of,	66

	PAGE
Black knot, <i>Plowrightia morbosa</i> ,	169
Black spot or scab, appearance on fruit,	166
Appearance of the leaves,	166
Appearance on the twigs,	166
<i>Cladosporium carpophyllum</i> , Thum.,	165
Blood, dried, quality of,	65
Bone, dissolved, quality of,	63
Ground, quality of,	63
Botanist, report of,	75
Brown or fruit rot, <i>Monilia</i> ,	161
Symptoms on flowers,	162
Symptoms on fruit,	162
Symptoms on the leaves,	164
Symptoms on the twigs,	163
Peach and plum, methods of control,	164
Buildings,	30
By-products and refuse substances, compilation of analyses of,	314
Candidates for Babcock test, examination of,	69
Carbohydrates, soluble, in asparagus roots,	135
Castor pomace, quality of,	65
<i>Cercospora circumscissa</i> ,	170
Chemical department, summary of work in,	51
Chemical research, laboratory work in,	52
Chemicals and refuse salts, compilation of analyses of,	304
Chemist, report of,	51
<i>Cladosporium carpophyllum</i> , Thum.,	165
<i>Cladosporium</i> in connection with gummosis,	172
Climatic adaptations of apple varieties,	177
Commercial shortages (fertilizers),	59
Control work,	28
Corn fertilizer <i>v.</i> fertilizer richer in potash,	45
Correspondence,	20
In chemical department,	51
Cottonseed meal, quality of,	65
Cows, pure-bred, testing of,	74
Cranberry, fertilizer experiments in substation,	27
Insect work,	28
Substation,	26
<i>Cylindrosporium Padi</i> ,	170
Dairy law,	29
Execution of,	69
Dairy products, compilation of analyses of,	247
Table of analyses of,	272
Demonstrations, lectures and,	20
Determination of arsenic in insecticides,	122
Digestion coefficients obtained with poultry, average,	302
Digestibility, tables of, literature consulted,	303
Director, report of,	13
Entomologist, report of,	77
Ethyl esters, distillation of, in vacuo,	133
<i>Ezoascus deformans</i> ,	167
<i>Ezoascus pruni</i> ,	169
Experiments, general,	21
Extension work, future provision for,	20
Fatty acids, crystallization from alcohol,	132
Distillation in vacuo,	131
Purification of,	131

	PAGE
Feed and dairy section, miscellaneous work in,	73
Report of,	67
Feed law,	29
Analytical work under,	67
Compliance with,	68
Execution of,	67
New law needed,	68
Feeds, weight of sacked,	69
Feldspar, non-availability of,	42
Fertilizer ingredients of fodder articles,	266
Fertilizer ingredients, trade values of,	56
Fertilizer law,	28
Fertilizer section, miscellaneous work of,	66
Report of,	54
Fertilizers, analyzed,	55
Collected,	55
Commercial shortages in,	59
Complete, analyses compared with guarantees,	57
Comparative cost of plant food in different grades,	62
Composition of different grades,	61
Grades of,	60
Licensed,	54
Quality of plant food in,	60
Unmixed,	63
Fish, dry ground, quality of,	63
Fodder articles, coefficients of digestibility,	273
Experiments with calves,	301
Experiments with horses,	299
Experiments with poultry,	300
Experiments with ruminants,	274
Experiments with swine,	296
Fodder articles, compilation of analyses of,	247
Composition and digestibility of,	249
Digestibility of American, coefficients of,	273
Fertilizer ingredients in, tables of,	266
Food stuffs, definition of,	69
Fruit and garden crops, compilation of analyses of,	324
Fruits, fertilizer constituents of,	325
Relative proportion of phosphoric acid, potash and nitrogen in,	334
Garden crops, compilation of analyses of,	324
Fertilizer constituents of,	327
Nitrogen fertilizers and potash salts for,	38
Relative proportion of phosphoric acid, potash and nitrogen in,	334
Glassware, examination of,	70
Gössman, Charles Anthony, tribute to,	80
Guanos, compilation of analyses of,	309
Gummosis, histological changes accompanying,	173
Of the peach,	171
On fruit-bearing wood,	172
Probable cause of,	171
Suggestions for treatment of,	174
Hay, top-dressing for,	48
Information, dissemination of,	16
Insecticides, compilation of analyses of,	323
Determination of arsenic in,	122

	PAGE
Iodine method for arsenates,	129
For determining arsenic,	124
Kainit, influence on hay crop,	41
Leaf curl of peach,	167
Lectures and demonstrations,	20
Lime compounds, compilation of analyses of,	310
Lime-sulphur solution, concentrated,	176
Machines, Babcock, inspection of,	70
Mailing lists, numbers in,	19
Manure <i>v.</i> manure and sulfate of potash for hay,	44
Manure, winter, <i>v.</i> spring application of,	48
Marl, compilation of analyses of,	310
<i>Monilia</i> , spore dispersal of,	164
Spores of,	164
Milk, composition of, effect of protein on,	86
Cream and feeds, free examination of,	72
Milk secretion, studies in,	86
Conclusions,	120
Milk yield and shrinkage,	118
Muriate compared with sulfate of potash,	36
Muriate of potash, influence on rowen crop,	42
Nitrate of soda, quality of,	65
Nitrogen, comparison of materials as sources of,	34
Nitrogen fertilizers for garden crops,	38
Relative efficiency of,	35
Nutrients, effect on weight of animals,	89
Onions, nitrogen fertilizers and potash salts for,	40
Organization,	11
Papers, technical, list of,	23
Peach and plum troubles,	161
Peach gummosis,	171
Peach leaf curl, <i>Ectoascus deformans</i> ,	167
Peach shot hole, <i>Cercospora circumscissa</i> ,	170
Phosphates and guanoses, compilation of analyses of,	308
Phosphates, comparison of,	42
Phosphoric acid compounds, quality of,	66
<i>Plowrightia morbosa</i> ,	169
Plum leaf spot, <i>Cylindrosporium Padi</i> ,	170
Plum pockets, <i>Ectoascus pruni</i> ,	169
Potash compounds, quality of,	65
Potash, low-grade sulfate, influence on rowen crop,	42
Muriate and sulfate compared,	36
Potash salts for garden crops,	38
Relative value of different,	40
Protein, influence on composition of milk,	86, 109
Influence on milk shrinkage,	119
Influence on milk yield,	86, 90, 108
Publications,	16
Available for distribution,	17
Circulation of,	18
Purification of insoluble fatty acids,	131
Refuse substances, compilation of analyses of,	314
Report of agriculturist,	34
Botanist,	75
Chemist,	51

	PAGE
Report of director,	13
Entomologist,	77
Feed and dairy section,	67
Fertilizer section,	54
Treasurer,	33
Research,	23
Rock, ground, comparative worthlessness of,	64
Rusts, an outbreak of,	144
Seed germination records, tables of,	141, 142
Seed work, 1910,	141
Shot hole effect caused by improperly mixed Bordeaux,	170
Soil test, north acre,	47
South acre,	46
Spinach disease new to Massachusetts,	146
Staff, changes in,	13
Station staff,	11
Strawberries, nitrogen fertilizers and potash salts for,	39
Stump growths, abnormal, conclusions relative to,	159
Experiments in inoculation,	154
Leaves, chemical test of,	157
Relation of root area to intensity of disease,	156
Relation to mosaic disease,	154
Abnormalities of,	149
Sulfate of potash compared with muriate,	36
Summer spray mixture, directions for making,	174
Sweet pea troubles,	145
Tankage, quality of,	63
Top-dressing for hay,	48
Trade values of fertilizing ingredients,	56
Treasurer, report of,	33
Work, lines of,	16

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PART II.,

BEING PART IV. OF THE FORTY-EIGHTH ANNUAL REPORT OF
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JANUARY, 1911.



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GENERAL REPORT OF THE EXPERIMENT STATION.

CONTENTS.

PART II.

	PAGE
Summary of leading conclusions, by the director,	7
Top-dressing permanent mowings,	10
General plan,	11
Slag meal and muriate of potash both with and without nitrate of soda,	12
Slag meal and low-grade sulfate of potash both with and with- out nitrate of soda,	13
Slag meal and high-grade sulfate of potash both with and with- out nitrate of soda,	13
General observations on results,	14
Method of applying fertilizers,	17
Top-dressing pastures,	18
Conditions under which likely to be profitable,	20
Materials used in top-dressing,	21
Season for top-dressing,	23
Alfalfa in Massachusetts,	24
Number of crops per year, and yield,	24
Conditions essential to success with the crop,	25
Topography,	25
Soil,	25
Necessity for lime,	26
Fertilizer requirements,	26
Seeding to alfalfa,	27
Season for sowing,	27
Preparation of the soil,	28
Nurse crops for spring sowing,	29
Preparation for summer sowing,	29
Date of sowing,	29
Alfalfa seed,	30
Quantity of seed,	30
Inoculation,	30
Diseases of alfalfa,	31
Harvesting alfalfa,	32
Top-dressing alfalfa,	33
Secondary value of alfalfa,	33

	PAGE
Experiments relating to the prevention of the clogging of drain tile by roots,	35
Results of pot experiments,	36
Experiments in boxes,	39
The clogging of drain tile by roots,	43
The spraying of trees,	47
Shade tree troubles,	52
The chestnut disease (<i>Diaporthe parasitica</i>),	56
Crown gall,	58
Fusarium disease of cucumbers and other plants,	62
Condition of fruit trees in general,	66
A new type of spray nozzle,	69
Distillery and brewery by-products,	72
Distillers' dried grains,	72
Brewers' dried grains,	76
Malt sprouts,	80
The feeding value of apple pomace,	84
The effect of protein upon the production and composition of milk,	87

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION
OF THE
MASSACHUSETTS AGRICULTURAL COLLEGE,
AMHERST, MASS.

TWENTY-THIRD ANNUAL REPORT.
PART II.

SUMMARY OF LEADING CONCLUSIONS.

WM. P. BROOKS, DIRECTOR.

The papers included in this part of the annual report cover a wide variety of subjects, and many of them are of such a character that the conclusions cannot be briefly stated. A full list of the papers is included in the table of contents, and in cases where deemed desirable the principal sub-topics are included. The papers themselves are concise, and should be read in full by those interested in them. Some of the more important conclusions may be stated as follows:—

1. Profitable hay crops may be produced in permanent mowings by top-dressing with fertilizers only.

2. A combination of slag meal and a potash salt produces hay made up chiefly of Kentucky blue grass and white clovers. The addition of nitrate of soda in amounts varying from 150 to 200 pounds per acre is usually profitable. The hay produced ranks exceptionally high in nutritive value, especially where the slag meal and potash only are used.

3. The use of slag meal and low-grade sulfate of potash is strongly recommended as a top-dressing for pastures. In experiments continuing two years it has profoundly modified the character of the herbage, the most striking change being a re-

markable increase in the proportion of white clover. It is estimated that the amount of feed now produced is at least three times as great as that on the part not top-dressed.

4. Experiments and observations lead to the conclusion that alfalfa can be successfully grown in Massachusetts. Experiments with the crop are urged. The type of soil, and the method of fertilization and sowing believed to be best are described.

5. It has been found that either excelsior or sawdust first saturated with creosote and packed about the joints of drain tiles prevents the entrance of roots, while at the same time the treatment seems to protect the materials used from decay.

6. The conditions under which roots are likely to penetrate drain tiles are described, and observations are presented which indicate under what conditions the roots of trees are found to be particularly dangerous.

7. Spraying shade trees by the methods first perfected for fruit trees is found to be exceedingly costly. The equipment essential both for satisfactory work and to insure the least possible cost is described. Briefly, powerful machinery capable of maintaining a pressure of 200 to 250 pounds per square inch and special types of nozzles are recommended.

8. Some of the more important of the agencies acting unfavorably on our shade trees are described. The more important are contact with wires of telephone, electric light and trolley lines, putting in of water mains and gas pipes, marked deficiency in rainfall and severe climatic conditions. These appear to have caused extensive root killing and gradual death of the trees, while both sun scald and sun scorch have seriously injured some species. The methods of distinguishing between injuries due to the several causes are carefully presented.

9. The fact that the chestnut disease seems to be gaining a foothold in Massachusetts is stated, and the localities are mentioned where it has been found. It is suggested that the unfavorable condition of the trees due to climatic causes may have rendered them peculiarly susceptible. Owners of chestnut lumber of merchantable size where the disease is found are advised to cut at once.

10. The extent to which crown gall affects fruit trees, and the nature and probable seriousness of the disease are dis-

cussed. The importance in the purchase of nursery stock of securing trees from localities free from this disease is urged.

11. The occurrence of a fusarium disease of cucumbers and allied plants, the first symptom of which is wilting which usually results in the death of the plant is pointed out. This at present affects chiefly hothouse crops, but in some localities is found in out-door crops. In the case of hothouse crops, excessive crowding and forcing seem to produce plants with tissues peculiarly susceptible. Growers are advised against such treatment.

12. The fact that large numbers of fruit trees of all kinds are in unsatisfactory condition due to unfavorable climatic causes, and the presence of San José scale is pointed out. The gradual death of the feeding roots due to the excessive drought and extreme cold, the presence of sun scald often followed by canker are among the more important results. Methods of treatment are suggested.

13. The essential features of a satisfactory nozzle for spraying, especially the larger trees, are described; and briefly stated, the most essential points appear to be the capacity to throw the material long distances and yet to break it into a mist-like spray. A nozzle believed to be a great improvement on any type previously made is described and illustrated.

14. The general character, digestibility and the best methods of use of distillery and brewery by-products are stated, and rations for different classes of farm animals are suggested.

15. The composition, digestibility and feeding value of apple pomace lead to the conclusion that if used in a balanced ration about four pounds of the pomace will equal in value one pound of good hay.

16. The minimum digestible protein needed daily by a cow weighing 1,000 pounds and yielding 20 pounds of milk is about 1.4 pounds; but an increase of about 35 to 50 per cent above this amount seems likely to yield profitable returns. For a 900 pound cow giving 12 quarts of milk per day about 1.8 pounds of digestible protein in the feed daily should be satisfactory. An increase in the protein above the minimum does not appear to affect the composition of the milk.

TOP-DRESSING PERMANENT MOWINGS.

BY WM. P. BROOKS, DIRECTOR.

Between the County Road and that portion of the college estate where the dormitories stand lies an area of about 30 acres which is treated as a part of the campus. It is crossed by numerous foot paths and portions of it are occasionally used for company or battalion drill. The surface is rolling and the soil of somewhat variable character; for the most part, however, it is a strong retentive loam, well suited for grasses and clovers. The greater part of this area has certainly not been plowed during the past twenty-two years and probably not for a considerably longer period. It was in 1889 that the writer of this article first became responsible for its management. At that time much of it had the appearance so common throughout New England of a somewhat neglected mowing, although it was much more productive than such mowings usually are. The prevalent species of grass were Kentucky blue and sweet vernal. In places there was considerable orchard grass, and meadow fescue was abundant especially in the moister places. Whiteweed (*Chrysanthemum leucanthemum*) was extremely abundant in all the drier portions. Dandelions, buttercups and common plantain were very abundant in places. Some portions of this area have been plowed and reseeded during the period intervening since 1889, but on most of it an effort has been made both to eradicate the weeds and to improve the product both in quality and quantity by top dressing without plowing and reseeded. This seemed desirable in view of the preference of college authorities to treat this area like a campus rather than as farm land.

The most effective method for the eradication of the whiteweed has been found to be early cutting to prevent ripening of seed, and top dressing with materials favorable to the

clovers and grasses. In such portions of the area as have been plowed and reseeded, it has always been found that we had a crop of whiteweed to contend with. Undoubtedly the soil, formerly rather indifferently managed, like that of so many of the New England farms, is heavily stocked with seeds of this as well as of many other weeds, and every time it is turned over conditions have been made right for the germination of some of those which have previously been buried too deeply to germinate.

The statement of the conditions affecting this area must have made it apparent that they do not afford a satisfactory basis for close comparison on limited areas. The total area involved, however, is so large that the unequalities and disturbing conditions which have been referred to are somewhat equalized and it was therefore thought to be worth while a few years since to undertake comparisons between different fertilizer combinations with a view to affording at least object lessons on the possibilities of modifying and improving the herbage in permanent grass land by varying use of fertilizers.

GENERAL PLAN.

In each of the principal sections into which the area is naturally divided by roads and principal walks, a few half-acre sections were laid off and throughout the period of the experiment, which is now some six years, these have received no fertilizer whatever. In two of the natural subdivisions of the area, plots of substantially one-half acre each have been laid off and these throughout the entire period have been fertilized annually with nitrate of soda only at the rate of 150 pounds per acre.

On the balance of the entire area basic slag meal has been applied annually at the rate of 500 pounds per acre. This on different sections of the area has been used in connection with the different leading potash salts as follows:—

(1) On that portion of the area lying north of the "Cross Walk" so-called, the potash salt used is muriate at the rate of 150 pounds per acre.

(2) On that portion of the area south of the Cross Walk

and west of the college pond and the stream which runs into it, high grade sulfate of potash is used at the rate of 150 pounds per acre.

(3) On the balance of the area which lies south of the Cross Walk and east of the college pond and stream, the potash salt used is the low grade sulfate at the rate of 300 pounds per acre.

With each of these differing combinations we are applying nitrate of soda on about one-half of the total area to three substantially equal plots. The rates respectively are 150, 200 and 250 pounds per acre.

Owing to the large area covered by these experiments, and the varying conditions as to weather, often showery, in which hay must be handled, it has been found difficult to obtain weights which are strictly comparable. The general results have, however, been clearly apparent, and the following figures, based upon such weights as have been taken during the past three years, in a measure indicate what they have been.

1. SLAG MEAL AND MURIATE OF POTASH BOTH WITH AND WITHOUT NITRATE OF SODA.

In the section of the field where these fertilizers have been used, the yields on the plots to which no fertilizer has been applied have varied between 867 and 1,833 pounds per acre. The average for the past three years has been 1,419 pounds per acre.

Top-dressing with slag meal and muriate of potash produced an increase in crop which has varied during the past three years from 1,588 to 1,902 pounds per acre. The average increase has been at the rate of 1,714 pounds per acre. The total crop produced where slag meal and muriate of potash have been applied as top-dressing has averaged 3,133 pounds per acre.

The gain resulting from top-dressing with nitrate of soda at the rate of 150 pounds per acre in connection with the slag and muriate of potash has varied between 557 and 1,205 pounds per acre.

The use of 200 pounds of nitrate of soda per acre has produced an increase varying from 543 to 2,775 pounds, the average for the past three years being 1,419 pounds per acre.

The use of 250 pounds of nitrate of soda per acre in connec-

tion with slag and muriate of potash has produced an increase varying from 736 to 2,265 pounds per acre, the average being 1,283 pounds per acre.

The figures above given have all referred to the first crop. In years characterized by normal rainfall these fields have always produced a moderate crop of rowen, but the past two seasons have been so abnormally deficient in rainfall that the rowen crops have been small, — in some years, indeed, so small that the fields have not been cut. The amount of rowen produced on plots where nitrate of soda is used in connection with the slag and potash has been less than where the slag and potash alone have been used. This difference, it will be readily understood, is due to the fact that clover is relatively more abundant on those portions of the field where slag and potash alone are applied.

2. SLAG MEAL AND LOW-GRADE SULFATE OF POTASH BOTH WITH AND WITHOUT NITRATE OF SODA.

It has so happened that we have but few weights that can be regarded as entirely reliable pertaining to the results on the field where these fertilizers are employed; but examinations of the fields at various times have shown that the result of the employment of slag and low-grade sulfate of potash alone has been a remarkable increase in the proportion of white clover, which has attained a height and luxuriance that the writer has seldom seen equaled. The increase in crop resulting from the application of this combination of fertilizers has clearly been large. The employment of nitrate of soda in connection with slag and low-grade sulfate of potash in amounts varying from 150 to 250 pounds per acre on different plots has resulted in a very small increase.

3. SLAG MEAL AND HIGH-GRADE SULFATE OF POTASH BOTH WITH AND WITHOUT NITRATE OF SODA.

In one section of the field the plots top-dressed with slag and high-grade sulfate of potash have given a yield of hay during the past three years varying from 2,732 to 3,866 pounds per acre, the average being 3,351 pounds per acre.

In this field nitrate of soda is used on one plot in connection with the slag meal and high-grade sulfate of potash at the rate of 200 pounds per acre. This has given an increase, as compared with the plots to which the slag and potash alone are applied, varying from the insignificant amount of 26 pounds to 3,375 pounds per acre in one year. The average increase for the three years was at the rate of 1,479 pounds per acre.

In another section of the field slag meal, high-grade sulfate of potash and nitrate of soda in three different amounts have been applied. The increases produced during the past three years have been at the following rates per acre:—

For the slag, high-grade sulfate of potash and 150 pounds of nitrate of soda per acre, 2,730 to 4,220 pounds, the average being 3,279 pounds.

For the slag, high-grade sulfate of potash and 200 pounds of nitrate of soda per acre, 2,460 to 2,960 pounds, the average being 2,710 pounds.

For the slag, high-grade sulfate of potash and 250 pounds of nitrate of soda per acre, 2,080 to 5,470 pounds, the average being 3,747 pounds.

GENERAL OBSERVATIONS ON RESULTS.

The character of the vegetation has been greatly influenced by the system of management which has been followed. The most marked effects are the following:—

(1) The amount of white weed produced has greatly decreased in all portions of the field which have been top-dressed, and especially on those which have been top-dressed without reploting. The same is true, though to a somewhat less extent, concerning the buttercups and plantain. The dandelions, which come up very early in the spring, before the grasses and clovers have made much growth, are still relatively abundant.

(2) On those parts of the field which have not been top-dressed bluets (*Houstonia carulca*) are becoming increasingly abundant, while the yield of hay has become very small, usually varying between 1,000 and 1,500 pounds per acre.

(3) On all parts of the field top-dressed with a combination of slag meal and a potash salt, the clovers have become very

abundant. They appear to be somewhat less abundant on the muriate of potash than on the sulfates, and there seems to be a difference in the relative proportions of white and red clovers on the two sulfates, the former being relatively most abundant on the low-grade sulfate, while the red clover has been most luxuriant on the high-grade sulfate of potash. It should be remembered, in estimating the significance of this observation, that no seeds of any kind have been sown in these fields; and it is further important to keep in mind the fact that the soil conditions, as has been indicated, vary quite widely in different portions of the area under consideration. It may be, therefore, that the differences in proportion of white and red clovers just referred to are due either to accidental conditions or to variations in soil, and not to the difference between these two salts.

(4) The use of slag and either of the potash salts produces on the average an increase in the crop considerably more than sufficient to pay the cost of top-dressing with these materials. The results demonstrate the ability of soils naturally adapted to grass to produce profitable hay crops without frequent re-plowing.

(5) Close observation of the crops produced and of the general conditions prevailing leads to the conclusion that these fields are improving from year to year. The proportion of weeds is decreasing, while that of clovers is increasing.

(6) The use of nitrate of soda in connection with slag meal and a potash salt usually gives a considerable increase in the hay crop, in most cases more than sufficient to pay the cost; but an application at the rate of 250 pounds per acre appears to be in excess of requirements. If the season is characterized by normal or abundant rainfall, the crops receiving nitrate of soda at this rate almost invariably lodge badly, and, as a result the yields are somewhat lessened. During years with abundant rainfall, nitrate of soda at the rate of 150 pounds appears to give as much increase in the crop as is produced by nitrate in any larger amount, and while the yield on 200 pounds sometimes exceeds that produced by the lesser amount, it is the writer's belief that the 150-pound rate for mowings similar to

those under consideration will usually be found most profitable.

(7) The proportion of clover on those portions of the field receiving nitrate of soda in connection with slag meal and a potash salt is somewhat less than where the slag and potash salt are used alone, but the product is still characterized by a liberal proportion of clovers.

(8) The product of these fields has exceptionally high nutritive value. The hay is made up of a large variety of grasses, principally Kentucky blue grass, sweet vernal and fescues, with considerable orchard grass in some portions of the fields. It contains, as has been pointed out, a very large proportion of clover, and it contains also a considerable proportion of a number of different species, some of which have been mentioned, commonly looked upon as weeds. It will be recognized that such a product would not ordinarily sell well in the markets. It is, however, exceptionally palatable to cattle, and it has been noted again and again that milch cows, when receiving it in connection with liberal grain rations, give a considerably larger yield of milk than when fed on the best of mixed timothy, red top and clovers in connection with similar grain rations. This difference seems usually to amount to about 10 per cent. more milk on the product of these permanent mowings. The superintendent of the college farm, who during the past year or two has had some experience in feeding good alfalfa hay to milch cows, and who is a close observer, has recently stated that he believes the product of these old fields to be superior to the best alfalfa hay as a food for milch cows.

The facts to which attention has just been called lead to the conclusion that where the production of hay for market is the object, such a system of management as is used in these fields is not likely to give satisfactory results, but where hay is to be fed to stock on the farm, especially to cows or sheep, the system has much to commend it under certain conditions.

It is not infrequently the case that certain of the fields of the farm lie at such distances from the farmstead that their use in the production of hoed crops is impracticable. It is out of the question to haul manure to them. The conditions affecting

farm labor may render it rather impracticable to break them up and reseed them frequently. Under such conditions, such fields as we are considering on many farms are simply neglected. The product of hay soon sinks to less than a ton to the acre and hardly pays the cost of cutting. For such fields the system of top-dressing with slag meal and a potash salt, either without nitrate of soda or in connection with a small amount of that material is likely to be profitable.

METHOD OF APPLYING FERTILIZERS.

In the experiments to which reference has been made, the fertilizers have invariably been applied in spring, and this will probably, as a rule, be the best season. It should be the rule to make the application at about such time as grass fairly begins to grow, and this in average seasons will usually be between about the 20th of April and the 1st of May.

TOP-DRESSING PASTURES.

BY WM. P. BROOKS, DIRECTOR.

The results obtained in top-dressing the permanent mowings, which comprise a large proportion of the college campus, have demonstrated most conclusively that the character and growth of the forage produced may be profoundly modified by the nature of the fertilizer applied. It was early noticed that the continued, moderate use of basic slag meal and a potash salt had a marked effect upon the proportion of clovers, and therefore upon the nutritive value of the hay produced. This hay is made up largely of Kentucky blue grass and white clover, and is found to be much superior as forage for milch cows to the best grades of hay (composed of timothy, red top, alsike and red clovers) produced in our rotation mowings, these mowings being usually cropped two years in corn and then from two to four years in hay.

These observations led to the belief that similar systems of top-dressing would prove highly beneficial to many of our pastures. These, as is generally recognized, are often of very inferior character. On the average, several acres are required to yield pasturage for a single cow, and this even in the case of pastures free from brush or other obstructions. In the Connecticut valley, especially, in the month of May, when the young grasses and clovers should be making a vigorous growth, producing rich green turf, it is common to find pastures almost as white as the driven snow with a thick crop of bluets (*Houstonia carulea*), while the grasses are making little growth and white clover is scarcely to be found. In many cases close examination shows areas where mosses are replacing the grasses. Such conditions indicate a sour soil, and such pastures will produce relatively little feed.

In the spring of 1909 an experiment in top-dressing was

begun in one of these pastures in the northern part of the town of Amherst, on the farm of Herbert S. Dickinson. The portion of the pasture selected was level and entirely free from brush and stones. It is land which was under cultivation a considerable number of years ago. The soil is made up principally of the finest grades of sand and silt, and is quite retentive of moisture. The amount of feed produced in recent years had been small, and the pasture presented the characteristics above referred to in their most typical development.

Four plots of equal area in a part of the pasture, seemingly of very even quality, were laid off. Plots 1 and 3 received an application of basic slag meal and low-grade sulfate of potash (sulfate of potash-magnesia), mixed together before spreading at the following rates per acre: basic slag meal, 500 pounds; low-grade sulfate of potash, 300 pounds. Plots 2 and 4 were left untreated. The materials referred to were applied in the early spring. Before the end of the first season there was a marked difference in the character of the growth upon the fertilized and unfertilized plots. On the former, white clover was found to be coming in, while the grasses showed a much greener color and more vigorous growth.

The pasture in which these plots lay was heavily stocked with milch cows throughout the summer, and it was observed that they grazed upon the top-dressed plots a much larger proportion of the time than on the untreated plots, or the other portions of the pasture.

In the spring of 1910 the top-dressing of plots 1 and 3 was repeated. The differences of the previous season which have just been referred to became still more marked, and the preference of the cows for the forage produced on these plots became yet more noticeable. As a result of the superior character of the forage produced on the top-dressed plots, and the preference of the cows for feeding upon them, they were kept much more closely grazed throughout the entire season, and were especially far more closely grazed late into the autumn than is favorable to the best development. It is fair to suppose, therefore, that the fertilizers applied would have produced yet more marked effects under more favorable conditions. In

spite of these facts, however, the change in the character of the herbage, shown by examination early in the month of May, 1911, is nothing less than astonishing. In place of the dull, lifeless, moss-infested turf, thickly starred with bluets, we find in these plots a rich, green turf, in which white clover is much the most prominent species. Indeed, so thick is the clover in these plots that in most places it constitutes a perfect mat. This change, it should be pointed out, is the result simply of such modification of the soil conditions as fits it for clovers, for no seed of any kind has been sown. It can safely be inferred that the plots which have been top-dressed are now producing fully three times the amount of feed produced by those which have not been so treated.

From the description of the conditions under which this experiment has been tried it will be recognized that no figures can be presented which will indicate the extent of the improvement produced. An experiment is now being laid out in which two plots of equal area, one to be top-dressed and the other not, will be separately enclosed, and a record of the number of days of pasturage each affords will be kept. It will be understood that until we have this record it is not possible to state whether the improvement referred to has been produced at such cost as to make the system of top-dressing followed financially profitable. It is the belief of the writer, however, that it must have been so.

CONDITIONS UNDER WHICH LIKELY TO BE PROFITABLE.

The fact has been referred to that a large proportion of our pastures is producing relatively little feed. Whether they can be profitably improved by top-dressing is an important question. In a great many of our pastures improvement by top-dressing is the only practicable method, since, owing to the conditions existing, it is impossible to plow them. Not all pastures, however, are in such condition that top-dressing can be advised. It is not believed it will be found profitable except in those cases where the turf is mostly free from foreign growths, such as shrubs, bushes, hardhack (*spiraea*) and ferns. If any considerable proportion of the area is occupied by such foreign

growths, the first step in improvement should be their removal. It has been common among our farmers to cut such vegetation in their pastures from time to time. My observation convinces me that this treatment is usually disappointing in results. At whatever season of the year such vegetation is cut it is likely to spring up again, and it may be cut year after year for a long series of years and still not be exterminated. While the initial outlay is, of course, much heavier, results ultimately much more profitable and satisfactory will, in my judgment, be obtained by uprooting bushes, etc., at the outset of any efforts towards improvement. When cleared of foreign vegetation a pasture may, in many cases with advantage, be harrowed and seeded if the surface is much broken as the result; but if the obstructions have been widely scattered, it may be advisable simply to level the areas dug up in connection with the removal of the foreign vegetation and to seed those areas only. Kentucky blue grass and white clover will be more useful than any other varieties, and will, I think, as a rule be the only kinds desirable. After the surface has thus been cleared, such pastures, as well as those which are now clear, may be expected to repay judicious top-dressing.

It may be here pointed out that improvement of our pastures will not only increase the amount of stock which a farmer can keep, but it will be likely to increase the milk yield of a given number of cows, since in improved pastures the animals will be able to gather sufficient food in a much smaller number of hours, and will have leisure to ruminate, and to convert a larger portion of the feed consumed into milk.

In pastures in which the surface is occupied in considerable measure by rocks, top-dressing is of course likely to prove less profitable than in those which are free from such obstructions. It will be apparent, further, that the more nearly level the pasture the less probability that the materials used in top-dressing will be washed away.

MATERIALS USED IN TOP-DRESSING.

It is believed that the basic slag meal used in the experiments referred to is peculiarly suited to meet the requirements of a

large proportion of our pasture soils. Especially must this be true of those naturally poor in lime, with soils which are retentive of moisture, and where white clover is scantily produced. Slag meal is likely to produce less striking effects in pastures which now produce white clover abundantly, or in those having excessively dry soils. Its special fitness for the improvement of pastures deficient in lime and not now producing white clover is undoubtedly connected with the fact that it is rich in lime. Its tendency, therefore, is to sweeten soils which are naturally sour, and thus to bring them into condition such that clovers can thrive. It is now generally understood that clovers cannot flourish in soils containing free acid. Basic slag meal, moreover, is a relatively low-priced fertilizer, and it may be pointed out still further that it has for many years been profitably used for top-dressing pastures in various parts of Europe, especially in England.

A potash salt, as well as the slag meal or some substitute for the latter, will in almost all cases be required, for without a liberal supply of potash in the soil clovers will not thrive, and a good permanent pasture without white clover is, in our climate, practically an impossibility. There are several potash salts which might be used. Most important among these are the muriate, the high-grade sulfate and the low-grade sulfate. In the experiments described the latter has been employed. The writer was led to select it chiefly because of his observations upon the results of top-dressing with the different potash salts in the permanent mowings referred to at the beginning of this article. It appears to be peculiarly adapted to bring in white clover; but observations upon the permanent mowings, where the different potash salts are under comparison, show that either the muriate or high-grade sulfate also will increase the proportion of white clover. These salts cost rather less in proportion to the actual amount of potash they supply than the low-grade sulfate, and in localities where transportation counts as an especially important item they should perhaps be preferred, since to obtain an equal amount of potash it would be necessary to use them in only half the quantities required of the low-grade sulfate. The writer would, however, call attention to the fact

that the latter supplies a large amount of magnesia as well as potash, and that it is not unlikely that this, while inferior to potash in its effects upon clover, may nevertheless exert an influence favorable to its more vigorous development.

SEASON FOR TOP-DRESSING.

For level pastures it is the writer's belief that top-dressing with a mixture of slag meal and a potash salt had best be done in the autumn, but in all cases where the slopes are excessive it will be preferable to apply the materials in the early spring.

ALFALFA IN MASSACHUSETTS.

BY WM. P. BROOKS, DIRECTOR.

As time passes the number of successful experiments with alfalfa in Massachusetts increases. This is true not alone of the experiments in progress on the station grounds and on the college farm in Amherst, but of experiments which have been conducted by private individuals in various parts of the State as well. The question may arise, Why is the degree of success attending such experiments at present greater than in the case of the earlier experiments? It is the belief of the writer that the answer is, Because we have learned, as a result of our failures and successes, many things to avoid, and what conditions are best calculated to insure success. We now have very little difficulty in securing good catches of alfalfa, and on the station grounds and on the college farm in Amherst are a number of plots of some five or six years' standing which are yet in good condition; so that it would seem that we have not only learned what steps to take to secure a good catch, but also how so to manage as to insure a reasonable degree of permanence.

The writer would not be understood that he is as yet prepared to endorse too exclusive dependence upon alfalfa as a forage crop. He believes that there is still a considerable element of risk, but that at least the crop is worth careful trial.

NUMBER OF CROPS PER YEAR AND YIELD.

Alfalfa makes a more rapid growth in early spring than any other forage crop, unless it be rye. The first crop is usually ready to cut early in June, and at least two additional crops may be counted upon; while in seasons which are exceptionally favorable as to rainfall and other climatic conditions alfalfa may probably be safely cut four times. With three crops per

acre, which number has been the rule here, our yields in good fields have ranged from about $3\frac{3}{4}$ to $5\frac{3}{4}$ tons per acre of well-made hay for the three. Such yields are greater than those which can usually be counted upon from the clovers, or mixtures of grasses and clovers, and since in nutritive value alfalfa considerably exceeds the product of the ordinary hay field, such a yield indicates that the crop, where successful, is of unusual value.

CONDITIONS ESSENTIAL TO SUCCESS WITH THE CROP.

Topography. — Experience and observation convince the writer that fields which have a moderate slope are to be preferred to those which are nearly level. Their superiority is due to the fact that it is relatively easy, in preparing for the crop, to leave the surface of such fields in such shape that water cannot possibly stand upon any part of them, and therefore that ice will never form on the surface. Ice on the surface of an alfalfa field is sure to destroy it, and as it is almost impossible to avoid places which are slightly depressed below the ordinary level, from which there is no outlet, in fields which are nearly level, slopes should be preferred.

Soil. — Alfalfa will succeed upon a considerable variety of soils provided certain conditions exist. First and most important of these is good drainage. The writer is convinced that it would not be advisable to undertake the cultivation of alfalfa in fields in which the water table will usually be found within less than five or six feet of the surface. It is possible that a fair degree of success might be obtained with the water table from three and one-half to four feet below the surface; but in all cases where the water table is at this level the percentage of water in the surface soil is likely to be relatively large, unless the soil is of exceedingly coarse texture; and with too large a percentage of water in the surface soil heaving and winter-killing will be more probable than on soils with less moisture at the surface. What has been said suggests that the necessary depth of the water table below the surface may vary somewhat with the texture of the soil above it. Where this is coarse the water table nearer the surface than the extreme depth above in-

licated may not be productive of injurious consequences, since the capacity of the soil to conduct and to retain moisture is relatively small.

On the other hand, although alfalfa is a very deep-rooted plant, observation during the past two years, which has been characterized by exceptionally small rainfall, leads to the conclusion that it is quite sensitive to the injurious effects of extreme drought, and that soils and sub-soils of excessively coarse texture, with a water table far below the surface, can hardly be expected to give satisfactory crops. Soils which would be ranked as well adapted to grasses and clovers, provided the drainage conditions are such as have been indicated, seem likely to give the most satisfactory crops of alfalfa.

Necessity for Lime. — Alfalfa is a lime-loving crop. Success in producing it is impossible if the soil is poor in this element. The soils in many parts of this State are characterized by relative deficiency in lime, and in most localities, therefore, a moderate application of lime is necessary in preparing for alfalfa. The quantity needed will usually range between one and one-half and two tons per acre. There are a number of different forms of lime which may be made to serve the purpose. On the heavier soils freshly slaked lime or fine-ground lime will best meet requirements, since these forms of lime will at the same time improve the mechanical condition and correct the chemical faults. On the lighter soils, of coarser texture, and especially if these are deficient in organic matter, air-slaked lime or marl may be preferable. For the ordinary loams some of the various forms of so-called agricultural lime, or waste lime which has slaked in heaps at the kilns, will meet the requirements.

Fertilizer Requirements. — Alfalfa, in common with other legumes and clovers, does well only when there is a liberal supply of potash in available forms in the soil, and potash fertilizers should be freely used in preparing for alfalfa.

While the crop seems to depend in most marked degree upon an abundance of lime and potash in the soil, it is not indifferent to a supply of other plant food elements, and if the soil is not

naturally abundantly stocked with phosphoric acid, this element must be furnished.

A large amount of nitrogen in the soil cannot be regarded as essential; indeed, from some points of view it is undesirable; but, on the other hand, unless there is a fair amount of nitrogen in available forms in the soil the crop will fail to make a good start. When well established under the right conditions it can, like other legumes, draw the needed nitrogen from the air.

The application of manure to soils which are to be used for alfalfa in preparing for the crop will, it is believed, in general be found inadvisable. Manure, it is true, helps to give the soil the desired texture, and increases the proportion of humus which may be beneficial, but it usually carries many weed seeds, and increases the difficulty of getting a good catch of alfalfa. A free use of manure will, moreover, be likely to increase the competition of the grasses with the alfalfa, enabling these in a measure gradually to crowd the latter out. Manure used rather liberally for crops which immediately precede alfalfa, may, on the other hand, prove quite beneficial, especially on the lighter and poorer soils.

SEEDING TO ALFALFA.

Season for Sowing. — Success with alfalfa has been obtained both by early spring and summer sowing. In the experiments which the writer has carried out the latter has given the best results. If alfalfa is spring sown, it is commonly necessary to sow a nurse crop with it. If this is not done it must, in almost all soils, suffer greatly from the competition of annual weeds which tend to come in so freely in all fertile soils during the spring months. In the one case, then, it must share the soil with a nurse crop, in the other with weeds, and in either case the competition for plant food and moisture is somewhat unfavorable. Further, whether weeds grow up with the crop or whether a nurse crop is sown with it, the alfalfa, when these are removed, is exposed to the intense heat of the sun in midsummer, and if at this time there is a deficiency of rainfall, it almost invariably suffers a serious check.

When alfalfa is sown later in the summer it is possible to sow it alone, since by preparatory tillage the annual weeds, which tend to come in during the early part of the season, can be destroyed. Under these conditions the alfalfa is likely to make a better start than when it must meet the competition either of weeds or a nurse crop. The showers which almost invariably come in midsummer will give, in all except soils of very coarse texture, such moisture conditions as to insure quick germination of the seed.

Preparation of the Soil. — The essentials in the preparation of the soil are such tillage operations as will produce a fine seed bed and such application of fertilizers as will supply the natural deficiencies. It is a great mistake to sow alfalfa in imperfectly prepared ground. The seed bed should be as perfect as possible, and no amount of labor which is essential to produce a fine surface tith should be spared. While the selection of fertilizers and the amounts of the several materials to be used should of course be varied to suit varying conditions, the writer recommends, as likely to prove satisfactory in the majority of cases, the following kinds and amounts per acre: —

Lime or marl,	1½ to 2 tons.
Basic slag meal,	1,500 to 2,000 pounds.
High-grade sulfate of potash,	250 to 300 pounds.
Nitrate of soda,	100 to 125 pounds.

The following method of applying the fertilizers is recommended: —

- (1) Apply the lime on the rough furrow and disk in.
- (2) Mix together the potash and all except about 200 pounds of the slag meal, apply after disking the land once and work in deeply by further disking or harrowing.
- (3) Just before the final harrowing-in preparation for the seed, mix together the 200 pounds of slag meal and the nitrate of soda, and spread this evenly and harrow it in.

In case the alfalfa is to be spring sown, apply the lime in the autumn, and if convenient apply the mixture of slag meal and potash also in the autumn, although this is less essential. It may be applied, if preferred, just before the first disking in the spring.

In the case of summer sowing, apply the lime in the early spring and immediately disk it in. A little later apply the mixture of basic slag meal and potash and disk or harrow this in deeply, and spread the nitrate of soda and 200 pounds of slag before the last harrowing.

Nurse Crops for Spring Sowing. — For nurse crops for sowing with alfalfa in spring beardless barley and oats are among the best, barley being the safer nurse crop of the two, as it is far less liable to lodge. Whichever of the two crops is selected, the amount of seed should not be too great. A bushel of barley or a bushel and a half of oats to the acre will usually be sufficient.

Preparation for Summer Sowing. — It is sometimes possible to secure good conditions for summer sowing on land used the same season for the production of a crop; but it is desirable, if this is undertaken, that the crop be one permitting of absolutely clean culture, and which can be harvested not later than about the middle of July. In the case of all soils not already highly productive and in good tilth, a summer fallow, with most careful tillage in preparation for alfalfa, is highly desirable. The very best results which have been obtained in the writer's experience have followed this method of preparation. The land is plowed in early spring, the lime and fertilizers applied as indicated above, and thereafter the soil is worked with the harrow at intervals sufficiently frequent to destroy the successive crops of weeds which are likely to start. The frequency of harrowing advisable must, of course, vary with conditions, but will usually be once in about ten days to two weeks.

Alfalfa is sometimes sown in late summer in fields of growing corn, and sometimes the results by this method are satisfactory. In the States of the middle west, where it has been most largely tried, there have been numerous failures. It is, perhaps, needless to say that if this method is to be tried the corn should not be planted over thick, its cultivation should be level and most thorough, and in fertilizing for the corn crop the needs of the alfalfa which is to be sown later in the summer must not be overlooked.

Date of Sowing. — In spring sowing, alfalfa should be put in just as early as the soil can be brought into condition. For

summer sowing the best conditions will usually occur about July 25 to August 10. If sowing is deferred much later than the middle of August, the alfalfa does not get sufficiently well rooted nor make sufficient growth to go through the winter successfully. When sown about the last of July the crop frequently attains a height of a foot before cold weather, and should on no account be cut, as this growth is needed for winter protection.

Alfalfa Seed.—No pains essential to procuring the best possible seed should be spared. Numerous varieties of alfalfa have been introduced and extensively tried in different parts of the country, and a number of them have been under trial in this experiment station. So far, however, as the experiments of the writer enable him to judge, none of the newer varieties appears to be superior to the common type of alfalfa as cultivated in our northwestern States. Northern-grown seed, bright, heavy, free from impurities of all kinds, and especially free from dodder (a parasite which, if present in any amount, will destroy the crop), should be looked for. The seeds of dodder are extremely minute, and will be easily overlooked by the casual observer. The dealer should be asked to guarantee freedom from seed of this parasite, and in all cases of doubt samples should be sent to the experiment station for examination.

Quantity of Seed.—As is the case with all farm seeds, the quantity which may wisely be sown varies with conditions, and should be greater in proportion as these are unfavorable. With the best conditions for germination, and with seed of the best quality, about 25 to 30 pounds per acre should be sufficient. A thick stand of plants is, however, of the very highest importance. When the alfalfa is thin, weeds, grasses and clovers come in, and the latter especially tend to crowd the alfalfa out. It is the belief of the writer that the quantity of seed should therefore, even under the best soil conditions, be not less than 30 pounds to the acre, and in seeding with corn it would seem to be advisable to use from 5 to 8 pounds more.

Inoculation.—It is now generally understood that legumes have the capacity to take nitrogen from the air only in partnership with bacteria which live in nodules on their roots. These

bacteria are not ordinarily present in soils where alfalfa has not previously been grown. A possible exception is afforded by soils where sweet clover (*Melilotus alba*) is indigenous and abundant. This plant, however, is comparatively rare in Massachusetts, and in almost all cases, therefore, it is advisable to bring in the appropriate alfalfa bacteria by inoculation. Two methods may be followed:—

(1) Soil from a well-established alfalfa field where root nodules are abundant may be worked into the soil where the seed is to be sown. The quantity needed will range between about 300 and 400 pounds per acre. Care should be taken that soil which is to be so used be not long exposed to the light nor allowed to dry excessively. It should be spread, if possible, towards night or on a cloudy day, and immediately harrowed in.

(2) A culture may be used. A number of different artificial cultures are now produced and recommended for the inoculation of the different legumes. The United States Department of Agriculture sends out a material known as "Nitroculture." This is in fluid form. An American agency of a European company produces and offers a jelly-like culture known as "Nitragin." A New Jersey company sends out a culture known as "Farmogerm," which is also a jelly-like material. The writer's recent experience has been mainly with the latter, and the results have been satisfactory. Full directions for the use of cultures accompany every package, and these should be exactly followed.

DISEASES OF ALFALFA.

The only disease which has been serious in the experiments in growing alfalfa in this State is a species of rust or leaf-spot. This seems to be most likely to affect newly sown areas. The spots referred to are yellow in color. They are likely to appear first on the lower leaves of the plant; but in cases of bad infection the trouble rapidly spreads from leaf to leaf, and the entire foliage of the plant soon becomes yellowish in color and the leaves begin to fall. If the disease is allowed to take its natural course the plants, especially if young, are greatly enfeebled. Grasses and clovers under these conditions in many fields will be likely to displace the alfalfa.

No preventive treatment is known, but the disease can be checked and a healthy growth re-established by the simple process of cutting. This should be the rule whenever alfalfa, young or old, begins to show leaf-spot abundantly, and when the trouble is rapidly spreading towards the upper leaves it is best to cut at once. If the field is newly sown, and the crop only a few inches high, the cutting should not be too close to the ground. What is cut may be allowed to lie where it falls. Should the growth which follows in turn become infected, the trouble should be met in the same way, that is, the alfalfa should be recut.

In the case of an established field of alfalfa, if leaf-spot has become abundant the crop had best be cut and fed, or made into hay at once, even although the alfalfa may not have come into bloom.

HARVESTING ALFALFA.

Alfalfa should usually be cut while in early bloom. If the stems close to the root be examined at this time it will be found that they carry buds which are beginning to develop. This indicates that it is ready to make a second crop. If allowed to stand much beyond the period of early bloom the plants start much less promptly after being cut, and the total yield of the season will be relatively small.

The last cutting in any season should not be too late. It is desirable that there should be a considerable growth remaining on the field for winter protection.

Alfalfa may sometimes, with advantage, be fed green; it has been successfully ensiled, but, as is the case with other legumes, the resulting silage is strong in flavor and not wholly satisfactory. It is preferable in most cases to make the crop into hay.

After cutting, alfalfa should be allowed to lie, with possibly one turning, until it is wilted. It should then be put into windrows and then into cocks, where it should be allowed to remain until cured. Hay caps are very desirable; indeed, almost a necessity for entirely satisfactory results. The length of time which alfalfa must remain in the cock will vary greatly with the weather. If this is showery or rainy it of course cures

slowly, in which case, in order to avoid injury to the plants below, the cocks should be moved. It is desirable, as in the case of clover, which is often similarly handled, to remove the caps and open and turn over the cocks on the morning of a good day, when it is judged to be sufficiently cured to be put in.

TOP-DRESSING ALFALFA.

If the crop has been successfully inoculated, and the nodules which have been referred to are abundant on the feeding rootlets of the plants, it is not ordinarily necessary to top-dress with materials furnishing nitrogen; or at least, if such materials are at all required, as may be the case upon soils which are naturally very poor and light, they should be used only in moderate quantities.

Top-dressing with manure cannot as a rule be recommended, for this will increase the tendency of grasses and clovers to come in. It is better to depend upon chemical fertilizers, and in order to secure large crops for a series of years the more important mineral elements of plant food must be supplied in abundance. The following mixture of materials is recommended, per acre, annually:—

	Pounds.
Basis slag meal,	1,200 to 1,500
High-grade sulfate of potash,	250 to 350

Or, in place of the latter, low-grade sulfate of potash, 500 to 700 pounds. This mixture may be applied either in the autumn or in very early spring.

SECONDARY VALUE OF ALFALFA.

Alfalfa, when successful, as has been pointed out, is not only a valuable forage crop, furnishing large yields of highly nutritious forage in proportion to area, but is also a crop of much importance because its introduction will mean much improvement in the soils on which it is grown. Wherever alfalfa is successfully cultivated the soils are sure to be rendered more productive. This improvement is a consequence, first, of the

deep sub-soiling due to the penetration of the great tap roots of the plant; and second, to the accumulation of nitrogen in the roots and stubble, drawn in the first instance from the air. It will be understood that when an alfalfa sod is plowed, and the roots and stubble decay, the large amount of nitrogen which they contain becomes available to succeeding crops.

EXPERIMENTS RELATING TO THE PREVENTION OF THE CLOGGING OF DRAIN TILE BY ROOTS.

BY G. E. STONE AND G. H. CHAPMAN.

For the past three years experiments have been carried on in our conservatory for the purpose of studying the effects which various antiseptic substances would have in preventing roots of different kinds from entering drain tile. The clogging of drain tile by roots is a serious matter, many drains being rendered useless in a short time. The only remedy in such cases is to dig up the tile, clean it out and lay it over again. This is expensive and unsatisfactory in any case, particularly so with sewer pipes or the drainage tile under steam-heating conduits.

Our experiments were carried on in different ways. In one series we buried 3-inch Akron tile vertically in boxes containing soil. The lower ends of these tile were cemented and the tile filled with water to the joints. The joints were then calked with various antiseptically treated fibers, and the antiseptic substances with which the joints were treated proved quite effective in preventing the access of roots to the tile.

Another method consisted in growing various plants in small pots, the bottoms of which were filled with chemically treated fibers. The pots were then filled with soil and planted with different seeds. It is well known that plants when grown in small pots soon fill the soil with roots, which seek new sources of supply by passing through the hole at the bottom of the pots. Our experiments were arranged in such a way that the roots, in order to accomplish this, would have to pass through or around the chemically treated fibers, and the ability of these fibers to prevent root development constitutes a test of their efficiency. This method proved quite satisfactory. After a

year or two trial of the above method we devised another, which has also proved to be very satisfactory. This consisted in growing plants in boxes, the bottoms of which were covered with wire netting. Over the wire there was spread about an inch of variously treated or untreated fibers, as some checks were left in these experiments. The boxes were then filled with soil in which various plants were grown. They were placed over large trays filled with water, a space being left between the bottom of the wire and the surface of the water for the purpose of observing the roots. The object of this test, as before, was to determine what substances would prevent roots from penetrating into the water below.

RESULTS OF POT EXPERIMENTS.

These experiments were started in the spring of 1908 and were conducted along the lines previously described; that is differently treated fibers were packed into the bottom of common flower pots for the purpose of determining what effect they would have on root penetration.

About 1 inch of the fiber was packed in 4-inch pots. In some of the pots the fiber was packed rather tightly and in others laid in loosely. On top of the fiber were placed 3 or 4 inches of soil and clover and grass seed sown; in some cases willow cuttings and other plants were also used. Several series of pot experiments were conducted. In all cases the pots were placed in saucers or in galvanized iron trays containing about half an inch of water, although the pots were watered occasionally from the top.

The substances used in these pot experiments and the treatment given are as follows:—

- Excelsior and creosote.
- Excelsior and Carbolinum.
- Sawdust and creosote.
- Sawdust and Carbolinum.
- Asbestos and creosote.
- Asbestos and Carbolinum.
- Asbestos and arsenate of soda.
- Oakum and creosote.
- Oakum untreated.
- Cocoa fiber and creosote.

The excelsior was the ordinary kind used for packing, and when boiled with creosote absorbed it very readily. A coarse sawdust, principally pine, was used in these experiments. Ordinary asbestos fiber was used, and the oakum came in large masses, and was the same as that used by plumbers in calking joints. Cocoa fiber is a refuse product from the manufacture of fiber mats, and was obtained from the Heywood Manufacturing Company, Boston. It has occasionally been recommended for mulching plants. In all cases these fibers were boiled for a long time in creosote or whatever medium was used. They were then air dried before using. The excelsior before being used was chopped up into a finer condition, so that it would pack more closely in the pots. The cocoa fiber and the asbestos did not take the creosote to any great extent, both being practically failures in this respect, and the oakum did not take it as well as the sawdust and the excelsior, which proved to be the best in this respect.

The results of this series of experiments in pots may be summarized as follows:—

The untreated oakum had no appreciable effect in checking root development, the roots growing unharmed in the oakum and penetrating through the bottom of the pots into the water below.

The oakum treated with creosote did not entirely prevent the roots from passing through the oakum to the bottom of the pot. Many of the roots, however, were browned and dead where they came in contact with the treated oakum. The nature of the oakum was such that a less degree of compactness was maintained than in any other of the substances.

Asbestos treated with arsenate of soda had no appreciable effect, the roots penetrating the treated fibers freely, due undoubtedly to the solubility of this compound in water.

The asbestos and creosote treatment was more effective, and few if any roots extended through the pots, although there was a healthy root development extending for some distance into the fiber.

Cocoa fiber treated with creosote did not prevent root development to any great extent, the roots penetrating freely unharmed through the bottom of the pot.

Sawdust treated with creosote proved to be one of the best substances for checking the development of the roots. In all but a few cases the roots in direct contact with the sawdust were killed, although in one instance, where the sawdust was not compacted enough, one root developed along the side of the pot without being injured. Where the sawdust was well compacted in the pots all the roots which came into contact with it were killed.

The excelsior and creosote were fully as effective as the sawdust. The excelsior, however, being more loosely compacted, allowed some roots to penetrate further into it before being killed than was the case with the sawdust, but in no case did any of the roots penetrate through or around the excelsior through the hole in the bottom of the pot.

Not quite as good results were obtained from the use of excelsior and Carbolinum and sawdust and Carbolinum as with excelsior and creosote and sawdust and creosote. Both the excelsior and sawdust retained the creosote the best, as was evident from the color and odor as well as from the results of root killing and penetration. A greater compactness of both the sawdust and excelsior would undoubtedly prove even more effectual in preventing root growth.

The substances, arranged as regards their degree of efficiency, may be grouped as follows:—

- Excelsior and creosote.
- Sawdust and creosote.
- Excelsior and Carbolinum.
- Sawdust and Carbolinum.
- Cocoa fiber and creosote.
- Asbestos and creosote.
- Oakum and creosote.

The sodium arsenate treatments were all failures, as this substance seemed to wash out very quickly, and in one case, where asbestos was treated with creosote, 40 per cent. of the roots passed through the hole in the bottom of the pot.

No better results were obtained with asbestos and Carbolinum.

Cocoa fiber failed to absorb and retain the chemicals any

length of time. For this reason it was unsatisfactory. However, in some experiments a large percentage of roots were killed when they came in contact with this substance, especially when the creosote was retained by the fibers.

The creosoted and untreated oakum did not prove of much value.

There was little difference between the excelsior and sawdust treatment; one was about as good as the other, although the excelsior was easier to manipulate. On the other hand, the sawdust was more compact, and this was in its favor. Creosote in these tests appeared to be slightly superior to Carbolineum, but the latter would be an excellent substance for this purpose.

EXPERIMENTS IN BOXES.

A. — Experiments in boxes provided with vertical tile, with one end plugged, have been carried on for two years. In these boxes were grown tomatoes, grass and willows. The boxes were 14 by 14 by 14 inches, and contained about 1 foot of soil. A vertical 3-inch Akron tile extended to the bottom of the boxes, the joints being 4 inches below the surface of the soil. The bottoms of the tile were plugged with cement and the tile was kept filled with water to the level of the joints. One tile was placed in the middle of each of the four boxes, the joints being treated with the following substances: —

- Sawdust and creosote.
- Excelsior and creosote.
- Cocoa fiber and creosote.
- Oakum untreated.

The results of this experiment are as follows: —

The treated sawdust prevented any roots from penetrating the tile, and when there was any attempt made to penetrate the treated substance, the roots turned brown and died.

The creosoted sawdust appeared as good as when first applied, and was characterized by a strong creosote odor.

The results of treatment with excelsior and creosote were practically the same as those with sawdust. In a few cases, however, roots forced their way along the tile to the joint. The

roots which attempted to grow in excelsior were browned and dead. The results obtained from the use of cocoa fiber and creosote were not nearly as good as the two preceding ones. The roots penetrated the fiber and came through into the water. About 35 per cent. of the roots which penetrated the fiber were alive and healthy.

The results obtained from the untreated oakum showed that it had little effect, the roots appearing to be healthy, and not at all injured by this substance.

B. — The experiments described here were made in three boxes, each being 14 inches wide, 22 inches long and 14 inches high. The bottoms of these boxes were covered with $\frac{1}{4}$ -inch mesh galvanized wire. On each wire in one-half of each box there was placed about 1 inch of sphagnum, the other half being covered with some treated material. Box No. 1 had sphagnum 1 inch thick in one end and the same amount of excelsior treated with creosote in the other end. Box No. 2 was likewise provided with untreated sphagnum in one end, the other being filled with sawdust treated with cement. Box No. 3 was treated in the same way as No. 1. These boxes contained about 12 inches of soil, and rested on galvanized-iron trays containing 2 inches of water. A space of about half an inch, however, was left between the bottom of each box and the water in the tray for the purpose of observing the roots. Several crops of tomato and tobacco plants and grass were grown in these boxes, with the results that none of the roots had penetrated through the treated substances into the water in the tray, whereas in every case where untreated sphagnum was employed the root penetration was invariably common.

The results obtained from these various methods of treatment show that it is possible at the present time to prevent root growth by the use of certain chemical substances. Our results seem to indicate, also, that these various treatments possess a lasting effect, and that chemically treated fibers could be used in a practical way to prevent the clogging of drain tile. In these experiments it must be borne in mind that a vast number of roots come in contact with the treated substances, and that ordinarily if these substances had not been there thousands of roots

would have developed and occupied the space given up to the treated fibers; and probably in all cases a large number of the roots would have penetrated through the bottom of the pots into the water below. In only a very few instances did any of the roots in the experiments where creosote was used penetrate to any depth where sawdust and excelsior were used. Practically all the penetration occurred close to the surface of the pot, where the chemically treated fibers were packed rather loosely, and especially in those experiments where excelsior was used.

A more or less thorough calking of the joints of Akron tile with either creosoted excelsior or sawdust would undoubtedly prevent the occurrence of roots in the joints, and consequently in the tile itself. Some sewer pipes have been calked with these chemically treated fibers, but it is as yet too early to state how effectually they may have accomplished their purpose. Akron tiles, or those provided with flanges, are best adapted to treatment. Ordinary land drain tiles, however, are not provided with flanges, and it is a question whether root penetration could be successfully prevented by using these fibers, at least by placing them loosely over the joints. It would be possible and no doubt practicable, however, to clamp masses of treated asbestos or excelsior around the joints of ordinary land tile, which would prove effective. Such clamps could be constructed from heavy galvanized wire, so as to hold the excelsior very firmly around the joint, and at the same time not affect materially the inflow of drainage water. It would be possible, also, to make use of small sections of tile of larger diameter (collars), which could be placed over each joint and the treated fibers packed in tightly around the joints.

Creosote appears to be the best substance with which we have experimented, since it is not only one of the best preservatives, but possesses excellent toxic properties. No doubt there are other fibers than those which we have used, and there are many substances which possess properties toxic to roots, such as tannin, etc.; but many others, like sodium arsenate, wash out quickly and lose their effectiveness in a short time.

From the results of these experiments it would appear that chemically treated fibers would undoubtedly remain for many

years in the soil without serious deterioration, and if this treatment would succeed in doubling or trebling the usefulness of drain tile, it would be well worth while to employ it.

There is also the possibility of killing roots in tile by treatment with chemicals or gases, but little or no attention has been given to this phase of the subject.

Further experiments are being made along this line, and in the mean time it is hoped that more extensive and practical tests can be arranged.

THE CLOGGING OF DRAIN TILE BY ROOTS.

BY G. E. STONE.

Quite frequently trouble is experienced from roots of various trees entering drain tile, sewers, etc., and this often causes much vexation, labor and expense. The Carolina poplar, which is often planted as a shade tree in cities, frequently becomes a nuisance in consequence of its peculiar habit of working its roots through the joints of tile used for sewerage, etc. It is a comparatively easy matter for roots to gain entrance into the uncemented joints of tile, and even when tile is cemented they often manage to crowd in and fill the tile with a mass of roots which eventually clog it and render it useless. Instances are known of roots penetrating even sewers constructed of brick and cement. The roots of other trees besides Carolina poplars are known to be offenders in this respect. Willows, elms, etc., are responsible for considerable clogging of tile drains. There are also many instances even of fungi and algæ clogging up small drains. The writer some years ago had called to his attention a case where *Oscillaria*, one of the blue-green algæ, was constantly clogging tile, much to the annoyance of the landowner. On the Massachusetts Agricultural College grounds they have experienced much trouble with roots of various kinds clogging sewer pipes, and the drain tiles located under the steam pipes leading from the central heating system to the various buildings have become clogged.

In the case of the sewer tile referred to the joints were cemented with Portland cement, nevertheless, the roots gained entrance here and there through some of the joints, and in a short time they developed so profusely as to clog the tile, with the result that it had to be dug up and repaired. The joints of the 6-inch Akron tile underlying the steam-heating pipes are not cemented, and are located 5 feet or more below the surface. In two or three years after the tiles were laid some of them had

become clogged with the roots of elm trees. This clogging prevented the water from flowing through the tile, and caused a dam, as it were, resulting in the water flowing back into the conduit and flooding the steam pipes. A stream of cold water flooding steam pipes is not conducive to the best results, since it causes condensation and a decrease in the temperature of the steam. It is necessary, of course, to leave the joints of Akron tile open when used for the purpose of draining the conduit trench of a central heating and distributing plant, since these pipes must take off the water from the trench and prevent it from coming into contact with the steam pipes in the conduit. As long as the joints remain open it is with great difficulty that the roots of trees, etc., are kept from growing in the tile, and sooner or later it is made ineffective. Tree roots will penetrate tile protected with carefully cemented joints, and become a nuisance, as is shown by the following letter. In the city of Newark, N. J., the Shade Tree Commission has been requested by the department of sewers and drainage to omit the planting of Carolina poplars on streets since the roots of these trees proved to be a nuisance to drains, and the Shade Tree Commission has decided to plant trees which are less of a nuisance in this respect on the streets of Newark in the future. At my request Mr. Carl B. Bannwart, secretary of the Shade Tree Commission, Newark, secured this statement from Edward S. Rankin, engineer of sewers and drainage of the city of Newark:—

Replying to your letter of the 20th inst., we find that the roots go through the joints of tile pipe even when carefully cemented, and the trouble seems to be increasing. In 1909 we had 15 stoppages caused by roots; for the first eleven months of 1910, 23, of which 5 occurred in the month of November. These stoppages were all in house connections, and in addition to these we have also had a number of cases in our main pipe sewers. The roots after penetrating the pipe seem to spread out and practically fill the whole pipe. I have no way of knowing how long a time it takes for these roots to grow. To the best of my knowledge we have had no trouble with any of our brick sewers. The trouble seems to have been caused in all cases by poplar trees.

There recently came to our attention, through Mr. C. N. Minott, field superintendent on the gypsy and brown-tail moth work, a notable case where the small root from a pear tree had

gained entrance to a drain tile. This tile was 12 inches in diameter, and was laid about seven years ago to take the seepage waters from a reservoir located in the town of Belmont, Mass. This pipe passed through land owned by the Hittinger Brothers of Belmont, well-known and extensive market gardeners, and part of it passed near a pear orchard. There was a constant flow of water through this tile summer and winter, but the pipe was never full. At the time the tile was laid the joints were not cemented, and of course there was an excellent opportunity for roots of various kinds, if so disposed, to penetrate the joints of the pipes and secure an abundant supply of water. During November, 1909, about seven years after the drain pipes were installed, it became necessary to dig up a large part of them on account of their inefficiency and replace them. It was found on digging up this tile that it was badly congested by profuse root growth. A careful examination of the location showed that this growth of roots originated from a single off-shoot of a pear tree located some 7 feet away. This enormous mass of pear roots was removed from the tile and carefully laid aside, and we gladly accepted Mr. Minott's offer to present this to our museum. Mr. Minott later packed and shipped this to us, at the same time furnishing us full data concerning it. This mass of roots was found to measure 61 feet in length. Only a single root entered the tile, it having a diameter of about $\frac{1}{2}$ or $\frac{5}{8}$ of an inch. This root, when it entered the tile, immediately subdivided into innumerable rootlets, and these were again divided into countless smaller roots. At the time the tile was dug up and the roots removed the drain had been in operation seven years, although a cross-section of the root, together with an examination of the annular rings, where it entered the tile, showed that it was only five years old. Therefore it took only five years for this mass of roots to clog up a 12-inch tile.

The maximum diameter of these roots in the dry state is 6 or 7 inches, but when alive and flourishing in the tile their diameter exceeded this. The roots as they reached the laboratory had a decidedly bad odor, showing that if no sewage were present in the tile there was certainly a considerable amount of organic matter in the seepage, derived from the soil or some other source, which proved of value as plant food. Soon after the

specimens arrived at this laboratory they were spread out on the floor and measured. This was done by Mr. R. D. Whitmarsh, and was accomplished by laying out on the floor sections 5 feet in length. The number of roots in each 5-foot section was counted. This was multiplied by the length of the section and the whole tabulated (see table). The mass of roots was just 61 feet long, and the total length is 8,498 feet, equal to 1.61 miles in length. Adding to this the numerous small roots, which range from a few to several inches in length, and which were disregarded in our section count, the total length was estimated to be over 2 miles. This enormous development from a single root of a pear tree located 7 feet away is greatly in excess of what would take place if the roots were in the soil, since the conditions of the drain tile stimulate root development very materially. However, the root system of any tree or shrub is far in excess in length and area of what the layman imagines. The profuse growth of roots in water is also seen in cases where old wells become filled with root growth, but the pear tree root in question is one of the best examples which has ever come to our notice of root development in drain tile.

Table showing the Growth of Pear Tree Roots in Drain Tile.

NUMBER OF SECTION.	Length of Section (Feet).	Number of Roots in Section.	Length of Roots in Section (Feet).
1,	5	34	170
2,	5	41	205
3,	5	73	365
4,	5	153	765
5,	5	199	995
6,	5	313	1,565
7,	5	373	1,865
8,	5	447	2,235
9,	5	141	705
10,	5	53	265
11,	5	31	155
12,	5	36	180
13,	1	28	28
Total,	61	-	8,498

THE SPRAYING OF TREES.

BY G. E. STONE.

The great value and economic importance of spraying shade and fruit trees have resulted in placing on the market a large variety of fungicides and insecticides and types of machinery. Massachusetts has unfortunately been obliged to spend more money in spraying than any other State, and many towns and cities in the eastern part of the State, where the brown-tail and gypsy moths are so prevalent, spend thousands of dollars yearly in spraying.

Besides the larger spraying enterprises which are being carried on under the supervision of the Gypsy and Brown-tail Moth Commission, much private work is being done, and hundreds of tons of arsenate of lead are used annually in this work. While the above-named pests have not at present invaded the center and western part of the State to any extent, the presence of other pests necessitates spraying our shade trees.

The question of economical spraying on a large scale is an important one, and for a long time there has been a need for more efficient and cheaper methods. The writer, who has for many years had experience as tree warden, has had unusual opportunities to observe the work being done along this line in Massachusetts, and has felt the great necessity for improvements in the methods of spraying. It has often been a question whether our towns and cities can afford to use the methods which are recommended and practiced by the best orchardists for shade trees. The aim of the orchardists is to cover every part of the tree which needs protection with a very fine mist spray. This method cannot be too closely followed by orchardists, since it is not necessarily expensive when only orchard trees and small fruits and crops such as potatoes are concerned. When how-

ever, we have to spray large elms, the question is an entirely different one.

A few years ago some large elms located in the public square in one of our cities were sprayed by the same methods used by the best orchardists, at an expense of something like \$16 per tree. These trees, to be sure, were unusually large, but the cost was so great that in our opinion it set a limit to the amount of spraying which should be undertaken by such methods. Most of the former spraying of shade trees was done by this very expensive method at a cost of \$1.50 upwards for trees 14 to 18 inches in diameter. In much of this early spraying the Vermorel, Ware or similar fine spray nozzles on poles were used, and spraying had to be done at close range for the best results. The early gypsy moth work was done in this same way, any other method at that time being considered useless. This method entailed a great deal of climbing on the part of the sprayers, and was a slow and costly process.

Some years ago the Gypsy Moth Commission abandoned these fine nozzles and close-range methods of spraying, and now employs large nozzles and large hose, and exceptionally high pressure is obtained from powerful machine sprayers. With the larger area which has to be treated at the present day the older method would not only prove prohibitory on account of the expense, but also because of the time involved. Practically all the spraying with these large modern machines is done from the ground, doing away with the necessity for ladders and for climbing trees; and by the use of one or more long lengths of hose large areas can be treated from one spot. This method of spraying trees is very effective and very much cheaper, the average cost of spraying woodlands being something like \$12 or less per acre. With this method the spraying mixture is delivered to the nozzle through a large strong hose under a pressure of 200 to 250 pounds, the high pressure breaking the spray up into a fine mist. The spray has considerable spread when broken up, which is a desirable feature in treating woodlands and country roadsides, but on this account it is more or less objectionable for use on residential streets in cities and towns, as it is likely to dis-

figure anything it touches. The writer has been of the opinion, however, for some time, that the high-pressure, large-nozzle equipments are the cheapest and most practical for shade-tree work.

What might be termed a compromise between the fine-nozzle system and the high-pressure, coarse-nozzle system employed in the gypsy moth work is often used in spraying shade trees at the present day. This consists in the use of the Bordeaux nozzle, which has an aperture of $\frac{3}{32}$ of an inch. When used on a hand pump with a pressure of from 50 to 70 pounds, or even more, it does not give, in our estimation, a satisfactory spray. Where a small number of trees are to be sprayed, and where an expensive equipment cannot be afforded, small hand pumps will do the work, but when it becomes necessary to spray 500 or 1,000 trees in the course of a few weeks, power sprayers are necessary and more economical.

The most important factors necessary for economical work in spraying shade trees on a large scale are machines powerful enough to maintain a constantly high pressure; an efficient nozzle, and competent men to do the work. By high pressure we mean a pressure of 200 to 250 pounds, preferably the latter. This should be maintained constantly, and the capacity should be sufficient to maintain this pressure in a 1-inch delivery hose, if necessary.

In our work on spraying shade trees we endeavor to have a 1-inch aperture from the pump to the nozzle, care being taken to have no reducing valves or couplings anywhere on the line to reduce the volume of the spray, since it is better to have a good flow of the spraying mixture directly to the nozzle.

Too much attention cannot be given to the nozzle. It should be adapted to the work required of it, and a satisfactory nozzle is worth almost any price. It should be constructed on mechanical principles which will enable it to break up the spraying mixture into as fine a mist as possible, and to do this at a distance convenient for the economical application of the spray. The ideal nozzle for the economical spraying of trees either from the ground or a ladder should possess some carrying fea-

tures, and still break the spray up finely. The nozzle should not be encumbered, any more than the hose, with worthless mechanical devices which produce friction without adding anything to its efficiency, and for this reason we believe that it is better to employ mechanical devices to break up the spray after it has left the nozzle rather than in the nozzle itself. This applies, of course, to that type of nozzle intended to be used with high pressure, either from the ground or from a ladder, since in this case it is necessary for us to have nozzles adapted to throw a certain distance in order to reach the foliage, and have it broken up into as fine a mist as possible. This does not apply to types of nozzles like the Vermorel and Friend, which are well adapted to the purposes for which they are intended.

The question of competent men and good machinery is also important in spraying. Any good reliable man of common sense can learn to spray in a short time, and there should be little difficulty in securing such men if they are treated properly and well paid.

As regards spraying outfits, there is still a chance for improvement in many ways. There are, however, many good power sprayers on the market. The New Leader spraying machine, made by the Field Force Pump Company of Elmira, N. Y., of which there are several in use in the Connecticut valley, has proved to be satisfactory. This is provided with a $3\frac{1}{2}$ horse-power engine, and is one of the cheapest and best machines on the market. A machine of this type, while not so thoroughly constructed in some respects as the larger and more expensive machines, is capable of doing good work for some years. The type of machines which depend upon charging with carbonic acid gas for their power we consider failures for any kind of work, since the pressure is never constant, and much of the time is too low for any kind of spraying. The company which manufactures these has recently constructed a machine in which the power is compressed air instead of gas. This air is constantly pumped and pressed into large cylinders, which are attached to the truck. One of the difficulties in a machine of this type for high-pressure work consists in the use of very heavy

cylinders, which, on account of the weight, must have a limited capacity for storing the air. There are on the market many good hand pumps which will maintain a pressure of 50 to 70 pounds with an ordinary nozzle, and these may be purchased for \$12 to \$20. For general purposes they are the cheapest and most satisfactory spraying devices produced at the present time.

SHADE TREE TROUBLES.

BY G. E. STONE.

If the amount of correspondence is any criterion of what people are interested in it might be inferred that the citizens of Massachusetts place a high value on shade trees, and we are receiving an ever-increasing number of such inquiries. Such organizations as civic leagues, village improvement associations, the Massachusetts Forestry Association and the different horticultural societies are very largely responsible for this awakened interest in the subject of shade trees, although landscape gardeners and highway and park commissions have had no small influence in this direction.

Shade trees have enough to contend with ordinarily, but the extreme climatic conditions which have prevailed during the past few years have been an additional burden on them. The more extensive use of telephones, electric lights, trolley transportation, gas, sewers, aqueduct water, etc., made necessary by modern conditions, has been hard for our shade trees, and the severe winterkilling of roots, which occurred a few years ago, has been responsible for the death of thousands. Many trees which were not so seriously injured a few years ago as to die outright were left to a lingering existence, and many of them are constantly deteriorating and in a few years will be dead. The trees which have shown this slow dying back of the root system most prominently, and which later completely collapse, are the elm, red maple, black and white ash, and, to a less extent, the rock maple. The writer has had opportunity to observe the condition of a large number of these trees each year and the effect which root killing has had upon them. Many large elms, which a few years ago were in perfect condition, may be seen slowly dying from the effects of severe climatic conditions, and

many of them gave promise of living at least one hundred years in favorable environments. The black and white oak, ash and red maple are dying more rapidly than the elm. The European birch, so commonly used for ornamental purposes, has been dying everywhere this past summer from the effects of borers, and possibly the extreme drought.

The past summer the writer has had an opportunity to examine many black oaks along country roadsides, where the conditions for tree growth would be considered fairly good. These trees are located in different towns in the eastern part of the State, where the oak seems to be affected the most severely. Near one estate, where 19 black oaks (*Quercus velutina*, Lam.) were examined, the larger part of them were found to show evidence of root killing. These trees are located on a slight embankment, and that part of the root system nearest the road was invariably affected the worst. The trees showed various degrees of root killing, some of it being so far advanced that 75 per cent. or more of the tissues of the trunk were dead on the roadside. Some of the trees were in fairly good foliage, others had lost a little foliage, and many had considerable dead wood, the amount corresponding to the condition of the roots. On another roadside, where the conditions were somewhat similar, although in a different town, the same root killing was observed. In this locality there were 50 or more black oaks, many with scarcely any live limbs, and supporting only from 1 to 20 per cent. of the original foliage. An examination of these trees showed the trunks to be perfectly sound, and even the larger roots at the base of the tree were alive. When the soil was removed from the roots for a distance of 3 or 4 feet it was found, however, that practically the whole root system had collapsed, and conditions showed that there had been a slow but constant dying back of the roots for the last five or six years. For example, roots $\frac{1}{4}$ inch in diameter, which normally would extend 15 to 25 feet from the base of the tree, had died back to within 3 to 6 feet from the base. It could be plainly seen that the trees had made strenuous efforts to recover their root systems by repeatedly throwing out a profuse growth of side roots, but as the affected roots were continually dying back, the new laterals were of little or no use,

as they would die in turn. Had it been possible to prune these roots, their dying back could have been checked, a new system of secondary roots would have formed and the tree would have recovered. Oak trees in this condition have been fairly common in certain parts of eastern Massachusetts for the past few years, and many more will show the same symptoms later.

Another trouble which has been more or less common the last few years is known as sun scald of maples. This is responsible for injuring many valuable shade trees. On one avenue we recently observed 16 rock maples killed by sun scald. This affects the trunks and limbs on the side of the tree exposed to the sun. It is characterized by a drying up of the bark, which almost immediately becomes affected with a canker fungus (*Nectria cinnabarina*, Fr.). On smaller trees sun scald often kills the whole trunk. Generally only one side of the tree is affected, and occasionally one or more branches. The root system is not affected by sun scald, and limbs are much less likely to be affected than the trunk. The fact that the root system is not affected by sun scald, and that the bark usually becomes infected with *Nectria*, makes it easy to distinguish this type of injury from that caused by gas poisoning, since in this case the *Nectria* never appears, but, instead, profuse growths of *Schizophyllum* and *Polysticta* are present. Very similar effects are produced on the trunk when the tree is sprayed with kerosene or crude oils, since *Nectria* almost always accompanies such injury.

Sun scorch differs from sun scald very materially, as it affects only the foliage. This is very common on maples, and in recent years the white pine has been affected in this State. Sun scorch follows dry periods, and is usually associated with strong, drying winds, lack of water in the soil, etc.; in fact, it may be caused by various abnormal functions of the root system. It hardly ever completely defoliates trees, and on maples it simply burns the foliage, particularly on the windward side. Various conifers, such as arbor vitæ, when grown in dry soil invariably show sun scorch in the spring, particularly when there are drying winds and the ground is frozen. For many years past we have received a large number of inquiries concerning the effects of sun scorch on maples. These effects resemble those of leaf

blight (*Glæosporium*), and various atmospheric gases, or illuminating gas, escaping into the soil, often cause effects resembling those produced by sun scorch. Severe injury is caused especially by the illuminating gas. Under ordinary conditions trees seldom recover when once poisoned by this gas. It is possible, however, in certain cases of gas poisoning, especially in the incipient stage, to amputate certain roots at the base of the trunk, which prevents the further translocation of the poisonous substances and often saves the tree.

Every tree which dies along the roadside, however, is not necessarily killed by gas or electricity, notwithstanding the fact that this seems to be a popular belief. It should be said that the public service corporations of Massachusetts, on the whole, take a very sensible and unbiased view of the claims for gas injury, and if the people would meet them in this same spirit adjustments of legitimate claims for damages would no doubt be satisfactorily made in practically every case.

THE CHESTNUT DISEASE (DIAPORTHE PARASITICA).

BY G. E. STONE.

The chestnut disease, which has wrought such destruction in the vicinity of New York since 1904, has been observed quite extensively in some parts of our State the past summer (1910). Occasional reports of the disease occurring here and there have been received for three or four years, but such reports, when investigated, proved to be groundless. Whenever a chestnut tree in a more or less unhealthy condition has been observed, the cause of the trouble has promptly been put down as chestnut disease. It is possible that the chestnut disease has been present in Massachusetts for three or four years, but it has not been called to our attention, neither has any systematic attempt been made on our part to locate it.

It has been reported by J. F. Collins in Rhode Island, and he has traced it over the Rhode Island line into Massachusetts. The territory which appears to be most severely affected in this State is the Connecticut valley, where the disease may be seen over quite an extensive area. Mr. Sumner C. Brooks went over a considerable territory this past summer and reported several hundred trees affected. Some of them appear to have been dying for three or four years, according to the best information we are able to obtain, and some of the injury may date back even further than that. The disease exists, no doubt, in other parts of the State, although little has been found at the present time. From a more or less hasty survey of the State, made by this department last summer and fall, together with correspondence and inquiries, we were able to discover little, if any, of the disease outside of the Connecticut valley region. As in the case

of the elm-leaf beetle and other pests, the disease seemed to be more common at first in the Connecticut valley.

The writer has been informed by one who has had some opportunity to observe this disease that it appears to be less prevalent on high elevations than in the valleys. This opinion is, of course, based on merely casual observations. Whether there is really any distinct difference between valleys and high elevations as regards the prevalence of this disease would be interesting to observe. If this were the case, one might expect to find the disease most commonly in the valleys, like the Connecticut, Blackstone, Housatonic, etc., in this State. It is, however, quite significant that the Connecticut valley region should possess such a large amount of infection as compared with other sections. We have noticed for some time that there is a difference in the degree of winterkilling occurring in valleys and high elevations in this State. By far a greater amount of winterkilling of trees occurred in river valleys and on the lower elevations during the severe winter of 1903-04 than on the higher elevations, the Connecticut valley being especially notable in this respect. It is, moreover, a significant coincidence that the chestnut disease should make its appearance at about the same time that vegetation was so severely injured by the severe cold which occurred during the winter of 1903-04 all over the northeastern part of the United States.

Our observations on the effects of meteorological conditions on vegetation, and the unusual opportunities we have had to study shade-tree conditions for some years, have brought to our attention the unusually large amount of dead wood found on chestnut trees the past four or five years. From what we have seen of the chestnut during this period we are of the opinion that it has not been in the best condition during late years, and that the chestnut, like the native white and black oaks, elm, red and rock maples, ash, etc., has been more or less affected by the severe cold and drought of late years. It is intended during the coming year that a more serious and thorough investigation of the cause and distribution of the chestnut disease be made in this State. In the meanwhile it is essential that lumbermen cut off their diseased trees and make use of them now.

CROWN GALL.

BY G. E. STONE.

For many years a disease known as crown gall has affected raspberries in this State. The disease is characterized by large abnormal swellings or gall formations near the crown of the roots, and is well known to all raspberry growers. Raspberry plantations are almost invariably affected with crown gall after being set out for a few years, and in the course of time these galls affect the plant to such an extent that the crop is no longer profitable, and it becomes necessary to start a new plantation. In recent years other plants have become affected with crown gall, which is becoming more common on the roots of our fruit trees, notably the apple, pear and peach, although until five or six years ago galls on fruit trees were very rare in Massachusetts; at least, if they existed at all they were limited to certain areas, and were brought into the State on infected nursery stock.

It is quite certain that the germs of crown gall are not indigenous to our soil, and in all cases the disease has been introduced through nursery stock from outside the State. Apple trees have been grown in the State for years without being affected, and it is reasonable to suppose that they may be grown to-day in most of our soil without infection, providing clean stock is secured when planting an orchard. However, when crown gall is once introduced into an orchard it is difficult to prevent even clean stock from becoming infected. The writer knows of a large tract of land, which was, until three years ago, free from crown gall, where to-day it is impossible to plant even seedlings without their becoming infected. The soil in this instance was first infected by imported stock; and undoubtedly by the use of cultivators, etc., the disease germs have been spread over a large part of the cultivated area. The organism causing

the galls is, according to Smith and Townsend,¹ a species of bacillus; and, if true, this would explain the readiness with which the disease spreads and infects heretofore uninfected areas. It appears to be doubtful, however, whether the organism causing crown gall of the raspberry is identical with that causing the galls on the apple, at least in this territory, since raspberries have been affected for many years in this State, and fruit trees only recently; moreover, raspberries have been grown for years in close proximity to fruit trees in all stages of development without the slightest evidence of gall infection.

Unusual interest is now being shown in fruit growing in this State, and the appearance of a disease of this nature must be given consideration. Considerable difference of opinion exists in regard to the effect crown gall may have upon a tree, and there is still much to be learned in regard to the seriousness of this trouble. Some authorities claim that crown gall does no harm whatsoever, while others give alarming accounts of the serious damage it causes. It would appear, however, that crown gall is less to be dreaded in New England than in some other sections of the United States. This is the opinion of F. C. Stewart of the Geneva Agricultural Experiment Station, Geneva, N. Y., who has had unusual opportunities to observe crown gall in the New York orchards and nurseries. The most intelligent orchardists, however, prefer stock free from the disease, and most of them refuse to accept contaminated stock from a nursery firm. A very large amount of infected nursery stock has, however, undoubtedly been shipped into this State and planted without the buyer knowing that it was affected.

We have had many opportunities recently to observe crown gall on apple, pear and peach trees, and in some cases on the Carolina poplar, but we have seen only one or two instances where trees have been so badly affected that they have died from the effects of the disease. Much affected stock has been thrown away and burned, not being considered suitable to place on the market. Crown gall on fruit tree stock has become so general in nurseries at the present time that one large concern has found it practically impossible to obtain stock free from it, and this

¹ E. F. Smith and C. O. Townsend, *Science*, n. s., Vol. 25, April, 1907, pp. 671-673, also Vol. 30, No. 763, Aug. 13, 1909, p. 223.

firm is in a quandary as to what to do. When one has a young orchard with 50 per cent. or more of the trees affected, the question arises as to what should be done with it. It is possible, also, that one might obtain stock from a nursery free from galls, yet the soil from which they were taken may have been contaminated, and in this way the disease might break out later, when the stock was transplanted. Even though it is not certain that crown gall on fruit trees is of serious consequence, affected trees are certainly not in a normal condition, and the functions of the tree must be more or less interfered with, since the conductive tissues in the galls are to a greater or less extent misplaced and contorted, according to the severity of infection. There is, moreover, a risk in planting trees affected with gall, since one can never know when some complicated trouble may arise, owing to the presence of such malformed tissue.

There is a great deal known in regard to the effects of galls on plants in general, and it is known that they cause much injury.

The writer has devoted many years to the study of galls caused by eel worms (*Heterodera*). Some plants affected with eel-worm galls present few abnormal features as regards vigor and yield, while others become sickly, and many die outright.

Tomatoes grown under glass are often affected quite severely with galls caused by eel worms. These very rarely, if ever, kill the plant, and in the great majority of cases, so far as we have observed, do not affect them severely. On the other hand, cucumbers appear to be often seriously affected, and while many plants will live when the roots are covered with galls, others will die, and the yield is, in practically all cases, materially reduced. Muskmelon plants are even more severely affected with eel-worm galls than cucumbers; to such an extent, in fact, that it is seldom that an affected plant is not killed before reaching two or three feet in length. The roots of roses are also susceptible to eel worms, which form almost microscopic galls, and often reduce the productiveness of this crop 75 per cent. A considerable loss of money has been experienced by rose growers from this cause. This is also true of violets. According to our own experiments

the yield of violets is greatly affected by these galls, and the plants often die outright.

In conclusion it might be said that the effects of crown gall on fruit trees may have been often exaggerated. There is a probability of some young nursery stock affected with crown gall developing into good trees, but clean stock should be obtained from localities free from the gall, if possible. Many States have laws for the purpose of excluding crown gall stock, but this disease has become so common, and certain varieties of nursery stock so scarce, that it is a question whether at the present time Massachusetts nurserymen would be able to supply the demand for clean material for contemplated orchards if a prohibitory law were passed.

FUSARIUM DISEASE OF CUCUMBERS AND OTHER PLANTS.

BY G. E. STONE.

A type of disease caused by one or more species of *Fusarium* occurring on different plants gives rise to what are known as wilts, stem rots, etc. *Fusarium* troubles have become more common of late years, and many houses which have been entirely free from them in the past now seem to become affected sooner or later. The dry stem rot of the carnation, caused by *Fusarium*, was unknown to florists years ago, but for ten years or more it has been one of the most common and dreaded pests known to carnation growers. *Fusarium* stem troubles have been observed occasionally on greenhouse tomatoes for the past few years, but fortunately no great amount of damage has so far resulted from this disease. Asters, chrysanthemums, potatoes, etc., are affected with *Fusarium* stem rots, and in the case of the aster the disease is often quite common and destructive.

Fusarium troubles of a minor and insignificant character have in previous years been found on greenhouse cucumbers, and within the last year a few serious cases of infection have been brought to our attention. All these cases were confined to greenhouses, and were severe enough in some instances to entirely ruin the crop. The material sent in to the laboratory showed both roots and stems affected with the fungus.

The summer crop of muskmelons, grown in the department's conservatory, was also affected badly, the disease appearing first on a few plants, but eventually spreading over practically the whole house. It was first characterized by a wilting of the leaves, which was more noticeable in warm, sunshiny weather. At first there is a tendency for the leaves to recover in the night

after wilting occurs, but as the disease becomes more severe the plants wilt more badly, and after a time die. Examination of the roots and stems near the surface of the ground showed evidence of the fungus *Fusarium*. In some instances this fungus has been traced quite largely to the roots and stems. The fungus develops principally in the wood ducts, eventually clogging them by shutting off the water supply from the roots.

As the disease has been called to our attention only recently we have not had an opportunity to study it thoroughly or to give the matter of remedies much consideration. It may be found, however, that, like many others, it will prove to be merely sporadic, and little may be heard from it in the future; although on the other hand, it may become a permanent and serious trouble.

Cucumber crops are unusually susceptible to certain troubles which in many cases are traceable directly to mismanagement. Practically all cucumber growers force their plants to the limit, regardless of external weather conditions, in this respect differing from florists and other market gardeners, who endeavor to adapt their crops to weather conditions. Too much forcing in the fall months, when the sunlight is poor, produces a tender tissue peculiarly susceptible to disease, and is a bad practice. There is no doubt, in the writer's estimation, that crowding the plants and extensive forcing, especially when the sunlight is poor, are responsible for a large part of the modern *Fusarium* troubles. Some years ago we found in our experiments that young aster plants which had been forced under glass in sterilized soil were decidedly more susceptible to stem rot than those grown in ordinary soil out of doors. The sterilized plants grew so rapidly that the tissue was very tender; whereas those grown out of doors formed tissue of an entirely different texture, which was less susceptible to disease. The stems of cucumber plants are often in bad condition near the surface of the ground, due to a combination of circumstances. Mites, eel worms, bacteria, etc., often affect the stem at this point, causing lesions and serious disruption of the tissue, and stems in this condition easily become affected with one trouble or another. The *Fusarium*

trouble at present appears to be merely incidental, attacking the weakened stems at the surface of the ground; but further observations on this point are necessary.

Sunlight constitutes the best factor for hardening up tissue, and the degree of resistance of the stems to disease coincides with the amount of light they receive. Besides sunlight, plenty of air is needed for the hardening of tissue, and if more attention were given by cucumber growers to adapting their plants to external conditions, healthier and stockier plants would be produced. On cloudy days the night and day temperatures should be lower than on bright, sunshiny days, and in this way the new tissue, as well as the old, becomes hardened, and is less susceptible to attacks from various organisms.

Lettuce growers are always very careful to lower the day temperatures in cloudy weather, whereas in periods of sunshine higher temperatures are maintained. They force their plants, to be sure, but use the greatest judgment in doing it, whereas cucumber growers, as a rule, pay little or no attention to outside conditions.

Experiments are now under way for the further study of this trouble, and various treatments will be tried.

There have recently been reported from other States serious troubles affecting outdoor crops of melons and cucumbers, characterized by wilting and dying of the plants. Serious loss was reported in Rhode Island the past summer resulting from some blight. F. L. Stewart has described a serious blight of melons occurring in New York State,¹ and L. R. Jones has described a bacterial blight in Vermont.² Both of these blights are different from the one described above.

Our attention has often been called to the cracking or splitting of melons in the fall. This occurs on mature, ripe melons, and in our opinion it is caused by the absorption of water by the fruit. When melons are lying on the ground the water sometimes gains entrance to the blossom end of the fruit, causing an increased turgescence of the inner tissues which exerts such a pressure on the fruit that it cracks. We have been able to pro-

¹ Geneva, N. Y., Agricultural Experiment Station, Technical Bulletin No. 9, 1909.

² Vermont Agricultural Experiment Station, Bulletin No. 148, 1910.

duce this cracking of the fruit by placing the blossom ends in saucers of water. Sliced melons, when placed in a dish of water, will straighten out noticeably, from the excessive absorption of water by the inner cells. On the other hand, when sliced melons are placed in normal salt solutions of certain strengths the melon will contract or curl up.

CONDITION OF FRUIT TREES IN GENERAL.

BY G. E. STONE.

Any one who has been acquainted for any length of time with the fruit industry of this State must have noticed its condition the past few years. Massachusetts has never been noted as an extensive fruit-growing State, and very few large orchard enterprises have ever been developed. There have also been comparatively few orchards which have been kept in first-class condition; in fact, the condition of fruit trees has never been so bad in the history of the Commonwealth as during the past four or five years. The severe and erratic climatic conditions to which our fruit trees, in particular, have been subject, together with the San José scale, have been the means of killing thousands of our fruit trees, and greatly lessening their productiveness and the quality of the fruit. All this, combined with wholesale neglect, has placed the fruit industry at a very low level, and it is not at all surprising that apples bring at times a very low price. The severe winter of 1903-04 was not confined to our State, as its work may be seen throughout the whole north-eastern section of the United States, and in many instances large orchards were wiped out entirely.

From observations made in other States it would appear that our trees do not suffer so severely as in some other places, but the fruit has been of exceptionally poor quality. A large part of the injury to apple trees was confined to the roots, although a large amount of sun scald, which was subsequently associated with canker, was noticeable on the branches. Good systematic pruning, feeding and cultivation would have remedied much of this injury, but until the past year or so, when there has been a renewed interest in orcharding, no attempt has been made to renovate these neglected orchards. The remarkable price which

western apples bring in our markets has stimulated Massachusetts orchardists to make use of better scientific methods in fruit growing, and it is no exaggeration to state that there have been more pruning, spraying, cultivating and fertilizing apple orchards in the past year in this State than for thirty years before. This increased interest is being shown by professional orchardists as well as by smaller growers, and the quality and yield of fruit the past season is ample proof of the great value of this treatment. It is, however, a significant fact that the few first-class apple orchards which are to be seen here and there have not experienced the same setback, either from scale or winterkilling, that the neglected trees have, and some orchards have been producing good fruit each year, although the severe drought which we have experienced the last two or three years has affected trees somewhat.

Peach orchards have suffered severely of late years from root killing and other troubles, and some of the orchards which were in excellent condition a few years ago are looking badly now. Some growers attribute this deterioration to peach "yellows." A large part of what is supposed to be "yellows" is not this at all, and the yellow foliage and general unhealthy condition which have been common the past few years are nothing more or less than the effects of unfavorable climatic conditions. Pear, quince and cherry trees have likewise suffered from scale and winter injury in the same way that apple trees have. The pear, moreover, has been affected severely by aphid and surface molds. This could have been remedied by spraying with whale oil soap or kerosene emulsion. The quince has been rather badly affected by rust. Practically all the old cherry trees have suffered serious injury, and, as few new trees have been set out, cherries are becoming scarce. The small fruits, such as the raspberry, blackberry and strawberry, owe much of their present condition to unfavorable climatic conditions, and the cane blight, which has recently affected raspberries, etc., may be merely a secondary effect of some other cause.

It is, however, necessary that the work of spraying fruit trees be continued, since the results obtained fully justify the extra expense involved. The treatment necessary for fruit trees in

general may be summarized as follows: if scale is present, spray in the fall with some reliable oil. In the early spring spray again with lime and sulfur, before the leaves appear. About the time the petals fall, spray again with arsenate of lead, for codling moth. Ordinarily this spraying is sufficient, but if any fungous troubles appear, a later spraying with Bordeaux mixture, or with dilute or self-boiled lime sulfur, would be valuable. These various treatments are recommended for both fungi and insects, and although the oil, and lime and sulfur treatment are especially applicable for scale, it has been found that the latter, particularly, has proved to be the most effective fungicide we have. Even one application of lime and sulfur in the spring has a remarkable effect as a fungicide throughout the whole season, and in our opinion it is more efficient than any number of sprayings with Bordeaux mixture for certain troubles common to fruit trees. Arsenate of lead is primarily for codling moth, but this, too, has fungicidal properties, according to the writer's observations. We believe that for orchards which are well pruned, cultivated and fertilized the three sprayings recommended above would be sufficient for any ordinary year, and in case the scale is not present, the oil treatment could be left out. The lime and sulfur, however, is worth applying every year, whether the scale is present or not, owing to its remarkable fungicidal properties. There are now on the market many kinds of oils and concentrated forms of lime and sulfur which can be used to advantage. It is a question, however, whether the concentrated forms are as effective as the home-made. Much attention is now being given to the self-boiled lime and sulfur, but it is somewhat too early to state definitely its value as a fungicide.

The apple industry is now booming in this State. Many young orchards are being set out; more attention is being given to pruning, spraying and cultivating, and within a few years there will be many more good orchards than at present.

A NEW TYPE OF SPRAY NOZZLE.

BY G. E. STONE.

For some years the writer has given considerable attention to the improvement of nozzles, and has experimented with various types. In a preceding article on the spraying of trees we have already referred to the importance of nozzles being adapted to specific cases, and from time to time we have sketched and had constructed in a simple way new types of nozzles, which have been tested. The principles involved in these nozzles were in many cases new, but when the nozzles were constructed and tried out, some of them, as might be expected, were more or less failures. Various methods and devices were used and tested to break up the spray, and in one case a rotary wheel of a turbine type was tried.

Without going into a detailed description of the various types of nozzles which we have worked upon we will confine our attention to one of these which has proved to be remarkably satisfactory in spraying large trees from a high-pressure machine. This nozzle is shown in Fig. 1, at *A*. It consists of a nozzle screwed tightly onto the tip of a standard attachment provided with shut-off, such as is often employed in spraying work (see *B*). The attachment, however, is incidental, as it may be fitted to any suitable metal connection threaded to fit, and provided with a hose connection at the lower end. The essential part of the nozzle, as shown at *A*, consists of a small brass tip, *t*, about $1\frac{1}{2}$ inches long, provided with an aperture at the end $\frac{1}{8}$ of an inch in diameter, although sometimes an aperture of $\frac{5}{32}$ or $\frac{3}{16}$ of an inch in diameter has been employed. About an inch or more above the center of the aperture there is placed a solid brass rod, *c*, $\frac{1}{4}$ of an inch in diameter. This is attached to another rod, *d*, by means of a thin sheet of brass; the rod, *d*, works in a socket, and allows the pointed brass rod, *A*, to be thrown in or

out of center at will. The object of this center brass rod, *c*, is to take the spray as it comes out of the $\frac{1}{8}$ -inch nozzle under high pressure and break it up into a fine mist, and with the pressure which we used it is capable of throwing the mist 20 or 25 feet. This is sufficient to reach, from a ladder, most of the foliage on a large elm tree. In case it is necessary to reach higher, the ad-

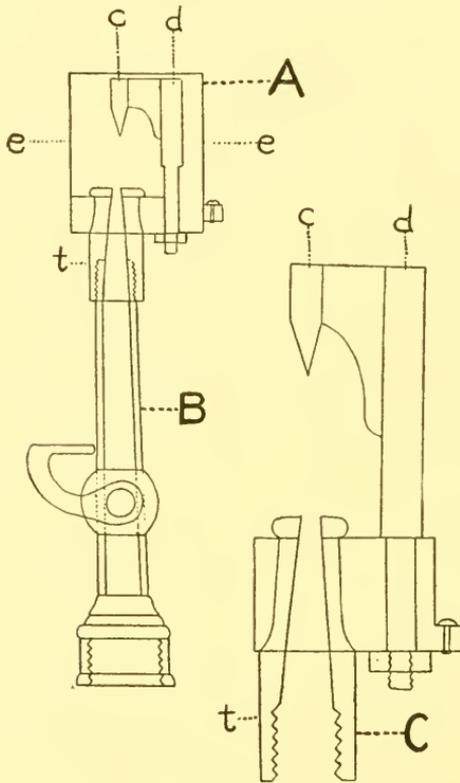


FIG. 1. — Showing a new type of spray nozzle adapted to high-pressure work on large trees. *A*, essential part of nozzle; *B*, ordinary attachment provided with shut-off; *C*, nozzle enlarged without a guard; *t*, small brass tip; *e*, guard; *c*, pointed brass rod to break the spray; *d*, rod to support the same.

justment is thrown out of the center and the spray goes directly through the $\frac{1}{8}$ -inch aperture. By this means a greater distance and carrying power are secured, although not so fine a spray.

This type of nozzle has proved to be very successful, and was used throughout the whole summer with the best results.

In the drawing the nozzle is shown surrounded by a shield, *e*, which was for the purpose of protecting the point, *c*. The nozzle as originally constructed was not provided with a shield, being used for some days without it, but with the hard usage which it received we found that the adjustment was likely to be injured. The nozzle was used in connection with a machine giving 250 pounds' pressure, and the spraying mixture was carried through a 1-inch hose.

This nozzle was used, the past summer, in spraying over 1,000 trees, having an average diameter of about 22 inches. Careful estimates made showed that the average amount of arsenate of lead per tree was 1.7 pounds, or about 17 gallons of arsenate of lead in solution. The cost of spraying each tree, including the labor, gasolene and lead, was 55 cents. A smaller number of the same trees were sprayed some years ago at a cost of \$1.50 per tree; but the spraying with the new nozzle and machine was in every way as good, and the cost about two-thirds less per tree, as by the more costly method, which consisted in the use of the Vermorel and other fine-mist nozzles.

DISTILLERY AND BREWERY BY-PRODUCTS.

BY J. B. LINDSEY.

A. DISTILLERS' DRIED GRAINS.

(a) *What they are.*

Distillers' dried grains represent the residue from the manufacture of alcohol, spirit and whiskey from the several cereals. Briefly stated, the process of manufacture consists in treating the ground grains with a solution of malt at a temperature of about 145° F., in order to convert the starch into sugar. The barley and other cereals from which the malt is made, as well as the malt sprouts, are added as a part of the malt solution. After the changing of the starch into sugar, the entire mass is cooled to a temperature of 60° to 70° F., and yeast added, thus changing the sugar into alcohol, which is distilled. The residue or distillery slop is filtered, dried by steam in especially constructed driers, and put upon the market as a cattle food. It consists chiefly of the hulls, germ and other nonfermentable portions of the grains. It has more or less of a sour taste and smell, due to the fermentation. In order to be of satisfactory quality, the mash should be dried at once after the process of fermentation is completed. If allowed to stand too long it is more or less contaminated with acid and other injurious products of fungous and bacterial action. If heated too hot during the drying process it is scorched, which causes a disagreeable burnt taste and odor, and a lessened digestibility. A well-dried product should be of a light brown color and possess a pleasant odor. Experienced parties state that the quality of the dried grains depends, first, upon the quality of the distillers' mashes (upon the kinds and proportions of the grains employed); second, upon the distillers' mode of mashing; and third, upon the process of drying.

(b) *Classification of Distillers' Grains.*

The grains may be classified as follows, according to the source from which they are derived:—

1. Alcohol and spirit grains are produced by the alcohol and spirit distillers, located in Indiana, Illinois and Ohio; they are the most uniform in grade, corn being practically the only grain used. The yearly product is from 50,000 to 60,000 tons.

2. Bourbon whiskey grains, from the whiskey distilleries, located mostly in Kentucky, vary in composition according to the proportion of corn, rye and malt in their mashes. The larger the proportion of corn and the smaller that of rye and malt (small grain, so called), the higher the grade of dry grains produced. The distilleries producing these grains run about one hundred and fifty days between November and July, and turn out from 27,500 to 35,000 tons.

3. Rye whiskey grains, from the rye whiskey distilleries, located near Pittsburg, Pa., and Baltimore, Md., run during the winter and spring, and may produce approximately 7,500 tons.

(c) *Disposition of Distillers' Grains.*

Formerly practically all of the dried grains were exported. About ten years ago the home market was sought, and considerable quantities were sold unmixed with other feedstuffs. Of late the better grades have been largely utilized by home manufacturers of proprietary feeds. The rye grains have never been very popular in the United States, and the entire product is usually exported. The present season (winter of 1910-11) the foreign market is said to have been poor, and the material has been freely offered at \$16 per ton in bags at wholesale, f. o. b., Boston points, which would be equivalent to substantially \$1 per hundred at retail. Such a price renders this article quite economical for northern feeders.

(d) *Composition of Distillers' Grains.*

The following summary represents the average percentages of the ordinary food groups in the several varieties of grains:—

	Number of Samples.	Water.	Ash.	Protein	Fiber.	Extract Matter.	Fat.
Distillers' grains (alcohol and spirit),	81	8	1.7	31.7	12.3	34.1	12.2
Distillers' grains (whiskey), . . .	1	7	2.5	26.2	11.5	43.0	9.8
Distillers' grains (rye),	5	7	1.6	15.6	13.5	55.4	6.9

The alcohol grains are the only ones usually found in the Massachusetts markets. They contain 30 or more per cent. of protein and about 12 per cent. each of fiber and fat. The rye grains reach 15 to 16 per cent. of protein, and contain some 13 or more per cent. of fiber. Recent analyses show that substantially all of the crude protein in distillers' grains is present as true albuminoids.

(e) *Digestibility of Distillers' Grains (Per Cent.)*

	Alcohol and Whiskey (17 Trials, 8 Lots).	Gluten Feed for Comparison.	Rye Grains (2 Trials, 1 Lot).	Wheat Bran for Comparison.
Dry matter,	79	88	58	66
Protein,	73	85	59	77
Fiber,	95	87	50	39
Extract matter,	81	90	67	71
Fat,	95	81	84	63

The alcohol or corn grains show a somewhat lower digestibility than does the gluten feed, but are much more digestible than the rye grains. If the average percentage composition is multiplied by the above digestion coefficients, we have the percentage or pounds digestible in 100:—

	Alcohol Grains.	Gluten Feed.	Rye Grains.	Wheat Bran for Comparison.
Protein,	23.1	22.0	9.20	12.4
Fiber,	11.7	6.3	6.75	3.9
Extract matter,	27.6	48.0	37.12	37.8
Fat,	11.6	2.6	5.80	2.8
Total,	74.0	78.9	58.87	56.9

On the basis of the experiments and estimates made by Kellner, allowing for losses in the (*a*) feces or undigested material, (*b*) incompletely used material or urine, (*c*) work required in the processes of digestion and assimilation, the following net energy values (expressed in therms¹) are calculated in 100 pounds of the several feeds: alcohol grains, 80.2; gluten feed, 77.8; rye grains, 54.9; wheat bran, 49. It will thus be seen that the alcohol distillers' grains and gluten feed approach each other quite closely in feeding value, and likewise the rye grains and wheat bran.

A carefully conducted feeding trial with 6 cows,² in which a good quality of alcohol distillers' grains was compared with gluten feed, led to the following conclusions:—

1. The experiment has shown the distillers' grains to be fully equal, if not rather superior, to standard gluten feed in their nutritive value, and without objectionable effect on the health of the animal.

2. Their bulky nature enhances their value as a grain feed for most kinds of farm stock.

3. The flavor and keeping quality of the milk appeared in no way to be affected when this food constituted one-half of the daily grain ration.

It must be understood that grains that have undergone serious fermentation before drying cannot be considered as a first-class food, and their use is not recommended for either dairy animals or for horses.

(f) *How to use the Grains.*

For Horses.—Plumb,³ as a result of feeding distillers' grains to horses, found that some of the animals did not relish the product. The Massachusetts Agricultural College has fed its farm horses, with excellent results, a ration containing one-fourth distillers' grains; Pott⁴ reports favorably on the use of 6½ pounds distillers' grains in place of 8 pounds oats; also

¹ The therm represents the amount of heat required to raise 1,000 kilograms of water 1° C. It is to be preferred to the small or large calorie as a unit of measurement, because it can be expressed in fewer figures.

² Bulletin 94, Hatch Experiment Station, pp. 6-10.

³ Bulletin 97, Indiana Experiment Station.

⁴ Handbuch der tier. Ernährung, etc., von Pott, III Band, p. 293.

2¼ pounds distillers' grains, 2¼ pounds brewers' grains and 9 pounds corn in place of 9 pounds oats and 9 pounds corn.

For Fattening Cattle. — May¹ reports quite satisfactory results in feeding by weight one-half distillers' grains and one-half corn and cob meal to fattening cattle. It is believed that such a proportion is a desirable one, and that the distillers' grains can be thus utilized to good advantage.

For Pigs. — The distillers' dried grains are less desirable as a food for pigs, owing, partially at least, to the considerable amount of fiber present. They could probably be fed to better advantage in their natural state, *i.e.*, in the form of distillery slop.

For Dairy Animals. — The distillers' grains have been found to be exceedingly well suited to milk production. A few rations are suggested: —

I.	II.
100 pounds distillers' grains. 100 pounds malt sprouts. 150 pounds corn meal. 50 pounds cottonseed meal. Mix and feed 7 pounds (7 to 8 quarts) daily.	150 pounds distillers' grains. 150 pounds standard middlings. 100 pounds corn or hominy meal. Mix and feed 7 pounds or quarts daily.

III.

150 pounds distillers' grains.
 50 pounds corn or hominy meal.
 50 pounds cottonseed meal.
 Mix and feed 7 pounds or quarts daily.

B. BREWERS' DRIED GRAINS.

(a) *Character of the Grains.*

Brewers' dried grains are the kiln-dried residue from beer manufacture, and consist of a little of the starch and allied substances, together with the hull, germ and gluten of the barley. Most of the true starch is removed by the action of the malt and yeast. Grains that have been dried immediately are of a yellowish green color, and have a faint aromatic smell. Dark-brown colored grains have been injured before being dried, or

¹ Bulletin 108, Kentucky Experiment Station.

have been heated at too high a temperature, thus causing decomposition. Dried grains are fed quite extensively in Europe, and to some extent in the United States. European investigators consider freshly dried grains as healthful as untreated barley, oats or corn. At present there are some 40 breweries in Massachusetts. The residue is practically all sold undried to farmers living in the immediate vicinity. The comparatively small amount of dried grains consumed in this State comes from the vicinity of New York, Chicago and Milwaukee.

(b) *Composition of the Grains (Per Cent.).*

	Brewers' Grains (Average 19 Samples).	Wheat Bran for Comparison.
Water,	10.0	10.0
Ash,	3.6	6.2
Protein,	24.0	16.1
Fiber,	13.4	10.5
Extract matter,	42.8	52.6
Fat,	6.2	5.0

In chemical composition the brewers' grains differ from the bran in having noticeably more protein, somewhat more fiber and less extract matter. Two samples of grains recently collected show 27 and 33 per cent. of protein; the latter figure is unusual, and may have been due to the use of some corn in the mash.

(c) *Comparative Digestibility.*

On the basis of the average analysis, 100 pounds of the brewers' grains and of the bran contain the following amounts of digestible nutrients:—

	Brewers' Grains (Per Cent.).	Wheat Bran (Per Cent.).
Protein,	19.4	12.4
Fiber,	6.6	3.9
Extract matter,	24.4	37.8
Fat,	5.5	2.8
Total,	55.9	56.9

Each of the two feedstuffs contains substantially the same amounts of digestible nutrients. The net energy values expressed in therms are as follows: brewers' dried grains, 56; wheat bran, 49; or the brewers' grains are worth 10 per cent. more than the bran.

An experiment conducted at this station with 6 dairy cows, in which brewers' grains were compared with wheat bran, led to the following conclusions:—

1. The brewers' grains ration produced slightly more live weight, milk and milk ingredients than did the bran ration.

2. Brewers' grains did not show any objectionable effect either on the general condition of the animal or on the flavor and keeping quality of the milk. They are nearly as bulky as bran, and serve as a distributor of the heavy concentrates.

(d) *The Use of Brewers' Grains.*

Only those grains that have a light color and are free from rancidity or sour taste and smell should be used. Grains that have stood for any length of time before drying have fermented, and are not satisfactory as a food.

For Horses.—Brewers' dried grains serve excellently as a partial oat substitute for horses, 2 pounds of the grains being equivalent to 2½ pounds of oats.¹ Voorhees² states that brewers' dried grains are a wholesome, nutritious and palatable horse feed. He recommends for work horses, on the basis of 1,000 pounds live weight, 2 pounds bran, 4 pounds corn, 8½ pounds brewers' grains and 6 pounds hay. Very satisfactory results are reported when hard-worked team horses received a daily ration of brewers' dried grains and hay.¹ The total amount of dried grains to be fed daily will naturally depend upon the size of the animal and the amount and character of the work performed. From 3 to 8 pounds may be considered satisfactory, the balance of the grain to consist of corn and oats, or corn and wheat bran.

For Pigs.—Because of their deficiency in ash and starch, and of the excess of hulls, the dried grains are not to be partic-

¹ Pott, already cited, pp. 241, 242.

² Bulletin 92, New Jersey Experiment Station.

ularly recommended either for growing or fattening pigs. When fed in connection with skim milk in place of corn, they have not produced as satisfactory a gain in live weight.

For Fattening Cattle. — The brewers' grains are quite satisfactory for fattening beef animals, in the proportion, by weight, of one-third of the grains and two-thirds of corn.

For Milk Production. — The dried grains are very satisfactory as a food for the production of milk; they may be used in place of wheat bran.

I.	II.
125 pounds brewers' grains.	150 pounds brewers' grains.
100 pounds corn or hominy meal.	75 pounds flour middlings.
75 pounds cottonseed meal.	50 pounds cottonseed meal.
Mix and feed 7 pounds or quarts daily.	Mix and feed 7 pounds or quarts daily.

III.

100 pounds brewers' grains.
100 pounds coarse middlings.
100 pounds gluten feed.
Mix and feed 7 pounds (8 quarts) daily.

The above rations are for average-sized cows yielding 10 to 12 quarts of average milk daily. The amount may be increased or diminished, depending upon size of animals, yield of milk, etc.

For Young Stock. — Because of their deficiency in ash, not over 25 per cent. of the grain ration should consist of brewers' dried grains. They may be combined with bran, coarse middlings and cottonseed meal, by weight, one-fourth brewers' grains, one-half coarse middlings, one-fourth cottonseed meal; or one-fourth brewers' grains, one-fourth corn and cob meal, one-fourth coarse middlings, one-fourth cottonseed meal.

(e) *Brewers' Wet Grains.*

Brewers' wet grains contain 75 to 77 pounds of water in 100, and are practically all sold to farmers living in the immediate vicinity of the brewery, at prices ranging from 10 to 12 cents a bushel. Assuming that 33 bushels weigh a ton, the cost would

be from \$3.30 to \$4 at the brewery, to which the cost of cartage should be added. Four tons of wet grains contain nutritive material equivalent to that found in 1 ton of dry grains, or in 1.1 tons wheat bran, or in $\frac{3}{4}$ ton gluten feed. With these data at hand, the purchaser of this material can calculate at what price he can secure an equal amount of nutrients in the various dry feedstuffs. The writer has not had any experience in feeding wet grains, but believes that 25 pounds is a fair allowance daily for average-sized cows.¹ In addition, 2 to 4 pounds of dry grain may be fed daily, such as a mixture of equal parts by weight of (1) mixed wheat feed and gluten feed, (2) wheat bran and fine middlings, or (3) wheat bran and corn meal.

The succulency of the wet grains is a factor not to be overlooked in estimating the value of the feed. It is not believed that the brewers' wet grains are an objectionable feedstuff when fed in a fresh condition and in moderate quantities. It must be remembered, however, that they are likely to spoil easily, excepting when the temperature is low, and the partly decomposed grains would not be considered suitable for producing first-class milk. When milk is intended for the use of infants, young children or invalids, it is better not to use the wet grains.

C. MALT SPROUTS.

(a) *Method of Preparation.*

Malt used in the manufacture of beer is prepared by moistening barley and allowing it to sprout in a warm atmosphere, thus producing a ferment called diastase, which readily converts starch into sugar. After the sprouting process has continued a number of days, the barley is dried, the sprouts removed by machinery and sold for cattle feed: each 100 pounds of malted barley yields about 4 pounds of sprouts. Sprouts of first quality are about $\frac{1}{4}$ of an inch long, thread-like in appearance, slightly curled, of a yellow or of a brownish yellow color, and form a crisp, porous and bulky mass. Mixed with the sprouts one often notes more or less malted barley kernels.

¹ It is understood that 50 or more pounds are frequently fed daily. It is believed, however, that the smaller quantity is preferable when the grains are fed continuously, and it is desired to retain the same animals in the herd from year to year.

dust and ash. The presence of the dust and ash is due to the fact that some of the sprouts are particularly rich in ashy matter, and because this ashy matter and dust have not been fully removed. Well-cleaned sprouts should be given the preference.

(b) *Composition (Per Cent.).*

	Average 32 Samples.	Average German Sprouts. ¹
Water,	11.0	10.0
Ash,	5.9	7.2
Protein,	26.4	24.4
Fiber,	12.3	14.0
Extract matter,	43.1	42.4
Fat,	1.3	2.0
Total,	100.0	100.0

The sprouts are characterized by a high percentage of crude protein, considerable fiber and little fat. While the nitrogenous matter in the sprouts is usually designated as true protein, it is well known that from one-fourth to one-third of the nitrogen exists in the form of amids,² hence the sprouts contain about 18 per cent. of true protein. Amid bodies are sources of heat and energy, and seem to protect the rapid breaking up of the true protein in the animal body, but they cannot produce flesh or milk casein. The extract matter contains a large amount of cane sugar, a little invert sugar and a considerable amount of pentosans. The fiber content is often increased by the presence of barley hulls. The ash is rich in potash and phosphoric acid and deficient in lime.

¹ E. Pott, already cited, p. 222.

² In the process of growth the plant elaborates the nitrates of the soil, first, into amid compounds, — partially developed protein, — and finally into the completed product, or true protein which is largely deposited in the seed. When the seed begins to sprout the true protein is converted back into the soluble amids, to enable the young sprouts to utilize it. Amids may be defined, so far as their use in the plant is concerned, as transportable protein.

(c) Digestibility.

One hundred pounds contain:—

	Pounds.
Protein,	20.1
Fiber,	12.2
Extract matter,	36.6
Fat,	1.1
	<hr/>
Total,	70.0

The sprouts have a relatively high digestibility and a net energy value of 56.4, just about equivalent to that for brewers' dried grains.

(d) The Use of Malt Sprouts.

Malt sprouts are at present used in considerable quantities as a component of many proprietary dairy feeds. They are particularly suited for dairy animals and for fattening cattle.

For Dairy Cows.—This station compared malt sprouts with gluten feed, using four animals in two three-week periods. The malt-sprout ration gave as satisfactory results as did the gluten-feed ration. Foreign investigators state that they are valued for milk production because of the stimulating effect of the amido bodies (and perhaps, also, of the betain and cholin which they contain) upon the mammary glands. If over 2 pounds daily are fed, it is advisable to mix them with water, otherwise digestive disturbances may result. Fed in dry condition in any considerable amount they are likely to be refused by many animals.

I.	II.
100 pounds malt sprouts.	100 pounds malt sprouts.
100 pounds corn meal.	125 pounds rye feed.
100 pounds cottonseed meal.	75 pounds cottonseed meal.
Mix and feed 7 pounds (7 to 8 quarts) daily.	Mix and feed 7 pounds (7 to 8 quarts) daily.
III.	IV.
3 pounds (5 quarts) malt sprouts.	3 pounds (5 quarts) malt sprouts.
2 pounds (3½ quarts) brewers' grains.	2 pounds (2 quarts) hominy meal.
2 pounds (1½ quarts) fine middlings.	2 pounds (1½ quarts) cottonseed meal.

In case of rations III. and IV., it would be advisable to thoroughly moisten the sprouts and then mix the other two grains with them. If the sprouts are not fed in excess of 2 pounds daily, they can replace wheat bran pound for pound in any grain ration. An excess of sprouts is to be avoided because they are deficient in lime, and also because they are likely to cause abortion and possible failure to breed. Pott states that over 3.5 pounds daily are likely to impart an aromatic bitter taste to the milk, sometimes diminishing and sometimes increasing its fat content.

For Fattening Oxen. — Some 2 to 4 pounds daily of malt sprouts (moistened) mixed with corn meal can be utilized with good results for fattening cows or steers.

For Young Calves. — According to F. Lehmann,¹ after the animals are three months old, malt sprouts, thoroughly moistened with boiling water, can be fed lukewarm, beginning with small amounts and gradually increasing to 1 to 2 pounds per day. A few pounds per day can also be fed to growing stock, mixed with middlings and corn meal if the animals receive a good quality of hay.

For Horses. — German feeders frequently, with satisfactory results, feed to horses 2 to 5 pounds daily of malt sprouts moistened with water, in place of a like amount of oats. The sprouts should be fed in small amounts at first (1 pound daily), until the animals become accustomed to them.

¹ Pott, already cited, p. 226.

THE FEEDING VALUE OF APPLE POMACE.

BY J. B. LINDSEY.

There is often considerable discussion in the agricultural press and among farmers concerning the value of apple pomace as a food for dairy and beef cattle. With a view to getting a few positive data, this station instituted a number of experiments, the results of which are here briefly stated.

(a) *Composition of Apple Pomace (Per Cent.).*

	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Sample I.,	81.40	.73	.94	3.00	13.03	.90
Sample II.,	80.20	.60	1.01	3.19	13.73	1.27
Corn silage for comparison,	80.00	1.10	1.70	5.40	11.10	.70

It will be seen from the above figures that apple pomace is a carbohydrate feed similar to corn silage. It contains about the same amount of water, rather less protein and fiber, and a larger proportion of extract matter. Whether the extract matter in the pomace is as valuable, pound for pound, as that contained in the corn, has not been thoroughly demonstrated.

(b) *Digestibility of Apple Pomace.*

The value of a feed cannot always be measured by its composition. A food is valuable as a source of nutrition only in so far as its various constituents can be digested and assimilated. This station has made two different experiments to ascertain the digestibility of the pomace, and the detailed results are to be found in the seventeenth report of this station. The summary follows:—

Summary of Experiments (Per Cent.).

	Number of Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Apple pomace (first experiment).	3	72.5	54.7	—	61.6	84.5	47.2
Apple pomace (second experiment).	3	70.6	42.8	—	67.3	84.3	43.4
Average,	6	71.5	48.7	—	64.4	84.4	45.3
Dent corn silage (for comparison).	17	64.0	—	52.0	62.0	69.0	85.0
Flint corn silage (small varieties).	11	75.0	—	65.0	77.0	79.0	82.0

The results show the total dry matter in apple pomace to be about as digestible as in the best grades of silage. The protein content of the pomace is small, — about 1 per cent., — and it has not been possible, by present methods, to ascertain its digestibility. Judging from the composition and digestibility of the pomace, one would feel justified in assuming that, pound for pound, it should approach in feeding value an average quality of corn silage.

(c) Experiments with Dairy Animals.

While this station has not carried out any exhaustive comparative tests with pomace and other coarse feeds, it has fed the pomace a number of seasons to dairy animals. The material was drawn fresh from the mill, and placed in a large pile under cover. A noticeable quantity of juice gradually drained from it, but it kept in good condition for two months. The animals received from 15 to 30 pounds daily, ate it readily, and the results were quite satisfactory. In one case 2 cows were fed alternately, four weeks at a time, on grain and hay, and on grain, hay and pomace; 25 pounds of pomace were compared with 5 pounds of hay. During the pomace period the animals produced 1,153 pounds of milk, and gained 24 pounds in live weight; during the hay period, 1,138 pounds of milk, and lost 6 pounds in weight. On this basis 5 pounds of pomace were more than equivalent to 1 pound of hay. Judging from this feeding test, and from the composition and digestibility of the

pomace, it seems probable that 4 pounds, when fed in what is termed a "balanced ration," would be equal in feeding value to 1 pound of good cow hay.

The Vermont Experiment Station has fed apple pomace for four years, using in all 20 cows in the several trials. The pomace was shoveled into the silo, leveled off, and kept in good condition without further care. In some cases it was placed on top of the corn silage after the latter had settled. The quantity fed varied from 10 to 35 pounds daily, with no unfavorable effects. As a result of the several experiments, the Vermont station concludes that the pomace is equivalent in feeding value to an equal weight of average corn silage,¹ and that it is without injurious effect on the flavor of milk and butter.

Farmers are cautioned not to feed too large quantities at first, but to begin with 10 pounds daily, and to gradually increase the quantity to 30 pounds, taking a week or more in which to do it. In this way, danger of a sudden milk shrinkage or of the animals getting "off feed," as is sometimes reported, may be avoided. Judging from all the data available, it is believed that farmers living in the vicinity of cider mills will find it good economy to utilize the pomace as a food for their dairy stock.

¹ There is doubt in the mind of the writer whether pomace would prove equal to well-preserved and well-cared corn silage; it certainly would approach it in feeding value, and ought to be fully utilized.

THE EFFECT OF PROTEIN UPON THE PRODUCTION AND COMPOSITION OF MILK.

BY J. B. LINDSEY.

Investigations and observations indicate that milk is not a simple fluid secreted directly by the blood, but a complex substance resulting from the activity of the milk cells. The cells and milk glands take from the blood and lymph vessels materials suited to their purpose, and by chemical and physiological processes convert them into a different substance, namely, milk. Milk, therefore, consists for the most part of reconstructed cell substance, and it is not possible, by any system of feeding, to produce very great modification in its composition. The composition of milk depends principally upon the breed and individuality of the cow, stage of lactation, and development of the milk cells.

German investigators, during the years 1868 to 1876, studied the additions to the different basal rations of increasing amounts of protein upon the composition of the milk, and noted only very slight variations. Danish observers, as a result of experiments by the group method with 1,152 cows, concluded that the protein was practically without influence in varying the proportions of the several milk ingredients. American experimenters report similar conclusions.

This station, from time to time, has conducted a number of experiments to observe the influence of different amounts of protein in increasing the quantity of milk, to note the protein requirements of dairy animals, and also to study its influence in modifying the proportions of the several milk ingredients. Some of these results have been published in reports of the station, and they have been recently summarized in detail in Part I. of this report. The following are the principal conclusions:—

1. By protein minimum is meant the amount of digestible protein required to support the daily life of an animal of 1,000 pounds live weight, and amounts to about .7 of a pound of crude protein daily; it also includes the amount contained in the milk, which is about .035 of a pound for each pound of milk, or .7 of a pound for 20 pounds of milk. Hence the protein daily minimum for a 1,000-pound cow producing 20 pounds of milk would be substantially 1.4 pounds of digestible protein.

2. A large excess of digestible protein (1.5 pounds, or 100 per cent.) above the protein minimum increased the flow of milk some 15 per cent. in experiments extending over periods of four weeks.

3. No particular difference was noted in the milk yield in case of two herds of cows receiving the same amount of total digestible matter, one receiving 65 per cent. and the other 122 per cent. of digestible protein above the protein minimum. Such a result indicates, at least, that the former excess was sufficient.

4. A 50 per cent. excess of digestible protein daily above the protein minimum in an experiment by the reversal method, extending over a period of nine weeks, produced some 5.9 per cent. more milk than did a ration with 21 per cent. excess protein.

5. Under similar conditions an excess, above the minimum, of 65 per cent. digestible protein produced 7.4 per cent. more milk than did an excess of 39 per cent. (Experiment covered twenty-six days.)

6. In Experiment VI., extending over a period of eleven weeks, with 12 cows by the group method, an excess of .54 of a pound of protein, 31.3 per cent., over the protein minimum, produced an apparent increase of 10 per cent. in the milk yield.

7. In Experiment VIII., extending over periods of twenty-four to thirty weeks, with 10 cows by the group method, the cows receiving the protein minimum did not shrink any more than those receiving each .44 of a pound daily, or 28 per cent., protein above the minimum.

The group method of experimentation is best suited for conducting experiments where a relatively large number of

animals — 20 or more — is available. With a less number the influence of individuality is altogether too pronounced.

8. An excess of 30 per cent. of digestible crude protein above the protein minimum (equal to 1.80 pounds of protein per day) will be productive of satisfactory results in case of cows weighing 900 pounds and producing daily 12 quarts of 4 per cent. milk.¹

An excess of 50 per cent. of digestible crude protein above the protein minimum is believed to be ample for all ordinary requirements.

9. Protein in excess of the above-suggested amounts may temporarily increase the milk yield, but it seems probable that in many cases the influence of individuality is likely to be more pronounced than the effect of the protein consumed.

10. Under the usual conditions, varying amounts of protein appear to be without influence upon the composition of the milk.

¹ Armsby, in *Farmers' Bulletin* No. 346, United States Department of Agriculture, expresses substantially the same idea in allowing .05 of a pound of digestible true protein for each pound of average milk, in addition to the maintenance requirement of .5 of a pound of digestible true protein per 1,000 pounds live weight. It is possible that animals can even do very good work with .04 of a pound of protein for each pound of milk.

I N D E X.

INDEX.

	PAGE
Alfalfa, conditions essential to success with the crop,	25
Date of sowing,	29
Diseases of,	31
Fertilizer requirements of,	26
Harvesting,	32
In Massachusetts,	24
Inoculation of,	30
Kind of seed needed,	30
Lay of the land (topography) for,	25
Method of applying fertilizers in preparation for,	28
Necessity of lime for,	26
Number of crops and yield per year,	24
Nurse crops for spring sowing,	29
Preparation for summer sowing,	29
Preparation of the soil for,	28
Quantity of seed needed,	30
Season for sowing,	27
Secondary value of,	33
Seeding to,	27
Soils best suited for,	25
Top-dressing,	33
Apple pomace, composition of,	84
Feeding experiments with dairy animals,	85
Feeding value of,	84
Brewers' dried grains, character of,	76
Comparative digestibility of,	77
Composition of,	77
Use of,	78
Use of, for fattening cattle,	79
Use of, for horses,	78
Use of, for milk production,	79
Use of, for pigs,	78
Use of, for young stock,	79
Brewers' wet grains,	79
By-products, distillery and brewery,	72
Chestnut disease (<i>Diaporthe parasitica</i>),	56

	PAGE
Clogging drain tile, experiments bearing on,	36, 39
Clogging of drain tile by roots,	43
Conclusions, leading, summary of,	7
Crown gall of fruit trees,	58
Cucumbers and other plants, fusarium disease of,	62
Dairy animals, feeding experiments with apple pomace for,	85
Diseases of alfalfa,	31
Distillery and brewery by-products,	72
Distillers' dried grains, classification of,	73
Composition of,	73
Digestibility of,	74
Disposition of,	73
How to use for fattening cattle,	76
How to use for dairy animals,	76
How to use for fattening pigs,	76
How to use for horses,	75
What they are,	72
Drain tile, clogging, by roots of pear tree,	44
Chemically treated fibers for preventing,	36, 38, 39
Creosote fiber effective in preventing,	41
By roots,	35
Danger of clogging by roots,	43
Feeding value of apple pomace,	84
Fertilizer requirements of alfalfa,	26
Fertilizers, methods of applying in preparation for alfalfa,	28
Fruit trees, crown gall of,	58
General condition of,	66
Fusarium disease of cucumbers and other plants,	62
Harvesting alfalfa,	32
Inoculation for alfalfa,	30
Lime, necessity of, for alfalfa,	26
Malt sprouts, composition of,	81
Digestibility of,	82
Method of preparation,	80
Summary of feeding experiments with,	85
Use of,	82
Use of, for dairy cows,	82
Use of, for fattening oxen,	83
Use of, for horses,	83
Use of, for young calves,	83
Materials used in top-dressing pastures,	21
Milk, production and composition of, effect of protein on,	87
Mowings, permanent, top-dressing, general plan of,	11
Mowings, permanent, top-dressing of,	10
New type of spray nozzle,	59

	PAGE
Pastures, top-dressing,	18
Conditions under which likely to be profitable,	20
Materials (chemicals) used in,	21
Season for,	23
Permanent mowings, method of applying fertilizers in top-dressing for,	17
Muriate of potash and slag meal both with and without nitrate of soda for,	12
Nitrate of soda with slag meal and high-grade sulfate of potash for,	13
Nitrate of soda with slag meal and low-grade sulfate of potash for,	13
Nitrate of soda with slag meal and muriate of potash for,	12
Results of top-dressing, summary of general observations on,	14
Slag meal, and high-grade sulfate of potash both with and without nitrate of soda for,	13
Slag meal and low-grade sulfate of potash both with and without nitrate of soda for,	13
Slag meal and muriate of potash both with and without nitrate of soda for,	12
Sulfate of potash, high-grade, and slag meal both with and without ni- trate of soda for,	13
Sulfate of potash, low-grade, and slag meal both with and without ni- trate of soda for,	13
Protein, effect of, upon the production and composition of milk,	87
Roots, clogging of drain tile by,	35
Shade tree troubles,	52
Spraying of trees,	47
Spray nozzle, new type of,	59
Summary of leading conclusions,	7
Top-dressing alfalfa,	33
Pastures,	18
Permanent mowings,	10
Trees, spraying of,	47

TWENTY-FOURTH ANNUAL REPORT
OF THE
MASSACHUSETTS AGRICULTURAL
EXPERIMENT STATION.

PART I.,

BEING PART III. OF THE FORTY-NINTH ANNUAL REPORT OF THE
MASSACHUSETTS AGRICULTURAL COLLEGE.

JANUARY, 1912.



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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

PART I.
DETAILED REPORT OF THE EXPERIMENT STATION.

INTRODUCTION.

In accordance with the provision of the act of the Legislature relative to the publication of the reports of the Massachusetts Agricultural College, the report of the experiment station, which is a department of the college, is presented in two parts. Part I. contains the formal reports of the director, treasurer and heads of departments, and papers of a technical character giving results of research work carried on in the station. This will be sent to agricultural colleges and experiment stations and to workers in these institutions as well as to libraries. Part I. will be published also in connection with the report of the Secretary of the State Board of Agriculture and will reach the general public through that channel. Part II. will contain papers of a popular character, and will be sent to all those on our general mailing list as well as to agricultural colleges and experiment stations, to workers in these institutions and to libraries in Massachusetts.

WM. P. BROOKS,

Director.

CONTENTS.

PART I.

	PAGE
Station organization,	9
Report of the director,	11
Changes in staff,	11
Lines of work,	12
General experiments,	12
Research,	12
Cranberry substation,	14
Asparagus substation,	25
Control work,	28
Dissemination of information,	29
Buildings,	33
Report of the treasurer,	35
Report of the agriculturist,	37
Comparison of different materials as a source of nitrogen,	37
Muriate compared with sulfate of potash,	39
Manure alone compared with manure and sulfate of potash,	40
Average corn fertilizer compared with fertilizer richer in potash,	41
Top-dressing for hay,	42
Poultry work,	43
Report of the horticulturist,	44
Report of the chemist,	46
Correspondence,	46
Numerical summary of substances examined in the chemical laboratory,	46
Work in the research section,	47
Report of the fertilizer section,	48
Report of the feed and dairy section,	63
Report of the botanist,	70
Report of the entomologist,	72 ✓
Report of the veterinarian,	77
Hereditv, correlation and variation in garden peas,	82
Heredity,	84
Correlation,	93
Variation,	94
Discussion of the results,	100
Seed work for the year 1911,	102
Rust on Vinca,	108
Frost cracks,	110

	PAGE
A new method for the approximate mechanical analysis of soils,	115
The present status of soil sterilization,	121
Influence of soil decoctions from sterilized and unsterilized soils upon bacterial growth,	126
Protozoa as a factor in the bacterial flora of soils,	132
Conclusions,	134
The effects of positive and negative electrical charges on seeds and seedlings,	135
Electrical resistance of trees,	144
Experiments with cut branches of trees,	156
Experiments with small plants,	160
Relation of electrical resistance to flow of sap,	162
Electrical resistance of different tissues,	163
Relationship of electrical resistance to other factors,	167
Influence of temperature on resistance,	167
Conclusions,	175
The chemistry of arsenical insecticides,	177
General introduction,	177
Paris green,	183
Calcium arsenite,	194
Lead arsenates,	201
The natural fertility of cranberry bogs,	208
Types of corn suited to Massachusetts,	221
Soil, cultivation, size of plots, fertilizers used,	221
Description of varieties,	223
Yield per acre of entire corn plant,	225
Effect of season on yield,	227
Composition of different varieties of corn fodder (entire plant as harvested),	229
Composition of different varieties of corn fodder (entire plant dry matter),	229
Digestibility of the plant,	231
Proportions and composition of parts,	234
Condition of crop when cut and character of season,	235
Average composition of parts,	237
Relative proportions of grain and cob,	238
Composition of grain and cob,	240
Summary,	242
The digestibility of cattle foods,	244
Series XII,	244
Discussion of the results,	253
Series XIV,	257
Discussion of the results,	263
Series XV,	266
Discussion of the results,	273

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION
OF THE
MASSACHUSETTS AGRICULTURAL COLLEGE,
AMHERST, MASS.

TWENTY-FOURTH ANNUAL REPORT.

PART I.

ORGANIZATION.

Committee on Experiment Department.

CHARLES H. PRESTON, <i>Chairman.</i>	THE PRESIDENT OF THE COLLEGE, <i>ex officio.</i>
J. LEWIS ELLSWORTH.	THE DIRECTOR OF THE STATION, <i>ex officio.</i>
ARTHUR G. POLLARD.	
CHARLES E. WARD.	
HAROLD L. FROST.	

Station Staff.

WILLIAM P. BROOKS, Ph.D., Director, 28 Northampton Road.
JOSEPH B. LINDSEY, Ph.D., Vice-Director, 47 Lincoln Avenue.
FRED C. KENNEY, Treasurer, Mount Pleasant.
CHARLES R. GREEN, B.Agr., Librarian, Mount Pleasant.

Department of Plant and Animal Chemistry.

JOSEPH B. LINDSEY, Ph.D., Chemist, 47 Lincoln Avenue.
EDWARD B. HOLLAND, M.Sc., Associate Chemist, in charge of Research Division,
28 North Prospect Street.
FRED W. MORSE, M.Sc., Research Chemist, 44 Pleasant Street.
HENRI D. HASKINS, B.Sc., In charge of Fertilizer Section, Amherst House.
PHILIP H. SMITH, M.Sc., In charge of Feed and Dairy Section, 102 Main Street.
LEVELL S. WALKER, B.Sc., Assistant, 19 Phillips Street.
JAMES C. REED, B.Sc., Assistant, Nutting Avenue.
JOSEPH F. MERRILL, B.Sc., Assistant, North Prospect Street.
CLEMENT L. PERKINS, B.Sc., Assistant, 32 North Prospect Street.
RUDOLF W. RUPRECHT, B.Sc., Assistant, 31 Amity Street.
JAMES T. HOWARD, Collector, North Amherst.
HARRY J. ALLEN, Laboratory Assistant, 89 Main Street.
JAMES R. ALCOCK, Assistant in Animal Nutrition, North Amherst.

Department of Agriculture.

WILLIAM P. BROOKS, Ph.D., Agriculturist, 28 Northampton Road.
H. J. FRANKLIN, Ph.D., In charge of Cranberry Investigation, Wareham.
EDWIN F. GASKILL, B.Sc., Assistant, North Amherst.

Department of Horticulture.

FRANK A. WAUGH, M.Sc., Horticulturist, Massachusetts Agricultural College.
FRED C. SEARS, M.Sc., Pomologist, Mount Pleasant.
JACOB K. SHAW, Ph.D., Research Assistant, 1 Allen Street.
DAVID W. ANDERSON, B.Sc., Graduate Assistant, 32 North Prospect Street.

Department of Botany and Vegetable Pathology.

GEORGE E. STONE, Ph.D., Botanist and Vegetable Pathologist, Mount Pleasant.
GEORGE H. CHAPMAN, M.Sc., Research Assistant, 13 Fearing Street.
EDWARD A. LARRABEE, B.Sc., Assistant, Clark Hall.

Department of Entomology.

HENRY T. FERNALD, Ph.D., Entomologist, 44 Amity Street.
BURTON N. GATES, Ph.D., Apiarist, 42 Lincoln Avenue.
ARTHUR I. BOURNE, B.A., Assistant, 66 North Pleasant Street.

Department of Veterinary Science.

JAMES B. PAIGE, B.Sc., D.V.S., Veterinarian, 42 Lincoln Avenue.

Department of Meteorology.

JOHN E. OSTRANDER, A.M., C.E., Meteorologist, 35 North Prospect Street.
R. N. HALLOWELL, Observer, Massachusetts Agricultural College.

Other Officers of the Experiment Station.

HERBERT J. BAKER, B.Sc., Secretary to the Director, Experiment Station.
MRS. LUCIA G. CHURCH, Stenographer to the Director, 4 Hallock Street.
MISS ALICE M. HOWARD, Stenographer, Department of Plant and Animal Chemistry,
North Amherst.
MISS F. ETHEL FELTON, Stenographer, Department of Plant and Animal Chemistry,
Phillips Street.
MISS JESSIE V. CROCKER, Stenographer, Department of Botany and Vegetable
Pathology, Sunderland.
MISS BRIDIE O'DONNELL, Stenographer, Department of Entomology, Hadley.

REPORT OF THE DIRECTOR.

CHANGES IN STAFF.

During the past year there have been no changes in the more important positions in the experiment station staff. A number of our younger assistants, however, have resigned for various reasons, among which the offer of higher salaries, plans to pursue graduate studies, or to engage in business are among the more prominent. The changes in detail are as follows:—

Summer C. Brooks, B.Sc., assistant in botany, replaced by Edward A. Larrabee, B.Sc.; Joseph F. Merrill, B.Sc., assistant in plant and animal chemistry, resigned; Clement L. Perkins, B.Sc., assistant in plant and animal chemistry, resigned; David W. Anderson, B.Sc., graduate assistant in department of horticulture, resigned, this position still being vacant. Erwin S. Fulton, B.Sc., assistant agriculturist, resigned, his position being taken by Edwin F. Gaskill, B.Sc., promoted. Charles M. Damon, observer in the meteorological department, replaced by R. N. Hallowell.

The position of second assistant agriculturist has not been filled, but instead the position of secretary to the director has been created. This position has been filled by the appointment of Herbert J. Baker, B.Sc., a recent graduate of the Massachusetts Agricultural College. This change has made possible a sharper division between outdoor and office work, Mr. Gaskill taking charge of the former, while Mr. Baker takes charge of the books, attends to routine correspondence, assists the director in preparation of material for publication, as well as in many other directions.

Two of our most experienced and valuable stenographers, Miss Brown and Miss Cobb, have resigned during the year, their places being taken by Mrs. Church and Miss Felton.

LINES OF WORK.

There have been no important changes in the general character of station work during the year, although in scope and amount it constantly increases. It includes general experiments both on the home grounds and at substations as well as in co-operation with farmers, research, police or control work, and dissemination of information.

GENERAL EXPERIMENTS.

In order to give a general idea of the nature of the work which is being carried on I cannot do better than to quote a statement in the last annual report:—

Under this head are included a large number of experiments relative to the following subjects: soil tests with fertilizers, with different crops in rotation; comparisons of different materials which may be used as sources, respectively, of nitrogen, phosphoric acid and potash for different field and garden crops; the results of the use of lime; systems of fertilizing grass lands, both mowings and pastures; comparisons of fertilizers for both tree and bush fruits; different methods of applying manures; variety tests of field and garden crops and of fruits; trials of new crops; determinations of the digestibility of feed-stuffs; methods of feeding for milk; systems and methods of management in feeding poultry for eggs; and co-operative work with selected farmers in the trial of crops and systems of fertilizing them.

In addition we have two substations where work of a highly diversified character is being carried on, viz., asparagus substation in Concord and cranberry substation in Wareham. In later pages will be found brief reports on the work in these substations, while a short account of the results of our co-operative experiments with alfalfa will be found in Part II. of this report.

No full general account or discussion of experimental work in progress will be given. Brief reports on some of the general experiments will be found under the departments in which they are being prosecuted.

RESEARCH.

The research work in progress at the station is, for the most part, carried on under the Adams fund. The work during the past year along certain lines has been somewhat interrupted owing to the necessity of making extensive additions and im-

improvements in our chemical laboratory. These improvements were, however, very carefully planned and executed under the general supervision of Dr. J. B. Lindsey and his associates, and the extent to which they were allowed to interfere with the progress of laboratory work was, on the whole, surprisingly small.

The following are the principal Adams fund problems which at present engage our attention:—

1. To determine the principles which should underlie practice in the use of fertilizers for the cranberry crop.

2. To determine the principles which should underlie practice in the use of fertilizers for asparagus.

3. Work in plant breeding in the endeavor to produce more rust-resistant types of asparagus. (In co-operation with the Bureau of Plant Industry, United States Department of Agriculture.)

4. Investigation of the solubility effect of ammonium sulfate on the soil of one of our experimental fields. (Field A.)

5. The effect of food on the composition of milk and butter fat and on the consistency or body of butter.

6. The cause of the digestion depression produced by molasses.

7. Why insecticides burn foliage.

8. The relations of climate to development of plants and crops both in health and disease.

9. The causes of calico or mosaic disease as affecting especially the tobacco and the tomato.

10. Malnutrition of plants; causes and prevention.

11. The intensity and amount of sunshine as affecting disease of plants.

12. The causes of winter-killing.

13. Determination of physiological constants.

14. Plant breeding, especially with peas, beans and squashes, to determine the extent to which the Mendelian laws appear to govern heredity.

15. The relations of climate to variation in leading varieties of apples.

16. The economic importance of digger wasps in relation to agriculture.

17. Color vision in bees.

A number of these lines of investigation are well advanced, though none can be regarded as brought to completion. Sufficient progress has, however, been made in connection with a number of them to warrant publication, and technical papers covering some phases of this work will be found in later pages. The more important are as follows:—

The natural fertility of cranberry bogs.

Tobacco injury due to malnutrition or overfertilization.

Variation, correlation and heredity in garden peas.

The effect of fertilizer on variation in corn and beans.

The chemistry of arsenical insecticides.

CRANBERRY SUBSTATION.

Dr. H. J. Franklin remains in local charge of the business and investigational work connected with our cranberry substation. He has devoted himself to the matters in his charge with the greatest faithfulness and enthusiasm, and it is a pleasure to testify to the great value of his services.

During the past year our equipment for work in the interests of cranberry growers at the substation in East Wareham has been much increased and a large amount of construction work has been done. The principal improvement made has been the erection of a building. This building contains a large screening and packing room, living and office rooms for the local officer in charge, a small laboratory, and large basement and cellar storage rooms. The cost of the building was about \$2,000.

Dr. Franklin furnishes the following description of special construction at the station bog completed during the year:—

1. *Flooding Areas.*—Five separate areas were diked off on the station bog for experiments in flooding. Four of the areas contain about one-fifteenth of an acre each and the fifth contains about an eighth of an acre. These areas are all separated from each other by dikes and narrow check strips. The dikes were built of turf and sand in the usual way, and average about 20 inches in height and 3 feet in width. In all, about 1,100 running feet of this diking was built. A canal, about 450 feet long and 3 feet wide, was constructed around the margin of the

bog, and connected with the main flooding canal in order to flow and drain these areas. Short side canals were dug to connect this canal with the separate areas. Small canals were also dug to connect the check strips with this canal system. In these various canals 13 wooden flumes were built for controlling the water.

2. *Skinner System Installation.* — On the station bog at East Wareham two lines, 70 and 100 feet long, respectively, of $\frac{3}{4}$ -inch galvanized piping were installed, 60 feet apart, after the usual manner of Skinner system installation. The longer line was supported at intervals by concrete posts of sufficient height to allow a man to walk beneath the piping without stooping. The other line was hung in rings suspended from a wire cable drawn taut between two concrete posts. Both of these methods of support have disadvantages. In the former the concrete posts are too numerous and too heavy to give good satisfaction on the usually soft bottom of a cranberry bog. In the latter it is hard to get rid of a certain amount of sag in the piping, which makes proper pipe drainage difficult in freezing weather. Probably a better method than either of these would be to support the piping on wooden posts reaching up only a foot or two from the surface of the bog, and placed close enough together to prevent the pipe from sagging perceptibly. Skinner "Outdoor No. 2" nozzles were used in this installation. The water for running the system was pumped from Speetacle Pond by means of a Myer's pump driven from the big engine used in flooding the bog. It was arranged to pump this water through 350 feet of $1\frac{1}{4}$ -inch galvanized piping before it reached the Skinner unions, leading into the $\frac{3}{4}$ -inch pipe lines. This $1\frac{1}{4}$ -inch pipe was, for the most part, buried in the ground. A special device driven by water pressure, for turning the pipes back and forth so as to throw the water on both sides, was also installed. The piping in the pump house was arranged to provide for heating the water by pumping it first through the cooling jacket of the 40 horse-power Fairbanks-Morse engine, and then through a coil in the exhaust pot of the engine.

For this installation, the Skinner Irrigation Company, Troy, O., through the courtesy of its president, Mr. W. H. Coles, pro-

vided nozzles and Skimmer unions and loaned the station a Skinner drilling machine.

The small piece of upland referred to in the last report as desirable in order to give better access to our building has been purchased during the year.

The Crop of 1911.

The yield of fruit on the station bog during the past year was in round numbers 850 barrels of berries. These were sold for the sum of \$4,988.33. The ordinary running expenses for the season amounted to \$1,817.08. The bog, therefore, yielded a net income over and above ordinary running expenses of \$3,171.25.

The crop of the season was probably better than the average crop will be, and it sold for good prices. We can hardly anticipate so large a net income annually, but there would seem to be no question that the product of the bog will be sufficiently large to furnish a considerable share of the funds that will be needed for paying the costs of experimental work.

Principal Lines of Cranberry Work.

Three principal lines of investigation with cranberries are in progress. These relate respectively to the fertilizer requirements of the crop, the relations of insects to the cranberry industry, and the study of injurious fungi.

Fertilizer Experiments.

The fertilizer experiments in Red Brook bog at Waquoit have again given indecisive results. These experiments will be discontinued. We have found it exceedingly difficult to care for them properly on account of their distance from our center of operations, and we are convinced, moreover, that certain natural inequalities in the character of the bog soil in the different plots must always considerably reduce the value of the results obtained.

During the past season a new series of plots has been laid out in the station bog. The results of the season do not show a well-defined benefit following from the use of either of the

different fertilizers employed. The crop where nitrate of soda is applied, indeed, showed a small average decrease. Both acid phosphate and high-grade sulfate of potash show a very small average increase, — not in either case enough to cover the cost of the fertilizer material applied. The results of the year, therefore, do not lend encouragement to the belief that the use of fertilizers on bogs of as good productive capacity as that belonging to the station will be followed by a profitable increase in the crop. It is important, however, to point out that the application of fertilizers this season was not made until about the middle of July. It seems probable that this is too late for the best results.

Dr. H. J. Franklin furnishes the following report concerning some of his principal lines of investigation during the past two years: —

Cranberry Investigations, 1910.

I. INSECTS.¹

Of the important cranberry pests heretofore known, those which received attention were the fruit worm, the fire worm and the cranberry girdler.

THE FRUIT WORM (*Mineola vaccinii* (Riley)).

Experiments in submerging cocoons containing larvæ of this insect, for varying lengths of time during the fall of 1909 and winter and spring of 1910, were carried on without very satisfactory results, due, perhaps, to failure to perfectly imitate natural bog conditions.

Spraying experiments were also carried on, the insecticides used being mostly combinations of adhesives and arsenicals. The combination found most effective consisted of the following mixture in 50 gallons of water: —

	Pounds.
Resin fish-oil soap,	4½
Bordeaux mixture: —	
(a) Stone lime,	4
(b) Copper sulfate,	3
Paris green,	1

As the soap had adhesive and spreading qualities, and the Bordeaux mixture gave body to the combination and also acted to some extent as an adhesive, this combination spread over the smooth surface of

¹ Dr. H. T. Fernald has aided Dr. Franklin in the insect work in an advisory way, and for his helpful suggestions Dr. Franklin acknowledges his indebtedness and expresses his appreciation.

the partly grown berries and adhered to it much better than did any arsenical with water alone. In this mixture, Paris green seemed to give better results than arsenate of lead. Best results were obtained by spraying twice with an interval of at most only a few days between the two applications, the first application thus acting as a basis for putting a thicker coating of poison on the fruit than would be possible with one spraying alone. This spraying was done about July 20 on berries of a late variety on a strictly dry bog (*i.e.*, no winter flowage). The fruit at this time varied greatly in size, the largest berries being nearly half grown. On some plots the fruit worm injury was reduced as much as 60 per cent.

THE FIRE WORM (*Eudemis vacciniæ* (Paek.)).

The work with this insect consisted entirely of spraying experiments. In the spring, arsenicals alone and in combination with Bordeaux mixture and resin fish-oil soap were tested as insecticides for the larvæ. It became evident that an insecticide of good sticking properties was needed for this purpose as the new foliage of the cranberry is smooth and glossy and holds the water sprays very poorly. Furthermore, this new growth develops rapidly during the time of the hatching of the first brood, and sometimes this hatching period is strung out for fully a month. The experiments indicated that a combination of Bordeaux mixture, Paris green and resin fish-oil soap, like the one given above for the fruit worm, would be most effective for this insect also. One test with this combination showed about three-fifths as much arsenic present on the foliage, after an all day's rain followed by a complete ten-hour flooding, as was present when the spray was first applied. The material for this combination is about as cheap as the arsenate of lead capable of doing the same work. The work connected with its preparation, however, is considerable.

Late in the fall, the value of sealecide and commercial lime-sulfur, as insecticides for destroying the eggs of this insect, was tested. Several plots were sprayed with different strengths of each of the two insecticides mentioned. On some plots a plank drag was used in advance of the spraying to turn the vines over, in order better to allow the spray to reach the lower surfaces of the leaves (on which the eggs are usually laid). The results of this spraying were observed early in June, 1911. Though many eggs hatched on all the plots, it was evident that on those treated with sealecide, a large percentage had been destroyed. However, on all plots on which many of the eggs were killed by the treatment, a large percentage of the winter buds were destroyed also. The fire worm injury appeared to be considerably worse on the plots which had been sprayed with the lime-sulfur than on unsprayed portions of the bog, though the reason for this was not apparent. This method of treatment does not appear promising.

CRANBERRY GIRDLER (*Crambus hortuellus* (Hübner)).

The work with this insect was confined to applying different depths of sand to infested plots, to find out what depth was necessary to smother the insect and prevent the moths from coming through. The sand was applied evenly, late in May, to depths varying from 1 to 3 inches. Means for catching and counting the moths which came through the sand on the various plots were provided. An unsanded check plot was also placed under observation and control. No moths came through the sand on any of the sanded plots, while a large number were captured from the check plot. Future work may show that less than a full inch of sand, when evenly spread, is sufficient. However, an inch is not too much to be practicable, especially as the vines are usually heavy where this insect becomes troublesome. To be effective, this treatment must be applied between December 1 and the following June 1 (when the insect is in its cocoon under the vines), and the sand must be spread evenly.

A NEW PEST.

During 1910 a Lepidopterous insect, known to science as *Gelechia trialbamaculella* Chambers, did great injury to a few strictly dry bogs. Neither the food plant nor the life history of this insect had been heretofore known. Its habits and life history were largely worked out during the season. The insect passes the winter in the moth state, as does the yellow-headed cranberry worm (*Peronca minuta* Robinson), and its larvæ, though considerably smaller, resemble somewhat the larvæ of that insect, both in general appearance and in habits. It is heavily parasitized, and will probably never do noticeable injury on winter-flowed bogs.

II. FUNGI.

The 1910 fungus work, done in co-operation with the Bureau of Plant Industry, consisted in obtaining the assistance of certain of the cranberry growers in practical spraying experiments, and in collecting specimens for examination by Dr. C. L. Shear, the expert of the Bureau of Plant Industry.

INVESTIGATIONS DURING 1911.

During 1911 the cranberry investigation work was divided between experiments and observations and construction work for future investigations.

EXPERIMENTS AND OBSERVATIONS.

This work came under the seven following heads, viz: Insects, Fertilizers, Fungous Diseases, Weather Observations, Fertilization of the Cranberry Blossom, Prolificness of Varieties, and application of Skinner Irrigation System to the Needs of the Cranberry Industry. The work under these heads is here outlined:—

1. *Insects.*

Observations were continued and experiments conducted with the fruit worm and the fire worm (black-headed cranberry worm). Numerous growers treated the yellow-headed cranberry worm (or, as it might be called in Massachusetts, the dry-bog fire worm), under advice given out by the station, apparently with universally satisfactory results. Heavy sanding done by various growers, in some cases, proved successful against the cranberry girdler. In others it failed to give satisfaction, the failure in every case observed being due to the fact that the sand was not applied evenly over the infested areas.

THE FRUIT WORM (*Mineola vaccinii* (Riley)).—Work was begun on the natural enemies of this insect, with the following objects in view:—

1. To find out what these enemies are.

2. To determine their relative abundance on flowered and dry bogs.

Spraying experiments with arsenicals and adhesives were continued. It was learned that too much resin fish-oil soap had been used in 1910. While the spraying was not timed so as to give the best results, the experience of 1911 indicates that the following formula will be found more satisfactory than the one given as the result of the 1910 experiments:—

Resin fish-oil soap (pounds),	2
Bordeaux mixture:—	
(a) Stone lime (pounds),	5
(b) Copper sulfate (pounds),	2½
Paris green (pound),	1
Water (gallons),	50

Much more of the soap than is here recommended causes bad clogging of nozzles and pumps.

While the fruit worm injury was reduced about one-third, this gain was largely offset by the loss due to tramping on the vines and berries while spraying, so that the amount of fruit obtained from the sprayed plots was but little greater than that picked from equal areas on the surrounding bog.

THE FIRE WORM (*Eudemis vacciniana* (Pack)).—The season's observations on this insect seem to indicate that the character of the vine growth has a strong influence on the length of the hatching period of the spring brood. Among thin vines most of the eggs seem to hatch within a few days after hatching begins. With deep, dense vines, this period seems to be so drawn out that numerous eggs are always present throughout the year, the two broods overlapping in this stage. If these observations are correct, the character of the

vine growth must have an important bearing on the efficacy of both flowing and spraying treatments. In practice, it seems to be an easy matter, on a thinly vined bog, to control this insect sufficiently to keep it from doing serious injury, either by spraying with arsenate of lead or by flowing, while it is apparently impossible to prevent serious injury on a densely vined bog by either of these treatments. The control of this insect, therefore, seems to hinge on the acquirement and maintenance of a thin vine growth, which is also the most desirable condition for maximum crops. Unfortunately, it seems difficult to get a thin vine growth on some bogs. However, this can probably be readily accomplished in most cases, at least, by heavy sanding and proper adjustment of water conditions. This adjustment might be along either or both of the following distinct lines:—

1. Early withdrawal of winter flowage with no long-continued re-flowage.

2. Sufficient drainage.

Experiments to test the methods of controlling this insect, here suggested, have already been started. Observations seem to show that large bogs, when compact (*i.e.*, approaching a circle or square) in general form, are, other conditions being the same, much more troubled with this insect than are small ones. Probably the chief reason for this is the fact that, during the summer, parasitic and predacious insects and spiders do not become so thoroughly distributed over the large bogs, at least until the periods of fire-worm activity are nearly over, and so do not become to so great an extent a controlling factor. On a winter-flowed bog, most of these forms are probably either destroyed or driven ashore by the flooding every year. They should not, during the summer, become as uniformly distributed on a large, compact bog as on a small one for two reasons, *viz.*:—

1. The distance which the parasitic and predacious forms must go to reach the central portion of the bog is, of course, greater on a large bog.

2. As the area from which these forms come onto the bog is probably restricted, for the most part, to a fringe at most only a few hundred feet wide, the area of the bog as it increases in size, if it is compact in shape, increases out of proportion to the increase of the area of this fringe. This argument agrees well with the following previously reported observations:—

1. The fire worm is only very rarely, if ever, troublesome on strictly dry bogs in Massachusetts.

2. When a winter-flowed bog becomes infested the infestation first noticed is always some distance away from the upland, usually where the winter flowage is deep.

The fact that, on a compact bog, there is a larger acreage within a given distance of any point, up to a distance that would take in the

whole bog, than there is on a long, narrow one of equal acreage, may also be, to some extent, a factor in favor of this insect. If it gained a foothold on one portion of such a compact bog, it would more readily and quickly spread to all other portions.

It seems probable, from the various observations made, that if a large bog, round or squarish in shape, is by any means whatever entirely freed from this insect (even by burning or by long-continued summer flowage), it will not, as a rule, long remain so if all the following conditions are allowed to exist:—

1. Winter flowage, especially if it is deep, over a considerable portion of the bog.
2. Not more than one reflowage after the 25th of May.
3. Conditions favoring heavy vine growth.

NEW PESTS. — During the season two new insect pests did considerable injury in some localities on cranberry bogs. One of these is a scale insect (*Aspidiotus oryococcus* Woglum) which superficially resembles the San José scale somewhat but is very distinct from that species. This species did much injury on a bog in Yarmouth and was noted in smaller numbers in a few other places.

The other insect is a species of white grub (*Lachnosterna* sp.). It caused the dying of circular areas on several bogs, principally in Carver, these patches varying in diameter from 3 to 30 feet. This injury observed superficially might easily be mistaken for the "ring-worm" injury caused apparently by fungous disease.

2. Fungous Discases.

This work, as during the previous season, was done in co-operation with the Bureau of Plant Industry. Co-operative spraying experiments were carried on by several practical growers. In addition 3 plots on the station bog, each 4 rods square, were sprayed with fungicides and the results noted, as shown by the quantity and keeping quality of the fruit obtained. The amount of fruit gathered from these plots in every case was somewhat less than that from checks marked on the surrounding bog. This was due, apparently, to the injury done by tramping on the vines while spraying. Loss due to decay up to December 4 was reduced, on an average, about one-half by the treatment. One plot was sprayed three times and the others twice with mixtures and on dates as follows:—

FUNGICIDE.	PLOTS.				
	A.	B.	C.	D.	E.
Bordeaux mixture, . . .	{ June 22 July 17 }	July 17	July 17	July 17	July 18
Neutral copper acetate, .	August 2	August 2	August 2	August 3	August 3

The Bordeaux mixture was made up with 3 pounds of lime and 4 of copper sulfate to 50 gallons of water. One pound of the neutral copper acetate was used to 50 gallons of water. Two pounds of resin fish-oil soap were used with the Bordeaux mixture in all cases and with the acetate.

3. *Weather Observations.*

The weather instruments were installed on May 15, from which date until October 15 observations were taken every morning at the station at East Wareham, and records of the following made:—

Maximum thermometer in shelter.

Maximum thermometer on bog.

Minimum thermometer in shelter.

Minimum thermometer on bog.

Precipitation.

Wind direction.

Continuous thermograph readings.

Continuous barograph readings.

The readings of the maximum and minimum thermometers and the amount of precipitation were telegraphed to the local office of the Weather Bureau at Boston every morning after May 15 during the spring and fall periods of frost danger.

4. *Fertilization of the Cranberry Blossom.*

Numerous experiments were carried out and observations made on the cross-fertilization of the cranberry blossom. Bees of all kinds were shut out from half a square rod of vines, during the blossoming period, by means of a mosquito-netting tent, with the result that only about 2½ quarts of berries developed, while on any equal area on the surrounding bog as much as 20 quarts were picked, the average crop of the entire bog being about 70 barrels to the acre. From a check plot of equal area laid off close to this tent 28 quarts were gathered. Another larger tent was erected and the honey bee alone allowed to enter it during the bloom, a hive being placed so as to open into it. Under this tent as good a crop developed as on the surrounding bog. These experiments seem to prove that bees are necessary to the satisfactory cross-pollination of the cranberry blossom and that the honey bee is efficient in this work.

As the vines approached full bloom under the tent from which the bees were excluded the blossoms quite generally began to take on a peculiar vivid pink color, and as the blossoming advanced this became more and more striking. Only a small percentage of the blossoms on the bog outside of the tent took on this color, while inside there were few which did not show it strikingly. This tent was on Early Black vines. The tent into which honey bees were admitted was placed on

Howe vines. This variety came to full bloom in the midst of a period of unusually hot weather in July, and had a larger percentage of the pink blossoms than did the Early Blacks which blossomed earlier. The vines under the tent, into which the honey bees were admitted, had a very noticeably smaller proportion of these pink blossoms than did the surrounding bog. They were, in fact, almost entirely absent. These observations seemed to indicate that the peculiar pink color of the bloom was a sign of fertilization failure. This pink coloring certainly always accompanies lack of fertilization with the Early Black variety, for it was just as noticeable in a 1910 experiment, in which bees were shut out by mosquito netting, as it was in the 1911 experiment. To make this matter more certain a large number of Howe blossoms, showing this pink coloring, were marked with yarn and examined late in August. Hardly 2 in 11 had succeeded in producing berries. This was less than one-half of the proportion of berries to blossoms on the bog as a whole. In other words, a much smaller proportion of pink blossoms than of normally colored ones produced berries, thus confirming the indications obtained from the tent experiments. To go with this there is the possibility that fertilization may take place to some extent, though abnormally retarded, after a blossom has taken on the pink color.

After the unfertilized blossoms turned pink in the tent experiments the corolla always hung on abnormally, so that the vines under the tent, from which bees were excluded, appeared to be in full bloom when, on the surrounding bog, the bloom was almost entirely past.

The conclusion arrived at, from these and other observations, is that it will often pay to keep honey bees near cranberry bogs during the blossoming season. There are, undoubtedly, years in which this practice will not repay anything for the extra labor and expense involved. It is probable, however, that it will pay well to keep bees in any season in which wild bees are scarce, or in which there is much bad weather during the blossoming period to reduce the length of time in which the bees can work. Unfortunately, we have not yet sufficient data to make an estimate of the number of hives necessary for the satisfactory pollination of a bog of any given acreage.

With most varieties, an upright having 5 blossoms will probably, as a rule, produce as many berries, if only 2 of those blossoms are cross-fertilized, as it would if all were fertilized. This is because the cranberry, in common with other plants, always produces the means of reproduction far in excess of what it uses. This is borne out by the fact that the crop of berries under the hive-bee tent was not greater than on the surrounding bog, though the lack of pink blossoms seemed to indicate a more perfect pollinization.

5. *Prolificness of Varieties.*

Examination of a considerable number of varieties on numerous bogs showed a marked variation, between varieties, in the average number of berries borne by the individual upright and in the proportion of berries to blossoms. Moreover, this variation seemed, to a certain degree, constant for the different varieties wherever found, even when they were side by side on the same bog and under the same conditions. Some varieties averaged less than 2 berries, and others more than 3, to the upright. Then, too, there was a noticeable varietal variation in the proportion of sterile uprights present. This condition of things obviously is not due to relative lack or abundance of pollen-carrying agents (bees), or to differences in fertility of the bottom on which the vines grow, but is the result of a varying quality of natural prolificness in the vines themselves.

During the season, work was begun with the idea of eventually producing, if possible, a much more prolific variety than any at present known. A large number of uprights of three different varieties were selected and marked for planting in separate plots in the spring. Only uprights were marked which produced during the season 4 or 5 good berries. It will be observed that this is in line with similar work already carried out successfully with corn, potatoes and other crops.

6. *Skinner System of Irrigation.*

This plant has been installed to test thoroughly the value of this system as applied to the following needs of a dry cranberry bog: irrigation, frost protection, winter protection and possibly spraying. This system is not expected to supplant water supply by other methods in vogue, where these methods are available. Late in the fall, the feasibility of heating the water so as to raise the temperature by radiation, without sprinkling over the entire surface of the bog, was tried. It was thought that the amount of piping and the size of the pump necessary in practice might in this way be reduced. The tests, however, showed this to be impracticable.

ASPARAGUS SUBSTATION, CONCORD.

Mr. Charles W. Prescott, to whose hearty interest, enthusiasm and efficient supervision we are greatly indebted, has continued in charge of the details of the work in progress.

Two distinct lines of investigation are being carried on: —

1. Breeding experiments which have for their object the production of a rust-resistant type of asparagus of good commercial quality.

2. Fertilizer experiments planned with a view to determining if possible the relation of different fertilizer elements to the crop as regards yield, quality and capacity to resist rust.

Breeding Experiments. — The breeding work in progress is conducted on the basis of a co-operative understanding with the Bureau of Plant Industry of the United States Department of Agriculture. The details of the work have been looked after the past season by Mr. J. B. Norton, who has carried it forward with the same enthusiasm and energy which has characterized his work heretofore.

A number of rust-resistant types have been produced. From among these those which show the best commercial characteristics and the greatest vigor will be propagated as rapidly as possible for further trial and ultimate distribution. In view of the great improvement already made it is confidently anticipated that complete success in attaining the ends in view will soon be realized.

Fertilizer Experiments. — The results of the fertilizer experiments in progress are not as yet sufficiently decisive to make it seem advisable to publish a full report. Owing to the thorough preparation which the entire field received before it was divided into plots, even those to which no manure or fertilizer has been applied still continue to give an excellent yield. These plots, however, are now beginning to fall behind those which receive the different applications of manure and fertilizer materials which are under trial. The field contains 40 plots of one-twentieth acre each, and the past season was the fifth since the plots were set. The yield was fairly satisfactory both as to quantity and to quality. The cutting season lasted from May 8 to June 24. The total yield of all the plots was 9,347 pounds, 5 ounces.

On the basis of recorded yields and observations the following conclusions appear to be warranted: —

1. Nitrate of soda used in connection with acid phosphate and muriate of potash proves beneficial, but an increase above the rate of 466 pounds per acre does not appear to be useful.

2. Nitrate of soda used in connection with an application of barnyard manure at the rate of 10 tons per acre proves benefi-

cial, but in this case, also, an increase above the rate of 466 pounds per acre of nitrate is not followed by a further increase in the crop.

3. Nitrate of soda has been applied according to three distinct plans:—

(a) All applied in early spring.

(b) One-half applied in early spring and the balance at the close of the cutting season.

(c) All at the close of the cutting season.

These variations in method of applying have been tried with nitrate of soda in differing amounts and in varying combinations.

The variation in season of application is not followed by any well-defined difference in yield, but the amount of rust has appeared to be less with the larger applications applied at least in part after the cutting season. In other words, nitrate of soda so applied and in such liberal quantities as to promote a continuous vigorous growth of the plant after the close of the cutting season seems to increase the capacity of the plants to resist rust.

4. Among the different materials used as the source of potash, viz., muriate, high grade sulfate, low grade sulfate, wood ashes, and kainit, the plot receiving the latter showed the least rust. It is important, however, to point out that this may have been in part a consequence of the fact that the plot was located on the side of the field lying at the greatest distance from the fields which are believed to have been the chief sources of rust infection. The comparative freedom from rust of the plants on the kainit plot, therefore, may have been due in large measure to location. The decided difference, however, in the amount of rust on this plot and on the one immediately adjoining it, the location of which with reference to rust infection is not very different, lends probability, at least, to the conclusion that the kainit exercised a favorable influence in preventing rust.

5. Acid phosphate used in connection with nitrate of soda and muriate of potash has given a considerable increase in crop. This increase is greatest where the acid phosphate is used at the maximum rate of 188.7 pounds per acre.

6. Muriate of potash used in connection with nitrate of soda

and acid phosphate increases the crop, but an increase in the quantity of muriate above the rate of 260 pounds per acre does not result in further increase in the crop.

CONTROL WORK.

Reports in full detail covering the various lines of control work carried on by the station have been prepared by the chemists in charge. These will be found in later pages of this report.

Fertilizer Law. — The fact was pointed out in the last annual report that a new law had been drafted for presentation in the Legislature of 1911. This law was enacted by the Legislature and went into effect Dec. 1, 1911. The new law is working smoothly and satisfactorily. It is bringing in the increased revenue needed for more thorough work, and the principal change introduced, viz., bringing agricultural lime under its provisions, is proving of much value to our farmers.

Dairy Law. — The draft for a new dairy law referred to in the last annual report failed of enactment in the Legislature of 1911. It will be reintroduced in the Legislature of 1912, and it is confidently anticipated that it will be enacted. The most important change from the existing law consists in bringing milk inspectors, and the Babcock machines and apparatus which they use, under the provisions of the law.

Feed Law. — The fact was referred to in the last annual report that the appropriation received from the State for carrying out the provisions of the existing feed law were proving insufficient to cover the costs of thorough work. During the past year a draft for a new law has been prepared. Its preparation has involved a great deal of study and many conferences with parties affected by the law. The principal changes proposed are to bring the various wheat offals under the provisions of the law, to require a guarantee of the maximum percentage of crude fiber present, to require the statement of ingredients contained in each feeding stuff, and to require the registration of each brand of feeding stuff before it is sold. The amount of the appropriation provided under the new draft is \$6,000 in place of \$3,000 as under the present law. Besides these changes the phraseology has been made more explicit, violations are

more clearly defined, and the director is given discretionary power regarding prosecutions.

In form and general content the new draft has been closely modeled after the uniform feed law adopted by the Association of Feed Control Officials of the United States. It is believed that the provision of a uniform feed law for the entire country is desirable in the interests alike of the buying public and manufacturers and dealers.

DISSEMINATION OF INFORMATION.

The station endeavors to reach the public with helpful information in three rather distinct lines: distribution of publications, private correspondence, and lectures and demonstrations.

Publications. — The station issues three classes of publications: an annual report in two parts, bulletins and circulars.

Part I. of our annual report contains the formal reports of the director, treasurer, and heads of departments and technical papers giving the results of research work. Part II. contains papers of a more popular character. It is our aim to include in this part of the report such matters as are of most immediate interest on the farm.

The demand for bulletins and circulars constantly increases. With the further growth and development of the extension department of the Massachusetts Agricultural College it is expected that this demand will be increasingly met by means of its publications, while our own publications will be, for the most part, restricted to such as deal with the results of our investigations. It must be recognized that satisfying this popular demand is extension work rather than experimental.

The following tables show the publications of the year 1911 and those of that and earlier years which are still available for free distribution: —

Publications during 1911.

Annual report: —

Part I., 356 pages; Part II., 95 pages.

Bulletins: —

No. 136. Inspection of Commercial Feed Stuffs, P. H. Smith and C. L. Perkins. 56 pages.

- No. 137. The Rational Use of Lime, Wm. P. Brooks; The Distribution, Composition and Cost of Lime, H. D. Haskins and J. F. Merrill. 19 pages.
- No. 138. Tomato Diseases, George E. Stone. 32 pages.
- No. 139. Inspection of Feed Stuffs, P. H. Smith and C. L. Perkins. 32 pages.
- No. 140. Inspection of Commercial Fertilizers, H. D. Haskins, L. S. Walker, J. F. Merrill and R. W. Ruprecht. 86 pages.

Circulars:—

- No. 30. Balanced Rations for Dairy Stock, J. B. Lindsey. 7 pages.
- No. 31. Lime and Sulphur Solutions, G. E. Stone. 4 pages.
- No. 32. An Act to regulate the Sale of Commercial Fertilizers (chapter 388, 1911). 4 pages.
- Meteorological bulletins, 12 numbers. 4 pages each.

Publications Available for Free Distribution.

Bulletins:—

- No. 33. Glossary of Fodder Terms.
- No. 64. Concentrated Feed Stuffs.
- No. 76. The Imported Elm-leaf Beetle.
- No. 84. Fertilizer Analyses.
- No. 90. Fertilizer Analyses.
- ✓ No. 115. Cranberry Insects.
- No. 123. Fungicides, Insecticides and Spraying Directions.
- No. 125. Shade Trees.
- No. 127. Inspection of Commercial Fertilizers.
- No. 130. Meteorological Summary—Twenty Years.
- No. 131. Inspection of Commercial Fertilizers, 1909.
- No. 132. Inspection of Commercial Feed Stuffs, 1910.
- No. 133. Green Crops for Summer Soiling.
- No. 134. The Hay Crop.
- No. 135. Inspection of Commercial Fertilizers, 1910.
- No. 136. Inspection of Commercial Feeds, 1911.
- No. 137. The Rational Use of Lime.
- No. 138. Tomato Diseases.
- No. 139. Inspection of Commercial Feed Stuffs, 1911.
- No. 140. Inspection of Commercial Fertilizers, 1911.
- Index to bulletins and annual reports of the Hatch Experiment Station previous to June, 1895.
- Index to bulletins and annual reports, 1888-1907.

Circulars:—

- No. 12. The Unprofitable Cow and how to Detect her.
- No. 20. Lime in Massachusetts Agriculture.
- No. 25. Cottonseed Meal.
- No. 26. Fertilizers for Potatoes.

- No. 27. Seeding Mowings.
No. 28. Rules Relative to Testing Dairy Cows.
No. 29. The Chemical Analysis of Soils.
No. 32. An Act to regulate the Sale of Commercial Fertilizers.
Summer Soiling Crops.
Home-mixed Fertilizers.
Dairymen losing Money on Low-Grade Feeds.
Balanced Rations for Business Cows.
Orchard Experiment.
Fertilizers for Turnips, Cabbages and Other Crucifers.
Fertilizers for Corn.
Annual reports: 10th, 12th, 13th, 14th, 15th, 16th, 17th, 20th; 21st, Part II.; 22d, Parts I. and II.; 23d, Parts I. and II.

Circulation of Publications.—As provided by act of our Legislature, Part I. of our annual report is printed with the report of the secretary of the State Board of Agriculture, and those on the mailing list of that Board will receive this publication. The act provides, also, that 5,000 copies of Part I. shall be furnished to the station. These are used in supplying libraries and directors of agricultural experiment stations, libraries and presidents of agricultural colleges, the public libraries of Massachusetts and other public libraries on our mailing list, individuals on the mailing list of the United States Department of Agriculture, and institutions and periodicals on our exchange list.

The State prints an edition of 16,000 copies of Part II. of our annual report for the use of the station. This part of the report and our bulletins are sent to all those on our general mailing list, to the public libraries of the State, to individuals on the mailing list of the United States Department of Agriculture likely to be interested, and to experiment stations and the agricultural colleges.

It is our practice to reserve a considerable number of each publication to meet subsequent demands, but such demands have of late been so numerous that our supply of most of our earlier editions is exhausted.

Our meteorological bulletins are sent only to agricultural college and experiment station libraries, presidents and directors of agricultural colleges and experiment stations, to the depart-

ment of agriculture and office of experiment stations, to newspapers and libraries and to individuals who have especially requested them.

The circulars which we issue are not sent out to a regular mailing list. They are prepared for use in connection with the correspondence of the station, for it is by the use of such circulars only that we find it possible to give the full information and advice needed by those consulting us by letter. Any of these circulars, however, will be sent on special request.

The newspapers of the State receive an abstract of all important publications, and as a rule we find them ready to publish such abstracts.

Mailing Lists. — A large amount of work is required in keeping our mailing lists accurate and thoroughly alive. We are constantly dropping names and as constantly adding new ones. The tendency is towards an increase, although just at present our total is a few hundred less than shown in the last annual report, owing to the fact that some lists not previously revised for a number of years have undergone very careful revision resulting in dropping a number of addresses which had undoubtedly been for some time dead. The following table shows the nature of the lists which we maintain and the number of addresses in the several classes: —

Residents of Massachusetts,	12,651
Residents of other States,	2,438
Residents of foreign countries,	242
Newspapers,	518
Libraries,	306
Exchanges,	151
Cranberry growers,	1,395
Beekeepers,	2,866
Meteorological,	389
	<hr/>
Total,	20,956

Correspondence. — During the year 1911 the number of letters of inquiry answered by members of the station staff has been about 12,000. This is a somewhat smaller number than

for 1910. It is apparent that the public in increasing degree is recognizing that the extension department is especially manned and equipped for service of this character, and it would seem, therefore, that we may confidently anticipate still further relief from this work in the near future, — a consummation long wished for, as it will give station men more time for the more legitimate station work of research and experiment.

Lectures and Demonstrations. — The public demand for lectures and demonstrations has been particularly active, and station men have been frequently engaged in service of this character. The general management and arrangements are, for the most part, looked after by the extension department, but even under this plan the draft upon the time of some of our men has been so heavy as to leave little opportunity for attention to experiment or research. This has been particularly true of the men in our poultry and apicultural departments, which are greatly in need of additional men in order that the requirements of both lines of work — extension and research — may be more fully met.

BUILDINGS.

Extensive improvements and repairs have been made during the year in the chemical laboratory of the station at a cost of \$7,500, appropriated by the last Legislature. The following are the principal improvements secured: two additional rooms for research work; enlarged office room; greatly increased space for storage of apparatus, chemicals and samples; a fire-proof vault; and a library and reading room. Central steam heat has been introduced in place of the independent hot-water system. Numerous minor repairs have been made and the entire building has been replumbed, rewired and repainted. As a consequence of the various changes and improvements the building now fairly satisfies the needs of the chemical department of the station, but the chemical work increases so rapidly that it cannot be many years before additional laboratory accommodations will be needed.

There has been but one other important building operation during the year, — the erection of the building at the cranberry

substation in East Wareham, already mentioned and briefly described in the report on the work at that substation. The cost of the building (about \$2,000) was nearly covered by an unexpended balance of the \$15,000 appropriation made by the Legislature in 1910.

WM. P. BROOKS,

Director.

REPORT OF THE TREASURER.

ANNUAL REPORT

OF FRED C. KENNEY, TREASURER OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

For the Year ending June 30, 1911.

The United States Appropriations, 1910-11.

	Hatch Fund.	Adams Fund.
<i>Dr.</i>		
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1911, under acts of Congress approved March 2, 1887 (Hatch fund), and March 16, 1906 (Adams fund),	\$15,000 00	\$15,000 00
<i>Cr.</i>		
By salaries,	\$13,269 05	\$11,659 35
labor,	321 49	1,079 94
publications,	8 50	—
postage and stationery,	2 89	51 44
freight and express,	—	—
heat, light, water and power,	1 38	170 47
chemicals and laboratory supplies,	31 74	137 54
seeds, plants and sundry supplies,	478 69	356 20
fertilizers,	542 04	75 27
feeding stuffs,	196 35	1 46
library,	—	7 53
tools, machinery and appliances,	—	4 50
furniture and fixtures,	61 75	50 00
scientific apparatus and specimens,	86 12	1,343 17
live stock,	—	—
traveling expenses,	—	18 13
contingent expenses,	—	—
buildings and land,	—	45 00
Total,	\$15,000 00	\$15,000 00

State Appropriation, 1910-11.

Cash balance brought forward from last fiscal year,	\$4,198	48
Cash received from State Treasurer,	13,500	00
fertilizer fees,	6,239	83
farm products,	2,068	85
expert services,	25	00
miscellaneous sources,	9,601	69
		<u>\$35,633 85</u>
Cash paid for salaries,	\$9,875	92
labor,	10,342	73
publications,	2,443	03
postage and stationery,	982	42
freight and express,	407	18
heat, light, water and power,	579	55
chemicals and laboratory supplies,	636	97
seeds, plants and sundry supplies,	2,507	67
fertilizers,	350	99
feeding stuffs,	1,548	98
library,	451	10
tools, machinery and appliances,	69	50
furniture and fixtures,	408	79
scientific apparatus and specimens,	649	06
live stock,	44	00
traveling expenses,	2,303	89
contingent expenses,	250	00
buildings and land,	895	17
balance,	866	90
		<u>\$35,633 85</u>

REPORT OF THE AGRICULTURIST.

WM. P. BROOKS.

As has been the case for many years, the problems which have chiefly engaged the attention of the department of agriculture during the past year are such as are connected with the selection, adaptations, and methods of application of manures and fertilizers. In most cases a definite and uniform plan of experiment has been followed for a considerable number of years. The work will not be reported in detail, but attention is called to a few of the more striking results.

I. COMPARISON OF DIFFERENT MATERIALS AS A SOURCE OF NITROGEN (FIELD A).

The different materials under comparison are manure, one plot; nitrate of soda, two plots; dried blood, two plots; and sulfate of ammonia, three plots. In the case of both nitrate of soda and dried blood one of the two plots receives muriate as a source of potash; the other, high-grade sulfate. The sulfate of ammonia is used on two plots in connection with muriate, and on one in connection with sulfate of potash. The field contains three no-nitrogen plots, on two of which muriate is used as a source of potash; on the other, high-grade sulfate. All the plots in the field receive an equal liberal application of dissolved bone black as a source of phosphoric acid, while all the different materials furnishing either nitrogen or potash are used on the different plots in such amounts as to furnish, respectively, equal quantities per plot of nitrogen and of potash.

The crops grown in this experiment in the order of their succession have been: oats, rye, soy beans, oats, soy beans, oats,

soy beans, oats, clover, potatoes, soy beans, potatoes, soy beans, potatoes, oats and peas, corn, clover for four years and corn.

The corn crop of the past season made an excellent growth, but was rather seriously injured by an exceptionally early and severe frost on September 13. So serious was the injury that it was deemed best to allow the crop to stand until the ears were thoroughly dry. It is believed that the proportion of sound corn obtained by following this plan was greater than it would have been had the crop been cut and shocked in accordance with the usual custom.

On the basis of 100 for nitrate of soda, the relative standing of the different nitrogen fertilizers and the no-nitrogen plots as measured by total yield during the past season was as follows: —

	PER CENT.	
	Grain on Cob.	Stover.
Nitrate of soda,	100.00	100.00
Barnyard manure,	98.20	100.00
Sulfate of ammonia,	101.41	98.25
Dried blood,	101.58	101.58
No nitrogen,	95.67	108.06

The relative standing of the different materials as indicated by total yield for the twenty-two years during which the experiment has continued is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	94.26
Dried blood,	92.80
Sulfate of ammonia,	87.53
No nitrogen,	73.04

In making up the table on relative standing for the twenty-two years the grain only for 1911 was included, as, owing to the manner in which the crop was handled, there had been breakage and waste from the frost-bitten stalks and leaves, the amount of which was not uniform for the different plots.

On the basis of increase as compared with the no-nitrogen plots the relative standing for the different nitrogen fertilizers for the twenty-two years is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	78.71
Dried blood,	73.29
Sulfate of ammonia,	53.74

It will be noted that nitrate of soda, as in previous years, shows a much greater average increase than either of the other sources of nitrogen.

One of the most striking results of the past season was the relatively large yield produced on the no-nitrogen plots. It amounts to about 95 per cent. of the average yield on all the different plots which have received an application of nitrogen annually. This result, it will be readily understood, was no doubt due to the fact that clover for three years had preceded the corn crop of the past year. The figures emphasize in a most striking way the extent to which rotations including a legume may be made to take the place of the use of nitrogen fertilizers.

II. MURIATE AS COMPARED WITH SULFATE OF POTASH.

These comparisons were begun in 1892. Five pairs of plots are under comparison. From 1892 to 1899 potash salts were used in quantities (varying in different years, but always in equal amounts, on the two members of a pair of plots) ranging from 350 to 400 pounds per acre. Since 1900 the quantity used has been uniform on all plots, and at the rate of 250 pounds per acre annually. The only other fertilizer material applied has been fine-ground bone to each plot at the uniform rate of 600 pounds per acre. The past year is the twentieth year of these experiments. The crops during the year were alfalfa on one pair of plots, clover on one pair, and asparagus, rhubarb and blackberries, each occupying a part of a pair of plots. The rates of yield per acre on the different potash salts are shown in the following table: —

	RATE PER ACRE (POUNDS).				
	Alfalfa.	Asparagus.	Rhubarb.	Blackberries.	Clover.
Muriate of potash, . . .	1,627.9	6,181.2	14,128	2,086.5	2,905.4
Sulfate of potash, . . .	2,041.4	5,161.6	19,315	5,907.4	3,689.6

It will be noted that the asparagus is the only crop which gives a larger yield on the muriate, and that the superiority of the sulfate is quite marked in the case of each of the others.

There was a characteristic and remarkable difference in the appearance of the alfalfa on the two salts throughout the entire season, that on the sulfate being of a richer, darker green and far more vigorous growth. A similar difference characterized the appearance of the clover on the two salts. In the case of rhubarb the proportion of leaf to stalk, as in previous years, was considerably greater on the sulfate than on the muriate. This appears to be a highly characteristic effect, and is one for which at present we are unable to offer an explanation.

III. MANURE ALONE COMPARED WITH MANURE AND SULFATE OF POTASH.

This experiment has been in progress since 1890. It occupies the south corn acre, which is divided into 4 plots of one-quarter acre each. On two of these plots good barnyard manure from well-fed dairy cows has been applied at the rate of 6 cords per acre. On the other two plots similar manure has been applied, at first at the rate of 3 cords per acre, but since 1895 at the rate of 4 cords per acre, and together with these smaller applications of manure high-grade sulfate of potash at the rate of 160 pounds per acre has been applied. The object in view is to determine the crop-producing capacity of the smaller amount of manure combined with sulfate of potash as compared with that of the larger application of manure.

The general practice has been to apply manure annually, but in a number of instances, when it was feared that if this should be done the newly seeded grass and clover would lodge badly, the customary application has been withheld; but in all cases if withheld from one plot it was of course withheld from all.

The plan of cropping this field for the last thirteen years has been corn and hay in rotation in periods of two years for each. During the past season the crop has been corn. The rates of yield per acre are shown in the following table:—

	YIELD PER ACRE.		
	Hard Corn (Bushels).	Soft Corn (Bushels).	Stover (Pounds).
Plot 1, manure alone,	89.140	2.460	4,780
Plot 2, manure and potash,	85.260	1.430	4,740
Plot 3, manure alone,	88.570	2.230	4,580
Plot 4, manure and potash,	83.490	1.890	4,580
Averages:—			
Plots 1 and 3, manure alone,	88.855	2.345	4,680
Plots 2 and 4, manure and potash,	84.375	1.660	4,660

The crop on all the plots was an excellent one, and it will be noted that the larger application of manure alone gave a yield of hard corn about $4\frac{1}{2}$ bushels greater than that produced on the smaller amount of manure and potash. The combination produced a slightly smaller yield both of soft corn and stover. The difference in crop is not sufficiently great to cover the difference in cost between the two systems of manuring.

IV. AVERAGE CORN FERTILIZER COMPARED WITH FERTILIZER RICHER IN POTASH.

These experiments are carried on on what is known as our north corn acre, which is divided into 4 one-quarter acre plots. The experiments began in 1891. Continued corn culture was the rule at first, but for the past sixteen years corn and hay, two years of each, have regularly alternated. Two of the plots in the field, 1 and 3, are fertilized with a home-made mixture furnishing nitrogen, phosphoric acid and potash in highly available forms, and in the same proportions in which they are contained in the average corn fertilizer offered on our markets. The other two plots are fertilized annually with a home-made mixture containing much less phosphoric acid and more potash than is applied to the other plots.

The crop of the past season was corn, and it was an excellent one on all plots. The average yields were at the following rates per acre:—

	Hard Corn (Bushels).	Soft Corn (Bushels).	Stover (Pounds).
On the fertilizer rich in phosphoric acid and low in potash,	88 66	1 89	4,230
On the fertilizer low in phosphoric acid and rich in potash,	86 69	2.02	4,456

The larger proportion of phosphoric acid has evidently been favorable to the production of sound, well-ripened grain.

V. TOP-DRESSING FOR HAY.

Since 1893 we have been using barnyard manure, wood ashes, and a mixture of bone meal and muriate of potash as top-dressing for permanent mowing. The total area included in these experiments is about 9 acres divided into 3 plots, so that each year each system of top-dressing is represented. The order in which the different materials is applied to any given plot is as follows: barnyard manure; next year, wood ashes; and in the succeeding year a combination of fine ground bone and muriate of potash. The rates of application per acre:—

1. Barnyard manure, 8 tons.
2. Wood ashes, 1 ton.
3. { Fine-ground bone, 600 pounds.
Muriate of potash, 200 pounds.

The crop of the past year was very much lighter than usual on account of the marked deficiency of rainfall and the extreme heat. The average yield for the entire area this year was at the rate of 3,993 pounds per acre. The yields on the different materials used in top-dressing were at the following rates per acre:—

Barnyard manure,	Pounds.
Barnyard manure,	3,840
Fine-ground bone and muriate of potash,	4,304
Wood ashes,	3,736

The average yields to date under the different systems of top-dressing have been at the following rates per acre: —

	Pounds.
Barnyard manure,	6,211
Wood ashes,	5,681
Fine-ground bone and muriate of potash,	6,061

POULTRY WORK.

For a considerable number of years experiments on the best methods of feeding poultry for egg production have been conducted in this department. In the spring of 1911 all poultry work was transferred to the head of the poultry department of the college. There has been so much construction work in this department during the past year, however, in the effort to get it properly established and equipped, that the poultryman has no report to offer at this time.

REPORT OF THE HORTICULTURIST.

FRANK A. WAUGH.

The work in horticulture has gone on during the year on much the same lines as heretofore, but plans have been forming for certain new kinds of work. The work on heredity and variation in peas has developed a considerable mass of data from which publication is made in this report. Certain correlative topics are still under study and will be reported on later.

The work on Mendelism in beans has been going on successfully during the last year. We now have on record full data for about 15,000 plants. It is expected that one or two years further study will be required to bring this subject to the point of publication. Somewhat similar work with squashes is also under way and will be carried forward as fast as opportunity permits. A few minor problems are studied as time and opportunity offers.

The work in apple variation, already reported upon in one or two publications, still progresses. The plan of work now contemplates a more intensive study of variation and its correlation with local climatological factors.

A research experiment in the mutual influence of stock and cion has been planned to extend over a period of twenty years or more. Work has begun on a small scale, but it will probably require another year or two to get the experiment fully under way. The planning and inauguration of this experiment have been chiefly due to the efforts of Dr. J. K. Shaw.

There is a strong demand for experimental work in other lines of horticulture aside from those already taken up at this station. Work is urgently needed in lines of market gardening

and floriculture, and some steps should be taken at once to serve these important and significant industries. For this purpose additional funds should be provided by the State.

All the experimental work herein referred to has been under the direct management of Dr. J. K. Shaw. In order to carry out the work now under way, and other work imperatively needed, it will be very desirable to have an additional assistant within the year.

REPORT OF THE CHEMIST.

JOSEPH B. LINDSEY.

This report gives a brief outline of the work of this department for the year ending Dec. 1, 1911.

1. CORRESPONDENCE.

There have been sent out substantially 5,500 letters during the year, the estimate being based on the number of stamps used. It is not believed that more than the usual number of letters of inquiry have been received by this department. The increase of 500 over the year 1910 was probably due to the increased correspondence in connection with the control and cow testing work.

2. NUMERICAL SUMMARY OF SUBSTANCES EXAMINED IN THE CHEMICAL LABORATORY.

The following substances have been received and examined: 114 samples of water, 527 of milk, 2,799 of cream, 204 feed-stuffs, 209 fertilizers and fertilizer refuse materials, 63 soils, 36 lime products, 27 ash analyses of plants and 4 miscellaneous. There have also been examined in connection with experiments in progress by the several departments of the station 116 samples of milk and cream, 57 cattle feeds and 377 agricultural plants. In connection with the control work there have been collected 1,063 samples of fertilizer and 773 samples of feed-stuffs. The total for the year was 6,369.

The above does not include the work of the research section. In addition, 15 candidates have passed the examination and

secured certificates to operate the Babcock test, and 4,466 pieces of Babcock glassware have been tested for accuracy, of which only 12 pieces or .27 of 1 per cent. were condemned as inaccurate.

3. WORK OF THE RESEARCH SECTION.

Work has continued along much the same lines as heretofore. It has been considerably impeded, however, by the extensive repairs made to the laboratory during the summer and autumn.

(a) Messrs. Holland and Reed have devoted a large amount of their time to the devising of methods for the making of chemically pure insecticides, and have furnished the entomological department with Paris green, acid arsenate of lead and metarsenite of lime. A paper on this work will probably be found elsewhere in this report. Some progress has been made in the quantitative determinations of the insoluble fatty acids, and numerous factors have been studied such as strength of alcohol, ratio of fatty acids to solvent, amount of precipitant, conditions favoring the formation of a crystalline precipitate, etc. This work will be given more attention during the present year.

(b) Mr. Morse has continued his studies relative to the effect of fertilizers on asparagus and has brought together a considerable amount of data on the subject. It is not believed, however, that the work is sufficiently advanced to warrant an extended paper on the project. The same chemist has also continued his work with cranberries, devoting his time principally to a chemical examination of the drainage water in the cylinders. These cylinders, it may be stated, are made of large, glazed tile sunk in the earth and filled with peat and sand so as to represent miniature cranberry bogs.

(c) Dr. Lindsey has continued his work on the cause of the digestion depression produced by molasses. Butyric acid — a product of carbohydrate fermentation — has been fed to sheep in different amounts, but without apparently causing any noticeable depression. This work is being continued.

Numerous digestion experiments have been made including plain and molasses beet pulp, grain screenings and Creamo feed.

Attention has also been given and experiments are now in

progress relative to calf meal substitutes for milk in rearing dairy calves, and also to the cost of milk production.

Papers relative to the digestibility of cattle feeds and on corn best suited for the silo in Massachusetts will be found elsewhere in this report.

4. REPORT OF THE FERTILIZER SECTION.

Mr. H. D. Haskins makes the following report:—

The work of the division has been devoted chiefly to the inspection of commercial fertilizers, although quite a variety of other work has also claimed attention. The collection and analysis of the various brands of agricultural lime sold in the Massachusetts markets was made during the early winter months; these have served in the preparation of a lime bulletin (No. 137), which was published in April. The complete ash analysis of 19 samples of asparagus roots has also been made in connection with the Concord field experiments; analytical work has likewise been completed on 44 samples which was begun during the previous year. Complete ash analyses have been made on 4 samples of corn kernels and 4 samples of corn stover in connection with field experiments conducted by the agricultural department. Considerable work has been done in the study of normal tobacco soils and subsoils in order to obtain comparative data in connection with cases of overfertilization or malnutrition; the analyses will be found in a short article entitled "Tobacco Injury due to Malnutrition or Overfertilization," to be found on later pages in this report. An unusually large amount of time has been devoted to co-operative work in connection with the Association of Official Agricultural Chemists. Work was done on nitrogen and potash, and the writer has served in the capacity of referee on phosphoric acid. The planning of this work, the preparation of the samples to be used by various chemists in obtaining analytical data, and the subsequent preparation of the report presented to the association took both time and energy. As the object, however, is to improve our present methods of analysis, and to introduce new and better methods, the time was unquestionably well spent. The examination of home-mixed fertilizers, refuse by-products

and soils sent on by farmers has been attended to as in the past, and a more detailed report of this portion of the work will be found on a subsequent page.

The work of the collection and analysis of registered fertilizers shows a substantial increase over that of the previous year; in fact, a larger number of commercial fertilizers has been registered, collected and analyzed during the season than for *any previous year*. A new fertilizer law was enacted during the season and went into effect Dec. 1, 1911. The full text of the law is given in Bulletin No. 140.

As a result of co-operative studies made by the experiment stations of New England, New York and New Jersey we have been able this year, for the first time in the history of the fertilizer control work, to publish analytical data as to the character of the organic nitrogen supplied by the various brands sold in the State. The additional work entailed has required the assistance of one extra man during the greater part of the season.

On a few subsequent pages will be found summaries covering the fertilizer control work: —

- (a) Fertilizers licensed.
- (b) Fertilizers collected.
- (c) Fertilizers analyzed.
- (d) Trade values of fertilizing ingredients.
- (e) Unmixed fertilizing material.
 - (1) Nitrogen compounds.
 - (2) Potash compounds.
 - (3) Phosphoric acid compounds.
- (f) Grades of fertilizer.
- (g) Summary of analyses and guarantees.
- (h) Quality of plant food.
 - (1) Nitrogen.
 - (2) Phosphoric acid.
 - (3) Potash.
- (i) Miscellaneous fertilizers, by-products and soils for free analysis.

(a) Fertilizers licensed.

During the year, 88 manufacturers, importers and dealers, including the various branches of the trusts, have secured certificates for the sale of 492 different brands of fertilizer, agricultural chemicals and raw products in the Massachusetts markets. Inspection fees have been paid on 27 more brands than during the previous year. These brands may be classed as follows:—

Complete fertilizers,	332
Fertilizers furnishing phosphoric acid and potash,	10
Ground bone, tankage and dry ground fish,	53
Chemicals and organic nitrogen compounds,	97
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Total,	492

(b) Fertilizers collected.

The samples were taken by our regular inspector, Mr. Jas. T. Howard, assisted by Mr. E. C. Hall and Mr. E. L. Winn. An effort has been made in all cases to get representative samples. At least 10 per cent. of the bags found present have been sampled by means of an instrument taking a core the entire length of the bag. In no case has there been less than 10 bags of each brand sampled wherever that number has been found in stock. In case of bulky mixed goods, which might have a tendency to mechanical separation in transit, a sample has been taken from both sides of the bag, so that in case any of the fine heavier chemicals, such as potash salts, had sifted through the more bulky portion, the sample taken would be more representative.

Whenever possible, samples of the same brand have been collected in various parts of the State, the object being to sample as large a proportion of the tonnage shipped into the State as possible. In most cases, where duplicate samples have been drawn, a composite made up of equal weights of the various samples served for the analysis. In some instances several analyses have been made of the same brand; this has been done at the request of large consumers who have bought heavy shipments of some special brand.

It is difficult to tell how large a per cent. of the total tonnage shipped into the State has been sampled. An effort was made at the end of the season of 1910 to ascertain approximately the number of tons sold, but some of the larger manufacturers refused to furnish the data. As complete and extensive a collection as possible has been made in the limited time at our disposal and with the means available for the work.

During the season 116 towns were visited and 1,063 samples representing 519 distinct brands were drawn from stock found in the possession of 284 different agents, as against 897 samples and 487 distinct brands collected and examined in 1910. Some of these brands represent private formulas which would have been sent to the station for analysis by the consumer had they not been taken by our inspectors. Arrangements can be made in most cases to have large shipments of private formulas sampled by one of our regular collectors, provided notification is given sufficiently early in the season so that the various places may be visited while the collectors are in that vicinity.

(c) *Fertilizers analyzed.*

Six hundred and sixty-two analyses have been made in connection with the 1911 fertilizer inspection. The analyses made may be grouped as follows: —

Complete fertilizers,	427
Fertilizers furnishing phosphoric acid and potash, such as ashes, etc.,	18
Ground bones, tankage and fish,	73
Nitrogen compounds, including the mineral forms of nitrogen; also the various organic forms, both animal and vegetable,	69
Potash compounds,	50
Phosphoric acid compounds,	25
	<hr/>
Total,	662

(d) *Trade Values of Fertilizing Ingredients.*

The following table of trade values was adopted by the experiment stations of New England, New York and New Jersey at a conference held the 1st of March, 1911, and have served as the basis of valuing the fertilizers published in this bulletin. The schedule for 1910 is also given for comparison.

Trade Values of Fertilizing Ingredients in Raw Materials and Chemicals for 1910 and 1911.

	CENTS PER POUND.	
	1910.	1911.
Nitrogen:—		
In ammonia salts,	16	16
In nitrates,	16	16
Organic nitrogen in dry and fine-ground fish, meat and blood,	20	23
Organic nitrogen in fine ¹ bone, tankage and mixed fertilizers,	20	20
Organic nitrogen in coarse ¹ bone and tankage,	15	15
Organic nitrogen in cottonseed meal, castor pomace, linseed meal, etc.,	—	21
Phosphoric acid:—		
Soluble in water,	4½	4½
Soluble in neutral ammonium citrate solution (reverted phosphoric acid), ²	4	4
In fine ¹ ground bone and tankage,	4	4
In coarse ¹ bone, tankage and ashes,	3½	3½
In cottonseed meal, linseed meal and castor pomace,	3½	3½
Insoluble (in neutral ammonium citrate solution) in mixed fertilizers,	2	2
Potash:—		
As sulfate, free from chlorides,	5	5
As muriate (chloride),	4¼	4¼
As carbonate,	8	8
In cottonseed meal, castor pomace, linseed meal, etc.,	—	5

The basis for these trade values was the average wholesale quotations of chemicals and raw materials as taken from the commercial publications during the six months preceding March 1, 1911, plus about 20 per cent. They are supposed to represent the average cost per pound for cash at retail of nitrogen, phosphoric acid and potash as found in unmixed fertilizing material in the principal markets in New England and New York. There has been but little change in the cost of the various forms of plant food, with the exception of the better forms of organic nitrogen which have shown a considerable advance as compared with the previous year.

(e) *Unmixed Fertilizing Material.*

Thirty-three samples of ground bone have been collected and analyzed. Ten were found deficient in phosphoric acid and 5 in nitrogen. The average retail cash price for ground bone has been \$31.32 per ton, the average valuation \$29.80, and the per-

¹ Fine and medium bone and tankage are separated by a sieve having circular openings one-fiftieth of an inch in diameter. Valuations of these materials are based upon degree of fineness as well as upon composition.

² Dissolved by a neutral solution of ammonium citrate, specific gravity 1.09, in accordance with method adopted by Association of Official Agricultural Chemists.

centage difference 5.10. Two of the brands analyzed showed a commercial shortage of 50 cents or over a ton.

Eighteen samples of tankage have been analyzed. Three were found deficient in nitrogen and 5 in phosphoric acid. The average retail cash price per ton was \$34.14, the average valuation per ton \$32.69, and the percentage difference 4.43. Nitrogen in fine tankage has cost on the average 20.89 cents; nitrogen in coarse tankage has cost 15.65 cents per pound. Three samples have shown a commercial shortage of over 50 cents per ton.

Twenty-two samples of dry ground fish have been examined. Three were found deficient in nitrogen and 2 in phosphoric acid. The average retail cash price per ton was \$41.90, the average valuation \$42.71, and the percentage difference in excess 1.93. Nitrogen from dry ground fish has cost on the average 22.56 cents per pound. None of the brands showed a commercial shortage of over 50 cents per ton.

(1) *Nitrogen Compounds.* — Three samples of sulfate of ammonia have been analyzed and found well up to the guarantee. The average cost of a pound of nitrogen in this form has been 16.78 cents.

Twenty-three samples of nitrate of soda have been analyzed and 3 were found deficient in nitrogen. The average cost of nitrogen in this form has been 16.19 cents per pound.

Four samples of dried blood have been examined which, with one exception, showed overruns in nitrogen. The pound of nitrogen from blood has cost 23.29 cents.

Four samples of castor pomace have been analyzed. The average cost of nitrogen in this form has been 26.11 cents per pound.

Twenty-three samples of cottonseed meal have been examined, all of which were purchased as a nitrogen source for tobacco. Nitrogen from this source has cost on the average 23.08 cents per pound. Six samples have shown a nitrogen deficiency which has, in 3 cases, amounted to 50 cents or more per ton.

(2) *Potash Compounds.* — Twenty-one samples of high grade sulfate of potash have been examined, and the potash guarantee was maintained in all but one instance. The pound

of actual potash in this form has cost on the average 5.2 cents. Two cases of misbranding were discovered by our inspectors. Material put out by the Nitrate Agencies Company as high-grade sulfate of potash proved upon analysis to be muriate of potash. The sale of the material as sulfate of potash was discontinued and the material was properly labeled.

Six samples of potash-magnesia sulfate have been examined and all but 2 were found fully up to the guarantee. The pound of actual potash in this form has cost 5.91 cents. Several cases have been detected where high-grade sulfate of potash has been reduced with sand and kieserit. The parties registering the material have disclaimed any knowledge of such a practice, and state that the material was bought for potash-magnesia sulfate and sold by them in the original bags as imported from Germany. The matter was taken up with the German syndicate, who traced the adulteration back to the mine that originally produced the goods. A statement was made by the importers that the mine had been heavily fined for the practice, and large shipments of the adulterated product had been returned to the mine. The importers offered to compensate the buyers, who in turn would rebate the farmer, for the value of the deficient magnesia less the value of the overrun in potash.

Eighteen samples of muriate of potash have been examined and 3 were found deficient in potash. The pound of actual potash as muriate or chloride has cost on the average of 4.43 cents. Two brands have shown a commercial shortage amounting to 50 cents or over per ton. There seems reason to believe that it is not improbable that some cases of apparent shortage in case of muriate of potash may be due to absorption of moisture, resulting, of course, in a greater weight of the material without any actual loss of potash, provided the material is sold in the original package and each package is only credited with a weight of 200 pounds.

Three samples of kainit have been analyzed and found well up to the guarantee. The pound of actual potash from kainit has cost 4.34 cents.

(3) *Phosphoric Acid Compounds.* — Two samples of dissolved bone black have been analyzed and both showed a commercial shortage of over 50 cents per ton. The pound of avail-

able phosphoric acid from this source has cost on the average 6.11 cents.

Fifteen samples of acid phosphate have been examined and all but 2 were found well up to the minimum guarantee. No commercial shortage of over 50 cents a ton occurred. The pound of available phosphoric acid from acid phosphate has cost 5.44 cents.

Seven samples of basic slag phosphate have been analyzed and all were found well up to the guarantee. The pound of available phosphoric acid from basic slag, as determined by Wagner's method, has cost on the average 5.12 cents.

(f) *Grades of Fertilizer.*

The grouping of the complete fertilizers into three different grades furnishes a convenient means of showing the superior advantages to be derived from the purchase of *high-grade fertilizers*. In the tables below the high-grade fertilizers are represented by those brands having a commercial value of \$24 or over a ton; the medium grade by those which value between \$18 and \$24; and the low grade by those which value \$18 or less per ton. A table showing average cash price, commercial value, money difference between cash price and valuation, and percentage difference of the three grades of fertilizer follows: —

	HIGH GRADE.		MEDIUM GRADE.		LOW GRADE.	
	1910.	1911.	1910.	1911.	1910.	1911.
Average cash price per ton, . . .	\$38 40	\$40 87	\$33 51	\$35 08	\$27 80	\$29 61
Average ton valuation, . . .	\$28 81	\$28 89	\$21 04	\$21 04	\$15 61	\$15 37
Average money difference, . . .	\$9 59	\$11 98	\$12 47	\$14 04	\$12 19	\$14 27
Percentage difference, . . .	33.28	41.47	59.26	66.73	78.08	92.84

Table showing the Average Composition of the Three Grades of Fertilizer.

GRADE.	Number of Brands.	Per Cent. of Whole Number.	Per Cent. of Nitrogen.	PER CENT. OF PHOSPHORIC ACID.			Per Cent. of Potash.	Pounds of Available Plant Food in 100 Pounds of Fertilizer.
				Soluble.	Reverted.	Available.		
High,	153	46.22	4.12	4.00	3.32	7.32	7.61	19.08
Medium,	103	31.12	2.61	2.93	2.94	5.87	5.12	13.60
Low,	75	22.66	1.66	4.53	2.82	7.35	2.90	11.91

What is shown by the above tables:—

1. That the average ton price for the three grades of fertilizer has been nearly \$2 more for 1911 than for the previous year, although but little difference is noticed in the average valuation per ton for the two years.

2. That the percentage excess of the selling price over the valuation in the low-grade fertilizers is about two and one-fourth times more than it is in the high-grade goods, and over one and one-half times more than in the medium-grade fertilizers.

3. That with a 38 per cent. advance in price over the low-grade fertilizer, the high grade furnishes about 88 per cent. increase in commercial value.

4. The average high-grade fertilizer with a 16.5 per cent. advance in price over the medium goods, furnishes 47.6 per cent. more plant food and 37.3 per cent. increase in commercial value.

5. That with a 38 per cent. advance in price over the low-grade fertilizer, the high-grade furnishes more than 60 per cent. increase in available plant food.

6. A ton of the average high-grade fertilizer furnishes 49.2 pounds more nitrogen and 94.8 pounds more of actual potash than does a ton of the low-grade goods.

7. A ton of the average high-grade fertilizer furnishes 30.2 pounds more nitrogen and 50.4 pounds more potash than does a ton of the medium-grade goods.

Table showing the Comparative Pound Cost, in Cents, of Nitrogen, Potash and Phosphoric Acid in its Various Forms in the Three Grades of Fertilizer.

ELEMENT.	Low-grade Fertilizer.	Medium-grade Fertilizer.	High-grade Fertilizer.
Nitrogen,	38.6	33.4	28.3
Potash (as muriate),	8.2	7.1	6.0
Soluble phosphoric acid,	8.7	7.5	6.4
Reverted phosphoric acid,	7.7	6.7	5.7
Insoluble phosphoric acid,	3.9	3.3	2.8

This table shows: —

1. That the purchase of high-grade fertilizers in place of low-grade goods has saved over 10 cents on every pound of nitrogen and over 2 cents on every pound of potash and phosphoric acid.

2. That the purchase of high-grade fertilizers in place of medium-grade goods has saved over 5 cents on every pound of nitrogen and over 1 cent on every pound of potash and phosphoric acid.

3. Taking the average analysis of the high-grade fertilizer as a basis, the purchase of the high-grade in place of the low-grade goods would mean a saving of \$14.23 on every ton purchased; the purchase of the high-grade in place of the medium-grade would mean a saving of \$7.12 on every ton purchased.

4. About 54 per cent. of the number of brands sold in Massachusetts are classed as medium or low-grade fertilizers. Assuming that the tonnage of these goods was as large as for the high-grade brands, there would have been a tremendous saving to the Massachusetts farmer had he bought only high-grade fertilizer.

5. The purchaser of fertilizers should look to the guaranteed analysis and remember that he is buying pounds of plant food as well as tons of fertilizer. He should know the form and about the proportion of the various elements of plant food and should purchase the brand which sells for the least money which comes nearest fulfilling his requirements.

6. Every one should consider and profit by the lessons taught by the above data.

(g) *Summary of Results of Analyses of the Complete Fertilizers as compared with the Manufacturers' Guarantee.*

MANUFACTURERS.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
W. H. Abbott,	2	-	1	-	2	-
American Agricultural Chemical Company,	73	30	69	29	14	-
Armour Fertilizer Works,	13	8	13	5	-	-
Atlantic Fertilizer Company,	4	1	3	1	1	1
Baltimore Pulverizing Company,	2	1	2	-	1	-
Beach Soap Company,	6	3	5	1	1	1
Berkshire Fertilizer Company,	8	5	8	2	1	-
Bonora Chemical Company,	1	-	1	1	-	-
C. M. Bolles,	1	1	1	-	-	-
Bowker Fertilizer Company,	32	10	26	16	6	-
Jos. Breck & Sons,	3	3	3	-	-	-
Buffalo Fertilizer Company,	8	4	7	3	1	-
E. D. Chittenden Company,	6	3	5	2	1	-
Clay & Son,	1	1	1	-	-	-
Coe-Mortimer Company,	18	1	12	9	7	1
Eastern Chemical Company,	1	1	1	-	-	-
Essex Fertilizer Company,	11	1	8	9	1	-
C. W. Hastings,	1	-	-	1	-	-
Listers Agricultural Chemical Works,	9	4	9	5	-	-
J. E. McGovern,	1	1	1	-	-	-
Mapes' Formula and Peruvian Guano Company,	20	10	19	8	2	-
National Fertilizer Company,	17	7	14	7	3	-
Natural Guano Company,	1	1	1	-	-	-
New England Fertilizer Company,	7	1	3	3	2	1
New England Mineral Fertilizer Company,	1	1	1	-	-	-
Nitrate Agencies Company,	1	-	1	1	-	-
Olds & Whipple,	6	3	6	3	-	-
Parnienter & Polsey Fertilizer Company,	10	1	5	6	2	1
Patrons' Co-operative Association,	2	2	2	-	-	-
Pulverized Manure Company,	1	1	1	-	-	-
Rogers Manufacturing Company,	9	7	9	2	-	-

(g) *Summary of Results of Analyses of the Complete Fertilizers as compared with the Manufacturers' Guarantee — Con.*

MANUFACTURERS.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
Rogers & Hubbard Company,	8	5	7	3	-	-
Ross Bros. Company,	4	1	4	2	1	-
N. Roy & Son,	1	-	1	1	-	-
Sanderson Fertilizer and Chemical Company,	7	6	7	1	-	-
M. L. Shoemaker & Company,	2	1	2	1	-	-
Swift's Lowell Fertilizer Company,	17	7	15	5	5	-
20th Century Specialty Company,	1	1	1	-	-	-
Wm. Thomson & Sons,	2	1	2	1	-	-
Whitman & Pratt Rendering Company,	4	2	4	2	-	-
Wilcox Fertilizer Company,	9	6	9	3	-	-
A. H. Wood & Co.,	3	1	3	2	-	-

The above table shows:—

1. That 334 brands of registered complete fertilizers have been collected and analyzed.

2. That 191 brands (57 per cent. of the total number analyzed) fell below the manufacturers' guarantee in one or more elements.

3. That 135 brands were deficient in one element.

4. That 51 brands were deficient in two elements.

5. That 5 brands were deficient in three elements.

6. That 41 brands (over 12 per cent. of the whole number analyzed) showed a commercial shortage; that is, when the overruns were used to offset shortages they did not show the amount in value of plant food as expressed by the smallest guarantee.

The deficiencies found were divided as follows:—

96 brands were found deficient in nitrogen.

90 brands were found deficient in available phosphoric acid.

66 brands were found deficient in potash.

As compared with the previous year the guarantees have not been as generally maintained. Thirty-six more brands were found deficient in nitrogen and 10 more in available phosphoric acid than for the season of 1910. The brands showing a commercial shortage were 17 more than during the previous year; in many cases, however, the commercial deficiency was small, amounting to less than 25 cents per ton.

Table showing Commercial Shortages (25 Cents or Over) in Mixed Complete Fertilizers for 1910 and 1911.

COMMERCIAL SHORTAGES.	NUMBER OF BRANDS.	
	1910.	1911.
Between \$1 and \$2 per ton.	6	9
Under \$1, not less than 25 cents per ton,	18	17

Some brands have suffered serious deficiencies in some element of plant food without showing any commercial shortage, the deficiency being made up by an overrun of some other element. This is due, probably, either to carelessness or poor mixing rather than a disposition to furnish less plant food value than is called for in the guarantee. It furnishes a condition not to be commended, however, as the fertilizer may be rendered seriously out of balance.

(h) *Quality of Plant Food.*

(1) *Nitrogen.* — Sixty or more per cent. of the total nitrogen in the average mixed fertilizer is derived from organic sources, and until recently it has not been possible to tell the consumer much concerning its activity or immediate availability. Heretofore there has been published the nitrogen from nitrates and ammoniates as well as the water soluble and water insoluble organic nitrogen. It has seemed evident, however, that some of the brands contained at least a portion of their nitrogen in low-grade forms, but a lack of a suitable method of analysis has rendered it impossible to procure sufficient evidence to definitely substantiate the supposition. In 1910 the chemists in charge of the fertilizer control work in New England, New York

and New Jersey co-operated in an effort to make a careful study of the Jones' modification of the "Alkaline permanganate method" and Street's "Neutral permanganate method" for testing the activity of the water insoluble organic nitrogen in mixed fertilizers. Satisfactory results were obtained with the Jones' modification, which were confirmed on the same samples by means of vegetation experiments conducted at the Rhode Island Experiment Station. The work proved so satisfactory that in March, 1911, the Jones' modification was adopted provisionally by the New England, New York and New Jersey experiment stations.

All of the complete fertilizers reported in this bulletin have, therefore, been tested as to their organic nitrogen activity. Out of a total of 334 brands analyzed, 43 or nearly 13 per cent. of the whole number, have shown an activity of their water insoluble organic nitrogen of less than 50 per cent.

So far as one is able to judge from the analytical data and the explanations furnished, the following facts may be deduced:—

1. Some manufacturers used nitrogen-containing material of a low availability.

2. In some cases it was used as a direct source of nitrogen to bring the material up to its minimum guarantee. In other cases it was used to raise the guarantee above the minimum. In still other cases it was employed as a filler or to improve the mechanical condition of the fertilizer.

3. It is possible that the inactive materials employed were not sufficiently treated to render their nitrogen available.

It is hoped that manufacturers will endeavor to improve conditions another season, for it is believed that the consumer of commercial fertilizers — at least of the better grades — is entitled to receive all of his nitrogen in such an available form as is called for by the 50 per cent. alkaline permanganate standard.

(2) *Phosphoric Acid.*—Many of the fertilizer mixtures contained large overruns in total phosphoric acid, while the available phosphoric acid on the same brands has shown a considerable shortage. This may have been due to incomplete acidulation of the bone or raw mineral phosphate used, or to the addition of considerable unacidulated rock phosphate, bone

or roasted iron or alumina phosphate. Of the total phosphoric acid found in all of the brands analyzed, 84 per cent. was present in available forms. In case of the available phosphoric acid found, 58 per cent. was present in water soluble form.

(3) *Potash.* — As in previous years, the form in which the potash was present has been noted in every fertilizer analyzed. Very few cases have been found showing the absence of chlorides in those brands where sulfate is guaranteed. In the majority of cases, however, the amount of chlorine found present has been so small as to be counted as incidental. A quantitative test, however, has in all cases been made. In case of some of the tobacco brands, quite a considerable quantity of chlorine has been found where carbonate of potash was guaranteed. This would indicate the use of carbonate of potash from the beet sugar industry. The latter material frequently contains as high as 10 to 12 per cent. muriate of potash. It is reasonable to suppose that if the consumer pays for carbonate of potash he expects that the fertilizer will exclude both soluble chlorides and sulfates.

(i) *Miscellaneous Fertilizers, By-products and Soils for Free Analysis.*

Including the materials which have been tested for the various departments of the experiment station, there have been received and analyzed 339 different substances. They may be grouped as follows: 209 fertilizers and by-products used as fertilizers, 63 soils, 36 lime compounds, 27 ash analyses of plants and 4 miscellaneous products. Whenever possible, the fertilizer and lime samples have been taken by one of our regular inspectors and by means of the regulation sampling tube. In all other cases the samples have been taken according to printed instructions furnished from this office. In reporting results, information has been furnished as to the best manner of using the material, and in case of soils the rational treatment of the same as regards fertilizers, cultivation and crop rotation. The analyses of most of the lime products appear in Lime Bulletin, No. 137. The analyses of home-mixed fertilizers and private formulas collected by our inspectors will appear in a table by themselves in the fertilizer bulletin. The other analyses mentioned will not be published.

5. REPORT OF THE FEED AND DAIRY SECTION.

Mr. P. H. Smith submits the following: —

The Feed Law (Acts and Resolves for 1903, Chapter 122).

During the year 733 samples of feeding stuffs have been collected and examined. A regularly employed inspector covers the State at intervals during the year, collects samples and ascertains if the provisions of the law are being complied with. Protein, fat, fiber and in some instances moisture and ash determinations are made. It is a matter of satisfaction to note that practically all feeding stuffs are as represented. This statement should not be interpreted to mean that all feeding stuffs offered are of good quality, but that all articles in the market correspond to the guarantee placed upon them.

Violations of Law. — The principal violation of the law as heretofore has been that local dealers, either through carelessness or through the neglect of shippers to furnish tags, fail to guarantee. The experiment station, through its representative, does what it can to prevent violations of this character. In order that the law may be fully enforced in this respect, the co-operation of consumers is needed. The consumer can be of material assistance by insisting that all feeding stuffs that he purchases, with the exception of wheat by-products and ground whole grains, shall bear the guaranteed analysis together with the name and address of the manufacturer.

It is believed that adulteration is seldom practiced. There are some feedstuffs on the market to which low-grade products are occasionally added. Wheat feeds and hominy feed to which ground corn cobs have been added are of this character. The manufacturers ship these goods with the proper guarantee, but they occasionally reach the consumer with the tags removed. It seems evident that the local dealer is responsible for this, desiring to conceal the real identity of the article. The purchaser should not without careful investigation purchase wheat feeds or hominy feeds that are unguaranteed or that are offered very much below the ruling price.

New Law. — The officers in charge of the feeding stuffs law have felt for some time that the present law was inadequate to

meet present conditions, and this year a new law will be presented to the General Court for its consideration and adoption. The proposed law differs from the present law in the following particulars:—

1. It is modeled as closely as local conditions will permit after the uniform law proposed by the Association of Feed Control Officials.

2. It carries an increase in revenue which is necessary if it is to be satisfactorily enforced. This increase is also made necessary by the increase in number of brands at present on the market.

3. Wheat feeds, now exempt, have been included.

4. It has been so revised as to render it easier of enforcement and more explicit.

The Dairy Law (Acts and Resolves for 1901, Chapter 202).

This law requires that all persons who are using the Babcock test as a basis of payment for milk and cream, either in buying or selling, must secure a certificate of proficiency from the experiment station. It also requires that Babcock machines be inspected by an experiment station official annually, and that all glassware used be tested for accuracy by the station.

Chapter 425, Acts and Resolves for 1909, added to the law by giving the director of the experiment station the authority to revoke a certificate if it is found that an operator is using dirty or untested glassware, or if he is doing the work in an improper manner.

The station makes the following suggestions to operators:—

1. Every operator must have a certificate, and no person without a certificate is legally entitled to make the test. The operator may employ a person without a certificate to *aid* him in his work, but he must work with him and be responsible for the working of the machine, and must read the tests in person.

2. Great care should be taken in getting accurate samples. The test from a sample carelessly drawn will not represent the value of the milk or cream from which it is taken, no matter how carefully the testing is done.

3. Cream and curdled samples of milk should be weighed and not pipetted. The only reason that milk or cream is ever pi-

petted is as a matter of convenience and on the supposition that 18 cubic centimeters of cream or 17.6 cubic centimeters of milk will weigh 18 grams. It is difficult and often practically impossible to get exactly 18 grams of sour milk or thick cream with the use of the pipette.

4. In reading the *milk* test include the *entire* fat column. In *cream* tests read from the lowest point of the fat column to the bottom of the upper meniscus or curve. In case of *cream* tests, if the entire fat column is included the reading will be about 1 per cent. too high.

Summary of Dairy Inspection. — During the year 15 candidates have been examined and given certificates to operate the Babcock test. Four thousand, four hundred and sixty-six pieces of glassware have been examined for accuracy and only 12 have been condemned, a smaller percentage than for any preceding year.

Following is a summary for the eleven years the law has been in force:—

YEAR.	Number of Pieces tested.	Number of Pieces condemned.	Percentage condemned.
1901,	5,041	291	5.77
1902,	2,344	56	2.40
1903,	2,240	57	2.54
1904,	2,026	200	9.87
1905,	1,665	197	11.83
1906,	2,457	763	31.05
1907,	3,082	204	6.62
1908,	2,713	33	1.22
1909,	4,071	43	1.06
1910,	4,047	41	1.01
1911,	4,466	12	.27
Totals,	34,152	1,897	5.56 ¹

The testing outfits in 30 creameries and milk depots have been inspected. Nine of these, an exceptionally large number, required reinspection. A machine that vibrates badly, caused

¹ Average.

by worn bearings or an insecure foundation, cannot be expected to do satisfactory work, neither can a machine give a clear separation of fat where the speed is insufficient. A number of operators were found using untested glassware. The director of the experiment station has the right to prosecute the owners of the plant where this is being done, and also to revoke the license of the operator. Thus far this matter has been corrected when called to the attention of the creamery men. Continued violations will, however, make prosecution necessary.

Following is a list of creameries and milk depots visited:—

1. Creameries.

LOCATION.	Name.	President or Manager.
1. Amherst,	Amherst,	R. W. Pease, manager.
2. Amherst,	Fort River, ¹	E. A. King, proprietor.
3. Ashfield,	Ashfield Co-operative,	Wm. Hunter, manager.
4. Belchertown,	Belchertown Co-operative,	M. G. Ward, manager.
5. Brimfield,	Crystal Brook,	F. N. Lawrence, proprietor.
6. Cummington,	Cummington Co-operative,	D. C. Morey, manager.
7. Egremont,	Egremont Co-operative,	E. A. Tyrell, manager.
8. Easthampton,	Hampton Co-operative,	W. S. Wilcox, manager.
9. Heath,	Cold Spring,	F. E. Stetson, manager.
10. Hinsdale,	Hinsdale Creamery Company,	W. C. Solomon, proprietor.
11. Monterey,	Berkshire Hills Creamery,	P. A. Campbell, manager.
12. North Brookfield,	North Brookfield,	H. A. Richardson, proprietor.
13. Northfield,	Northfield Co-operative,	C. C. Stearns, manager.
14. Shelburne,	Shelburne Co-operative,	I. L. Barnard, manager.
15. Wyben Springs,	Wyben Springs Co-operative,	H. C. Kelso, manager.

2. Milk Depots.

LOCATION.	Name.	President or Manager.
1. Boston,	D. W. Whiting & Sons,	Geo. Whiting.
2. Boston,	H. P. Hood & Sons,	W. N. Brown.
3. Boston,	Boston Dairy Company,	W. A. Graustein.
4. Boston,	Boston Jersey Creamery,	T. P. Grant.
5. Boston,	Walker-Gordon Laboratory,	G. Franklin.
6. Boston,	Oak Grove Farm,	C. L. Alden.
7. Boston,	Maine Creamery Company,	E. H. Smith.
8. Boston,	Turner Center Dairying Association,	L. L. Smith.
9. Boston,	Plymouth Creamery Company,	W. L. Johnson.
10. Cambridge,	C. Brigham Co.,	J. R. Blair.
11. Cheshire,	Ormsby Farms,	W. E. Penniman.
12. Dorchester,	Elm Farm Milk Company,	J. K. Knapp.
13. Sheffield,	Willow Brook Dairy,	F. B. Percy.
14. Southborough,	Deerfoot Farm Dairy,	S. H. Howes.
15. Springfield,	Tait Bros.,	Tait Bros.
16. Springfield,	Emerson Laboratory,	H. C. Emerson.

¹ Pays by test. Testing done at Massachusetts Agricultural Experiment Station.

Milk, Cream and Feeds for Free Examination.

With certain restrictions the resources of the experiment station are available to residents of Massachusetts who desire information relative to the composition of milk, dairy products and cattle feeds. When necessary, samples taken in accordance with the directions furnished will be analyzed free of cost. On account of the large amount of data on file, it is often possible to furnish the information desired without recourse to analysis. The experiment station will not undertake to act as commercial chemists, and, on account of the limited funds at its disposal, must use its own discretion as to what samples it will analyze.

Water Analysis.

The station has analyzed 114 samples of water. All probably came from private water supplies. Public water supplies are under the charge of the State Board of Health, and all matters pertaining to such supplies should be referred to them. Of the 114 samples received 80 were from wells, 30 from springs and 4 were taken from ponds.

The results show that farm wells situated near buildings are quite susceptible to pollution and may become sources of infection for typhoid fever and other bacterial diseases, while springs situated at a distance from all buildings are the most satisfactory and safest. Where a good spring is not available the well should be located as far as possible from dwellings and barns.

Lead pipe was used in 49 cases. In 9 instances water flowing through such pipes contained lead in appreciable amount, rendering the water absolutely dangerous for consumption.

If a water analysis is desired, application should be made to the experiment station, when a container will be shipped to the applicant together with instructions for taking the sample. Water received in receptacles other than those furnished will not be analyzed. A fee of \$3 is charged for a water analysis. The experiment station does not make bacterial examinations.

Miscellaneous Work.

In addition to the work already described, this section has conducted investigations and made other analyses as follows:—

1. It has co-operated with the officials of the Massachusetts

Corn Exposition in making analyses of corn in connection with the awarding of prizes.

2. It has co-operated with the Bowker and Coe-Mortimer Fertilizer companies in making analyses of corn in connection with the awarding of prizes.

3. It has arranged and furnished exhibits and speakers, in co-operation with the extension department, for fairs, farmers' meetings and expositions.

4. It has co-operated with the agricultural department of the college in making analyses of milk in connection with the awarding of prizes at a dairy show held during "farmers' week."

5. In connection with the experimental work of this and other departments of the experiment station, this section has made analyses of 116 samples of milk, 57 samples of feed and 377 samples of agricultural plants.

6. In addition to the work already enumerated, it has received and tested 527 samples of milk, 2,799 samples of cream for butter fat, and 204 samples of feedstuffs.

Testing Pure-bred Cows.

The testing of pure-bred cows for advanced registry is in charge of this section. Work of this character can be grouped under two divisions. The yearly tests for the Guernsey, Jersey and Ayrshire breeds are based upon two-day monthly tests under the supervision of an experiment station representative; while the Holstein-Friesian tests are usually of from seven to thirty days' duration and require the presence of the supervisor during the entire testing period. The large number of yearly tests now in progress require the employment of two men continuously and of an additional man for a portion of the time. Work of this character can be planned ahead and more readily taken care of than the Holstein-Friesian tests. For this latter work a list of available men is kept, and applications for supervisors are filled in the order received. Men who make the Holstein-Friesian tests are recruited largely from the short-course graduates who have gone back to the farm and who do not find it difficult to get away during the winter months. During the summer months considerable difficulty is experienced in getting

men for the work. Fourteen different men have been used on work of this character during the year.

From Dec. 1, 1910, to Dec. 1, 1911, 38 Guernsey, 117 Jersey and a number of Ayrshire tests have been completed. There are now on test 43 Guernseys, 99 Jerseys, and 12 Ayrshires, located at 18 different farms.

For the Holstein-Friesian Association there have been completed 103 7-day tests, 2 30-day tests and 1 14-day test.

REPORT OF THE BOTANIST.

G. E. STONE.

The routine and research work of this department during the year has followed prescribed lines, although, as occasion has demanded, new lines of research were taken up. Mr. G. H. Chapman, besides assisting in carrying on the routine work, has had considerable opportunity for the study of special problems. He has completed his investigations on mosaic and allied diseases, as well as a piece of work on the "Microscopic Identification of the Components of Cattle Feeds."

Mr. Sumner C. Brooks, who served one year in the laboratory, resigned his position in October to take up graduate work at Harvard, but unfortunately just before his year expired he was severely stricken with typhoid fever and is at present in a convalescent state. Mr. Brooks is a keen and tireless observer, and our best wishes are extended to him in his graduate work. His place has been filled by Mr. E. A. Larrabee, of the class of 1911 of this college, who has had considerable experience in our laboratory as an undergraduate student. Miss J. V. Crocker, who is thoroughly familiar with our work, has been of great service in attending to correspondence, assisting in the seed work and in other ways. Much help has also been received from Mr. R. E. Torrey and Messrs. Larsen and Ellis, all of whom are associated with the laboratory as undergraduate students.

Besides giving considerable time to such routine work as correspondence and the diagnosis of diseases, our own attention has been directed to the investigation of a dozen or more original problems. Much time has also been spent in studying and devising apparatus designed for the better control of the various foci of plant life.

Besides the correspondence relating to seed work and the control of diseases, we are constantly called upon to answer letters of a very special and technical nature. These inquiries come from everywhere and cover a multitude of subjects, such as electricity and plant growth, electrical injury to trees, illuminating and other gases, chemical treatment of reservoirs, modern tree surgery, court decisions regarding shade trees, different stimulating factors in the growing of plants, requests for advice in regard to devices for the extermination of various pests, etc.

REPORT OF THE ENTOMOLOGIST.

H. T. FERNALD.

The work of the entomological department during 1911 has been mainly on subjects previously outlined, and any report is, therefore, practically a report of progress.

The insect collection of the station has received considerable attention during the year. Numerous additions by gift from former students of the college and others, and the addition of more cases and other equipment in order to provide room for the proper care and growth of the collection as a whole, have made it possible to put it in better condition than ever before. As it is in constant use for reference and study, this improvement has been greatly appreciated.

The time at the disposal of those working in entomology is divided between four different lines of work. These are: correspondence with persons desiring the assistance of the department; care and improvement of the station collections of insects and their work; experimental work and studies under the Hatch act; and research under the Adams fund. These may be considered in the order named.

The correspondence the past year has been as large or somewhat larger than heretofore, but very different in nature from what it was formerly. For many years most of the inquiries received were about noticeably injurious insects. More recently, however, the inquiries have had reference to the less evident, though often equally serious pests. This indicates progress in the knowledge of our injurious insects among those most concerned and is certainly gratifying, being at least indirect evidence of the efficiency of this department and of the other

sources through which entomological information has been distributed in this State. From this time on, however, it will be more difficult than formerly to determine from the correspondence itself the nature of the insect concerned, and it is probable that visits to places where damage is being caused will be much more frequently necessary in order to give intelligent advice as to the proper methods of control.

The importance of a collection of insects and of their work would seem to be almost self-evident. Any entomologist taking up duties either State or station in character, who finds no collection or only a small one where he goes, labors under an immense handicap, and within a year or two a number of letters expressing this in most emphatic terms have been received by the writer from friends laboring under such conditions. This station is fortunately situated in this regard, having a good collection, containing many entire life histories, and well cared for. It is far from complete, however, and is deficient in many different stages, even of common forms. To be what it should be, it is important not only to maintain it in its present condition, but to add to it as rapidly as possible specimens of all the injurious insects which can possibly be obtained, in their different stages, together with samples showing the nature of the injuries they cause. As much work of this kind as possible has been carried on during the past year.

Under the Hatch act experimental studies of various kinds have been continued. The destruction of seed corn by wire-worms has been studied as in previous years, in co-operation with Mr. Whitecomb. As stated in the last report, tests of tar and Paris green proved successful, but when tried by many different persons in various parts of the country were not always satisfactory. The trouble in most cases seems to have been that so much tar was applied as to give the corn a waterproof covering, which prevented germination. This was not the fault of the method, but was due to its improper application. A real defect of the method was that it required two treatments, first with the tar and second with the Paris green and dust. To avoid this, tests were made last spring with arsenate of lead diluted to the thickness of paint. The results were not wholly satisfactory, partly because wire-worms were not everywhere

abundant throughout the test fields, and partly because the arsenate showed a tendency to flake and drop off the corn. In most cases the corn made a good start and escaped all injury, even though wire-worms were clustered around the seeds in the row. In fact, the treatment, though it did not seem to kill the wire-worms, did appear to protect the corn from injury in nearly every case. Further experiments along this line will be made in 1912.

The testing of new spray materials has not usually been looked upon favorably by this department, as it has no trees under its control upon which these may be used. A new material called "Entomoid," for use against the San José scale, sent to the station last year for trial, seemed so promising, however, that considerable attention was given to it, trees loaned for the purpose by individuals being used. Entomoid is claimed by its inventor to be a combination of lime-sulfur and a miscible oil, and therefore to combine the good qualities of both of these materials. It was applied to young apple and plum trees considerably to badly infested with scale, shortly before the buds opened in the spring, at strengths of 1 part Entomoid to 20 of water, and to 30 of water, using a fine Vermorel nozzle. The trees were under almost continual observation thereafter, until October, and the results were very satisfactory with both strengths. Very few living scales could be found in June, and those were all in such protected positions as would indicate a probable failure of the spray to reach them. By late fall the trees were well infested again, but only to such a degree as would be easily accounted for by the few scales which escaped treatment, and by restocking from badly infested trees nearby. During the past year the inventor has modified his formula somewhat, and it is the intention to continue tests with this modified material the coming spring.

In addition to the experiments outlined above, observations on the dates of hatching of the oyster-shell scale, scurfy scale and pine-leaf scale have been continued, and it is planned to conduct tests of methods for the control of the onion maggot next season, should satisfactory opportunities become available.

While not forming a part of the work done under the Hatch act, it may be well to mention that exhibits of injurious insects

and their work, with directions for treatment to control these pests, have been prepared and exhibited at a number of fairs and exhibitions during the past year, the department co-operating with the extension department of the college whenever it has been requested to do so. Samples of pests and their work have also been put up and sent to libraries, schools and individuals in some cases where the material could be obtained and the time necessary to prepare these exhibits could be spared from more pressing duties.

Calls for the fumigation of houses to destroy various household pests have been frequent. As there is no one near Amherst who makes a business of work of this kind, and as experience in handling hydro-cyanic acid gas is necessary, if danger to human life is to be avoided, it has seemed wise to do more or less of this, partly as an educational measure. During the past year perhaps 15 or 20 places have, therefore, been fumigated by members of this department at the request of persons concerned, who were willing to meet the cost of the work.

Under the Adams fund the two projects previously accepted have been continued. Studies of the causes of the burning of foliage by arsenicals, postponed by failure to obtain materials of known composition and purity, have now been taken up, and 120 different spraying tests were made during the season, followed in each case by examination of the results, at least every second day for about a month. The results are interesting, but the work thus far represents only a small fraction of that which will be necessary before this subject has been developed to the point desired, and the results of such a fragmentary part of the work, it is, of course, not desirable to publish.

Study of the real value of wasps as parasitic friends of man have been continued, and one small paper incorporating a few of the more technical preliminary observations has been completed. Both of the Adams fund projects will be prosecuted farther the coming year.

Aside from what has thus far been mentioned, a study of the distribution of insect pests in the State has been continued. It is increasingly evident that some portions of Massachusetts are outside of territory liable to serious injury by certain insects. The determination of the limits of these areas and the reasons

for their existence are important problems awaiting solution. The possibility that in one part of the State certain southern crops can be successfully grown is supported by the continued existence in that section of plants, reptiles, birds and insects which normally occur much farther south. If this should prove to mean that some southern crops can be raised in that section, and our city markets be supplied with them after the supply from the south has ended, it might result in marked changes in the crops in that portion of the State. Evidence bearing upon this has been and is being gathered at every opportunity, in the hope that the results may justify practical tests of the idea here suggested.

REPORT OF THE VETERINARIAN.

JAS. B. PAIGE, D.V.S.

During the past year the veterinary department has carried on its work in accordance with the following scheme:—

1. Research.
2. Diagnosis.
3. Correspondence.

Since the inauguration of the department in the experiment station it has been the aim and practice to carry on each year one or more lines of original investigation of some of the obscure animal diseases or phase of the same, preferably one of immediate interest to the stock owners of the State. The large number of diseases occurring among the different farm animals, the cause, course, successful treatment or prevention of which are not fully understood, offers a large field for investigation and profitable study. Such obscure diseases exist among all varieties of farm animals, — horses, cattle, sheep, swine and poultry. The latter presents some of the most difficult and interesting problems for investigation.

For nearly two years prior to last September the head of the veterinary department, in addition to his regular work of instruction in the college, performed the duties, in part, of the dean of the college. This required a greater part of each afternoon of the days when college was in session. It was, therefore, during this time not possible to engage as extensively in the lines of original investigation as was desired. The remainder of the work in the station falling under divisions of diagnosis and correspondence were taken care of in a satisfactory manner.

For something more than two years an original investigation

has been carried on to determine to what extent unsterilized, mixed milk from herds of common dairy cattle, not tuberculin tested, may be responsible for the transmission of bovine tuberculosis. The work is nearly completed and will appear as a separate contribution to the report, or in bulletin form, at an early date.

The general plan of the experiment has been to make it of a practical nature by carrying it out under conditions as nearly like those as are found in the farmers' stables and herds, and at the same time sufficiently guarded against error to give it a scientific value in the determination of the relation of milk as an agency for the transmission of the disease under ordinary farm conditions. The investigation has its practical application in the eradication of tuberculosis from herds by the use of tuberculin as a diagnostic and by every other known means. If the disease is to be stamped out in a herd of cattle it is not alone sufficient to discover and remove those animals already affected, but also to discover and remove the source from which the infection comes. The experiences of the past of those who have tried to rid a herd of tuberculosis by the use of tuberculin and by slaughter of affected animals and disinfection of stables, have shown that it is not easily accomplished, owing to the difficulty of detecting the origin of the cases that are almost certain to appear after diseased animals have been removed and the stable thoroughly and effectively disinfected. It frequently happens that after a variable period of several weeks to as many months more indications of the existence of the disease are discovered among the animals which necessitate the repetition of the tuberculin testing and disinfection. The possible source of reinfection has in some instances been directed to milk from infected and nontuberculin-tested animals not showing marked physical symptoms of tuberculosis, but excreting tubercle bacilli in their milk.

In the case of large dairy herds or those of large public institutions, where sufficient milk is not produced by the herd at all seasons to supply a trade or for home consumption, it frequently happens that milk from untested cattle is purchased and brought onto the farm, and possibly some remaining unsold or unused is fed to calves or hogs and proves the source of the

infection, which accounts for the recurrence of the disease. To determine to what extent this may be the source of such recurrence of tuberculosis of farm animals is the chief aim of the present investigations.

In addition to the experiment with milk, to determine to what extent it may be the medium for the transmission of bovine tuberculosis, there have been started preliminary studies to determine the nature, cause, means of spread, treatment and prevention of several other animal diseases, including an extremely obscure and fatal one of fowls. The work has not progressed sufficiently, at this date, to warrant more than a mention of the fact in this report.

The diagnosis work consists of the examination of material that is sent in by stockmen from animals suffering with disease, and of material suspected of causing disease. During the past year specimens have been received in larger numbers than ever before, and from practically every part of the State. As soon as such specimens arrive they are subjected to a variety of examinations, microscopic and bacteriological, to determine the nature of the material and the possible relation to the disease causing a loss to the stockman. After the completion of the examination, a report upon the nature of the specimen and directions for the treatment or prevention of the disease is sent to the farmer from whom the material was received. While not possible to arrive at a correct diagnosis in every instance, in many cases it is possible to return to the sender of the specimen such definite information as to the nature of the material and the disorder as to enable him, by following the directions sent in the report, to eradicate, cure or prevent the disease.

Some of the most interesting and important specimens that have come under observation in the diagnosis work the past year are: tuberculosis of garbage-fed hogs; tubercular orchitis of bull; pulmonary phthisis of man; pericarditis of cattle due to foreign bodies; lobar pneumonia; papilloma and fibroma of bovines; Paris green poisoning of pigs; chicken pox; coccidiosis and favus of birds.

In addition, a large number of samples of fodder, grain, beef scrap and other food materials have been examined as to quality and the presence of substances liable to cause disease when fed

to animals. One particularly interesting sample of poor quality corn stover and corn on the ear was received that had caused the death of several cattle in a herd owing to the presence of large amounts of alcohol and other products of fermentation and decomposition that it contained.

Several samples of milk sent in for examination have been found to be contaminated with bacteria, giving rise to disagreeable odors, bitter tastes and offensive discolorations.

While the diagnosis work requires a great amount of time it certainly is fruitful of the best results. Notwithstanding the fact that it is not possible from the nature of the specimen sent, or the condition in which it may be received, to make a correct diagnosis in every instance, in the majority of cases it is possible to return to the farmer information of value that may enable him to avoid or arrest diseases that cause considerable loss. It is a means of bringing the veterinary service of the experiment station to the aid of those farmers who are so situated that they cannot avail themselves of the services of the private veterinary practitioner.

The correspondence branch of the service is closely co-ordinated with the diagnosis work. It frequently happens that farmers write to the department for information relative to some disease that exists among their animals. From the details of symptoms given in such cases it is often possible to arrive at a correct diagnosis of the trouble and advise the writer what course to follow to stamp out, successfully treat or prevent the disease. In other instances no satisfactory conclusions can be reached from the communication received and a specimen is asked for, by which a correct diagnosis of the trouble can be made and satisfactory directions given, by mail, for the successful treatment of the case. Specimens from diseased animals obtained in this manner not only furnish a means for making a correct diagnosis, and enable us to give intelligent advice to the owner of the animals, but they also supply materials of the best quality for classroom and laboratory demonstrations for students taking the courses in veterinary science and bacteriology in the department.

The correspondence of the past year has called for information covering a wide range of subjects relative to the care and

feeding of farm animals and numerous animal diseases, among which may be mentioned: milk fever of cows; contagious and sporadic abortion; hog cholera; intestinal parasites of horses, cattle, sheep and swine; tuberculin testing, etc.

An especially large number of letters have been received asking for information concerning the source, symptoms and treatment of hog cholera. From the increase of inquiries over previous years and the press reports, it appears that this disease has been much more prevalent in the State during the past twelve months than ever before.

If the stockmen could only realize that the great majority of the outbreaks of hog cholera have their origin in swill containing scraps of uncooked western pork from centers of infection, and that thorough cooking will destroy the infection, many of the troublesome outbreaks could be easily prevented, and the swill from hotels and boarding houses into which such contaminated pork scraps are almost certain to find their way could be fed with safety and profit in the rearing and growing of hogs in Massachusetts.

HEREDITY, CORRELATION AND VARIATION IN GARDEN PEAS.

J. K. SHAW.

During the past five years a portion of the time devoted to experimental work in the department of horticulture has been directed toward the solution of problems of plant breeding, the work being done mostly with garden peas. Certain phases of this work have been previously reported.¹ It is felt that sufficient progress has now been made to warrant a more complete and definite statement of results attained.

The original purpose of the work was a study of variation, and the subsequent development along lines of correlation and inheritance has been a gradual one, with no endeavor to prove or disprove any of the current theories bearing on these questions, but with an earnest purpose to secure facts. After five seasons' work it was felt that sufficient data had been accumulated to afford a basis for a few deductions, and following last season's crop, results have been worked over and are here presented. This explanation may make clear the seeming lack of definiteness and direction of the work towards the results obtained.

The work began in 1907 with a study of variation in a commercial lot of Excelsior peas, and in 1908 a lot of First of All was added; since then various commercial sorts have received more or less attention. The most important results have been reached by means of the Excelsior variety. This is a second early wrinkled pea growing usually about 40 centimeters in length and bearing about four pods to the vine. It is a sort considerably grown by gardeners in New England.

The principal characters dealt with have been vine length and pods per vine. The first gives a good measure of the vegetative

¹ Reports, Massachusetts Experiment Station, 20, p. 171; 21, p. 167; 22 Part I., p. 168.

vigor of the plant and the second of its productiveness, — two qualities of the greatest economic importance.

All the measuring for the past three years, when most of the plants have been handled, has been done by one individual, thus avoiding the slight differences that might result from the work of different men.

The vines have been carefully pulled when well ripened and carried to a convenient table where the measurements have been made. Vine length has been taken from the surface of the ground to the uppermost node of the main stem. Where there were branches they have been measured, but are not used in the computations, though it might have been more desirable to have done so. However, it is not felt that in that case the results would have been materially different. All pods have been counted whether large enough for commercial purposes or not, as have the peas in the pod. The measurements have been recorded on 5 by 8 cards, recording the data as shown in Fig. 1.

Plant.	Vine Length.	No. Pods.	Peas per Pod.	Total Peas.	Notes.
B-10-7-1	62	5	7-7-5-6-6	31	
2	85	6	5-6-3-6-7-4	31	
3	64	6	1-4-6-0-5-6	22	
4	70	6	4-6-5-6-5-5	31	
5	70	5	6-1-5-5-0	17	
6	53	5	4-2-0-4-4	14	
7	54	4	2-5-5-2	14	Seed
8	63	6	5-6-6-4-3-2	26	
9	50	3	3-6-2	11	
10	44	4	4-4-5-1	14	
11	52	5	4-5-6-5-3	23	
12	70	5	5-5-6-5-5	26	
13	64	6	0-6-6-6-6-4	28	
14	55	4	5-3-3-3	14	
15	63	6	5-5-5-7-5-2	29	
16	35	4	4-4-3-3	14	
17	45/36	8	4-3-5-2/3-4-3-3	27	
18	63	6	4-6-6-6-5-6	33	

FIG. 1. — Pea Record Card.

The plants have been grown each year upon a different plot of ground and these have not always been as satisfactory, especially as to uniformity, as might be desired. In 1908 the plot, while fairly uniform, was gravelly, and suffered somewhat from drought, which modified the character of the plants grown to a considerable degree. In 1909 the soil was heavier, but one end of the plot was inferior as shown by the appearance of the plants grown. In 1910 the soil of the plot seemed fairly uniform, but the error was made of applying fertilizer in the row. While an effort was made to have this uniform all through the plot, it appeared that it was not fully successful, some portions of the rows receiving more stimulus than others. The plots used in 1911 appeared to be more desirable than those used previously, and were so on the whole, yet they were not all that could be desired, some portions being evidently poorer than the average, as indicated by the slightly less flourishing plants. Perfect uniformity of soil, however desirable in work of this kind, is very difficult and perhaps impossible to attain, and this must be compensated for by duplication of results. It is felt that in this work sufficient duplication has been carried out to neutralize this variation in soil conditions, and that the conclusions reached are not materially affected thereby.

The mathematical calculations have been carried out with the aid of millionaire and comptometer calculating machines and fully checked, and it is felt that they are free from errors that could sensibly affect the results. The methods that have been used are for the most part the usual ones and substantially as set forth in "Principles of Breeding," by E. Davenport.

HEREDITY.

In what degree may individual pea plants be expected to transmit their characters to their descendants? Table I. sums up the measure of inheritance of vine length and productiveness of about 10,000 plants in an effort to throw light on this question. Before discussing this table it is necessary to set forth the history and nature of the four groups dealt with.

TABLE I. — *Coefficients of Heredity.**Vine Length.*

PLANT.	1908-09.	1909-10.	1910-11.	Average.
First of All,	-	+ .0486 + .0242	+ .0407 + .0257	+ .0447
Excelsior I.,	+ .2159 ± .0167	+ .0236 ± .0170	+ .0583 ± .0196	+ .0993
Excelsior II.,	-	+ .3095 ± .0172	+ .0892 ± .0236	+ .1994
Variety "C,"	-.0801 ± .0392	+ .0372 ± .0241	-.0161 ± .0409	-.0197

Pods per Vine.

PLANT.	1908-09.	1909-10.	1910-11.	Average.
First of All,	-	+ .0435 + .0242	-.0564 + .0256	-.0065
Excelsior I.,	+ .0782 ± .0174	-.0159 ± .0170	+ .0140 ± .0197	+ .0254
Excelsior II.,	-	+ .0145 ± .0189	+ .2317 ± .0225	+ .1231
Variety "C,"	-.0433 ± .0395	-.0914 ± .0239	+ .0046 ± .0399	-.0434

The plants grouped as First of All are from a lot of commercial seed of the variety bought in the open market. They were first grown in 1907, but the seed from individual plants was not saved separately until the fall of 1909, so that no coefficients of heredity are available except for the crops of 1910 and 1911. The number of plants of this group grown each year is in the vicinity of 700. The method of choosing seed plants is as follows: In the fall of 1908 seed from every tenth plant was saved, a special effort being made to make the tenth plant a random choice. In the following year the seed of one plant, chosen at random from the descendants of each of these tenth plants, has been saved for planting. In this way the number of plants has been kept fairly constant.

The same remarks will apply to the group Excelsior II., except that the number of plants has been greater, varying from 800 to 1,200 each year.

The groups called Excelsior I. and Variety "C" are both from the same lot of commercial seed, originally as Excelsior II., but these are descended from 10 plants selected in the fall of 1907, the seed of each being saved separately. In the spring of 1908 the seed of each of these plants was sown separately and 227 plants grown therefrom. The seed of each of these was separately saved and grown in 1909, resulting in 1,770 plants.

In the fall of 1909 and subsequent years a random selection of one plant from each of the groups of 1909 has been made, thus keeping the number of plants fairly constant. It will be seen that Excelsior I. and Variety "C" are made up of the descendants of 10 plants selected from commercial seed. The reason for separating one of the 10, "C", is that it has proved to be a distinct variety, being larger, more productive and a week or ten days later than the other 9. This difference was not suspected when the original plant was selected. Between these 9 lines of descent there are no evident differences, though some are shown later in this paper to be present.

With these explanations in mind we may proceed to a discussion of the figures shown in Table I. The following conclusions seem warranted:—

1. With three exceptions the coefficients are very small, many are insignificant and some are even negative.
2. They are very irregular both in the same groups in different years and in different groups in the same year.
3. They are generally lower for pods per vine than for vine length.
4. They are on the whole lower for Variety "C" than for the other groups.

It will be remembered that Variety "C" comprises the descendants from 1 of 10 plants selected from a lot of Excelsior in 1907, the progeny of the other 9 being brought together to form the group Excelsior I. We have the figures for these 9 lines taken separately, and we may inquire if they, like Variety "C", are insignificant or nearly so. They are given in Table II.

TABLE II. — *Coefficients of Heredity of Single Lines.*
Vine Length.

PLANT.	1908-09.	1909-10	1910-11.	Average.
A,	+ .1701 ± .0482	— .0632 ± .0454	— .1737 ± .0516	— .0223
B,	+ .2202 ± .0515	+ .2841 ± .0460	+ .0775 ± .0545	+ .1706
D,	— .0556 ± .0471	— .0016 ± .0459	+ .1242 ± .0477	+ .0223
E,	+ .0823 ± .0865	— .2122 ± .0587	— .0610 ± .0611	— .0636
F,	+ .1472 ± .0812	+ .1820 ± .0810	+ .1651 ± .1110	+ .1648
G,	— .1380 ± .0390	— .1652 ± .0351	— .0391 ± .0490	— .1141
H,	— .0549 ± .0462	+ .1232 ± .0450	+ .1353 ± .0498	+ .0679
J,	+ .1563 ± .0591	+ .2165 ± .0663	+ .2535 ± .0859	+ .0679
K,	+ .0298 ± .0554	+ .2348 ± .0570	+ .0689 ± .0720	+ .1112
Average,	+ .0619	+ .0663	+ .0534	+ .0450 + .0605

Pods per Vine.

A,	+ .1372 ± .0488	— .1948 ± .0438	— .2106 ± .0508	— .0894
B,	+ .2392 ± .0511	+ .1748 ± .0485	— .1423 ± .0534	+ .0906
D,	— .0521 ± .0471	+ .0872 ± .0456	— .0477 ± .0483	— .0042
E,	+ .0626 ± .0867	— .2371 ± .0642	— .0147 ± .0613	— .0631
F,	— .3311 ± .0775	+ .0986 ± .0835	+ .1414 ± .1102	— .0304
G,	+ .0277 ± .0390	— .2317 ± .0341	— .0453 ± .0490	— .0498
H,	+ .0681 ± .0436	— .0658 ± .0456	+ .1165 ± .0500	+ .0396
J,	+ .1398 ± .0594	— .0469 ± .0696	— .1180 ± .0905	— .0084
K,	+ .1337 ± .0545	+ .2293 ± .0572	+ .0463 ± .0718	+ .1364
Average,	+ .0472	— .0207	— .0305	+ .0024 — .0013

A study of this table shows it to be in harmony with the first three conclusions drawn from Table I. It indicates further that the true coefficient of heredity within these single lines of Excelsior peas is about +.06 for vine length and practically zero for pods per vine.

There is generally a positive correlation between seed weight and the size of the plant produced. The question which now arises is whether this is sufficient to account for the small plus correlation in vine length shown in Table II. We have a few figures bearing on this point, but not enough to determine positively whether this is the case or not. The seed weights avail-

able were taken from another selection of plants from Excelsior I., not already dealt with, and from a commercial lot of Alaska. The latter is a variety with small, round, green seeds and with somewhat longer vines than Excelsior. These selections were of the long and short vines, and the more productive and less productive vines. This explains the small number of medium-length vines in Tables III. and IV. A few points brought out in Table III. should be noted:—

TABLE III. — *Correlation of Vine Length and Average Weight of Seeds borne, Excelsior I.*

AVERAGE SEED WEIGHT (GRAMS).	VINE LENGTH (CENTIMETERS).													Total.
	13	18	23	28	33	38	43	48	53	58	63	68	7	
.10,	1	-	-	-	-	-	-	-	-	-	-	-	-	1
.15,	-	2	-	-	-	-	-	-	-	-	-	-	-	2
.16,	-	-	-	2	-	-	-	-	-	-	-	-	-	2
.17,	-	1	2	1	-	-	-	-	-	-	-	-	-	4
.18,	-	-	-	1	-	-	-	-	-	-	-	-	-	1
.19,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.20,	4	6	4	2	2	-	-	-	-	-	-	-	-	18
.21,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.22,	-	-	3	5	-	1	-	-	-	-	-	-	-	9
.23,	-	4	1	3	1	1	-	-	2	-	1	-	-	13
.24,	-	-	3	-	1	-	1	1	1	2	-	-	-	9
.25,	1	1	4	2	1	-	-	2	2	-	-	-	-	13
.26,	-	1	1	3	1	-	2	4	7	-	-	2	-	21
.27,	-	4	2	3	-	1	2	-	5	5	1	-	-	23
.28,	-	-	1	-	1	-	-	1	4	1	1	1	-	10
.29,	-	-	-	-	-	1	1	1	3	-	-	-	-	6
.30,	-	3	3	1	5	1	-	1	2	-	1	-	-	17
.31,	-	-	-	-	-	-	-	-	-	1	-	-	-	1
.32,	-	-	-	-	-	-	-	-	1	-	-	-	-	1
.33,	-	-	-	1	-	-	-	-	-	1	-	-	-	2
.34,	-	-	-	-	-	-	-	-	1	-	-	-	-	1
.41,	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Total,	6	22	24	24	12	5	6	10	28	11	4	3	-	-

TABLE IV. — *Correlation of Vine Length and Average Weight of Seeds borne, Alaska.*

AVERAGE SEED WEIGHT (GRAMS).	VINE LENGTH (CENTIMETERS).																		Total.		
	18	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	98	103		108	
.08,	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
.09,	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
.10,	1	2	5	2	-	1	2	1	-	-	-	-	-	-	-	-	-	-	-	-	14
.11,	-	-	-	1	-	-	1	-	-	-	-	1	-	-	1	-	-	-	-	-	4
.12,	-	-	2	2	4	3	5	2	1	-	1	1	1	1	-	-	-	-	-	-	23
.13,	-	1	-	4	4	2	3	-	-	2	-	1	1	-	1	1	-	-	-	-	20
.14,	-	-	-	-	3	5	5	3	1	-	1	2	3	3	1	-	-	-	-	-	27
.15,	-	1	1	3	2	5	6	5	2	1	1	-	2	4	5	2	-	-	-	-	40
.16,	-	-	-	-	-	5	7	4	-	1	1	3	4	4	3	2	2	-	-	-	36
.17,	-	2	-	1	2	6	3	1	-	-	-	1	6	2	3	3	1	2	-	-	33
.18,	-	-	-	-	1	2	2	1	2	-	2	-	1	3	1	1	-	-	-	-	16
.19,	-	-	-	-	-	-	-	-	-	1	1	-	2	2	1	2	1	-	-	-	10
.20,	-	2	-	-	-	-	1	-	-	-	-	1	-	1	-	1	-	-	-	-	6
.21,	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2
.22,	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Total,	1	8	8	14	16	30	35	17	7	5	7	9	21	22	15	13	4	2	-	-	-

1. No vine over 35 centimeters long produced seeds averaging less than .22 grams each.

2. Vines 35 centimeters or less produced many light seeds and also many fairly heavy seeds, but none as heavy as the long vines produced; the average weight is far more variable.

The same is true of the Alaska peas as shown in Table IV., though less strikingly so owing to the smaller variability of average seed weight in this variety.

TABLE V. — *Correlation of Vine Length and Average Weight of Seeds.*

Excelsior I., 40 centimeters or less,	+ .3038 ± .0635
Excelsior I., 41 centimeters or more,	+ .1669 ± .0833
Alaska, 60 centimeters or less,	+ .2779 ± .0534
Alaska, 61 centimeters or more,	+ .1662 ± .0663

In order to compute fairly the coefficient of correlation in these two groups it is necessary to compute for the short and long vines separately. The coefficients are given in Table V.

This table shows, in the case of both varieties, fairly large coefficients, and they are in both cases larger for the short vines than for the long vines. These figures form a too slender basis for a definite conclusion as to the correlation between vine length and the average weight of peas produced, but so far as they go they consistently favor the supposition that the correlation does exist and is fairly large. The average of the four is $+.2287$.

TABLE VI. — *Correlation of Average Seed Weight and Vines produced.*

Strain A, D, F, G, K,	$+.0710 \pm .0234$
Strain B, E, H, J,	$+.1045 \pm .0286$
Alaska,	$+.0146 \pm .0178$
First of All,	$-.0290 \pm .0390$

Turning now to the consideration of the question as to whether the heavier peas produce larger vines than do the lighter ones, we have the figures shown in Table VI. For reasons shown a little further on in this paper, the group Excelsior 1. is divided into two strains, one of 5 lines and the other of 4 lines as shown in the table. The group First of All is from a selection of this variety that is of the same nature as the others. The number of vines is relatively small, and the figures, therefore, of less value than the other groups. It is because of the small numbers that the correlation of parent vine length and weight of their seeds are not given, but as far as they go they are in reasonable agreement with those of the two groups that are given.

It appears from the limited data given in Table VI. that the correlation is larger for the wrinkled Excelsior peas than for the starchy Alaska and First of All varieties. Only the coefficients for the first two groups should therefore be compared with the correlation of about $+.06$ found to exist between parent and offspring as shown in Table II.

No positive conclusion in this matter can be drawn. The indications are that a part and possibly all of the correlation of $.06$ may be accounted for by the correlation between length of vine and seed weight.

TABLE VII. — *Averages of the Single Lines.*

ORIGINAL PLANT.	Vine Length (Centimeters).	MEAN VINE LENGTH.				
		1908.	1909.	1910.	1911.	Average.
A,	70	39.53 ±0.74	42.19 ±0.47	51.86 ±0.44	42.88 ±0.57	44.12
B,	53	30.19 ±0.76	36.16 ±0.50	45.61 ±0.46	35.75 ±0.52	36.93
C,	64	47.10 ±0.67	59.75 ±0.41	70.95 ±0.25	54.81 ±0.47	58.15
D,	57	37.78 ±0.78	47.56 ±0.54	43.46 ±0.48	42.43 ±0.51	42.81
E,	68	33.06 ±1.14	36.75 ±0.89	43.70 ±0.54	37.42 ±0.60	37.73
F,	63	41.43 ±1.48	48.83 ±1.02	37.62 ±0.66	41.71 ±1.07	42.40
G,	69	42.50 ±0.77	46.36 ±0.39	42.66 ±0.49	43.61 ±0.49	43.78
H,	61	34.35 ±0.61	41.15 ±0.41	36.44 ±0.36	38.76 ±0.46	37.68
J,	65	36.72 ±0.55	38.77 ±0.53	33.80 ±0.60	35.69 ±0.84	36.25
K,	55	44.88 ±0.67	46.55 ±0.51	38.24 ±0.54	35.90 ±0.75	41.39

ORIGINAL PLANT.	Pods per Vine.	MEAN VINE LENGTH.				
		1908.	1909.	1910.	1911.	Average.
A,	11	3.00 ±.13	5.23 ±.11	4.78 ±.08	5.85 ±.15	4.72
B,	17	2.91 ±.03	5.00 ±.13	4.70 ±.09	5.13 ±.13	4.44
C,	9	5.32 ±.31	12.45 ±.27	7.77 ±.08	8.62 ±.17	8.54
D,	7	3.26 ±.04	6.79 ±.14	3.88 ±.08	5.34 ±.11	4.82
E,	4	2.81 ±.05	5.52 ±.22	4.18 ±.11	5.36 ±.13	4.47
F,	3	3.57 ±.19	6.10 ±.26	3.16 ±.09	4.80 ±.20	4.41
G,	9	4.70 ±.09	5.96 ±.09	3.59 ±.05	5.61 ±.12	4.97
H,	11	3.15 ±.03	4.78 ±.09	3.02 ±.05	4.64 ±.11	3.90
J,	4	3.05 ±.03	4.92 ±.12	3.16 ±.11	4.56 ±.21	3.92
K,	4	3.75 ±.05	6.11 ±.20	3.62 ±.09	4.30 ±.12	4.45

A study of the averages of vine length and pods per vine of the 9 lines of descent, comprehended in the group Excelsior I., is of interest. These are shown in Table VII. and the remaining line, otherwise known as Variety "C", is included for purposes of comparison. The most striking thing brought out in the table is the fact that averaging the mean vine length for the four years under observation, we find that 5 of the lines A, D, F, G and K are grouped very closely around 43 centimeters while 4 others, B, E, H and J, are grouped closely around 37 centi-

meters.¹ The remaining line C being, as already stated, obviously a distinct variety, has a vine length much greater than any of the others.

The two groups above designated may be spoken of as strains, their component parts being known as lines, each of which is, as before explained, composed of the descendants of a single plant. The means of the several lines vary greatly from year to year, due to the varying conditions of weather and of the soil of the different plots on which the crops were grown. The relations of the mean lengths of the several lines in the same years also vary greatly. Much of this is obviously due to varying soil conditions. They are more consistent with the four-year averages, in 1911, than in the previous years, the only very marked departure being the case of line K, which is much below the average. They are extremely variable in 1910, when, as already stated, the unwise method of applying fertilizer in the row was followed.

Whether the slight departure of the averages of the different lines of either strain have any significance in inheritance is questionable. Only further testing under more uniform conditions would determine this.

Great differences are shown in the mean number of pods per vine. They follow the mean vine lengths only in a general way, and do not show very clearly the segregation into two strains as do the mean vine lengths. This might be expected in consideration of the slight coefficient of heredity of pods per vine already shown. Nevertheless, the average number of pods in the long-vined strain is about 15 per cent. greater than in the other, while the vine length is only about 16 per cent. greater. We have here a result of the greater variability of pods per vine over vine length that will be more fully discussed later in this paper.

¹ This explains the division of Excelsior I. in Table VI.

TABLE VIII. — *Coefficients of Heredity within Strains.**Vine Length.*

	1908-09.	1909-10.	1910-11.	Average.
A, D, F, G, K,	+.0081 ± .0225	-.0646 ± .0215	+.0682 ± .0260	+.0039
B, E, H, J,	+.1733 ± .0270	+.0355 ± .0276	+.0200 ± .0300	+.0763
Average,	+.0907	-.0146	+.0441 ± .0401	+.0401

Pods per Vine.

	1908-09.	1909-10.	1910-11.	Average.
A, D, F, G, K,	-.0169 ± .0220	-.0072 ± .0216	+.0059 ± .0261	-.0061
B, E, H, J,	+.0343 ± .0280	-.0722 ± .0276	+.0292 ± .0299	-.0032
Average,	+.0087	-.0397	+.0176 ± .0045	-.0047

If these strains are homogeneous, and if the positive correlation shown in the first three groups in Table I. is due chiefly to the mixture of distinct strains or lines having different means, as appears to be the case, we should get when we compute for each of the strains as a unit, coefficients similar to those given in Table II. They are given in Table VIII. It is seen that they are similar on the average, having a little lower positive correlation for vine length and an insignificant negative correlation for pods per vine.

CORRELATION.

The data on vine length and pods per vine already presented give some evidence of a positive correlation between these two characters which is in accordance with common observation. In Table IX. are given some figures that show the value of this

TABLE IX. — *Correlation Coefficients, Vine Length and Pods per Vine.*

PLANT.	Year.	Coefficient of Correlation.	Mean Vine Length.
Variety "C",	1910	.4070 ± .0101	71.0
Variety "C",	1911	.3104 ± .0359	54.6
Strain A, D, F, G, K,	1910	.6544 ± .0124	43.9
Strain A, D, F, G, K,	1911	.5653 ± .0178	41.8
Strain B, E, H, J,	19'0	1.7189 ± .0133	39.9
Strain B, E, H, J,	1911	.6016 ± .0191	37.2
Telephone,	1911	.4297 ± .0277	98.9
Champion of England,	1911	.4766 ± .0371	98.5
Gradus,	1911	.5152 ± .0264	52.3
Evolution,	1911	.5293 ± .0266	72.2
Alaska,	1911	.6103 ± .0231	56.3
Thomas Laxton,	1911	.6180 ± .0236	53.7
American Wonder,	1911	.6950 ± .0174	23.0

correlation. The nature of the groups in the first part of the table has already been explained. The remaining varieties have been grown from commercial seeds bought in the open market. The table shows that the correlation coefficient is closely related to the mean vine length in different varieties. The rule that is generally, though not invariably, followed is that the longer the vine the lower the correlation between vine length and pods per vine. This is reversed in the case of the different years shown in the first part of the table. This is due to the fact that the vines branched more freely in 1911, owing presumably to weather conditions. Vine length is taken as the length of the main stem, and when there are one or more branches bearing pods it is obvious that the correlation is lessened.

To this same factor is due in part, but not wholly, the smaller correlation in the groups having longer vines.

One or two pods may be borne at each node of the plant, but at many nodes no pod is produced. Whether or not a pod is produced depends presumably on environmental conditions at the time when the early development of the node has reached a certain stage. The period of growth and node production is much longer with long-vined plants, and the plant is subjected to a greater variation of conditions. As successive nodes develop some will experience favorable and some unfavorable conditions, and this will not be in very close correlation with vine growth. In some varieties and in some seasons the production of doubled podded peduncles is more common, and this operates to disturb the correlation. This question will be further dealt with in connection with the later discussion of variation in productiveness.

VARIATION.

We may now proceed to a discussion of the amount and nature of the variation that has been in evidence in the different groups from season to season.

In Table X. are given the standard deviations and coefficients of variability that are available, and the means are inserted for convenience of immediate comparison, though most of them have already been given in another connection.

TABLE X. — *Variation in Vine Length and Productiveness.*

PLANT.	Year.	VINE LENGTH.			PODS PER VINE.		
		Mean.	Standard Deviation.	Coefficient of Variability.	Mean.	Standard Deviation.	Coefficient of Variability.
A,	1908	39.53 ± 0.74	4.80 ± 0.53	12.15 ± 1.34	3.00 ± 0.13	.85 ± 0.09	28.07 ± 3.49
	1909	42.19 ± 0.47	9.45 ± 0.33	22.40 ± 0.83	5.23 ± 0.11	2.12 ± 0.07	40.54 ± 1.04
	1910	51.86 ± 0.44	9.68 ± 0.31	18.67 ± 0.62	4.78 ± 0.08	1.79 ± 0.06	37.45 ± 1.36
	1911	42.88 ± 0.57	10.70 ± 0.40	24.96 ± 1.00	5.85 ± 0.15	2.78 ± 0.10	47.52 ± 2.15
D,	1908	37.78 ± 0.78	6.01 ± 0.54	15.91 ± 1.50	3.26 ± 0.04	.29 ± 0.03	8.90 ± 0.74
	1909	47.56 ± 0.54	11.40 ± 0.38	23.97 ± 0.85	6.79 ± 0.14	3.06 ± 0.10	45.07 ± 1.78
	1910	43.46 ± 0.48	10.46 ± 0.34	24.07 ± 0.82	3.88 ± 0.80	1.68 ± 0.06	43.39 ± 1.65
	1911	42.43 ± 0.51	10.47 ± 0.36	24.68 ± 0.89	3.34 ± 0.11	2.36 ± 0.08	44.24 ± 1.79
F,	1908	41.43 ± 1.48	5.80 ± 0.00	14.00 ± 2.57	3.57 ± 0.10	—	—
	1909	48.83 ± 1.02	12.33 ± 0.72	25.24 ± 1.57	6.10 ± 0.26	3.03 ± 0.19	49.59 ± 3.72
	1910	37.02 ± 0.66	7.91 ± 0.47	21.03 ± 1.30	3.16 ± 0.09	1.11 ± 0.07	35.13 ± 2.34
	1911	41.71 ± 1.07	9.36 ± 0.75	22.44 ± 1.89	4.80 ± 0.20	1.75 ± 0.14	36.40 ± 3.30
G,	1908	42.50 ± 0.77	6.29 ± 0.55	14.80 ± 1.23	4.70 ± 0.09	.71 ± 0.02	15.11 ± 1.31
	1909	46.36 ± 0.39	9.93 ± 0.27	21.42 ± 0.62	5.96 ± 0.09	2.27 ± 0.63	38.09 ± 1.19
	1910	42.66 ± 0.49	9.47 ± 0.24	22.20 ± 0.59	3.59 ± 0.05	1.41 ± 0.04	39.28 ± 1.14
	1911	43.61 ± 0.49	9.91 ± 0.34	22.72 ± 0.83	5.61 ± 0.12	2.54 ± 0.09	45.28 ± 1.86
K,	1908	44.88 ± 0.67	3.95 ± 0.48	8.80 ± 1.06	3.75 ± 0.50	.28 ± 0.03	7.47 ± 0.89
	1909	46.55 ± 0.51	9.24 ± 0.36	19.85 ± 0.81	6.11 ± 0.20	3.55 ± 1.39	57.03 ± 1.87
	1910	38.24 ± 0.54	8.96 ± 0.38	23.43 ± 1.05	3.62 ± 0.09	1.54 ± 0.07	42.54 ± 2.12
	1911	35.90 ± 0.75	10.47 ± 0.53	29.16 ± 1.60	4.30 ± 0.12	1.73 ± 0.09	40.23 ± 2.35
A, D, F, G, K,	1908	40.70 ± 0.42	6.30 ± 0.30	15.48 ± 0.76	3.75 ± 0.08	1.19 ± 0.06	31.04 ± 1.65
	1909	45.97 ± 0.22	10.00 ± 0.16	21.67 ± 0.36	6.05 ± 0.06	2.80 ± 0.05	46.28 ± 0.88
	1910	43.92 ± 0.23	10.56 ± 0.16	24.04 ± 0.39	3.90 ± 0.03	1.60 ± 0.02	41.03 ± 0.72
	1911	41.86 ± 0.28	10.61 ± 0.20	25.35 ± 0.50	5.37 ± 0.06	2.47 ± 0.05	45.90 ± 1.01

TABLE X. — Variation in Vine Length and Productiveness — Con.

PLANT.	Year.	VINE LENGTH.			PODS PER VINE.		
		Mean.	Standard Deviation.	Coefficient of Variability.	Mean.	Standard Deviation.	Coefficient of Variability.
B,	1908	30.19 ± 0.76	5.37 ± 0.54	17.79 ± 1.81	2.91 ± 0.03	.21 ± 0.02	7.22 ± 0.72
	1909	36.16 ± 0.50	9.18 ± 0.35	25.38 ± 1.04	5.00 ± 0.13	2.31 ± 0.09	39.65 ± 1.74
	1910	45.61 ± 0.46	20.09 ± 0.32	20.09 ± 0.73	4.70 ± 0.09	1.82 ± 0.06	38.72 ± 1.56
	1911	35.75 ± 0.52	9.55 ± 0.37	26.72 ± 1.10	5.13 ± 0.13	2.40 ± 0.09	46.78 ± 2.16
E,	1908	33.08 ± 1.14	6.74 ± 0.80	20.39 ± 2.52	2.81 ± 0.05	.28 ± 0.03	9.96 ± 1.19
	1909	36.75 ± 0.89	10.23 ± 0.63	27.84 ± 1.84	5.52 ± 0.22	2.58 ± 0.16	46.74 ± 3.44
	1910	43.70 ± 0.54	8.17 ± 0.38	19.00 ± 0.92	4.18 ± 0.11	1.65 ± 0.08	39.35 ± 2.10
	1911	37.42 ± 0.60	9.80 ± 0.42	26.18 ± 1.21	5.36 ± 0.13	2.15 ± 0.09	40.15 ± 2.00
H,	1908	34.35 ± 0.61	5.29 ± 0.42	15.40 ± 1.29	3.15 ± 0.03	.26 ± 0.02	8.25 ± 0.68
	1909	41.15 ± 0.41	9.35 ± 0.29	22.72 ± 0.73	4.78 ± 0.09	2.14 ± 0.06	44.86 ± 1.63
	1910	36.44 ± 0.36	7.99 ± 0.26	21.93 ± 0.74	3.02 ± 0.05	1.13 ± 0.07	37.42 ± 1.37
	1911	38.76 ± 0.46	9.12 ± 0.33	23.53 ± 0.89	4.64 ± 0.11	2.08 ± 0.08	44.83 ± 1.90
J,	1908	36.72 ± 0.55	3.72 ± 0.37	10.13 ± 1.06	8.05 ± 0.03	.19 ± 0.02	6.23 ± 0.65
	1909	38.77 ± 0.53	8.82 ± 0.38	22.75 ± 1.02	4.92 ± 0.12	2.04 ± 0.07	41.46 ± 2.05
	1910	33.80 ± 0.60	8.61 ± 0.42	25.47 ± 1.33	3.16 ± 0.11	1.53 ± 0.08	48.26 ± 2.87
	1911	35.69 ± 0.84	9.16 ± 0.59	25.67 ± 1.77	4.56 ± 0.21	2.28 ± 0.15	50.05 ± 3.97
B, E, II, J,	1908	34.47 ± 0.40	5.80 ± 0.28	16.82 ± 0.84	3.03 ± 0.05	.76 ± 0.04	25.08 ± 1.30
	1909	38.86 ± 0.27	9.49 ± 0.19	24.42 ± 0.51	4.94 ± 0.06	2.23 ± 0.04	45.04 ± 1.06
	1910	39.94 ± 0.27	9.69 ± 0.19	24.26 ± 0.50	3.78 ± 0.05	1.69 ± 0.03	45.01 ± 1.04
	1911	37.19 ± 0.28	9.47 ± 0.20	25.45 ± 0.87	4.93 ± 0.07	2.24 ± 0.05	45.44 ± 1.15
C,	1908	46.12 ± 0.67	8.55 ± 0.48	18.53 ± 1.88	5.32 ± 0.31	2.60 ± 0.22	48.87 ± 4.81
	1909	59.75 ± 0.41	10.38 ± 0.29	17.38 ± 0.51	12.45 ± 0.27	6.71 ± 0.19	53.90 ± 1.86
	1910	70.95 ± 0.25	10.34 ± 0.18	14.56 ± 0.25	7.77 ± 0.08	3.22 ± 0.06	41.44 ± 0.82
	1911	54.81 ± 0.47	11.95 ± 0.36	21.80 ± 0.64	8.62 ± 0.17	4.33 ± 0.12	50.24 ± 1.73
Excelstor I,	1908	37.67 ± 0.33	6.81 ± 0.23	18.09 ± 0.64	3.40 ± 0.05	1.06 ± 0.04	31.29 ± 1.17
	1909	43.20 ± 0.19	10.68 ± 0.13	24.72 ± 0.32	5.63 ± 0.05	2.66 ± 0.03	47.25 ± 0.70
	1910	42.41 ± 0.18	10.39 ± 0.13	24.50 ± 0.31	3.85 ± 0.03	1.66 ± 0.02	43.12 ± 0.61
	1911	39.85 ± 0.21	10.43 ± 0.15	26.17 ± 0.39	4.57 ± 0.03	1.73 ± 0.02	37.86 ± 0.60

Considering first the figures for vine length, we find that in 1908 the standard deviation and coefficient of variability were much lower than in any of the following three years. This is due to two factors, the more potent of which, doubtless, was the soil of the plot on which the plants were grown; this was gravelly and the plants suffered severely from drought. The other was the small number of plants grown, the total of 1908 being 227, while in subsequent years the total of the same groups has been more than 1,000. During the years 1909-11 there seems not to have been in Excelsior I., or any of its sub-groups, any constant differences in variation that cannot be ascribed to seasonal influences. In Excelsior II. both constants are notably low in 1911. This may be due to the fact that they were planted later this year than previously and encountered the unusually hot weather of July, 1911, at an earlier stage of development than either the other lots of Excelsior, or this lot in earlier years had encountered the less severe midsummer heat of those years. A comparison of the two strains of Excelsior I. shows that A, D, F, G, K has had uniformly greater standard deviation than B, E, H, J, but this has not been in proportion to the higher mean, so the coefficient of variability is less in the longer vined strain. This same tendency is seen in the distinct varieties, although it is not invariably the case.

We may ask if the variation within the lines of the two strains of Excelsior I. give evidence of individuality of these several lines? Is any line constantly more or less variable than the others of the same strain? With the possible exception of line D, which has a standard deviation uniformly larger or at least as large as its fellows, there seems to be no evidence of such a condition of affairs. It appears that the differences in the variability within the different lines is mostly, if not entirely, environmental and due chiefly to varying soil conditions.

We may now turn our attention to the figures for the number of pods per vine. We see first of all that the coefficient of variability is nearly twice as large as that for vine length, and in many cases the difference is even greater than this. In general, a high variability in vine length is accompanied by a high variability of pods per vine and vice versa, as would be expected from the strong correlation already shown to exist between these

two characters. The differences in mean between different groups, more especially in different seasons, is marked. All through the groups of Excelsior I., 1909 was the most productive year, followed in order by 1911, 1910 and 1908. This order is not always followed in the other groups, owing to the fact that different planting dates and varying periods of growth caused the plants to experience different weather conditions at corresponding periods of development. These figures bring out in a striking way that fact familiar to all practical men, that productiveness is a delicate and uncertain character and tremendously influenced by environmental conditions.

The 10 plants of Excelsior selected in 1907 have given rise to at least three types of peas referred to as strains A, D, F, G, K and B, E, H, J and Variety "C." The groups Excelsior II. and First of All contain over 100 lines similar to those arising from these 10 plants, but in no case have we over 25 or 30 individuals in any one year. We may ask whether we have here any evidence of similar differences. No line is as distinct as Variety "C", but whether there are any of the more similar types, such as the two strains referred to, cannot be positively determined, owing to the small number of individuals grown. If we admit the general application of the very low heredity coefficients shown in Table II. to all such lines, a coefficient materially greater than these must indicate the presence of distinct strains. Reference to Table I. indicates a possibility of such condition in the case of Excelsior II., but with First of All the figures are about the same as those for single lines; it should be remembered, however, that the indications are that the correlation between seed weight and vine length is less in starchy peas. A study of the means of single lines for the two years available has been made, but is of no value, as the variation obviously due to environment, and the small number of individuals grown, totally obscures any inherited likeness that may exist. The existence of a relatively large coefficient of variability should indicate the presence of distinct strains, but these figures for Excelsior II. and First of All are variable and inconclusive.

The conclusion on this point is that there is some evidence of the presence of distinct strains in both Excelsior II. and

First of All, though we cannot say that their presence in either group is conclusively proven. In the opinion of the writer only the growing of these lines in greater numbers, for a period of two or three years under the most uniform conditions possible, can determine whether they are homogeneous or are, like Excelsior I., made up of distinct strains.

DISCUSSION OF THE RESULTS.

This work deals with two somewhat distinct characters of the garden pea, — vegetative vigor as expressed by vine length and the reproductive power as expressed by the number of pods per vine. The former seems much the more stable character, while the latter is extremely variable and much the subject of environmental influences. Vine length is, therefore, more dependable in studying heredity. The figures for vine length seem to indicate that some and perhaps all varieties of garden peas are composed of strains which have different hereditary vine lengths, which is in harmony with much of the recent investigation along these lines. They do not, in the opinion of the writer, indicate that the progeny of each individual under observation form distinct units which may be distinguished from each other, but rather that there are comparatively few distinguishable units composed of individuals of equal hereditary value to be found within the limits of what we commonly understand as a garden variety.

This work indicates nothing as to the origin or permanency of these units or strains. They may have arisen by mutation, by a gradual differentiation or by hybridization; they may endure permanently or they may not. It will require much further investigation to settle these questions.

It is a little unfortunate that no records of the number and length of internodes have been kept, for they would probably throw light on certain questions of productiveness. Each node, excepting possibly the lower ones, may be considered a possible location for a pod. It is probable that whether or not a pod is produced from any given node is entirely a matter of environment. We see no reason to believe that the number of pods per vine is in itself inherited in any degree. Vine length and pre-

sumably the number of nodes may be in some degree inherited, and inasmuch as a longer vine, and presumably more nodes, gives more opportunities for pod setting, productiveness may be thus indirectly passed over from one generation to another; but we see no indication in this work, or any other with which we are familiar, that the ability to produce pods is an inheritable character.

It follows from this that in careful work in selecting for productiveness in peas it will probably be more effective to follow the indirect method of selecting the long vines rather than to select directly the more elusive and variable character of pods per vine.

The difficulties in the way of studying heredity in plants lie largely in differentiating the inherited variations from the environmental; they may be reduced to a minimum by securing as uniform conditions as possible and growing large numbers of individuals. In such ways we may hope to learn the laws of breeding and reduce its practice to a science.

SEED WORK FOR THE YEAR 1911.

G. E. STONE.

The seed work for 1911 has included, as before, seed germination, seed separation and testing for purity. The 355 samples of seed sent in for germination exceeded the number for 1910, and was the largest number received since the work was inaugurated. Sixty-eight samples were tested for purity, and 135 samples were separated. This is not the largest number ever received for separation; the weight in pounds, however — 6,320 — was four times as great as ever before. Eighty-seven samples of tobacco seed and 42 of onion were sent in for separation. The smaller number of samples received is due to a co-operation among the farmers in buying their seed.

The average germination of onion seed for 1911 was 70 per cent., the highest 98 per cent. and the lowest 20 per cent. The average for tobacco was 84 per cent., the highest 95 per cent. and the lowest 21 per cent., neither seed being quite up to the standard.

TABLE I. — *Records of Seed Germination, 1911.*

KIND OF SEED.	Number of Samples.	Average Per Cent.	PER CENT. OF GERMINATION.	
			Highest.	Lowest.
Onion,	126	70.4	98.5	20.0
Tobacco,	11	84.9	95.0	21.0
Clover,	25	81.3	97.0	61.5
Rye,	5	84.5	97.0	63.0
Grasses,	38	77.7	99.0	15.5
Lettuce,	43	48.7	99.0	3.0
Celery,	21	30.2	91.0	—
Tomato,	9	58.3	98.0	—
Parsley,	5	56.4	85.0	20.0
Spinach,	7	28.0	39.5	12.0
Parsnip,	7	7.5	30.0	—
Miscellaneous,	65	42.8	98.5	—
	355	—	—	—

More seed separation is apparently being done at this station than at any other, and this work is constantly increasing. The advantages to be derived from seed separation are not fully appreciated as yet. Onion and tobacco growers, we believe, are realizing these advantages more fully year by year, and this is true of some lettuce and celery growers, but much more use could be made of the practice by market gardeners. Seed separation results in better seed, more perfect germination and much more uniform and larger plants, which in seedbeds saves space and a great deal of labor in selecting uniform seedlings.

The selection from strains is also being made much of in the growing of corn and other crops, but market gardeners and farmers are by no means making use of all the opportunities in any of these directions.

TABLE II. — *Records of Seed Separation, 1911.*

KIND OF SEED.	Number of Samples.	Weight (Pounds).	Per Cent. of Seed retained.	Per Cent. of Seed discarded.
Onion,	42	6,206.210	72.1	27.9
Tobacco,	87	85.820	86.3	13.7
Lettuce,	3	27.720	83.6	16.4
Celery,	6	.926	84.8	15.2
Total,	135	6,320.676	-	-

The percentage of onion seed discarded runs higher than usual, a fact due, apparently, to the relatively larger number of small seeds present than usual.

A summary of the seed work carried on at the station for a period of twelve years is shown in Table III. Previous to 1899 little seed testing and separation were done here, and no systematic records were kept of the work. Table III. gives a recapitulation of the work done in seed germination, purity testing and seed separation since 1899.

TABLE III.—*Showing Number of Samples of Seed Purity and Germination Tests made, and Seed Separation Work done, at the Station since 1899.*

YEAR.	NUMBER OF SAMPLES.			Pounds separated.
	Germination.	Purity.	Separation.	
1899,	27	-	-	-
1900,	17	-	-	-
1902,	53	-	-	-
1903,	42	-	-	-
1904,	131	-	-	-
1905,	217	-	-	-
1906,	126	18	87	144
1907,	247	27	112	472
1908,	196	12	160	1,370
1909,	273	100	143	1,501
1910,	296	30	115	1,552
1911,	355	68	135	6,320
Total,	1,980	255	752	11,359

This table gives some idea of the increased interest manifested in seed work by the farmers and market gardeners of the State. Nearly 2,000 tests have been made for germination. 255 tests for purity, and 752 separations made. The total weight of seeds separated is 11,359 pounds. It must be remembered that all the seeds separated were small, particularly tobacco seed, of which it requires a great many to make a pound. A record of the number of samples, with the average, maximum and minimum germination of onion, tobacco and celery seed, is shown in Table IV.

TABLE IV.—*Showing Germination of Onion, Tobacco and Celery received at the Station since 1899.*

YEAR.	ONION.				TOBACCO.				CELERY.			
	Number of Samples.	Average.	Maximum.	Minimum.	Number of Samples.	Average.	Maximum.	Minimum.	Number of Samples.	Average.	Maximum.	Minimum.
1899, . . .	27	72.0	90.0	45.0	-	-	-	-	-	-	-	-
1900, . . .	12	85.6	92.0	70.0	-	-	-	-	-	-	-	-
1902, . . .	6	89.0	94.0	83.0	-	-	-	-	-	-	-	-
1903, . . .	21	85.5	97.0	52.5	-	-	-	-	-	-	-	-
1904, . . .	25	77.8	96.5	45.5	-	-	-	-	-	-	-	-
1905, . . .	15	91.8	98.5	84.0	-	-	-	-	4	89.0	97	79
1906, . . .	32	79.0	100.0	28.0	-	-	-	-	6	67.0	99	43
1907, . . .	40	86.0	98.5	57.0	2	91.0	92	90	3	83.0	91	70
1908, . . .	65	74.2	98.5	-	10	78.0	97	20	24	79.0	98	35
1909, . . .	92	82.2	97.0	25.0	8	93.6	97	85	8	69.0	85	25
1910, . . .	75	77.4	100.0	3.0	7	95.0	99	89	-	-	-	-
1911, . . .	126	70.4	98.5	20.0	11	84.9	95	21	21	30.2	91	-
Total, . . .	536	-	-	-	38	-	-	-	66	-	-	-

During the period from 1899 to the present time 536 germination tests of onion seed, 33 of tobacco and 66 of celery have been made, representing about one-fourth of the seed which we have tested. The principal feature to be noted is, perhaps, the variation in the percentage of germination occurring from year to year in different seeds. While it is perhaps not legitimate with the data at hand to draw too close deductions, we have noted in our seed work the effects of unfavorable climatic conditions upon the size and weight of seeds and seed vitality. The lowest average for onion seed was obtained in 1911, most of this seed probably having been grown in 1910; the highest average germination for onion in 1905, and for tobacco in 1910. The tobacco seed are practically all grown in the Connecticut valley, and obtained from carefully selected plants the year before. The variation in vitality is of some significance here. The celery seed tested is of uncertain origin, and the variation has little

significance for us. There is no doubt but that unfavorable seasons and other factors show their effect in the percentages of germination given in these tables. In the case of tobacco seed another factor probably enters in, viz., gradual improvement in the vitality brought about by care in the selection of the seed plants.

TABLE V. — *Showing Number of Samples and Pounds of More Important Varieties of Seeds separated from 1906 to 1911, inclusive.*

KIND OF SEED.	Number of Samples.	Weight (Pounds).	Per Cent. of Seed retained.	Per Cent. of Seed discarded.
Onion,	187	8,923.30	83.6	16.3
Celery,	29	555.64	89.3	10.7
Tobacco,	418	272.43	85.4	14.6
Lettuce,	6	67.72	86.8	13.2
Total,	640	9,819.09	-	-

In Table V. is shown the number of samples and pounds of four typical seeds, with the percentage retained and discarded in our separation work, covering a period of five years, from 1906 to 1911. It will be seen from this table that the total number of samples separated is 640, equalling nearly 10,000 pounds in weight. The average percentage discarded was about 15 per cent., representing small, inferior seeds. Since these were all small seeds the weight in pounds is rather insignificant, as the number of onion seed in a pound is approximately 130,000, that of celery seed 2,000,000, of lettuce, 400,000 and of tobacco 7,000,000. All the seed work has been done here gratuitously since its inauguration, the only exception being in the case of retailers who sometimes wish their seed tested in large quantities. The only expense incurred by the grower at present is return postage or express charges, and we are glad to say that this condition is almost invariably complied with.

In our opinion this work has proved of great value to our agriculturists. So far as seed separation is concerned, the value is greater than some of them realize, and perhaps less than others of the more enthusiastic may believe. The many careful tests which we have been making for years have shown us what

seed separation actually accomplishes, and we therefore desire neither to overrate nor underrate the value of the work. The seed work of this station has shown a very healthy increase and growing interest on the part of the farmers. It has not been extensively advertised nor the value exaggerated, as we have regarded a slow, constant growth as of more value than one of a sporadic nature. The work, however, is now becoming so important in our State that it requires the services of a seed analyst who would devote most of his time to this work. We are of the opinion that this work should be done gratuitously for farmers and citizens, for the present at any rate, as it is more or less educational in nature, and that provision should be made for an assistant and improved testing appliances. Constant experimentation should be carried on to improve upon the existing methods of germination and separation. The work should be done systematically and collections of samples obtained throughout the State from dealers and farmers, and the results of these tests published here in bulletin form. This would greatly improve the seed problem as existing in this State.

All samples of seed to be germinated or separated should be sent to G. E. Stone, Massachusetts Agricultural Experiment Station, Amherst, Mass., and the express or freight should be prepaid.

RUST ON VINCA.

G. E. STONE.

An outbreak of rust on Vinca was recently brought to our attention by Mr. O. C. Bartlett, a graduate student at this institution. Mr. Bartlett, who is engaged in the summer in inspection work, became acquainted with this trouble through J. W. Adams & Co., of Springfield, Mass., a firm which maintains a nursery and general greenhouse establishment. The rust appears to be new in this country, and is apparently the same species as that occurring in Europe on Vinca,¹ although the specimens obtained by us do not correspond in every way to the European descriptions of this fungus. We have in our herbarium no European species with which to compare our specimens, but they were sent to Prof. W. G. Farlow, of Harvard University, and to Dr. J. C. Arthur of Purdue University, Indiana, who is a rust specialist. Professor Farlow writes that from a casual examination of material which we sent him, and which he compares with material in his own herbarium, the species differs considerably from his own type, *Puccinia Vincae* (DC) Cast. Dr. Arthur states that there are two distinct forms in Europe, both of which are referred to as *Puccinia Berkeleyi*, Pass., and *Puccinia Vincae* (DC), Berk., the former being a synonym of the latter, and that the specimens sent correspond with one of the European types.

The rust has apparently been present in the vicinity of Springfield and Chicopee for at least two or three years, corresponding to the period when there was more or less of an unusual epidemic of rust in this State and elsewhere. Vinca is grown out of doors during the summer from greenhouse cuttings, but we could find no evidence of the disease affecting

¹ Tubeuf & Smith, "Diseases of Plants," p. 356.

outdoor plants in the summer or early fall. It makes its appearance in the greenhouse in the late fall and persists during the winter, affecting the leaves of the young, vertical shoots more seriously than those of the older, pendant ones. We observed both the euredospore and teleutospore outbreaks, which occurred on the underside of the leaves on our material. In the spring it appears to affect the plants less seriously, probably owing to the practice of frequently cutting off the affected parts and destroying them, and to the vigorous growth of the plants in the spring. When starting new plants care has been taken to use only healthy cuttings from year to year, and in this way the rust has, perhaps, been held in check to some extent.

The disease affects both the green and variegated varieties, although the latter are usually more severely affected. It has been found on a large number of plants, but the loss has not been serious owing to a tendency on the part of the plants to outgrow the trouble.

We have not been able to learn whether the mycelium is perennial in the stem or not, or whether infection comes from the field, but the rust does not seem to be so serious this year as the past two years, agreeing in this respect with other rusts which have been more or less epidemic. If the infection occurs on outdoor plants, as in the case of chrysanthemum rust, it can easily be controlled by indoor or tent-cloth culture, or by any other means which would keep the dews off the plants, and even if the mycelium is present in the stem to some extent the disease can no doubt be practically controlled by careful selection of cuttings. We have been unable to trace the disease beyond the points mentioned. The stock in use was obtained from the immediate neighborhood where the infection occurred, although no doubt the rust at some time or other came in on stock imported from Europe.

FROST CRACKS.

G. E. STONE.

Many trees of different varieties are subject to frost cracks. These often remain open for several years, and so far as our observations go are almost always to be found on the sunny side of the tree, generally towards the south. They occur in winter, and it is generally believed that they are caused by sudden changes in temperature, and especially by very severe cold. They were very common in this section during the remarkably cold winter of 1903-04, when some fruit trees, 8 or 10 inches in diameter, had frost cracks which opened 4 or 5 inches wide.

In this section the elm tree is more liable to cracks from the action of frost than other varieties. These are often 12 or 15 feet long, and give rise to more or less serious bleeding during the summer months. Cracks in trees occur not infrequently from other causes, such as the splitting of limbs, and we have known a number of sugar maples to gradually bleed to death from the loss of sap.

Frost cracks open in winter when the temperature is low, and close in summer. When not very large they sometimes heal over and disappear through the activities of callus growths, but more often they persist for some years, and an extensive opening of the cavity prevents permanent healing, making the tree subject to bleeding in summer.

Frost cracks are difficult to treat satisfactorily by tree surgery methods, as they often extend quite deeply into the wood, and the orifice is constantly changing in width owing to changes in the temperature. For the same reason certain other cavities in trees are hard to treat, as they sometimes open in winter and allow water to enter, which often results in the displacement of the cement fillings. To obviate this difficulty we have experimented largely with elastic cement applied to the edge of the

filling as a means of preventing the access of water between the cement and the wood, but have found it practically impossible so far to prevent the bleeding of frost cracks or cavities in trees. There is no substance now in use which can successfully overcome the pressure exerted by the sap, which is bound to exude under certain conditions.

During the winter of 1907 Mr. E. G. Bartlett, at that time assistant in the laboratory, at my suggestion made measurements of the opening and closing of the orifices of some large frost cracks on the south side of elm trees located on the college campus. In the following table are given the results of these measurements, together with the mean temperature for the same period. The meteorological data were taken from the local station on the college grounds, and not a great distance from the trees.

Table showing Variation in the Width of Frost Cracks in Elm Trees (Ulmus Americana).

DATE.	Tree No. 1.	Tree No. 2.	Mean Temperature (Degrees F.).
February 4,	23	20	16.5
5,	24	21	11.0
6,	26	24	5.3
7,	32	28	2.5
8,	28	24	16.0
9,	26	23	13.0
11,	22	18	17.0
12,	36	32	1.3
13,	38	35	2.5
14,	24	20	31.7
15,	26	22	28.5
16,	21	17	26.7
18,	22	20	21.5
19,	22	18	14.5
20,	22	18	30.7
21,	25	21	20.5
22,	28	24	8.0
23,	32	28	.5
25,	22	28	20.3

Table showing Variation in the Width of Frost Cracks in Elm Trees
(*Ulmus Americana*) — Concluded.

DATE.	Tree No. 1.	Tree No. 2.	Mean Temperature (Degrees F.).
February 26,	28	24	7.7
27,	29	25	12.0
28,	28	24	7.5
March 4,	20	16	27.5
5,	20	16	21.3
6,	20	16	23.7
7,	21	17	22.5
8,	20	16	24.0
9,	20	16	23.7
10,	21	17	20.5
11,	20	16	29.7
12,	18	14	25.5
13,	18	14	37.3
15,	11	8	35.7
17,	9	9	41.7

Measurements were not taken on February 10, 17 and 24 (Sunday). The remainder of March the cracks were too small to measure conveniently.

In the following diagram are shown graphically the variations in the opening and closing of frost cracks based upon the average measurements of tree No. 1 and No. 2; also the barometer, mean temperature and mean relative humidity curve.

It will be noticed that the barometer and temperature curves coincide closely with those given by the opening and closing of the frost cracks, and the same is true to a certain extent of the curve given by the relative humidity. The temperature curve is based upon the mean of the maximum and minimum for each day.

During the periods of low temperature the cracks opened, and closed when the temperature was higher. They open wider in February than in March, as shown by the higher readings in the table.

The relative mean humidity curve in general corresponds with that of the opening and closing of the frost cracks. When

the humidity is low the cracks show a tendency to open, and to close when the humidity is great. The rise and fall of the



Showing curve of opening and closing of frost cracks in elm trees. The lower curve represents the variations in the opening and closing (scale, $\frac{1}{64}$ of an inch); the others represent the mean relative humidity, mean temperature and barometer in the order named.

barometer curve coincides very closely with that of the frost cracks; in fact, there was such a close relationship between the temperature and barometer readings and opening and closing

of frost cracks that considerable information as to the weather conditions might be obtained from observations on frost cracks. During the latter part of March, when the temperature was higher, the frost cracks did not open so wide, and it became more difficult to read them accurately. The same degree of variation in frost cracks may not occur in the summer months as in the winter; at any rate, the change was not so noticeable.

A NEW METHOD FOR THE APPROXIMATE MECHANICAL ANALYSIS OF SOILS.

G. E. STONE AND G. H. CHAPMAN.

According to the best authorities, and giving the definition used by the authors of Bulletin No. 24 of the United States Department of Agriculture, "The mechanical analysis of a soil consists in the separation of the soil particles into groups dependent upon the size of the grains, and in the determination of the percentage by weight of the particles constituting each group. The limits of these groups are arbitrarily chosen with reference to the ease in making the separation, and to the importance of the particles of any given size in determining the physical characteristics of the soil."

Many methods have been devised at different times by investigators, but the whole matter was somewhat hazy on account of each one using his own measurements for grading the soil particles, etc., until the present method of centrifugal analysis was devised by the authors of the bulletin previously noted. Since that time the methods described therein have been made use of by the United States Department of Agriculture and the experiment stations in general, where absolutely accurate results are desired for all characters of soils.

The chief objection to the methods heretofore devised has been the length of time necessary to carry through an analysis, even of the simplest soil.

In the work of this station there have arisen many occasions when it would have been of great advantage to know approximately the composition of a soil, more particularly of those used in greenhouses and market gardening. With a large amount of other routine station work always on hand it was found impossible to devote the time necessary to make an analysis of the soil samples by the ordinary centrifugal, or as we shall hereafter

call it, the "long" method, so it became necessary to devise a method which would materially shorten the process and still give accurate results within a reasonable limit of error.

After considerable experimentation a satisfactory method was devised and has been used with success in our work here the past year. It is not claimed that this method is absolutely accurate, nor is any for that matter, as the limit of error, even when using the most approved centrifugal methods where the greatest care is used, is admittedly large, dependent somewhat of course on the manipulator.

A great number of comparisons have been made of the results obtained by analysis of soils by the long method and the short method and are given in the following pages. The method used by us is more or less of an adaptation of the centrifugal method in general use.

In brief, the centrifugal method in general use is as follows: the soil is carefully sampled and a part of the sample which passes through a 2-millimeter sieve is used for analysis. Five grams are usually taken and dried at 110° C. This sample is then shaken with water, to which a few drops of ammonia have been added, for six hours or more. The sample is then placed in tubes and centrifuged until all but the clay particles have subsided; these, with the water, are then decanted off and evaporated to dryness and weighed. The silts are found by allowing everything larger in size than .05 millimeter to subside, decanting the liquid, evaporating, drying and weighing. The remaining sands are dried and weighed and then sifted by four sieves into five grades. The organic matter is determined usually by the chromic acid method, but should not be confounded with the "loss on ignition" which is often erroneously termed organic matter.

This process, as can plainly be seen, takes a long time to carry through, and is not applicable where quick results are desired.

The briefer method in use at this station is as follows: the sample of soil as brought to the laboratory is first thoroughly mixed and then dried at 110° C. It is then sifted through a 2-millimeter sieve and all that passes through is classed as soil. This is again mixed and 10 grams taken for analysis. This is heated to obtain the "loss on ignition," in a platinum or porce-

lain crucible, and the organic matter, water, etc., is driven off. The sample is then cooled and weighed and loss of weight recorded as "loss on ignition." It is then placed in a small mortar and rubbed gently with a medium hard rubber-tipped pestle to disintegrate the soil particles as far as possible. Then the sample is sifted carefully with constant brushing with a stiff camel's hair brush through 1-millimeter, .5-millimeter, .25-millimeter and .1-millimeter sieves, the last two being bolting cloth, as in the long method. The residue remaining consists of the very fine sand, the silts and clay. This remainder is weighed and the weight recorded, and one gram or fraction thereof is weighed out and used in the remainder of the process to determine the percentage of very fine sand, silts and clay.

This determination is made in the following piece of apparatus (see Fig. 1): A is a circular test tube having a diameter of approximately 2 centimeters and a length to the contraction of about 7 centimeters; B is a flat glass tube with thin walls,

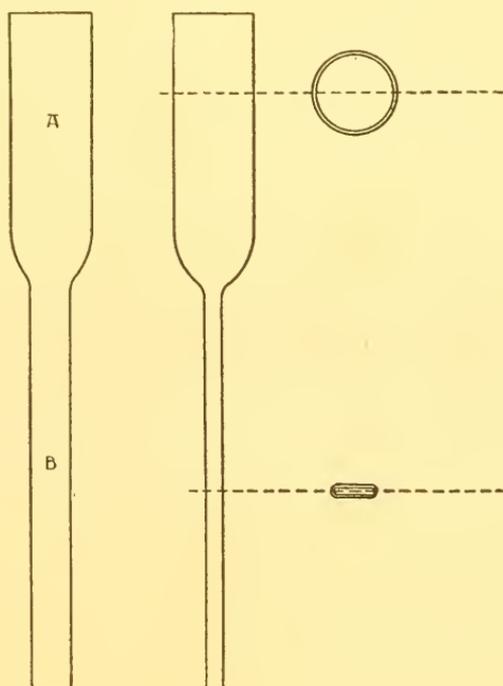


FIG. 1. — Showing special tube for mechanical analysis of soils: A, upper or circular part of the tube; B, lower or flat part of the tube. The figures to the right show cross sections, etc., of the tube.

one of which at least is perfectly flat, having an inside breadth of .8 centimeter and a width 1 to 1.5 millimeters. This tube is about 10 centimeters long. The lengths of A and B may be varied, however, but it has been found that tubes of these dimensions work well in the ordinary laboratory centrifuge. The method of procedure is as follows: the tube is filled to within about 4 centimeters of the top with distilled water and the gram of soil added. A rubber stopper is then placed in the tube and the soil thoroughly incorporated with the water by shaking for a few minutes. The tube is then placed in the centrifuge and run for a period of five minutes at a speed of about 1,200 revolutions per minute. The tube is then removed and clamped to an upright stand shown in Fig. 2, and a millimeter scale is attached so that with a horizontal microscope the size of the soil particles as shown by the eyepiece micrometer and the reading on the scale may be had at the same time or by swinging the microscope in a horizontal plane. 0 millimeter on the scale corresponds with the bottom of the soil column in the tube. The microscope is then focussed on the soil particles and raised until a majority of the particles are less than the minimum size of those of fine sand, *i.e.*, less than .05 millimeter; the scale reading is then taken and noted. The microscope is then raised until the particles are less than those of the minimum size for silts, *viz.*, .0005 millimeter; the scale reading is again noted and the scale reading at the top of the soil column also noted. We have the readings as follows:—

	Millimeters.
Very fine sand,	3.0
Very fine sand and silts,	4.5
Very fine sand and silts and clay,	7.0

The column is divided, therefore, into volume per cents. as follows:—

	Per Cent.
Very fine sand,	42.85
Silts,	21.43
Clays,	35.72

If there were 2.34 grams of soil left after the last sifting we should have weights of very fine sand, silts and clays as follows,

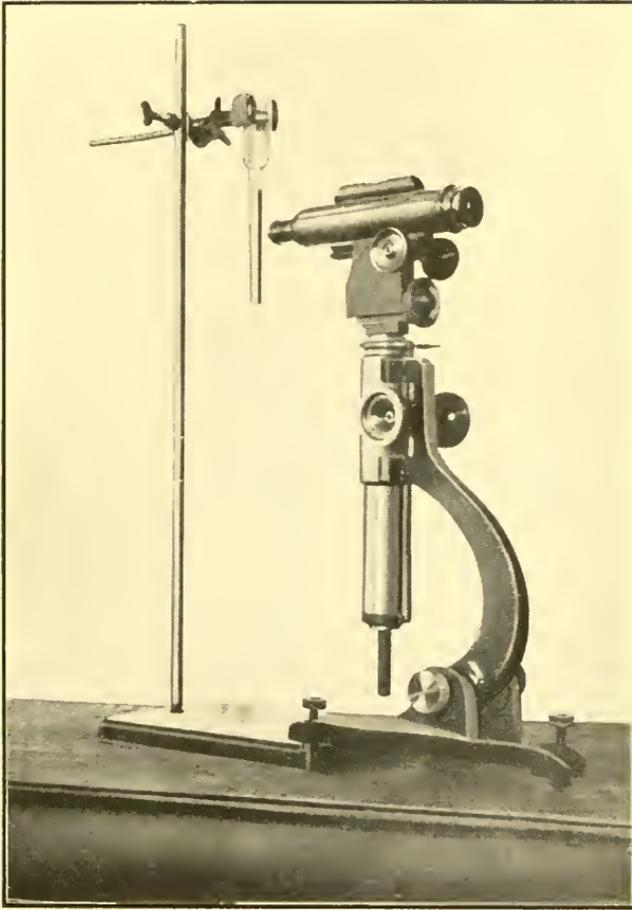


FIG. 2.—Photograph showing a horizontal microscope and methods of reading different percentages of soils in the tube.

using these volume percentages as weight percentages, which may be done, as experiment has shown that in the small tube the error is not great enough to be taken into consideration.

Very fine sand	= 2.34 × 42.85 per cent.	= 1.00 + grams.
Silts	= 2.34 × 21.43 per cent.	= .49 + grams.
Clay	= 2.34 × 35.72 per cent.	= .84 + grams.

Thus we have the weights of the very fine sand, silts and clay, and by following the same system used in calculating the percentages of the sands obtained by sifting in the whole sample we get the percentages of these constituents.

Below are given results of several typical soils which were analyzed by the long method and by the short method. It will be seen that the results vary but little and that for a close approximate analysis the results are accurate enough to warrant the use of this method where time is an important factor.

A criticism of this method may be raised, but its accuracy and ease of manipulation cannot be doubted, as it has been repeatedly proved to give as good results for general use as the long method, and in about half the time. Soils were analyzed by outside parties, and then the same soils were analyzed in the laboratory by the shorter method, and the results were well within the acknowledged limit of error, as can be seen from the following table:—

Table showing the Results obtained on Various Soils from Analyses by the "Long Method" and by the New Method.

[Per cent. of organic matter, gravel, sand, silt and clay in 20 grams of soil.]

Number.	Organic Matter.	Gravel (.2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.).	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay (.005-.0001 mm.).	
55, . . .	2.30	5.33	17.70	10.13	11.97	14.08	23.43	4.49	3.58	Long method.
	4.93	8.33	15.60	12.37	12.95	15.84	26.14		3.56	Short method.
49, . . .	7.44	6.55	9.20	4.23	23.52	22.36	15.89	3.92	5.12	Long method.
	8.70	6.03	8.76	9.74	20.84	21.11	17.66		4.94	Short method.
54, . . .	5.37	0.03	0.20	0.25	6.30	37.87	32.85	5.12	5.01	Long method.
	6.54	0.00	0.00	0.60	10.21	41.12	32.59		7.34	Short method.

There are admittedly several places where orthodox ideas have been differed from, but we have been unable to detect any bad effects as the result of these differences. The breaking up of the soil after beating in the mortar with a medium hard rubber pestle is one of these, and while error might creep in by careless or thoughtless manipulating, it is believed that with care any appreciable error can be easily obviated.

As there is a limit of error of from 2 to 5 per cent. by the long method in an analysis of the same soil, and as we came well within this limit in every case, we believe that we are justified in using this method for the breaking up of the soil particles.

In all probability it may not break up all the agglomerates, but so far in our experience the method has given perfectly satisfactory results, when reasonable care is used.

There may also be a slight loss of the finer particles in the sifting, but no more than is usual even by the long method.

In conclusion it may be said that where absolute accuracy is desired we do not recommend this short method, but for a close approximation it works very well.



FIG. 1. — Showing the effects of soil sterilization on the growth of melons. Two plants at the left grown in unsterilized loam; those at the right in the same loam sterilized.

THE PRESENT STATUS OF SOIL STERILIZATION.

G. E. STONE.

The term "soil sterilization" has long been applied by commercial growers to a system of heating soils, generally by the use of steam, to a temperature ranging from 180° to 212° F. for the purpose of destroying certain disease germs. In practice the heat is applied for only a short time, and as a matter of fact, only a comparatively small number of bacteria are destroyed. The process as usually employed by commercial men merely accomplishes what is termed "pasteurization."

The stimulating effects of sterilized soil on plant growth have long been recognized, and some large growers of lettuce and other crops have made extensive use of the practice largely for the effects produced on plant growth. Even as a young boy I remember observing the peculiar stimulating effects sterilized soil had on plant growth where charcoal pits had been burned. The soil and turf used in covering coal pits in the process of making charcoal are steamed and heated for many days, and become thoroughly sterilized. When the charcoal is taken out the soil is left spread out, and it often supports a vigorous and rank vegetation.

The extensive experiments which we made some years ago demonstrated that crops growing in sterilized soil are greatly stimulated; some crops, and lettuce in particular, showing the effects much more than others, however. This stimulation makes a different handling of lettuce necessary, and lower night temperatures must be maintained so that the characteristic heads will form properly and topburn be prevented.

Our experiments showed that while sterilization gives beneficial results with certain soils rich in organic matter, other soils

deficient in this respect may cause injury to the crop when sterilized.

We have maintained that the benefits resulting from soil sterilization are largely chemical in nature, as shown by experiments with seeds, etc. In two series of experiments,¹ in which a large number and several varieties of seeds were employed, we found not only a marked acceleration in germination, but considerable increase in the number of seeds that germinated in sterilized soil when compared with the same soil unsterilized. The stimulating effects produced in these tests were undoubtedly chemical in nature; that is, there were certain substances in the soil which were chemically changed by the process of steaming, and these being absorbed by the seed, increased germination followed. It is, however, not at all improbable that part of the stimulating effects on seeds grown in sterilized soils is due to the renovation of the gases contained in the soil, since the old gases are driven out by the process of steaming. Steaming, in other words, has to a certain extent the same effect as aerating the soil, which process greatly stimulates seed germination and growth. In one experiment where 3,000 lettuce seed were grown in two boxes, 1,500 in each box and one being aerated and the other not, it was found that 86 per cent. germinated in the aerated soil, while only 64 per cent. germinated in the unaerated soil. The average weight of seedlings was 46 per cent. greater in the aerated than in the unaerated soil.²

Our experiments³ in germinating seeds in decoctions of sterilized soil showed that the decoctions exerted a chemical stimulation, and that even decoctions from unsterilized loam had a similar effect on germination. The soil we used had never received any commercial fertilizer, but was a typical market-garden soil, frequently enriched with decomposed horse manure. It is well known that a great variety of chemicals stimulate seed germination, and it is not surprising that decoctions of soils would do the same.

The increase in the number of bacteria in sterilized soil has

¹ Hatch Exp. Sta., 15th Ann. Rept., 1903, p. 41; also Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 126.

² Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 124.

³ Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 129.



FIG. 2. — Showing the effects of sterilized loam on the growth of lettuce. In the upper figure are shown lettuce plants growing in unsterilized loam; in the lower, growing in the same loam sterilized. The difference in the average weight of these two crops, growing in the same house and the same soil, was 35 to 40 per cent.

been demonstrated by Prof. A. Vincent Osmun¹ and others, and the interpretation of these results we believe can be found in chemical stimulation. However, it is not at all unlikely that even in this case the aeration of the soil resulting from steaming may play a small rôle in the increased number of bacteria, since it is known that cultivation gives rise to an increase in the number of bacteria in soils.

There are great differences in soils as regards the stimulating effects of sterilization, and judgment must be exercised in drawing deductions from this fact alone. Many commercial florists and market gardeners in various parts of the United States have had some experience in growing different crops in sterilized soil, and the results of their experience in this work are not always the same. The best results which we have observed as arising from sterilization have invariably been given by lettuce.

The soils used in growing lettuce are rich in organic matter from the repeated application of horse manure year after year, and it is such soils as these, rich in humus, that sterilization affects most advantageously for plant growth. Some experiments, however, which we have made, with decomposed leaves (leaf mold) and decayed vegetable matter obtained from florists, gave results somewhat different from those obtained from soils rich in organic matter largely derived from horse manure. When seeds were soaked in decoctions of either sterilized or unsterilized leaf mold they showed little or no stimulation, and when the decoction was strong we obtained positive injury to seed. Neither did we obtain any stimulus to crops in sterilized forest humus except when the humus was first washed out and then sterilized.

The idea recently advanced by Russell and Hutchinson, that the increased bacterial flora characteristic of sterilized soil is biological rather than chemical, does not in the least appeal to us, at least for our conditions. The theory is to a certain extent an adaptation or application of the Metchinikoff phagocyte theory to the soil. Russell and Hutchinson report finding protozoa devouring bacteria in the soils, and they account for the increase of bacteria in sterilized soils by the absence of protozoa

¹ A Comparison of the Numbers of Bacteria in Sterilized and Unsterilized Soils, by A. Vincent Osmun, Hatch Exp. Sta. Rept., 1905.

and allied forms of animal life which prey upon micro-organisms.

It would be unjust for us to affirm what might take place in the soils of England or those on the continent, and it is to be assumed that the soil and climate, as well as the biological conditions, are different from those here; nevertheless, we are convinced that the biological theory does not hold in the soils we have experimented with for years, and as far as we are able to determine it possesses no significance. The matter, however, will be discussed in the following article prepared at our suggestion by Messrs. Smith and Lodge. These investigations were made under our direction in our laboratory during 1910 and 1911, when the men were taking senior work in the college, and prove to our satisfaction that protozoa, at least in our soil, have little or no part in accounting for the increased number of bacteria in our soils, although we cannot affirm that they do not play a more important rôle in England and elsewhere.¹

The stimulating effects which sterilized soils have upon bacteria are chemical in nature, and so far as we can determine with our soils biological factors exert no influence in this respect. Most observers, we believe, agree that ammonia is given off from sterilizing soils, owing apparently to denitrification, and in this connection we might relate that in some cases where horse manure was applied freely and sterilization followed we noted that if certain plants, such as tomatoes, were transplanted in the soil too soon after the sterilizing had been done, their leaves would present symptoms of ammoniacal burning.

The sterilizing of soils has been carried on very extensively for some years in this country, particularly in greenhouses, and we have had opportunities to observe various crops growing in many acres of treated soil. In practically all cases moist heat, that is, steam, is employed for this purpose, although hot water has been used with practically the same results. There are, as might be expected, a variety of opinions as to the effects which stimulation has upon plants, since a large variety of soils have been treated, and the crops have been grown under very variable conditions. Moreover, as has already been stated, some crops

¹ Mr. David Larsen, who is associated with the Hawaiian Sugar Planters' Experiment Station in Honolulu, informs me that protozoa are quite abundant in Hawaiian soils, and that carbon bisulfid applied to the soils there acts as a great stimulus to crop production.

are stimulated much more than others by this treatment. Most crops require special handling in sterilized soils, otherwise trouble is likely to follow.

Many different methods of sterilizing soils have been developed, and the writer has experimented with practically everything there is in this line. There is no doubt that many soils can be greatly improved by sterilization, and in the future it will be more extensively employed not only for the destruction of pathogenic organisms, but, like electricity and other stimuli, as a means of hastening crop production.

The writer at one time had experience with a soil which would not grow lettuce. When it was sterilized, however, no further difficulty was experienced with it. Even muck soils, which are rich in organic matter and generally injurious to plant growth, can be greatly improved by leaching and sterilizing.

In the south there are many acres of soil seriously affected with *Sclerotinia* which can be treated effectively at no great cost, and in the future soil sterilization is bound to become of practical use for field work. There is no reason why methods cannot be adapted for cheap and effective sterilizing of outdoor soils if the land be fairly level and free from stone.

INFLUENCE OF SOIL DECOCTIONS FROM STERILIZED AND UNSTERILIZED SOILS UPON BACTERIAL GROWTH.

C. A. LODGE AND R. G. SMITH,¹

An attempt has been made in the following experiments to ascertain the cause underlying the effects which sterilized and unsterilized soil decoctions have upon bacterial development. These questions have often arisen: In what manner does soil sterilization affect bacterial development? Is the cause underlying the development of bacteria in soils of a chemical or biological nature? Some investigators maintain that the increase of bacteria in sterilized soils is due to a chemical stimulus, while others insist that it is biological; *i.e.*, that minute animal organisms known as protozoa affect the bacterial flora of soils. In all probability the chemical factor is the important one, the biological factor playing little or no part in either increasing or retarding bacterial growth, at least in any of our soils.

We selected for use in our experiments two types of soils, — one an Amherst greenhouse soil or loam, somewhat modified by the addition of coarse sand and quite rich in organic matter, and which will be designated as loam; and the other a yellow loam or a typical Amherst subsoil, deficient in nitrogen and containing only a slight amount of organic matter, which will be designated as subsoil.

TABLE I. — *Showing Mechanical Analysis of Two Types of Soils used in these Experiments.*

[Per cent. of organic matter, gravel, sand, silt and clay in 20 grams of soil.]

	Organic Matter.	Gravel (2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.).	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay (.005-.0001 mm.).
Loam,	10.45	13.97	24.48	17.33	21.60	20.00	5.00	1.50	.12
Subsoil,	3.60	1.75	4.45	6.95	23.85	35.95	11.10	5.20	5.25

¹ This work was done at the instigation and under the direction of Dr. G. E. Stone when Messrs. Smith and Lodge were seniors in the college.

The soil decoctions used in our experiments were made as follows: four hundred grams of soil were placed in a percolation tube and lukewarm distilled water was allowed to percolate several times through the soil. This method was followed in each instance. The decoctions thus made (the percolated water) were then placed in flasks, each flask containing 100 cubic centimeters of percolate. Then these decoctions, composed of percolates from sterilized and unsterilized soils, were placed in the autoclave and subjected to steam pressure of 15 pounds for forty-five minutes at a temperature of 250° F.

Three series of experiments were carried on with each soil. In series No. 1 a sterilized and unsterilized loam were used, and the sterilized decoctions inoculated with ordinary soil bacteria. In the second series of experiments a sterilized and unsterilized loam, and in addition a sterilized and unsterilized subsoil, were used, and the sterilized decoctions inoculated with ordinary soil bacteria. In our third series of experiments a sterilized and unsterilized loam and subsoil were used, as in our second series of experiments, but with this difference, — inoculations were made from a pure culture of *Bacillus subtilis*. In the above series of experiments, where a sterilized loam or subsoil was used, sterilization was done as follows: about 1 liter of soil was placed in the autoclave and subjected to steam pressure of 15 pounds for forty-five minutes at a temperature of 250° F.

The following method of inoculation was used in our first two series of experiments, where ordinary soil bacteria were used. Ten grams of loam were placed in 100 cubic centimeters of sterilized water,¹ and this decoction placed in an incubator for three days, where a large number of bacteria developed. We used these decoctions to inoculate our sterilized percolates of sterilized and unsterilized soil in the two series of experiments, these percolates being inoculated with 1 cubic centimeter of the above culture and then incubated for twenty-four hours. The decoctions were removed from the incubator and plated, and the ordinary dilution methods followed. Cultures were made by adding ½ cubic centimeter of the dilution to agar-agar in Petri-dishes, and these were incubated for twenty-four hours, after which the colonies were counted. The agar-agar was .5 per cent.

¹ Distilled water was used in all cases in all the experiments.

normal acid in all the experiments. In the third series of experiments, where inoculation was made with *Bacillus subtilis*, the following method was used. A pure tube culture of *Bacillus subtilis* was made; from this pure culture a number of bacteria were transferred with a platinum loop to 100 cubic centimeters of sterilized water. From here on the method was followed as above indicated.

EXPERIMENTAL.

TABLE II. — *Showing Comparison of the Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam. (Inoculations made with Ordinary Soil Bacteria.)*

SOIL.	NUMBER OF BACTERIA IN 1 CUBIC CENTIMETER OF DECOCTION.			
	Experiment 1.	Experiment 2.	Experiment 3.	Average.
Sterilized loam,	5,680,000	3,842,000	5,218,800	4,913,600
Unsterilized loam,	276,000	402,000	391,240	343,746

The results shown in Table II. are of special interest for the following reason: in the three experiments recorded in this table the sterilized loam decoctions were found to contain a far greater number of bacteria per cubic centimeter of contents than the unsterilized loam decoction.

TABLE III. — *Showing Comparison between the Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam and Subsoil. (Inoculations made with Ordinary Soil Bacteria.)*

SOIL.	NUMBER OF BACTERIA IN 1 CUBIC CENTIMETER OF DECOCTION.		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam,	5,724,000	4,693,060	5,208,530
Unsterilized loam,	203,520	199,308	201,414
Sterilized subsoil,	76,320	81,134	78,726
Unsterilized subsoil,	178,080	185,138	181,608

The results given in Table III. are important since they show that decoctions made from different soils affect the growth of bacteria in them in a decidedly different manner. When a sterilized loam is used we find a greater number of bacteria present

as compared with the number in the unsterilized loam decoction; thus the experiments with loam soil in Table III. bear out the results recorded in Table II., where the same kind of loam soil was used in the decoctions. When a sterilized and unsterilized subsoil were used in the decoctions we found that a greater number of bacteria were present in the unsterilized decoction. This fact proves that the sterilizing of this particular soil resulted in adverse conditions for bacterial increase.

At this point it might be of interest to insert a table taken from a previous report of the Hatch Experiment Station,¹ showing the growth of soy bean in sterilized and unsterilized loam and subsoil. A glance at this will show that the greatest gain in plant growth was made in the loam soil, and the least in the subsoil. These results coincide with the relative growth of bacteria in the two soils, as shown in Table III.

TABLE IV. — *Showing Growth of Soy Bean in Sterilized and Unsterilized Loam and Subsoil (from Hatch Experiment Station Annual Report, 1906).*

	Total Number of Pots used.	AVERAGE LENGTH (CENTI- METERS) OF STEMS IN —		Gain or Loss in Sterilized Soil (Per Cent.).
		Unsterilized Soil.	Sterilized Soil.	
Loam,	4	9.53	10.87	+14.05
Subsoil,	4	9.79	4.14	-57.70

Glancing over this table one can readily see that there is a connection between the development of bacteria and the growth of soy beans in sterilized and unsterilized soils. The soy beans showed an increase of growth in the sterilized loam over that given in the unsterilized loam. In the subsoil the unsterilized soil produced a greater growth than the sterilized. The same held true in regard to the development of bacteria. Decoctions of the sterilized loam produced about twenty times the number of bacteria as the unsterilized. In the sterilized subsoil there is a decrease in numbers as compared with the unsterilized, or in other words, the unsterilized subsoil produced twice as many bacteria as the sterilized.

¹ Comparison of Sterilized Loam and Subsoil, by G. E. Stone, 18th Ann. Rept. of the Hatch Exp. Sta., pp. 125, 126, 1906.

That sterilization of soils produces different effects on crops according to the nature of the soil cannot be disputed. In this experiment we used two distinct types of soil, and found that sterilization affects both soils differently. In loams well supplied with organic matter the effect is a stimulation from the beginning on certain crops. In other soils, notably deficient in organic matter (like the subsoil used in this experiment), the effect may be a detrimental one.

Lyon and Bizzell¹ have shown us that steaming reduces the nitrates of the soil to nitrites and to ammonia, but most of the ammonia comes from the organic nitrogen. Russell and Hutchinson² claim that the increased productiveness of sterilized soils is due to an increase in the amount of ammonia present, and that the excess of ammonia is the result of the increased decomposition of soil substances by bacteria.

TABLE V. — *Showing Comparison of the Amounts of Ammonia in Decoctions of Sterilized and Unsterilized Loam. (Inoculations made with Ordinary Soil Bacteria.)*

SOIL.	AMOUNT OF AMMONIA IN DECOCTION OF 100 CUBIC CENTIMETERS (GRAMS).			
	Experiment 1.	Experiment 2.	Experiment 3.	Average.
Sterilized loam, . . .	.0051	.0052	.0051	.0051
Unsterilized loam, . .	.0032	.0031	.0030	.0030

Analysis of the soil decoctions from soils similar to those used in the experiments given in Table IV. show an increase of ammonia in the sterilized loam as compared with the unsterilized. In the subsoil we find just the reverse condition, the unsterilized subsoil containing more ammonia than the sterilized.

Analyses of the soil decoctions used in the experiments shown in Tables II. and III. give the same results as regards the ammonia content of the decoction as those enumerated above, but in our experiments (Tables II. and III.) we have sterilized decoctions of the various soils inoculated with soil bacteria. The increase and decrease in the number of bacteria found in these

¹ Effects of Steam Sterilization on the Soluble Matter in Soils, Lyttleton Lyon and J. A. Bizzell, Cornell Agr. Exp. Sta., Bul. No. 275, April, 1910.

² Effects of Partial Sterilization of Soil upon the Production of Plant Food, by E. J. Russell and H. B. Hutchinson, Journal of Agricultural Science, Vol. III., Part II., October, 1909.

decoctions correspond with the increase and decrease of ammonia content in each case, more ammonia being found in the decoctions which possessed the largest number of bacteria. This fact is not new, as it has been shown by Russell and Hutchinson in recent years.

TABLE VI. — *Showing Comparison between the Amounts of Ammonia in Decoctions of Sterilized and Unsterilized Loam and Subsoil. (Inoculations made with Ordinary Soil Bacteria.)*

SOIL.	AMOUNT OF AMMONIA IN DECOCTION OF 100 CUBIC CENTIMETERS (GRAMS).		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam, . . . . .	.0050	.0050	.0050
Unsterilized loam, . . . . .	.0031	.0032	.0031
Sterilized subsoil, . . . . .	.0020	.0021	.0020
Unsterilized subsoil, . . . . .	.0030	.0032	.0031

TABLE VII. — *Showing Comparison between the Amount of Ammonia in Decoctions of Sterilized and Unsterilized Loam and Subsoils. (Inoculations made with Water Cultures of B. subtilis.)*

Experiment 1.

SOIL.	Amount of Ammonia in Decoctions of 100 Cubic Centimeters (Grams).	SOIL.	Amount of Ammonia in Decoctions of 100 Cubic Centimeters (Grams).
Sterilized loam, . . . . .	.0031	Sterilized subsoil, . . . . .	.0010
Unsterilized loam, . . . . .	.0020	Unsterilized subsoil, . . . . .	.0020

This increase in the amount of ammonia in each case is certainly brought about by the action of the bacteria upon the organic matter in the soil. Now the question arises: What change takes place within the soil, when sterilized, in order to produce this increase in the number of bacteria? In the case of the subsoil, where the increase takes place in the unsterilized soil, it is a question as to what change takes place upon sterilizing that has a detrimental effect on bacteria.

Russell and Hutchinson¹ tried the effect of untreated soil

¹ The Effects of Partial Sterilization of Soil on the Production of Plant Food, by E. J. Russell and H. B. Hutchinson, *Journal of Agricultural Science*, Vol. III., Part II., October, 1909, p. 117.

upon sterilized soil and found a decrease in the number of bacteria and in the amount of ammonia present. This would show that there is some limiting factor in the original soil that limits bacterial action. They claim that this limiting factor is not chemical but biological.

In the experiments which we have described and in those which follow we are unable to comprehend how protozoan forms play any rôle whatsoever in the decrease of bacteria. If this is true this limiting factor must be a chemical or physical property of the soil, and one on which sterilization has a marked effect.

PROTOZOA AS A FACTOR IN THE BACTERIAL FLORA OF SOILS.

The remaining contents of the soil culture used in inoculating decoctions in the experiments of Tables II. and III. were subjected to a careful microscopic examination for various forms of protozoa. Our labors were without results, however, no protozoa being found; but it is quite possible that a few might have been introduced at the time of inoculation of the decoctions. To avoid any possibility of introducing protozoa into decoctions the experiments shown in Table VIII. were made.

TABLE VIII. — *Showing Comparison of Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam and Subsoils. (Inoculations made with Water Culture of B. subtilis.)*

SOIL.	NUMBER OF BACTERIA IN 1 CUBIC CENTIMETER OF DECOCTION.		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam,	5,952,960	4,913,800	5,423,300
Unsterilized loam,	127,484	111,964	117,324
Sterilized subsoil,	279,840	283,380	281,610
Unsterilized subsoil,	2,060,640	2,901,244	2,480,942

The data given in the above table show that *Bacillus subtilis* multiply in great numbers in all the decoctions. About the same relative number of bacteria were found here as in the decoctions shown in the experiments given in Tables II. and III. A greater number of *Bacillus subtilis* were found in the sterilized loam decoctions as compared with the unsterilized; also a greater

number of *Bacillus subtilis* were found in the unsterilized subsoil decoctions as compared with the sterilized decoctions.

A careful consideration of our work leads us to believe that protozoa were absent in all our decoctions, and the experiments shown in Table VIII. seem to substantiate this belief; moreover, protozoa were uncommon in the soils used. A number of samples of the loam and subsoil were subjected to examination, but very few protozoan forms¹ were found. In this vicinity great numbers of protozoa are found in pools of standing water, while few are observed in garden soils. In other localities protozoa may be more abundant in soil; however, no data are available. For protozoa to reduce the bacterial flora of the soil to an appreciable degree by devouring the bacteria, it is certain that the number of protozoa present in the soils of Amherst would have to be increased manyfold; besides, all protozoa do not consume bacteria. G. N. Calkins, professor of protozoölogy at Columbia University of New York, is the authority for the following: "All classes of protozoa except Sporozoa are bacteria eaters except the carnivorous forms." The same authority in a recent work² says: "Two of the most striking phenomena among the protozoa are the apparent choice of food and the selection of certain materials for building shell." The author notes that certain protozoa will live almost exclusively on other protozoa and such vegetable forms as *Oscillaria*, *Spirogyra* and diatoms. "Each protozoan will eat only its favorite food, although other food is abundant." If the above is true it means that hundreds of protozoan forms of the soil do not feed on bacteria, therefore it is impossible to credit the difference in the numbers of bacteria in a gram of soil³ — 7,000,000, and a gram of treated soil (sterilized) 37,000,000 — to the elimination of the protozoa. This remarkable increase in the number of bacteria of over fivefold of the original number in the untreated soil can only be explained by an increased food supply. In our experiments with soil decoctions, where the protozoa were entirely eliminated, we obtained a difference in numbers of bacteria present in the decoctions of sterilized and unsterilized soils ranging from fifteen to twenty

¹ The following species were observed: *Halteria*, *Enchelys*, *Paramœcium*, *Amœba*, *Euglena*, *Euplotes*, *Dileptus*, *Strombidium* and *Oxytridia*.

² *The Protozoa*, Columbia Biol. Ser., VI., p. 305.

³ Hall, *Harper's Magazine*, October, 1910, p. 681.

times as many in the sterilized as compared with the unsterilized decoctions. However, in the experiments where sterilized and unsterilized subsoil were used we found more bacteria in the unsterilized decoctions as compared with the sterilized decoctions. This fact proves that sterilization does not in every case result in an increased number of bacteria in the soil thus treated.

CONCLUSIONS.

1. The development of bacteria may be retarded or accelerated in soil decoctions by the use of sterilization.

2. In decoctions of soil rich in organic matter the development of bacteria is greatly increased, while in soils deficient in organic matter the development of these organisms is retarded by sterilization.

3. The stimulating or retarding effects on the development of bacteria of the two types of sterilized soil used by us are similar to those produced upon the growth of crops in these soils. (*Cf.* Table IV.)

4. From numerous microscopic examinations made of Amherst soils we do not find that protozoa are abundant; neither were they observable in our soil decoctions.

5. The question of protozoa as a biological factor was eliminated in the experiments. The stimulating or retarding effect on the development of bacteria was due to other causes.

6. Our experiments therefore, made with Amherst soils, do not confirm those of Russell and Hutchinson, who maintain that protozoa influence the number of bacteria in soils, since the development of bacteria differs in soil decoctions according to the composition of the soil used; that is, the number of bacteria which develop in a soil depends upon the chemical and physical condition of the soil rather than upon the number of protozoa.

7. These experiments do not necessarily preclude the idea that protozoa might play a much more important rôle in soils other than those with which we experimented.

THE EFFECTS OF POSITIVE AND NEGATIVE ELECTRICAL CHARGES ON SEEDS AND SEEDLINGS.

G. E. STONE.

Considerable interest is now being manifested in the effects of electricity on plant growth, and experiments are being made in this country and abroad to study this influence. Most of the experimenters at the present day are making use of high tension wires, the aim being to charge the atmosphere rather than the soil.

For many years we have been carrying on experiments along this line, and many of the results have been published from time to time.¹ However, we still have considerable data on the various phases of the subject of electrical stimulation which have not been published, as in many cases the experiments have not been completed.

The experiments given here were made under my direction in 1904 by Mr. N. F. Monahan, a former assistant in the laboratory, who while with us paid quite a little attention to the subject of electrical stimulation and plant reaction. They were made to determine the relative stimulating effect of positive and negative charges on seed germination and growth of seedlings. The seeds of lettuce and radish which we used were first moistened by soaking in water for a few hours and were then charged from a small friction machine, Töpler-Holtz model. They were then placed in electro-germinators, which consisted of a modified Leyden jar and Zurich germinator, and 10 small sparks from a Töpler-Holtz machine were applied to each germinator, which

¹ Electro-Germination, Hatch Exp. Sta., Bul. No. 43, 1897; The Influence of Current Electricity upon Plant Growth, Hatch Exp. Sta., 16th Ann. Rept., 1904; The Influence of Atmospheric Potential on Plants, Hatch Exp. Sta., 16th Ann. Rept., 1904; The Influence of Electrical Potential on the Growth of Plants, Hatch Exp. Sta., 17th Ann. Rept., 1905; Comparisons of Electrical Potential in Trees and in the Free Air, Hatch Exp. Sta., 17th Ann. Rept., 1905; Injuries to Shade Trees from Electricity, Hatch Exp. Sta., Bul. No. 91, 1903; Influence of Electricity on Micro-organisms, Bot. Gazette, 48; No. 5, November, 1909; Effects of Electricity on Plants, Bailey's *Cyclopedia of American Agriculture*, Vol. II., p. 30.

resulted in stimulation of the seed. The germinator was then placed in an autoclave and kept at a temperature of about 25° C. The results of the experiments follow:—

TABLE I. — *Showing the Results of the Stimulating Effect of Positive and Negative Electrical Charges on Radish Seeds and Seedlings (Raphanus sativus, L.).*

[Average of two experiments in each of which 60 seeds were used. Moist treated seed charged with 10 small sparks from a Töpler-Holtz machine. Measurements in millimeters, temperature 25° C.]

TREATMENT.	AVERAGE LENGTH OF —		PER CENT. GAINED IN LENGTH OF —	
	Hypocotyl (Centimeters).	Radicle (Centimeters).	Hypocotyl.	Radicle.
Normal,	1.13	1.07	—	—
Negative charge,	1.39	1.24	23.00	15.88
Positive charge,	1.72	1.76	52.21	64.48

It is quite evident that the electrical treatment stimulated the seed very materially, as shown by the growth of the hypocotyls and radicles given in this table. The average increased length of the radicles and hypocotyls of the negatively charged seeds over that of the normal was 23 per cent. for the hypocotyl and 15.88 per cent. for the radicle. The positively charged seeds gave an average increase of 52.21 per cent. for the hypocotyl and 64.48 per cent. for the radicle over that of the normal; showing that the positive charges induced the greater growth. No attention was given to accelerated germination in this experiment.

TABLE II. — *Showing the Results of the Stimulating Effect of Positive and Negative Electrical Charges on Lettuce Seeds and Seedlings (Lactuca sativa, L.).*

[Average of two experiments in each of which 60 seeds were used. Moist treated seed charged with 10 small sparks from a Töpler-Holtz machine. Measurements in millimeters, temperature 25° C.]

TREATMENT.	AVERAGE LENGTH OF —		PER CENT. GAINED IN LENGTH OF —	
	Hypocotyl (Centimeters).	Radicle (Centimeters).	Hypocotyl.	Radicle.
Normal,	0.96	1.52	—	—
Negative charge,	1.08	1.77	12.50	16.40
Positive charge,	1.21	2.18	26.00	43.42

In the experiments shown in Table II. the accelerated growth of the hypocotyl and radicle is somewhat similar to that shown in Table I., namely, the negative charges gave for the hypocotyl 12.5 per cent. increase, for the radicle 16.4 per cent., while the positively charged seeds gave 26 per cent. for the hypocotyl and 43.42 per cent. for the radicle. Here, too, the positively charged seeds gave the largest average increased growth for both hypocotyl and radicle.

The experiments shown in Tables I. and II. are typical of others made along the same line, although we have repeatedly found that it is quite an easy matter to charge the seed too strongly and obtain retardation in growth. Instead of using ten-minute sparks to stimulate the seeds in the electro-germinator we have found by subsequent experiments that it is better to use only two or three, and these should be very slight charges. The stimulating effect of positive and negative charges on germination is similar to that on growth, but there is no evidence to show that the treatment affects the germinating capacity of seeds, and we have stimulated many thousands. The following table gives an average of four experiments with seed germination.

TABLE III. — *Showing Results of the Stimulating Effects of Positive and Negative Electrical Charges on Germination of Lettuce Seed (Lactuca sativa, L.).*

[Average of four experiments, 20 seeds being used in each treatment; otherwise the same experiments as shown in Tables I. and II.]

TREATMENT.	Total Number of Seeds.	NUMBER OF SEEDS GERMINATED IN —		
		24 Hours.	48 Hours.	72 Hours.
Normal,	80	19	35	64
Negative charge,	80	24	51	64
Positive charge,	80	48	69	72

From the experiments in Table III. it will be observed that germination is accelerated to a considerable degree by electrical stimulation, and that the positive caused greater acceleration than the negative charges, corresponding to the effects produced on the growth of the hypocotyl and radicle. In Fig. 1 is shown a diagrammatic representation of seedlings based upon an aver-

age of all the data given in Tables I. and II. It will be noticed that the radicles are stimulated more in all cases than the hypocotyls, this difference being more pronounced in the positively than in the negatively charged seedlings. In Fig. 2 are shown

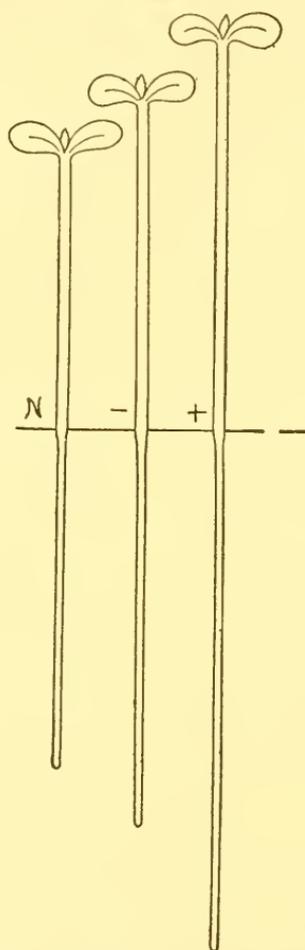


FIG. 1.—Showing the effects of positive and negative electrical charges on the growth of lettuce and radish seedlings. Average of the results in Tables I. and II.

the effects of positive and negative charges on the growth of radish seedlings, being an average of two experiments. Fig. 3 shows the effects of positive and negative electrical charges on the growth of lettuce seedlings, being an average of three experiments.

It is not surprising that the radicles show greater development than the hypocotyls since the former develop first, and for this reason electrical stimulation would show itself more prominently in the radicle than the hypocotyl. Accelerated germination is

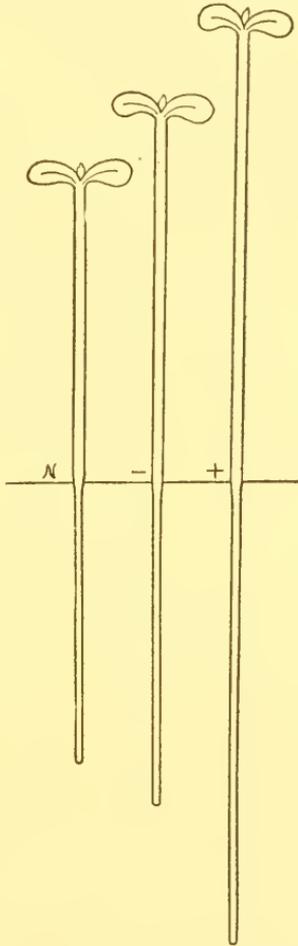


FIG. 2. — Showing the effects of positive and negative electrical charges on the growth of radish seedlings. Average of two experiments.

shown more prominently in the positively than the negatively charged seeds. The positive charges stimulated both the hypocotyl and radicle more than the negative charges, and if the difference in the time of the development of the hypocotyl and radicle is taken into consideration it will be seen that there is

little or no difference in the effects of the stimulation on the radicle and hypocotyl.

The effects of a series of charges from a static machine last only two or three days, the maximum effect of the stimulus showing itself shortly after stimulating.

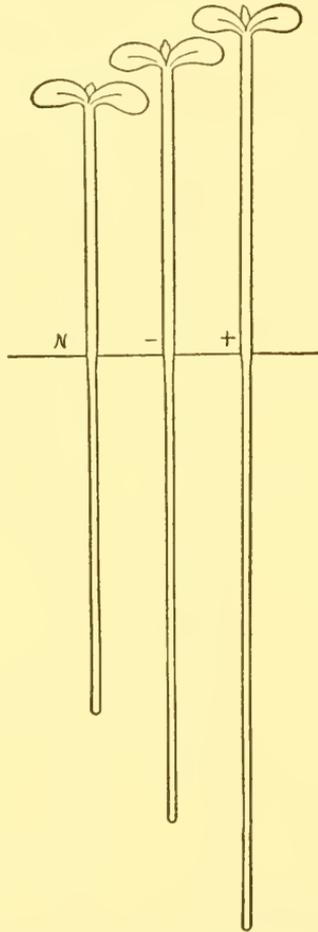


FIG. 3. — Showing the effects of positive and negative electrical charges on the growth of lettuce seedlings. Average of three experiments.

The roots and stems of plants react positively and negatively to various stimuli such as are afforded by gravity, light, moisture, chemical substances, etc. It is also well known that the same stimuli will induce reactions of an exactly opposite character in the same organism, or even in the same organ. Usually,

however, the stem reacts one way and the root another; for example, roots are positively and stems negatively geotropic. It is well known that the anode and cathode behave quite differently and characteristically when acting on metals, etc. Similar characteristic differences might be expected in the reaction of plants. Where trees have been injured by burning from direct current wires the extent of the injury is about 90 per cent. greater near the positive than near the negative point of contact, showing that the positive electrode is more disastrous to plant tissue.

In our various experiments, where we have employed electricity as a stimulus, we have never observed any difference in the behavior of plants in close proximity to either positive or negative electrodes, although in some of our previous experiments with radish plants, made some years ago, in which the plants were grown in soil, we found that the tops responded much more freely to electrical stimulation than the roots when acted on by galvanic currents. We found, however, that by substituting lettuce, which is cultivated exclusively for the leaves, the leafy part responded more freely to electrical stimulation than did the underground part or fleshy roots of radish.

On the other hand we found in our experiments in growing radishes in tightly closed, insulated glass cases, the atmosphere of which was charged each day positively to an electrical potential averaging 150 volts, that the reverse was true, viz., the roots or underground parts were stimulated more than the leaves or tops. The soil itself is generally negative, and the atmosphere positive; the roots therefore are accustomed to a negatively charged, and the aerial parts to a positively charged, environment.

In the decomposition of water by electrolysis it is assumed that the oxygen is in a negatively electrical condition and is attracted by the positive pole, while the hydrogen is in a positively electrical condition and is attracted by the negative pole. Metals are described as electro-positive elements, and are usually attracted to the negative pole, while the nonmetals are spoken of as electro-negative elements and are attracted to the positive pole. In the experiments just cited with radishes, which were grown in insulated glass cases where the atmosphere was charged posi-

tively, the leaves were stimulated least and the roots most; that is, the roots, which are normal to an environment negatively charged, were stimulated most by the positive charges. In the case of galvanic stimulation of roots it is known that weak currents induce negative bendings; that is, towards the cathode, while strong currents induce positive bendings, or towards the anode. In the negative reactions, which are induced by weak currents, there is a greater growth on the side of the root towards the positive pole or anode than towards the negative pole or cathode, but there is some doubt as to whether the reverse holds true for positive galvanotropic bendings. In the case of positive galvanotropic bendings Brunchorst has pointed out that the reaction is the result of pathological conditions, and it is maintained that bendings towards the anode are due to injury of the delicate root tip by the strong currents employed. This interpretation of the phenomena appears to harmonize with the results which we have obtained with positive and negative electrical charges on plants. The positive charges give the greatest and the negative the least accelerated growth. Since the positive charges stimulate mostly those cells on the surface of the root nearest to the anode, those cells would grow more rapidly and the normal downward direction of the root would be directed towards the negative pole or cathode. The burning effect on trees from positive and negative electrodes is similar, the positive producing the greater injury, and this coincides with our results obtained by using strong positive static charges on plants, viz., strong positive static charges cause a greater degree of retardation and injury than negative charges. The use of strong positive currents would result in the cells on the anode side of the root being retarded, hence bendings towards the anode would result.

To summarize we might state that the effect of positive and negative stimulation on plants offers a mechanical explanation of the positive and negative galvanotropism in roots. When plants are grown between positive and negative electrodes, each electrode exerts a characteristic influence on the root, and that surface of the root nearest to the anode will be affected according to the nature of the stimulus on that side; and conversely, that part of the root adjacent to the cathode will be affected accord-

ing to the nature of the stimulus characteristic of that pole. When weak currents are employed the positive current or anode gives the greatest stimulation to those cells on the anode side of the root, and induces bendings in the root towards the negative pole or cathode. On the other hand, when strong currents are employed the positive current induces bendings towards the anode due to a retardation or injury to the cells on the side of the root towards the anode.

From our various experiments in electrical stimulation we are of the opinion that increasing the electrical tension or potential of the atmosphere, either by the use of static charges or from high tension wires, gives rise to a greater degree of stimulation than passing the current through the soil. Alternating currents appear to be superior to direct currents in stimulating plants. There is, however, the question of increasing the number of micro-organisms in the soil by electrical stimulation as well as the importance of nitrification and nitrogen fixation resulting from electrical stimulation, a line of research on which we are now engaged and on which we hope to report later.

ELECTRICAL RESISTANCE OF TREES.

C. E. STONE AND G. H. CHAPMAN.

It has long been known that trees offer considerable resistance to electric currents, but at the time our experiments were undertaken we were not aware that much attention had been given to this subject, especially regarding the influence of certain factors on resistance. The effect of lightning strokes indicates that trees possess relatively high resistances, and that there is a difference in the resistance of their various tissues. Little or no data appear to be available concerning this subject, nor so far as we know concerning the resistance of different trees at different seasons of the year.

In a former publication¹ we have given the results of some observations on the electrical resistance of trees, and the numerous data which we obtained by passing electrical currents through trees and various plants helped to give us some idea of their electrical resistance. Our object in carrying on these experiments was to determine whether there were any variations in the electrical resistance of different sides of a tree trunk as regards points of the compass. Originally it was our purpose to learn whether the electrical resistance varied greatly from month to month during the year, and if so, what causes led to this variation; in fact, to study the effects of various influences on electrical resistance. But the temporary suspension of our work, made necessary by moving from one laboratory to another, and the change of assistants interrupted our plans somewhat, and the original idea of our investigation was not followed.

It might be supposed that since the several sides of a tree are exposed differently to light and heat they would show slight

¹ Injuries to Shade Trees from Electricity, by G. E. Stone, Mass. Agr. Exp. Sta., Bul. No. 91. 1903.

variations in temperature, and that there would also be differences in the flow of sap and the translocation of plastic substances. That this is true is shown by the fact that trees make more growth on one side than on another, the more or less localized photosynthesis causing a greater transmission of plastic substances on that side.

Some of these experiments were begun in 1907, a part of the observations being made by Mr. N. F. Monahan, our former assistant, while others were obtained in 1909 and later by Mr. G. H. Chapman.

These resistances were determined by a Weston Electric Company combination bridge, rheostat and galvanometer, provided with a battery of 6 or 8 large Samson cells.

TABLE I. — *Showing Daily Records of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), April 7-26, 1907. Resistances taken on the North, South, East and West Sides of the Tree at Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Temperature.	East.	South.	West.	North.
April 7,	35	19,000	18,840	22,000	22,000
8,	33	19,500	19,000	23,400	23,000
9,	31	23,000	23,000	23,000	24,000
10,	35	23,000	23,000	23,000	23,500
11,	39	22,000	21,500	23,000	23,500
12,	38	21,000	21,000	22,500	23,000
13,	37	21,500	21,000	22,900	23,000
14,	42	20,000	19,400	22,000	22,000
15,	39	19,100	18,900	21,200	20,800
16,	40	19,500	19,000	20,000	21,500
17,	40	20,500	20,500	21,500	21,000
18,	39	21,500	23,000	21,000	17,000
19,	34	21,000	20,000	19,000	21,000
20,	37	18,000	18,300	21,300	20,800
21,	36	19,500	19,500	22,000	21,000
23,	52	15,000	14,600	16,300	16,000
24,	49	16,000	17,300	17,000	16,500
25,	52	16,900	17,200	17,400	19,100
26,	56	15,700	15,000	16,000	18,200
Average,	—	19,857	19,055	19,310	20,890

TABLE II. — *Showing Daily Records of Electrical Resistance (in Ohms) of Elm (Ulmus Americana, L.), April 7-26, 1907. Resistances taken on the North, South, East and West Sides of the Tree at Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Temperature.	East.	South.	West.	North.
April 6,	35	29,000	29,000	29,500	29,000
7,	35	28,200	28,000	29,000	29,400
8,	33	29,000	28,500	29,500	29,500
14,	42	25,000	25,000	26,500	23,000
15,	39	25,500	26,500	26,000	26,000
16,	40	26,000	23,500	26,500	27,000
17,	40	26,000	29,000	25,000	23,000
18,	39	25,000	30,000	27,000	25,000
19,	34	25,600	32,000	24,900	24,200
20,	37	25,000	29,000	27,800	24,000
21,	36	25,000	29,900	28,000	25,000
23,	52	23,200	26,200	22,500	21,000 ¹
24,	49	19,600	26,000	22,100	18,000
25,	52	22,000	26,000	23,000	20,000
26,	56	19,000	21,400	19,300	19,700
Average,	-	24,666	27,466	25,777	25,253

The data shown in Tables I. and II. give the electrical resistance of a maple and elm tree covering a period of nearly one month in the spring, when there was an occasional flow of sap. The elm was a large tree, over 2 feet in diameter, and the maple was nearly as large. In both cases the electrodes, which were about 3 inches long and made of galvanized iron nails, were driven through the bark and into the wood. These were connected by solder with insulated copper wires leading to a combination bridge, from which the readings were made. The batteries consisted of half a dozen cells employed to take the readings. In these experiments the electrodes were 10 feet apart on the north, south, east and west sides of the trees. The lowest electrodes were placed about 2 feet above the ground, and the highest about 12 feet.

¹ Warm.

By comparing the results given in these tables it will be seen that the resistances obtained from the north, south, east and west sides of the tree showed some variation from day to day, and also on different sides of the tree. In the maple a slightly higher average resistance was shown on the north side of the tree than on any other side, followed by the east, west and south sides.

In the case of the elm (Table II.), however, the highest average resistance was shown on the south side for the same period, this being followed by the west side, while the east side showed the least resistance. The resistance in both cases showed a tendency to decrease towards the latter part of April, when the temperature increased, as is shown by a comparison of the mean daily minimum and maximum temperature records which were taken from the station's meteorological observatory located nearby, and which are given in both tables. The highest average resistance for the maple was given on the 9th of April, when there was the lowest mean temperature. The highest average resistance given by the elm occurred on April 6 and April 8 (the records were not taken on the 9th), while the lowest average resistance for the maple occurred April 23, during one of the highest mean temperature days. The lowest average resistance for the elm occurred April 26, which date gave the highest mean temperature.

TABLE III. — *Showing Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), covering a Period of Nearly Three Months. Resistances taken on the North, South, East and West Sides of the Tree about Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Tempera- ture.	East.	South.	West.	North.
April 7,	35	19,000	18,840	22,000	22,000
14,	42	20,000	19,400	22,000	22,000
21,	36	19,500	19,500	22,000	21,000
26,	56	15,700	15,000	16,000	18,200
Average for month, . . .	—	18,550	18,185	20,500	20,800

TABLE III.—*Concluded.*

DATE.	Tempera- ture.	East.	South.	West.	North.
May 8,	58	18,500	21,000	19,000	23,000
14,	68	14,000	14,600	15,000	16,000
21,	46	24,000	23,600	23,000	33,000
28,	45	27,800	23,000	29,600	26,000
Average for month, . . .	—	21,075	20,550	21,650	24,500
June 4,	55	18,600	19,100	23,600	21,700
12,	59	21,000	22,000	23,900	23,000
Average for month, . . .	—	19,800	20,550	23,750	22,350
Average for three months, .	—	19,775	19,761	21,883	22,550

TABLE IV.—*Showing Electrical Resistance (in Ohms) of Eln (Ulmus Americana, L.), made Weekly and covering a Period of Nearly Three Months. Resistances taken on the North, South, East and West Sides of the Tree.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Tempera- ture.	East.	South.	West.	North.
April 7,	35	28,200	28,000	29,000	29,400
14,	42	25,000	25,000	26,500	23,000
21,	36	25,000	29,900	28,000	25,000
26,	56	19,000	21,400	19,300	19,700
Average for month, . . .	—	24,300	26,075	25,700	24,275
May 8,	58	17,200	18,000	16,400	19,000
14,	68	10,800	11,200	11,000	12,600
21,	46	13,000	16,300	16,000	18,900
28,	45	11,100	17,500	15,900	19,000
Average for month, . . .	—	13,025	15,750	14,825	17,375
June 4,	55	9,000	13,000	12,000	12,300
12,	59	6,300	15,000	12,000	11,700
Average for month, . . .	—	7,650	14,000	12,000	12,000
Average for three months, .	—	14,992	18,608	17,508	17,883

The data in Tables III. and IV. cover weekly observations extending over a part of three different months, the same trees

being used as in the preceding experiments. The results shown in these tables present similar features to those in the preceding ones.

The lowest average resistance during any single day for the maple occurred May 14, when the temperature was highest, while the highest average resistance was on May 28, when the temperature was low, but not the lowest. The average resistance for the different sides of the tree for the whole period was the highest on the north side, followed by the west, east and south sides. For the elm the lowest average resistance for a single day was shown on May 14 and June 12, days when the temperature was highest. The highest average resistance shown corresponds to the lowest temperature, which was recorded on April 7. The average resistance for the different sides of the elm during the whole period was the highest on the south, followed by the north, west and east sides.

The experiments shown in Table V. were supervised by Mr. Chapman during the spring of 1909. The resistances were obtained from a large maple tree located near our laboratory which was a different specimen from the one used in the preceding experiments. The tree was a typical rock maple of this region, in fairly vigorous condition, slightly over 2 feet in diameter at the base. The resistance readings were obtained from a combination bridge, as in previous experiments, and a battery of 8 Samson cells was used. The electrodes consisted of galvanized iron nails about 3 inches long, which were driven through the bark into the wood for about $1\frac{1}{2}$ inches. The part of the electrodes extending beyond the surface of the wood was enclosed within porcelain insulators. Before the electrodes were inserted into the tree at the various points a part of the bark extending to the wood was removed with a chisel for a space of 2 inches. The electrodes were 8 feet apart in each case, the lower ones being placed about $2\frac{1}{2}$ feet from the ground, and the highest about $10\frac{1}{2}$ feet, hence the resistances were taken from that part of the tree between $2\frac{1}{2}$ and $10\frac{1}{2}$ feet of the trunk. The wires, 8 in all, were connected with the electrodes by means of solder and were run into the laboratory about 50 feet away, all the readings being taken under cover. The resistances were read three times each day, viz., at 8 A.M., 12 M. and 4 P.M. from March 18 to March 30, inclusive.

TABLE V. — *Showing Daily Records of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), March 18-31, 1909. Resistances taken Three Times Daily on the North, South, East and West Sides of the Tree.*

[Electrodes 8 feet apart.]

DATE.	8 A. M.				12 M.				4 P. M.			
	North.	West.	South.	East.	North.	West.	South.	East.	North.	West.	South.	East.
	March 18,	138,500	147,500	157,700	136,300	79,980	82,670	105,900	33,980	73,100	84,540	93,200	74,200
19,	56,460	63,500	76,500	62,000	37,900	38,760	44,140	36,470	35,900	34,100	36,500	35,600
20,	121,000	126,400	86,870	68,850	99,700	85,400	62,000	68,200	77,988	54,360	46,530	62,120
21,	182,000	170,000	86,200	58,180	78,500	53,100	42,000	35,900	43,100	30,000	32,750	33,800
22,	52,100	45,800	45,700	38,360	38,640	33,650	34,750	31,100	34,350	30,000	31,050	29,950
23,	32,100	32,100	31,680	28,990	28,890	28,870	28,600	26,980	29,910	29,800	30,000	27,950
24,	31,580	30,000	30,070	25,850	26,680	26,250	26,500	23,990	33,800	22,050	23,700	22,800
25,	69,860	73,700	58,960	52,870	66,400	49,980	37,650	35,600	37,100	26,000	32,100	31,000
26,	38,700	38,600	50,100	40,000	30,390	30,320	37,000	30,200	29,110	29,100	33,100	25,000
27,	29,100	32,080	37,000	26,400	23,100	27,500	29,600	23,000	28,000	29,760	32,100	27,900
28,	40,100	46,300	48,400	38,500	40,000	44,000	47,050	37,500	29,910	31,000	39,100	29,000
29,	37,000	-	38,500	34,700	33,400	-	37,750	29,400	32,000	-	31,400	28,700
30,	51,000	56,000	60,000	41,000	39,000	43,050	47,000	36,050	38,000	38,000	47,000	38,000
Averages,	67,654	71,832	62,130	50,155	48,044	45,300	44,610	37,567	40,174	36,560	39,580	35,847

TABLE VI. — *Showing Temperature Conditions, etc., during the Month of March.*

DATE.	8 A.M.			12 M.			4 P.M.		
	Weather.	Sap.	Temperature.	Weather.	Sap.	Temperature.	Weather.	Sap.	Temperature.
March 18,	Overcast, cool, no wind.	No flow.	37.0	Overcast, snow, no wind, cold.	No flow.	35.0	Overcast, sleet, no wind, cold.	No flow.	30.0
19,	Overcast, cool, no wind.	No flow.	34.0	Fair, cold, no wind.	No flow.	39.0	Fair, sunshine, windy, cold.	No flow.	35.5
20,	Fair, sun, wind.	No flow.	41.0	Fair, cool, no wind.	No flow.	37.5	Overcast, cold, no wind.	No flow.	32.0
21,	Clear, sun, slight wind.	Slow flow.	36.5	Clear, sunshine, no wind.	Flow.	46.5	Fair, cool, no wind.	No flow.	35.5
22,	Clear, sun, wind west.	Flow.	46.5	Clear, sunshine, wind west.	Flow.	48.5	Clear, cool, wind west.	Flow.	45.5
23,	Clear, sun, wind southwest.	Great flow.	45.5	Overcast, warm, no wind.	Great flow.	53.5	Overcast, rain, no wind.	Flow.	47.0
24,	Clear, sun, wind southwest.	Great flow.	50.0	Fair, sun, wind southwest.	Great flow.	55.5	Fair, warm, wind southwest.	Flow.	52.0
25,	Clear, sun, wind.	No flow.	35.0	Clear, sun, wind.	Flow.	35.5	Clear, cool, wind.	Great flow.	35.0
26,	Overcast, cold, windy.	Slow flow.	41.0	Clear, cold, high wind.	Flow.	53.5	Fair, cool, wind.	Great flow.	58.0
27,	Cloudy, warm, no wind.	Slow flow.	53.0	Fair, warm, no wind.	Flow.	64.5	Fair, warm, no wind.	Flow.	54.5
28,	Cloudy, warm, no wind.	No flow.	44.0	Rain, cool, no wind.	Flow.	46.5	Clear, warm, wind.	Flow.	61.0
29,	Rain, cool, no wind.	No flow.	47.5	Rain, cool, no wind.	No flow.	48.5	Rain, cool, no wind.	Flow.	46.5
30,	Clear, cool, moderate wind.	Flow.	42.0	Clear, cool, moderate wind.	Flow.	45.0	Clear, cool, moderate wind.	Flow.	44.0

The resistances in Table V. were taken in March and represent considerably higher readings than those given in the preceding tables, although there the distance between the electrodes was 10 feet, while in the readings shown in Table V. the distance was only 8 feet. The higher resistance is due, as shown in this table, to the cutting away of some of the outer tissue around the electrodes, a feature which will be discussed later; and also in part to the measuring of the resistances in March instead of in April, May and June, as was the case with the preceding observations.

The results obtained from these readings, however, are somewhat similar to those given in the preceding tables; the highest resistance occurring on cold days and the lowest on warm days. The highest resistance shown in any one observation was on March 21, at 8 A.M., on the north side of the tree. The temperature for this same period was 36.5° F., which is one of the lowest recorded. The lowest resistance was on the 24th of March, at 4 P.M., on the east side of the tree following one of the high temperature periods. The highest average resistance for any single day occurred March 18, and this coincides with the lowest average temperature. The lowest average resistance for any single day occurred March 24, followed by March 27, which were the two warmest days. The average temperature records for both days, taken at the time of the observation, was as follows: March 24, 52.5° F., the average temperature for the 27th being 57.3° F. The mean temperature (maximum and minimum) on this date was 38, and that for March 27 was 41. By referring to Table VI. it will be observed that March 24 was clear and sunshiny, with the wind southwest, and March 25 was fair and warm, and occasionally cloudy, with no wind. The average resistance for all periods was the greatest in the morning, followed by those given at 12 M. and 4 P.M. At 8 A.M. it was 62,942, at 12 M., 43,880, and at 4 P.M., 38,040 ohms.

TABLE VII.—*Showing Maximum and Minimum Resistances based on the Averages obtained from the North, South, East and West Sides of Maple Tree (Acer saccharum, Marsh) for Different Periods during the Day, March 18-31, 1909.*

8 A.M.	West, highest,	. . . . .	71,832
	North, . . . . .	. . . . .	67,654
	South, . . . . .	. . . . .	62,130
	East, least, . . . . .	. . . . .	50,155
12 M.	North, highest,	. . . . .	48,044
	West, . . . . .	. . . . .	45,300
	South, . . . . .	. . . . .	44,610
	East, least, . . . . .	. . . . .	37,567
4 P.M.	North, highest,	. . . . .	40,174
	South, . . . . .	. . . . .	39,580
	West, . . . . .	. . . . .	36,560
	East, least, . . . . .	. . . . .	35,847

This table is adapted from Table V. It will be noticed that the highest average resistance was obtained on the west side for the 8 A.M. observations, and the north side gave the highest average resistance for the two following observation periods, viz., at 12 M. and 4 P.M. The lowest average resistance from March 18 to 31 occurred on the east side for each of the three periods. The average daily resistance for the whole period—9 A.M. to 4 P.M.—was as follows: north side, 51,957; west side, 51,230; south side, 48,773 and east side, 41,189. These results coincide with those given in the preceding tables, that is, the north side shows in general the highest resistance.

TABLE VIII.—*Showing Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh) from March 18-31, 1909. Resistances taken at 8 A.M., 12 M. and 4 P.M. on the South Side of the Tree.*

[Electrodes 8 feet apart. Temperature same as in Table VI.]

DATE.	8 A.M.	12 M.	4 P.M.
March 18,	46,890	27,700	27,200
19,	23,350	20,400	20,900
20,	42,320	26,830	23,840
21,	53,900	22,510	19,300
22,	25,800	19,820	18,300
23,	18,790	16,700	16,500
24,	18,000	17,150	16,540
25,	39,690	21,000	15,600
26,	23,300	17,200	14,900
27,	18,300	15,700	15,100
28,	25,400	23,600	14,950
29,	20,200	16,800	16,000
30,	29,000	20,600	19,000
Averages,	29,610	20,462	18,318

The resistances given on the south side of the same maple tree as in Table V. are given here; in this case, however, the electrodes were attached differently, being driven through the bark into the wood, and none of the tissue around them was cut away.

The resistances given here run considerably lower than those shown in Table V. for the same tree for the same period, due to the fact that the electrodes were inserted differently into the tree. If we compare the average resistances obtained from the two experiments, those in Table VIII. and those in Table V., we obtain the following for the same period, with the same tree. The average resistances on the south side of the tree shown in Table V. are as follows for the three different periods: 8 A.M., 62,130; 12 M., 44,610; 4 P.M., 39,580, while those given in Table VIII. are 29,610, 20,462 and 18,318 ohms.

The higher resistance shown in Table V. represents not only that of the cambium, but of some of the wood as well.

The highest resistance readings were obtained at 8 A.M., while the lowest were obtained at 4 P.M. The midday temperatures were highest, as might be expected, with little difference in the morning and afternoon.

The after effects of the higher temperatures influenced the resistances taken at 4 P.M., since the tree, being generally exposed to the sun's rays for a considerable period in the day, would become warmer, and the heat would be retained for some time. It was thought desirable to make one experiment when the observations could be recorded hourly. The results of these observations are shown in Table IX.

TABLE IX. — *Showing Record of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh) for One Day, the Records being taken hourly, April 27, 1907.*

[Electrodes 10 feet apart.]

TIME.	East.	South.	West.	North.	Weather.	Remarks.	Temperature (Degrees F.).
6.15 A.M.,	24,700	23,100	22,400	26,000	Wind, cold.	Sap not started.	39
7.15 A.M.,	24,600	23,100	22,300	25,900	Wind, cold.	Sap not started.	40
8.15 A.M.,	24,600	23,000	22,200	26,000	Wind, cool.	Sap just started.	44
9.15 A.M.,	24,500	20,200	21,000	25,400	Wind, cool.	Sap flowing more freely.	48
10.15 A.M.,	23,500	18,600	19,000	24,700	Light wind, warm.	-	52
11.15 A.M.,	22,100	19,500	18,100	23,600	Light wind, warm.	-	55
12.15 P.M.,	21,200	18,800	17,700	22,500	Light wind, warm.	-	58
1.15 P.M.,	20,000	17,300	16,800	22,200	Calm, warm.	-	59
2.15 P.M.,	18,800	17,000	16,600	21,800	Calm, warm.	-	59
3.15 P.M.,	19,300	18,300	16,800	22,500	Calm, warm.	Sap flowing less freely.	60
4.15 P.M.,	19,800	18,700	16,800	22,500	Calm, warm.	-	60
5.15 P.M.,	20,000	19,400	16,900	22,700	Calm, cool.	Sap ceased flowing.	59
6.30 P.M.,	20,000	19,600	16,900	23,000	Calm, cool.	-	57
Averages,	21,760	19,738	18,576	23,753			

The data obtained from hourly readings on the north, south, east and west sides of the tree are given in Table IX. These were taken from the same tree (rock maple) as the records shown in Table I., and while they were continued only for one day, they undoubtedly show typical variations which occur. The resistances given are for 10 feet of the tree trunk, and the day selected for the readings was free from clouds, the sun being quite bright throughout the day for this period of the year (April 27).

At times, however, a slight haze was present which affected to some extent the intensity of the light. The highest resistance was shown in the early morning, when the temperature was the lowest, and as it had become warmer the resistance decreased. The lowest resistance occurred at 2.15 P.M., after which time there was a slight increase in the resistance. It will be noticed, however, that the least increase in the resistance after 2 P.M. occurred on the west side of the tree, which received at that time the benefits of the heat from the sun's rays during the afternoon. On the other hand, the north, east and south sides showed a greater increase for this period, as they were more or less shaded from the sun's rays. The north side of the tree gave the highest average resistance, followed by the east, south and west sides. The lowest average resistance occurred on the west side of the tree.

Sap commenced flowing freely at 9.15, and at 2.15, the time of the lowest resistance, it had commenced to cease flowing. As is well known, there is a relationship between the flow of sap and temperature, but there is no indication from these observations or from any of our experiments that there is any relationship between resistance and flow of sap.

EXPERIMENTS WITH CUT BRANCHES OF TREES.

A number of resistances were obtained from cut branches of maple trees by Mr. Chapman. These were taken when the trees were in a dormant condition, and in some cases when the buds were developing.

Experiment A.

A maple branch $1\frac{1}{2}$ inches in diameter and several feet long was used for this purpose. The branches showed slight bleed-

ing at first. Heavy galvanized iron nail electrodes were driven into the branch 20 inches apart, and several half-hour readings were taken. The branches were left out of doors where the temperature varied only a few degrees, and at the time the readings were taken it was just above freezing. The results follow: —

	Ohms.
8.30 A.M.,	136,000
9.00 A.M.,	132,000
9.30 A.M.,	131,000
10.00 A.M.,	132,000
10.30 A.M.,	120,000

This experiment was repeated several times with approximately the same results, and is not conclusive as regards influences of temperature.

Experiment B.

The same branch of maple was kept in the laboratory for five days at a room temperature (about 70° F.), the only difference between this experiment and the one preceding being the fact that the electrodes were placed 1 foot apart instead of 20 inches. The readings obtained are as follows, taking half-hour periods: —

	Ohms.
8.30 A.M.,	72,000
9.00 A.M.,	72,000
9.30 A.M.,	74,000
10.00 A.M.,	75,000
10.30 A.M.,	77,000

Very little variation was shown in the resistances.

Experiment C.

A branch of another maple of about the same diameter as the preceding was cut under water and allowed to stand at room temperature for five days, when a fresh cut was made under water. During this time the leaves and flowers had started, and there was evidently some transpiration. The electrodes were 1 foot apart. The following readings were obtained: —

	Ohms.
8.30 A.M.,	64,400
9.00 A.M.,	65,000
9.30 A.M.,	68,000
10.00 A.M.,	67,000

It will be seen that these resistances were all ranged between 64,000 and 67,000, and coincide very closely with those given in Experiment B.

Experiment D.

Another experiment, using the same branch as was used in Experiment C, was undertaken, but in this case the water in which the branches stood was heated to a temperature ranging from 100 to 130° C. The readings were taken at half-hour intervals, with the following results:—

	Ohms.
9.30 A.M.,	67,000
10.00 A.M.,	68,000
10.30 A.M.,	67,500
11.00 A.M.,	67,600
11.30 A.M.,	73,000
12.00 M.,	72,000
1.00 P.M.,	72,000
1.30 P.M.,	71,000
2.00 P.M.,	69,000
2.30 P.M.,	70,000
3.00 P.M.,	73,000
3.30 P.M.,	75,000
4.00 P.M.,	76,000

The rise in temperature had little or no effect on the resistance. On the other hand, the readings in some cases were slightly higher.

Experiment E.

The same branch was used in this experiment. After standing over night and the water brought to room temperature a space of $\frac{1}{2}$ inch down to the wood was removed halfway between the electrodes; in other words, the branch was girdled for this distance. The following readings were obtained:—

	Ohms.
8.30 A.M.,	122,000
9.00 A.M.,	121,000
9.30 A.M.,	124,000

all averaging not over 123,000. The results here show greatly increased resistances as the effect of girdling.

Experiment F.

The same branch was used here as in E, except the girdling was increased to 3 inches. The following readings were taken: —

	Ohms.
1.00 P.M.,	128,000
1.30 P.M.,	130,000
2.00 P.M.,	127,000
2.30 P.M.,	130,000
3.00 P.M.,	129,000

It will be noticed that these readings were slightly higher than those in Experiment E, due to girdling.

Experiment G.

The same branch under the same conditions was used for this experiment, except that the branch was completely girdled between the electrodes. The results follow: —

	Ohms.
8.30 A.M.,	150,000
9.00 A.M.,	151,000
9.30 A.M.,	150,000
10.00 A.M.,	150,000
10.30 A.M.,	149,000

It will be noticed that the readings obtained here are higher than in F or E, due to the greater girdling. These experiments demonstrate that the wood gives much higher resistance than the cambium, and shows that the resistance increased as the bark and cambium were removed. The highest resistances were given where there was the greatest amount of girdling. Even cutting away the bark for a distance of $\frac{1}{2}$ an inch or more in each direction from the electrodes greatly increases the resistance. This is what occurred in the experiment shown in Table V., where the bark was cut away from the electrodes, whereas in experiments shown in Table VIII. for the same distance, and where no bark was removed, the resistances were much lower.

Experiment H.

In this experiment a freshly cut branch about 1 inch in diameter was used, and the bark cut away for a space of 1 inch

around the electrodes, which were inserted 1 foot apart, as in the other experiments. The branch was placed in water at room temperature of from 68° to 70° F. The following results were obtained:—

	Ohms.
10.00 A.M.,	110,000
10.30 A.M.,	100,000
11.00 A.M.,	100,000
11.30 A.M.,	105,000

Experiment I.

The same branch was used as in Experiment II, and a fresh cut made under water, the water being heated for three hours at a temperature ranging from 149 to 150°. After three hours at this temperature the following readings were obtained:—

	Ohms.
1.30 P.M.,	140,000
2.00 P.M.,	135,000
2.30 P.M.,	138,000
3.00 P.M.,	142,000
3.30 P.M.,	150,000

It will be noted that the resistances were higher here than in the others, although the temperature of the water in the latter case was very much higher than in the former experiment.

EXPERIMENTS WITH SMALL PLANTS.

Some experiments were made with small plants in the greenhouse in February to determine the electrical resistance. For this purpose we made use of tobacco plants in pots, the plants being 3 feet high. The results of these experiments, made by Mr. Chapman, follow:—

TABLE X. — *Showing the Electrical Resistance of a Tobacco Plant (Nicotiana tabacum, Linn.).*

[Resistance in ohms.]

TIME.	Experiment I.	Temperature (Degrees F.).	Experiment II.	Temperature (Degrees F.).	Experiment III.	Temperature (Degrees F.).	Experiment IV.	Temperature (Degrees F.).
8.00	-	-	-	-	132,000	-	-	-
8.30	-	-	-	-	130,900	68	128,000	62
9.00	131,000	-	108,000	60	136,000	73	129,000	63
9.30	116,000	-	140,000	60	134,000	78	124,000	63.5
10.00	110,000	-	137,000	61	110,000	83	127,000	63
10.30	133,000	-	146,000	62	129,000	79	-	-
11.00	117,000	-	151,000	62	136,000	73	128,000	64
11.30	117,500	87	147,000	61	133,000	77	123,000	67
12.00	125,000	84	147,000	62	116,000	82	121,000	71
12.30	-	-	-	-	-	-	-	-
1.00	137,000	81	136,000	62	-	-	-	-
1.30	126,000	80.5	147,000	63	143,000	69	-	-
2.00	129,000	80.5	-	-	144,000	65	-	-
2.30	131,000	80	139,000	63	143,000	67	-	-
3.00	125,000	81	135,000	63	151,000	67	-	-
3.30	128,000	70	144,000	63	155,000	66	-	-
4.00	153,000	67	146,000	59	161,000	64	-	-
4.30	156,000	67	143,000	61	161,000	62	-	-
5.00	156,500	66	150,000	60	164,000	60	-	-

The object of the experiment was to determine what influence other factors might have on resistance, such as temperature, etc., but more particularly whether variations in temperature were discernible in resistance. The plants were under tolerably uniform conditions, although the temperature varied, as will be seen in the tables. Platinum electrodes were used, these being driven into the plant at a distance of 14 inches apart. One was driven in at the base and the other near the apex of the stem. There were no very marked coincidences between the changes of temperature and resistance in these experiments, but it should be remarked that the lowest resistance coincides with the highest temperature in Experiments I., II. and IV., while in Experi-

ment III. there was little variation in temperature, although variation in resistance occurred. In averaging up the temperature and resistance for those periods where all the data are present it is found that there is a relationship between the temperature and the resistance. For example, it was found that the lowest temperature occurred on the last three periods, that is, from 4 P.M. to 5 P.M., and that the highest average resistance occurred during these periods also. On the other hand, the lowest average resistance coincides in a general way with those periods which gave the highest temperature readings.

RELATION OF ELECTRICAL RESISTANCE TO FLOW OF SAP.

Some observations were made on a rock maple in regard to the relation of electrical resistance to the flow of sap, but these were not extensive and lasted only a few days. The following results were obtained by collecting sap on the north, south, east and west sides of the tree. The amount of sap represents the amount of flow between 9 A.M. and 12 M., and 12 M. and 4 P.M., but the table gives the total amount obtained as well as the average resistances for the whole period.

	North.	South.	East.	West.
Average resistance,	34,720	40,340	32,217	37,140
Total sap flow in cubic centimeters, .	5,945	6,180	5,820	5,150

The highest average resistance and greatest sap flow occurred on the south side of the tree. The sequence of the average resistance was as follows: north, south, east and west, and that for the sap flow, south, north, east and west. Our records, moreover, showed that sap flowed more freely in the morning than in the afternoon, also that the average resistance was higher in the morning than in the afternoon. Since these observations were not prolonged the results are not conclusive, but we do not believe that electrical resistance is affected materially by sap flow. Since our resistance readings were obtained from the trees offering the least resistance, which is no doubt in all cases the cambium layer, it is questionable whether sap flow, which is characteristic of the woody tissue, would affect our results.

The flow of sap, as is well known, is influenced by various conditions, a very important one being night temperature, as well as the conditions which prevail during the day. Temperature records were taken for the same period, but there was little or no direct relation between the temperature of this period and the sap flow. In all cases the air temperature was at freezing or below this point during the night, while in the daytime it ranges from 43 to 57°.

Jones, Edson and Morse¹ found that the maximum yield of sap occurred quite generally between the hours of 9 A.M. and 12 M. They also maintain that on a typical sap day the tree will yield more sap and sugar on a southern exposure than on any other, while on a cloudy day, when all the sides of the trees are subject to a uniform temperature, there is little or no difference in the sap flow as regards the cardinal points of the compass. It is known that the percentage of sugar varies in the tissues of a tree from day to day, and it is doubtful whether this variation in the chemical composition of the sap, or even the amount of flow, would affect resistance even if our observations were confined to the woody tissues alone. This opinion is based on laboratory experiments.

ELECTRICAL RESISTANCE OF DIFFERENT TISSUES.

It might be expected that there would be found considerable difference in the electrical resistance of various trees, as well as of the different tissues found in trees. The heartwood, sapwood, cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as would seem from various observations on lightning discharges. The minute burned channel found in trees caused by comparatively insignificant lightning discharges follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

¹ The Maple Sap Flow, by C. H. Jones, A. W. Edson and W. J. Morse, Vt. Agr. Exp. Sta., Bul. No. 103, December, 1903.

The resistance, however, may equal 25,000 ohms more or less, in 10 feet of the trunk of an elm or maple tree. This constitutes a comparatively high resistance. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the electrical resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. Chapman found the resistance of a freshly cut rock maple stem, $1\frac{1}{2}$ inches in diameter, to be 70,000 ohms when intact, *i.e.*, with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart.

Some experiments which have been made indicate that next to the cambium the phloem has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when this is moist, as during rain storms, the resistance may be somewhat decreased. When leakage occurs, owing to grounding of the electric currents from high tension wires in moist weather, burning results, but this is due to the presence of a film of water on the bark, and what is termed "arcing" occurs. The resistance obtained from an elm tree, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloem we obtained 11,300 ohms resistance. When driven $\frac{1}{4}$ inch into the wood the resistance was 98,700 ohms. The outer bark gave 198,800 ohms resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It must not be understood, however, that these readings gave the electrical resistance of 10 feet of the various tissues enumerated except in the case of the cambium, since if these tissues were isolated the resistance would be much greater. They show that there is much difference in the resistance of different tissues, but in all cases here we obtained merely a resistance of the cambium, together with that of a part of the other tissues, which the current had traversed from its various points of entrance to the cambium.

It is quite evident from our observations on the resistance of trees that the cambium gives the least resistance, the phloem next, and it is not at all unlikely that in some trees there may be some variation in this respect.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms, and the resistance given by a tobacco plant in which the distance between the electrodes was only 14 inches, was much higher (110,000 to 165,000 ohms) than that shown by trees. In the case of the pear tree, which was in a large box, filled with soil, one of the electrodes (metal plate) was in contact with the small roots, the other being in contact with the apex of the plant.

The presence of water and various salts undoubtedly plays a rôle in resistance, and it might be expected that the various plastic substances in the plant would influence resistance.

The path of a current in a tree, as already stated, follows the line of least resistance, but this line may not necessarily be a straight one between one electrode and another. Although in many lightning strokes a straight line is generally followed, we have seen instances where the whole cambium zone was involved, and when the tissue in a tree is twisted the discharge will follow the tissue. A lightning discharge may therefore completely circle a tree trunk, passing from the apex of the tree to the ground. In earth discharges the path follows up the trunk and is generally diverted to the branches, often causing them to split. When heavy lightning discharges occur and the tissues of the tree become shattered, as is often the case, the line of least resistance seems to be an unimportant factor, and in this respect the electric discharges resemble an avalanche in their behavior. In some of our experiments, where trees were connected with wires carrying relatively high currents and the electrodes were 1 foot apart vertically, all of the injury was done by burning on one side of the tree in close proximity to the electrodes, but even here the burning of the tissue covered an area of more than 1 foot in width on the trunk. Burning under these conditions, however, occurred only when the bark of the tree was moist, and was not caused by a decrease in resistance in the tis-

sue, but by the presence of a film of water, which is a far better conductor, on the bark, which became heated and killed the underlying tissue. In the case of some large trees which we observed and which had been killed by direct currents from trolley wires, the tissue was as a rule affected nearly equally around the entire trunk of the tree, although the point of contact was on one side of the tree. In both cases it was a heating of the film of water on the trunk caused by the escaping electric current which caused the injury.

The cambium ring is very insignificant in size, practically $\frac{1}{500}$ to $\frac{1}{1000}$ in diameter, and even on a large tree the total area is small. In all probability it is the protoplasm itself which offers the least resistance to the transmission of an electric current; and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was contiguous or there existed continuity, the strands would be so very small that they would undoubtedly offer some resistance. Whatever conditions prevailed trees showed relatively high electric resistances, a feature which is no doubt of some biological importance as trees are often struck by lightning. The high resistance of trees, therefore, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance they would be much more subject to injuries from burning from lightning strokes, and would be more seriously affected by currents from high tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low or even high tension wires except that produced by grounding when the bark of the tree is moist. Any escaping current which can be transmitted even through the least resistant tissue is likely to be insignificant.

The amount of current necessary to kill a plant depends upon its size, etc. A current equal to .01 amperes may be sufficient to kill a small plant, whereas a current ten times as great would cause no perceptible injury to a large tree even when passed through the tissue for months. The higher resistance shown by

small branches or woody stemmed plants may possibly be due to the presence of less conductive tissue, whereas in a tree the conductive zone, if we include the phloem, is larger.

It is known that there are minute currents of electricity in plants, but we have never noticed their effects on our galvanometers nor have we detected them by the use of a milliammeter. Trees frequently become charged with electricity, and sparks are given off from the apices of the leaves. Vegetation in general responds quickly to electrical stimulation, and trees undoubtedly play an important part in equalizing the differences in electrical potential between the atmosphere and earth. In this respect conifers appear to behave differently from deciduous trees, and in our experiments we have found that the atmospheric electrical potential under thick conifers was the same as that which characterizes the earth.

RELATIONSHIP OF ELECTRICAL RESISTANCE TO OTHER FACTORS.

We had little or no opportunity to observe the effects of winds, if such exist, on electrical resistance. Most of our records were taken while the tree was in a dormant condition. In some cases the trees were well protected from the winds. It is known that transpiration is increased by wind, and the movements of water in the tissues of the tree are accelerated. No relationship, however, between the wind and electrical resistance has been noted by us in comparing the records of the local meteorological station with our data, neither was there any specific relationship observable between barometer pressure and electrical resistance. A careful study of the humidity conditions, also, did not seem to affect the electrical resistance so far as we could observe. Aside from the temperature effects coincident with light intensity no special changes in resistance were observable except such as would naturally follow from the variations in temperature.

INFLUENCE OF TEMPERATURE ON RESISTANCE.

The most important factor which we have observed as influencing the electrical resistance of trees is temperature. The effects of temperature on various metals give rise to an increased

resistance, whereas plant tissues show a greatly reduced resistance when heated.

Our numerous experiments in subjecting seeds to electric currents have shown that when they have been soaking in water for some hours and are quite moist, and a relatively strong current is passed through them, the resistance is largely decreased owing to the development of heat, and the current increases very perceptibly. This also occurs to plants when subjected to currents of electricity of sufficient intensity, as it induces heat. The injury caused to plants by electricity generally arises from decreased resistance, which is likely to follow after a more or less prolonged application of the current; in other words, the injurious effect is caused by heat, although it is possible that electricity will kill plants without generating heat sufficient to injure the protoplasm.

Experiments made some years ago by us seemed to indicate that when strong currents are applied to small plants and they become excessively heated, after a short period of time the protoplasm is destroyed, and the current, which first increases in strength very rapidly, suddenly drops to almost nothing.

A low temperature in trees gives rise to a high resistance, and a high temperature to a low resistance; in other words, the resistance of trees resembles that of moist seeds in their behavior to temperature, and the relationship between temperature and resistance is quite general. There may be, of course, other factors which influence resistance besides temperature, such as, for example, the degree of moisture in the tissue, as well as the nature of the substances in the tissue.

The relationship existing between temperatures and resistance is shown in Figs. 1, 2 and 3. Fig. 1 shows the curve given by an elm tree, and is based upon the data given in Table II., being the average daily resistance obtained from the north, south, east and west sides of the tree during April, the upper curve with broken lines being that of the mean temperatures for the days when the observations were made. In Fig. 2 A the average electrical resistance of the south side of a maple tree is shown from the data given in Table VIII. The readings are averages of three daily readings at 8 A.M., 12 M. and 4 P.M., and in B is given the average electrical resistance of a maple tree from data

obtained in Table I., the curve being based on daily readings on the north, south, east and west sides of the tree. All of these figures show that there exists a marked relationship between the temperature curve and that for the electrical resistance, since as the temperature curve goes up the resistance curve goes down.

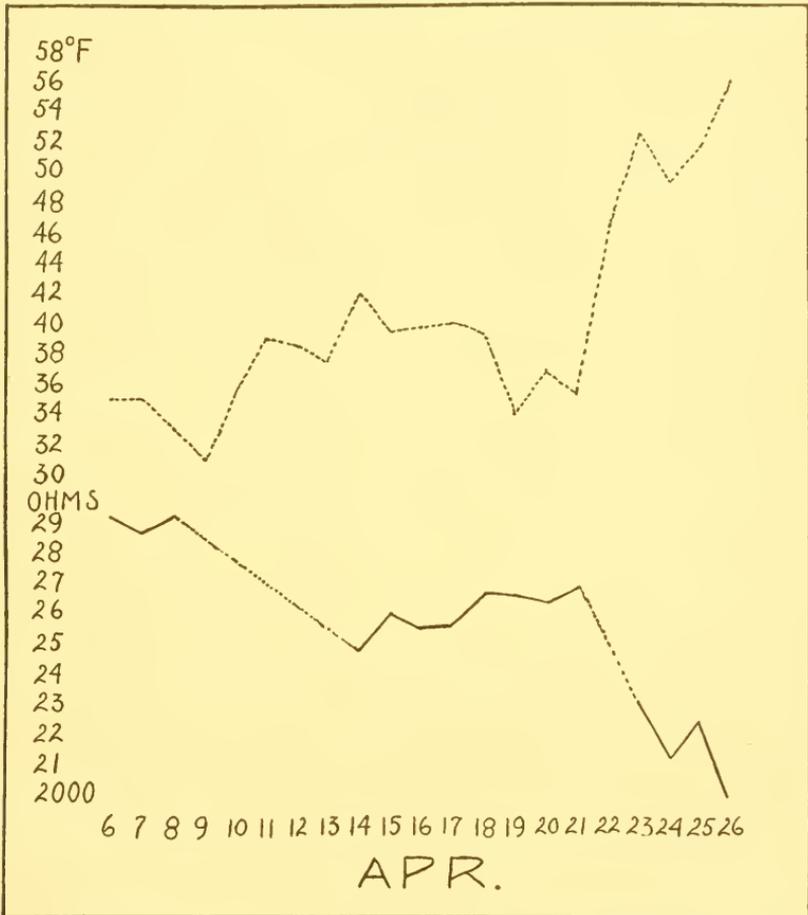


FIG. 1.— Showing curve of electrical resistance and temperature of elm, *Ulmus Americana* (Table II.). The lower curve gives the average resistance of the north, south, east and west sides of the tree from April 6 to 26; the upper curve gives the mean of the minimum and maximum temperature for the same period obtained from the local meteorological station.

In Fig. 3 is shown the hourly temperature and electrical resistance of the north side of a maple tree for a single day, the data being obtained from Table IX. In both Figs. 1 and 2 the temperature is taken from mean temperature records, while in the case of Fig. 3 they correspond with the hours of observation.

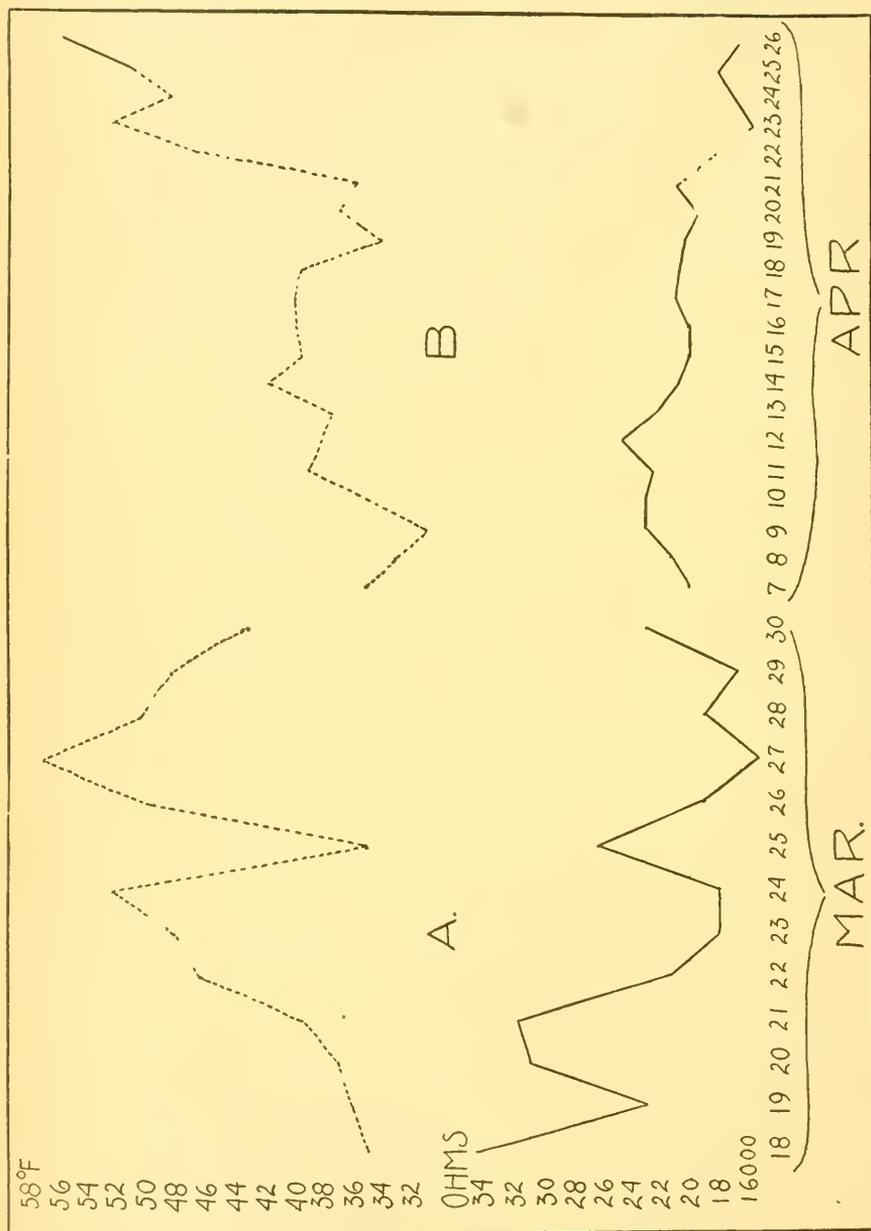


FIG. 2. — Showing electrical resistance and temperature curve of maple tree, *Acer saccharum*. The lower curves give the resistance of trees in ohms; the upper curves give corresponding mean temperatures obtained from the local meteorological station. A. Resistance given by the south side of a maple tree from March 18 to 30, inclusive, the resistance being averages of three daily observations taken at 8 A.M., 12 M., and 4 P.M. (See Table VIII.) B. Average resistance of the north, south, east and west sides of a maple tree. Observations taken daily from April 7 to 26. (See Table I.)

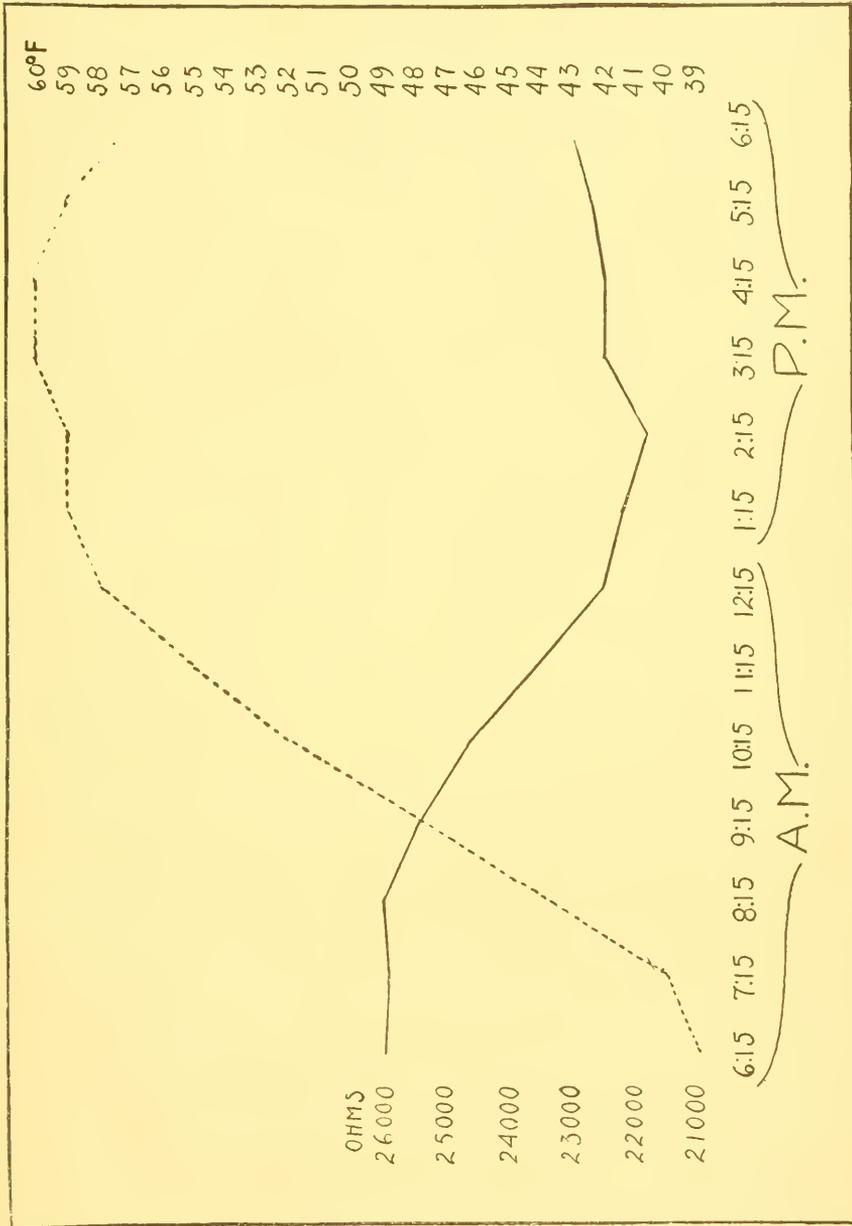


FIG. 3. — Showing electrical resistance and temperature curve of north side of maple tree, *Acer saccharum*. (See Table IX.) Observations taken hourly for one day, from 6:15 A.M. to 6:30 P.M. Lower curve represents the resistance curve, and the upper, the hourly temperature obtained from Draper records of the local meteorological station.

In the curve shown in Fig. 3 it will be observed that there is a close relationship between temperature and resistance.

Light, so far as we have observed, influences resistance only so far as it modifies temperature. The southeast side of the tree receives the most light, since the morning light is more intense than the afternoon light. Photosynthesis is more active on that side of the tree, and growth greater. Since there is a relationship between photosynthesis and light intensity, and also between growth, there occurs more activity, as a rule, on the southeast side of the tree than on any other, but whether the greater flow of plastic substances in any given tissue would affect resistance, our data do not show. So far, however, as the greater light intensity is associated with increased temperature, we should expect to find corresponding modifications in resistance.

Influence of temperature is shown in the difference existing between the resistance occurring on the north and south sides of trees. Some of our temperature records taken on the north, south, east and west sides of a rock maple were not satisfactory on account of the constant breakage of thermometers. These temperatures were taken three times daily, at 8 A.M., 12 M. and 4 P.M., for a period of five days. The records, however, gave the lowest average temperature on the north side of the tree, followed by the west, east and south sides respectively.

Other observations carried on for a brief period on a rock maple tree gave the following results. In both cases the thermometers were inserted into holes bored in the tree. The records obtained in the second series of observations, which are averages for a period of seven days, are as follows:—

The average of three observations daily, at 8 A.M., 12 M. and 4 P.M. on the north, south, east and west sides of a rock maple tree, gave the lowest temperature on the north, this being followed by the west, east and south sides respectively. These temperatures were taken in December, when the tree was in a dormant condition, and the temperature given by the north side of the tree was invariably the lowest.

Jones, Edson and Morse obtained careful temperature records from a rock maple tree. The observations were made on the north and south exposures, and extended from February 8

to March 20, and were made at 8 A.M., 12 M. and 6 P.M. each day. Corresponding air temperatures were made for the same period. These observations were made with centigrade thermometers, which were carefully protected from external influences. We transposed their readings into Fahrenheit and found that the average temperature given by the south side of the tree was 31.43° F., while that for the north side was 30.57° F. The air temperature for the same period, as might be expected, was variable, averaging slightly higher than that for the inside of the tree.

The average temperature readings obtained by Jones, Edson and Morse from the north and south sides of the tree showed that the temperature on the north side was about 3 per cent. lower than on the south side. The average obtained from all our electrical resistances and temperature readings are given below in sequence: —

	Average Electrical Resistance.	Average Temperature of Trees (Degrees F.).
North side,	27,081	30.91
West side,	25,714	32.14
South side,	25,566	33.60
East side,	23,708	32.28

It will be noticed that the highest average resistance of trees was given by the north side, followed by the west, south and east sides, and this sequence was closely followed by the temperature readings, the lowest being given by the north, followed by the west, east and south sides. The temperature readings lasted seven days only, and were too incomplete to obtain a true average. It will be noticed, however, that there was a difference of about 8 per cent. between the resistance of the east and west sides of the tree, a feature which would result from the greater intensity of the morning light. In our temperature readings, which are probably not as good averages as those obtained by the authors noted above, we find that the north side of the tree showed a temperature equal to 7 per cent. lower than the south side, as compared with 3 per cent. given by Jones, Edson and

Morse, whereas the average resistance for the north side of the tree runs about 5 per cent. more than that for the south side. The relationship of temperature to resistance manifests itself throughout; the higher temperature giving rise to a low, and conversely a low temperature giving rise to a high resistance.

The sun strikes the tree on the east, south and west sides, and each side is exposed for the same length of time; but the angle of the sun is variable as it strikes the tree's surface. In the early morning and late afternoon the sun's rays are more or less at right angles to the tree trunk, whereas at noon the angle is more oblique. The surface of a tree is not a good reflector of light and heat, and in the early morning and late afternoon, when the rays are more at right angles to the surface of the trunk, there is less loss of light and heat by reflection. Assuming that the light intensity is uniform throughout the day, and that the temperature is the same, we would expect to find fairly uniform resistances for the east, south and west sides of the tree. This, however, is not the case, as the temperature is seldom uniform, neither are the light conditions, as is shown by the flow of sap.

The north side of the tree gives the highest average resistance, followed by the west, south and east sides. From the point of view of influence of temperature this might be expected, especially during seasons when there is considerable difference between the night and day temperatures, and very likely for long periods of observations thermometers placed in trees would demonstrate this. Electrical resistances taken in the afternoon usually run lower than those taken in the morning on all sides of the tree, which results from a general increase in the temperature of the surrounding air and of the tree occurring in the daytime. The electrical resistance is less in the warm than in the cold months, and less on warm than cold days. In the morning the sun affects the east side of the tree most markedly, and in the afternoon the west side.

In experimenting with cut branches of maple trees we did not find, however, that this held true. The resistances obtained from branches placed out of doors when it was cold were in no wise different from those taken from the same branch when placed in the laboratory, where it was warm, or even when

they were placed in hot water, although trees and various potted plants with an intact root system all showed the influence of temperature on resistance.

CONCLUSIONS.

1. The electrical resistance of trees shows a close relationship to temperature, their higher resistance corresponding with the low temperature, and the low resistance corresponding with the higher temperature.

2. The electrical resistance of trees is lower during warm than cold days, and less during warm than cold seasons. It is usually less during afternoons than mornings: in other words, it corresponds to changes in the temperature.

3. The average electrical resistance of trees is highest on the north side, followed by the west, south and east sides respectively.

4. The temperature of trees given by our experiments, which were of limited duration, is less on the north side, followed by the west, east and south sides, and coincides in a general way with the variation in the resistance of the different sides of the tree. Extensive observations regarding temperature and resistance would undoubtedly show very close relationship between these two factors.

5. The average electrical resistance for the east side of the tree is about 8 per cent. lower than the west side, due, undoubtedly, to differences in temperature existing between the east and west exposures. The difference, however, in the light intensity of morning and afternoon is variable from day to day and from year to year, and may range from 1 or 2 per cent. to 30 per cent. or more per month, but averages between 10 per cent. and 17 per cent. per annum.

6. The difference in the average electrical resistance of the north and south sides of the tree is about 5 per cent., the average difference in the temperature being about the same.

7. The cambium layer offers the least electrical resistance, as shown by lightning discharges and by our experiments. This is followed by the phloem and sapwood.

8. Small plants and branches of trees in general give higher electrical resistances than trees, probably due to the greater

amount of conductive tissue, possessing less resistant qualities in the trees.

9. The high resistance and consequent nonconductivity of trees serves, no doubt, as a protection for the tree against lightning stroke and other electrical discharges.

10. Sap flow did not, so far as we were able to observe, exert any influence on the electrical resistance.

11. Temperature constitutes a determinative factor in variations of electrical resistance of trees. Other meteorological factors, such as relative humidity, barometric pressure, winds, etc., exert no discernible specific influence.

THE CHEMISTRY OF ARSENICAL INSECTICIDES.

BY E. B. HOLLAND AND J. C. REED.

GENERAL INTRODUCTION.

The work on arsenical insecticides, at the chemical laboratory of this station, has advanced sufficiently to warrant a second report ¹ on the subject dealing particularly in this instance with the composition, manufacture and use of Paris green, lime arsenite and lead arsenate. In this connection it may be of interest to consider briefly the monetary loss resulting from injurious insects, and note the insecticides available to check their depredations previous to the introduction of arsenicals.

The aggregate loss in the United States from insect injury to agricultural products of all kinds including live stock, forest and shade trees and ornamental plants, together with the subsequent damage to manufactured goods, is impossible to compute with any degree of accuracy. It has been estimated ², however, at \$1,000,000,000 annually, and may exceed that amount. Without question the successful production of many, if not most, crops is dependent in a large measure upon their protection from noxious insects. The rapidity with which such pests multiply and are disseminated, and the readiness with which they adapt themselves to new conditions, occasionally undergoing considerable change in character, size and appearance, demands thorough scientific treatment for their control, as eradication is practically impossible. The tendency of injurious insects to feed on a greater variety of plants and to become more destructive in a new country than where indigenous, due to more favorable climatic conditions or absence of natural enemies, renders the problem even more difficult to handle.

¹ First report in Mass. Exp. Sta. Rept., 23, p. 122 (1911), entitled The Determination of Arsenic in Insecticides.

² Economic entomologists allow 10 per cent. loss on all produce.

The substances formerly employed as insecticides were usually characterized by offensive or caustic rather than poisonous properties. An acrid or bitter taste and a pungent odor were evidently deemed necessary qualifications for insecticides, and the more unpleasant the greater merit they were supposed to possess. Among the more prominent, enumerated by early writers,¹ might be mentioned water, hot water, brine, urine, lye, lime water, whitewash, clay wash, soapsuds, vinegar, petroleum, tar infusion, turpentine, fish oil, whale oil, sulfur, decoctions of aloes, dwarf elder, pepper, quassia chips, rue, tobacco, walnut leaves, wormwood and dustings of wood ashes, quick lime, soot, sulfur, hellebore and tobacco. It is not surprising that the use of such repellants (as a class they could not be designated otherwise) was often ineffectual. The farmers were hampered further by a very imperfect knowledge of the life history and habits of the insects to be combated. To be sure, some of the materials had insecticidal value, largely, however, as contact² rather than as internal poisons, effective as an irritant, also, by penetrating the cuticle or entering the body tissue through breathing pores, and possibly in some cases by closing the tracheæ,³ resulting in the asphyxiation of the insect. The application of these substances, singly or several together, constituted the best recognized treatment both in this country and abroad previous to 1860-70.

Several materials deserve especial notice not only because they possess merit, maintaining a place even to the present time, but more particularly on account of the part taken in the development of modern practice. These are hellebore, pyrethrum, kerosene and lime-sulfur. Hellebore, though known to possess poisonous properties, received little attention until about 1842 in England⁴ and later in this country.⁵ Pyrethrum has been a

¹ Wm. Speechly, *A Treatise on the Culture of the Pine-Apple* (1779); J. A. E. Goeze, *Geschichte einiger schädlichen Insecten* (Leipzig, 1787). Cited by E. G. Lodeman, *The Spraying of Plants*, p. 5, (1902); Samuel Deane, *The New England Farmer or Georgical Dictionary*, 2d edition (1797); Wm. Forsyth, *A Treatise on the Culture and Management of Fruit Trees* (1802); Jas. Thatcher, *The American Orchardist* (1822); Thos. G. Fessenden, *The New American Gardener*, 6th edition (1832); Wm. Kenrick, *The New American Orchardist* (1833); Thos. Bridgeman, *The Young Gardener's Assistant* (1857); J. C. Loudon, *The Encyclopedia of Gardening* (1878).

² How Contact Poisons Kill, Geo. D. Shafer, Mich. Exp. Sta. Tech., Bul. No. 11 (1911).

³ No attempt was made to differentiate tracheal poisons from contact poisons in general.

⁴ A. Mitchell in *Gard. Chron.*, 1842, p. 397.

⁵ J. Harris in *Country Gentleman*, 1865, p. 413.

commodity of southwestern Asia for a long time, but appears to have been overlooked by early European and American agriculturists, being introduced into France about 1850. The efficacy of kerosene, fish and whale oils, and turpentine was acknowledged comparatively early, though they were seldom used on account of the liability to injure the plant. The fact that such substances must be miscible with water to be applied safely was recognized long prior to an understanding of how it could be accomplished. An emulsion¹ of kerosene with soap and water was apparently not used until 1870. Soap and water has probably been more extensively employed in the past than any other substance, both for its effect and as a vehicle. Whale oil soap² was recommended in 1842. Lime and sulfur were almost invariably mentioned by early writers on insecticides. They jointly appeared in a number of mixtures, and where heat was employed in their preparation³ partial combination, at least, must have taken place. This product was a forerunner of the lime-sulfur compounds which have since proved so valuable in checking the San José and other scales.

While the above summary may fail to convey a clear understanding of the subject, it will serve to show that practically no active "food" poison had been used as an insecticide previous to 1860.

The advent of the potato beetle⁴ in Nebraska in 1859 and its rapid spread eastward created a demand for a more powerful insecticide than those commonly employed. In a measure this was true also of the imported currant worm which appeared in the eastern States about 1858. The poisonous nature of arsenic was well understood, and its salts would naturally be expected to possess a like property. Paris (Schweinfurt) green had long been known as a pigment under various trade names and was first applied⁵ as an insecticide for the potato beetle about 1868, from which time its use was gradually extended to the cotton worm, cankerworm, codling moth and other insects. Subsequently a number of other arsenicals were recommended, of

¹ Geo. Cruickshank in *Gardener's Monthly*, 1875, p. 45.

² David Haggerston in *History of Mass. Hort. Soc.*, 1829-78, p. 256.

³ Kenrick, *loc. cit.*, p. XXXVI., and for grape mildew, p. 328 (1833).

⁴ C. V. Riley, *Potato Pests*, pp. 12-24 (1876).

⁵ Geo. Liddle, Sr., in *Amer. Ent.* 1, p. 219 (1869).

which Scheele's green ¹ in 1875, London purple ² in 1877, lime arsenite ³ in 1891 and lead arsenate ⁴ in 1893 are the most important. Paris green and lead arsenate are to-day the most extensively employed food poisons for leaf-eating insects. Lime arsenite is more particularly a farm preparation. Scheele's green and London purple have been largely superseded by the other compounds.

THE INVESTIGATION.

The object of the investigation, planned by Dr. H. T. Fernald of the entomological department, was "to ascertain why and under what conditions insecticides burn foliage." The principal arsenicals were to be applied "under differing known conditions of light, temperature and humidity," and where injury resulted, its character and extent carefully determined. Work of this type would naturally extend over a considerable number of growing seasons to furnish sufficient data to warrant positive deductions. The chemical department of the experiment station was required to co-operate so far as to provide the necessary amount of chemicals of known composition, suitable for the purpose intended, together with any information relative to solubility, hydrolysis and power of suspension, that would be of service in their application.

At the outset the laboratory phase of the project appeared an easy matter, — simple analytical work on a relatively small number of samples of similar nature. In February, 1908, letters were sent to several large manufacturers of high-grade chemicals stating the object of the investigation and asking if they could supply Paris green, copper arsenite, lime arsenite and lead arsenate of the necessary purity and, if not, the best method of securing such salts. The replies were rather unsatisfactory, though the order was finally placed with a firm making a specialty of guaranteed reagents. The dry salts were received, but on examination proved unfit for the purpose intended. Work on methods of analysis and study of arsenical reactions were continued, so far as other duties would permit, during the next two years.

¹ C. V. Riley, *Potato Pests*, p. 67.

² E. G. Lodeman, *Spraying of Plants*, p. 65.

³ N. Car. Exp. Sta., *Bul. No. 77b*, pp. 7-8, (1891).

⁴ Mass. Bd. Agr. Rept., 41, p. 282 (1894).

In March, 1910, a persistent effort was made to obtain all help possible in furtherance of the work, as it was then thought that it would be necessary for us to prepare the salts in the station laboratory. A circular letter was sent to manufacturers of chemicals, particularly those firms making insecticides, asking for information relative to the general process of manufacture of the several products. A statement was inserted to the effect that the station was not in quest of trade secrets, but merely wished to secure a fairly broad knowledge of the difficulties attending the manufacture, and of the impurities likely to be present, so as to be in position to handle the problem intelligently. The replies in general contained little or no information of value. Two large concerns, however, took a more liberal view of the matter and readily furnished any data at their command. One of these companies volunteered to supply any insecticides needed free of cost. Inasmuch as a manufacturer of arsenicals with adequate facilities was unquestionably in a better position to handle the matter, the offer was gratefully accepted. In May large, dry samples of Paris green, copper arsenite, lime arsenite and neutral and acid lead arsenates were received from the factory. A laboratory examination showed that not one of these specially prepared insecticides was entirely satisfactory, the Paris green alone being set aside for actual use in spraying tests.

The matter now began to assume rather a serious aspect. Was it possible to produce arsenicals of definite molecular ratios or not? Two companies had signally failed in the attempt, presumably using all the precautions they knew. Letters somewhat similar to those sent the manufacturers had also been addressed to several eminent chemists, requesting their opinions as to the preferable precipitants and conditions of manipulation to insure the proper equilibrium for the production of compounds of theoretical composition. The substance of their replies, while general in character, was to the effect that "the difficulties are inherent in the nature of the compounds," and that arsenites (particularly) are unstable, hydrolyzing in the presence of water. The latter fact had long been a matter of record¹ and might excuse slight discrepancies in composition.

¹ See p. 186 of this article.

but the gross differences noted in the several samples were evidently due to incorrect methods of production. This view was substantiated by a large number of tests in the station laboratory, the resulting compounds varying in composition with differing conditions attending their preparation. To be sure, our work was conducted in a small way (2 to 3 ounces at most), but there was no reason to doubt that it would hold equally true on a commercial scale under like circumstances.

After having failed to obtain satisfactory salts from two different companies, and realizing more than ever the lack of manufacturing facilities in the laboratory, the matter was brought to the attention of one of the largest American manufacturers of analytical chemicals with whom the problem had previously been discussed. This firm agreed to undertake the preparation of the arsenicals, following general directions furnished by the laboratory. Dry calcium metarsenite and neutral and acid lead arsenates were received from them early in August, and while all were more or less impure the results, on the whole, were encouraging though showing the necessity of further study in order to give more specific directions. Precipitations under varying conditions were continued into January, 1911, at which time the data at hand warranted placing another order with the last-mentioned firm for acid lead arsenate and calcium metarsenite in form of paste. Explicit directions were furnished by this laboratory as to the method of manufacture. The resulting lead salt proved to be approximately 97 per cent. pure and was accepted. The first lot of lime arsenite was rejected, but the next shipment, over 94 per cent. pure, was accepted and employed in spraying tests during the summer of 1911, together with the acid lead arsenate and Paris green.

The above is a brief statement of some of the difficulties encountered in securing these three insecticides. In the papers that follow will be found under the headings of Paris green, calcium arsenite and lead arsenates a somewhat detailed description of the work performed in this laboratory relative to the several insecticides. Deductions drawn from a small number of samples must be considered indicative rather than conclusive, and their accuracy can be proved only by additional work.

A. PARIS GREEN.

Historical.

Paris green was produced by Russ and Sattler¹ in 1814. The process was kept a factory secret until revealed by the independent investigations² of J. Liebig and Henri Braconnot in 1822. Liebig³ treated 4 parts of verdigris in acetic acid with 3 parts of arsenous oxide in boiling acetic acid. The acid retained the material in solution until the excess was expelled. Braconnot⁴ prepared a solution of potassium arsenite by boiling 6 parts of arsenous oxide with 8 of potassium carbonate, poured it while warm into 6 parts of copper sulfate, dissolved in a small quantity of warm water, and added acetic acid until the odor was perceptible. The methods of Liebig and Braconnot have since been modified by many chemists, but substantially they typify the two distinct manufacturing processes employed to-day, *i.e.*, the *instantaneous* and the *slow*.

The instantaneous method is thus described in Watts' "Dictionary of Chemistry:"⁵ "Five parts of verdigris are made up to a thin paste, and added to a boiling solution of 4 parts or rather more of arsenous acid⁶ in 50 parts of water. The boiling must be well kept up, otherwise . . . acetic acid must be added."

The slow process, as given by a manufacturing company,⁷ is as follows: 1,000 pounds of blue vitriol are dissolved in 480 gallons of hot water and run into a 1,200-gallon "striking vat." Four hundred and fifty pounds of sodium carbonate (Solvay) are dissolved in 480 gallons of hot water, and 795 pounds of arsenic "sprinkled" on and boiled to remove carbonic acid.

The boiling arsenic solution is "let down" into the blue vitriol solution, the temperature of which is about 140° F., well stirred, and 210 pounds of acetic acid (100 per cent.) mixed with an equal weight of cold water added. The mixture is

¹ B. B. Ross, Ala. Exp. Sta., Bul. No. 58, p. 4 (1894).

² H. Sattler, Ztschr. Angew. Chem., 1883, p. 35.

³ Repert. für die Pharm. 13, pp. 446-457 (1822).

⁴ Ann. Chim. et Phys. Ser. 2, 21, pp. 53-56 (1822).

⁵ 3d edition, 1, p. 10 (1893).

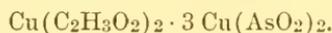
⁶ C. L. Bloxam states equal parts by weight of arsenic and copper acetate. (See Chemistry, 9th edition, p. 271 (1907).)

⁷ From correspondence on file.

allowed to stand two hours, then well stirred, after half an hour stirred again, and finally at the end of a quarter of an hour the liquid is drawn off and filtered. The resulting Paris green is dried on racks for four or five days at 185° F., or in a steam vacuum oven about 260° F. The yield is 985 pounds.

An electrolytic process for making Paris green from metallic copper, arsenous oxide and acetic acid was patented by Richard Franchot in 1902. No information relative to the character of the product is available.

Paris green is a copper aceto-arsenite for which Eugène Ehrmann's formula ¹ is generally accepted.



As a double salt it may be said to consist of 1 part of copper acetate to 3 of copper metarsenite, equivalent to 17.91 per cent. of the former to 82.09 per cent. of the latter. The structure of Paris green and its homologues was carefully studied by Avery, and while his results ² most frequently approached a ratio of 1:3, there was invariably a deficiency in arsenic. As the product is not recrystallizable he recognized that purity must be assured largely by a microscopical examination, which proved a questionable guide for so unstable a compound.

Although some chemists claim that the formula is only empirical it certainly expresses the proportion of cupric oxide to combined arsenic trioxide as found in well-formed greens. Four hundred and ninety-nine samples ³ collected in the open market by the Pennsylvania department of agriculture contained on the average:—

	Per Cent.
Cupric oxide,	29.41
Total arsenic trioxide,	56.56
Water soluble arsenic,	1.41

The relation of cupric oxide to "insoluble" arsenous oxide is 1:1.875, theory 1:1.865. Similar results are reported by others.

The comparatively high specific gravity of Paris green, as

¹ Bul. Soc.: ind., Mulhausen 7, pp. 68-80 (1834).

² Jour. Amer. Chem. Soc., 28, p. 1155 (1906).

³ J. W. Kellogg, Bul. No. 192, p. 37 (1910).

recorded by Miles ¹ and by Fernald ² of 3.29 and 3.42 respectively, results in a low power of suspension as shown by Colby ³ of five minutes for a coarse sample and seventeen minutes for a fine, in 1 foot column of water at the proportion ordinarily applied. Woods and Hanson ⁴ show as a result of a microscopical examination of 21 commercial samples of Paris green, slow process with possibly one exception, that on the average only 5.27 per cent. of the green particles exceeded a diameter of 19.2 microns (.00077 of an inch). The ammonia test for purity mentioned by Riley ⁵ and by Paddock ⁶ is now considered of little value except in determining the presence of insoluble materials such as flour and gypsum added as a filler.

The presence of free arsenic in Paris green in any appreciable amount is deemed objectionable by all investigators on account of possible injury to the foliage due to its corrosive action. While free arsenic can usually be detected by the microscope, its quantitative determination for a time proved a more difficult matter, and results by the earlier methods were of questionable value except in a comparative sense. Haywood ⁷ found that Paris green continued to yield arsenic to successive portions of warm water at 50° to 60° C., and also to repeated washings of cold water on a filter. He secured practically constant results by treating 1 gram of green in a flask with 500 cubic centimeters of water for twelve days, but subsequent tests ⁸ showed the presence of soluble copper, indicating either solution or breaking down of the green. He favored the latter view, but assumed that the decomposition was in proportion to original content and corrected the results accordingly.

Hilgard ⁹ acknowledged that warm water was not permissible and recommended a treatment conforming more nearly to orchard practice, 1 gram to 1,000 cubic centimeters of cold water for twenty-four hours with prolonged agitation. He questioned any dissociation of the green, but admitted that continued

¹ Va. Exp. Sta., Bul. No. 24, p. 16 (1893).

² Mass. Bd. Agr. Rept., 45, p. 355 (1898).

³ Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).

⁴ Me. Exp. Sta., Bul. No. 154, p. 114 (1908).

⁵ U. S. Ent. Com., Bul. No. 3, p. 56 (1880).

⁶ N. Y. Exp. Sta., Bul. No. 121, p. 219 (1897).

⁷ Jour. Amer. Chem. Soc., 22, p. 579 (1900).

⁸ Jour. Amer. Chem. Soc., 22, p. 705 (1900).

⁹ Jour. Amer. Chem. Soc., 22, p. 691 (1900).

percolation gave free arsenic. Avery and Beans,¹ working with a sample of perfect structure and of nearly theoretical composition, found that when treated in a stoppered flask, $\frac{1}{2}$ gram to 500 cubic centimeters of water, the arsenic continued to pass into solution for sixteen weeks, the duration of the experiment. Upon breaking the granules of Paris green by grinding in a mortar the disintegration was more rapid until a state of equilibrium was reached. Carbonic acid also increased the solubility of the arsenic. The decomposition was evidently due to hydrolysis, as the arsenic dissolved in much greater proportion of the original content than did the copper. They concluded that any method based on solubility in water was merely arbitrary, as "the amount of arsenic trioxide in solution appears to depend almost entirely on the length of time of action, the concentration of the solution and the state of division of the particles of Paris green." To distinguish free arsenic from that rendered free by hydrolysis, Avery and Beans recommended boiling 1 gram of green five minutes in 25 cubic centimeters of sodium acetate solution (1 to 2). It was found that the sodium acetate solution readily dissolved the free arsenic and at the same time largely prevented hydrolysis of the green. The Hilgard method, 1 gram to 1,000 cubic centimeters of water for twenty-four hours with agitation, indicates free and loosely combined arsenic, and while such results are invariably higher than the former, the increase for greens of perfect structure, free from broken particles, is comparatively slight. These two processes are now quite generally employed. The Association of Official Agricultural Chemists² recognizes the acetate method and the ten days' extraction method recommended by Haywood as provisional methods.

To prevent arsenical injury to foliage, Gillette³ and Kilgore⁴ advised mixing Paris green with milk of lime to neutralize the free arsenic, and Weed⁵ suggested combining the green with Bordeaux mixture.

¹ Jour. Amer. Chem. Soc., 23, p. 111 (1901).

² Methods of Analysis Bur. Chem. Bul. No. 107 (revised), p. 27 (1908).

³ Iowa. Exp Sta., Bul. No. 10, pp. 410-413 (1890).

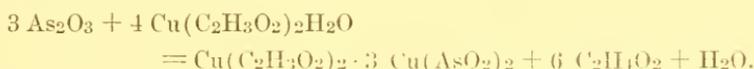
⁴ N. Car. Exp. Sta., Bul. No. 77b, pp. 4-7 (1891).

⁵ Ohio Exp. Sta., Bul. (Vol. 2) No. 7, p. 186 (1889); *Ibid.*, (Vol. 4) No. 2, pp. 39-42 (1891).

Experimental Results.

The terms "instantaneous" and "slow process" are used to designate Paris greens of different physical structure. While this classification may not be in strict conformity with some writers it appears, nevertheless, the most desirable for the purpose intended.

Instantaneous green is the result of a quick boiling process as previously shown. The ultimate reaction is illustrated by the following equation:—



If the process could be carried out with the ingredients in the proportion given there would be very little waste. In practice, however, instead of 1 part by weight of arsenous acid to 1.34 parts of copper acetate, an equal amount appears necessary to insure the desired change. This is probably due to the weak acid properties of the arsenic.

Slow process green is generally formed less rapidly and at a lower temperature than the instantaneous. From what could be learned the slow process seems to be the one employed by most of the large manufacturers. Blue vitriol is used as the source of copper, and sodium arsenite (NaAsO_2) in place of arsenous oxide, on account of its greater solubility and the necessity for a base to neutralize the sulfuric acid. Sodium arsenite is easily prepared by adding a thin paste of arsenous oxide in slight excess to a boiling solution of caustic soda or of a carbonate.



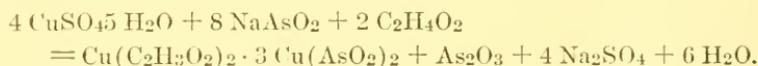
The soda and arsenic readily combine with volatilization of carbonic acid. As commercial salts were often employed in our work the analyses of two are given:—

Sodium Arsenite.

	Baker and Adamson (Per Cent.).	Kahlbaum (Per Cent.).	Theoretical (Per Cent.).
Arsenic trioxide,	78.68	74.71	76.15
Sodium oxide,	18.45	22.63	23.85
	97.13	97.34	100.00

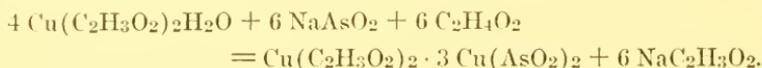
The sodium oxide was calculated from the alkalinity, determined by direct titration with methyl orange as indicator, a process sufficiently accurate for the purpose of checking quality.

The several reactions taking place in the manufacture of slow process green may be summarized in a single equation:—



Sodium arsenite reacts upon the blue vitriol with the production of a bulky, yellowish-green precipitate of copper arsenite (Scheele's green), which in turn is acted upon by the acetic acid with the formation of a greatly reduced volume of Paris green. Experience has shown, as indicated by the above formula, that about $\frac{1}{3}$ more arsenic is required for the production of the green than actually enters combination, as was the case with the instantaneous process. Acetic acid in excess of the 2 molecules stated (by nearly 66 per cent.) is needed for the reaction. It is evident from what has been said that the manufacture of slow process green requires considerable equipment, expensive reagents and expert control which, together with the unavoidable waste of chemicals, insures a costly product.

The two general processes for making Paris green and their several reactions were carefully studied in the station laboratory to ascertain the character of the product that might reasonably be expected. As a result of numerous experiments a combination process, using copper acetate and sodium arsenite, together with sufficient acetic acid to offset the alkalinity of the arsenite, was found the most acceptable.



The reaction was easy to control, could be carried out at any temperature from that of the laboratory to boiling and gave a product of variable physical structure and of fine color. Solutions of different concentrations were tried, of which $\frac{1}{5}$ molecular (M/5) for the acetate and $\frac{1}{2}$ molecular (M/2) for the arsenite proved satisfactory. This process appeared to require less arsenic in *excess* than the ordinary method, although the

work was performed on too small a scale to warrant positive statements to that effect.

Attention has already been called, on pages 180 and 181 to two samples of Paris green supplied by different manufacturers for the investigation, of which the second was employed in actual spraying tests. The sample of instantaneous green was made according to the method described, with the exception that crystallized copper acetate was substituted for verdigris. The slow process sample was selected from a factory run of commercial green manufactured substantially as has been stated.

Paris Green from Chemical Manufacturers.

	Instantaneous Green.	Slow Process Green.	Theoretical.
Manufacturer,	A	B	-
Character of product,	Dry powder.	Dry powder.	-
Color,	Pale green.	Bright green.	-
Shape of green particles, ¹	Irregular, angular.	Mostly perfect spheres.	-
Size of green particles, ¹	Average 10 μ .	12-30 μ , average 17.39 μ .	-
Uniformity, ¹	Very little variation.	Considerable variation.	-
Nature of impurities, ¹	Crystalline matter.	Crystalline matter.	-
Amount of impurities, ¹	Large amount.	Small amount, less than 5 per cent.	-
Flow,	Poor.	Excellent.	-
Film test,	Whitish.	Green.	-
Water (per cent.), . . . . .	.78	1.46	-
Cupric oxide (CuO) (per cent.),	31.74	30.94	31.39
Arsenic trioxide (As ₂ O ₃) (per cent.),	56.91	56.31	58.55
Acetic anhydride (C ₄ H ₆ O ₃) (per cent.),	10.37	9.91	10.06
Ferric (Fe ₂ O ₃) and aluminum oxides (Al ₂ O ₃) (per cent.),	-	.53	-
Sulfuric acid (SO ₃) (per cent.),	-	.29	-
Insoluble matter (per cent.), . . . . .	.00	.05	-
	99.83	99.55	100.00
Arsenic (As) (per cent.),	43.13	42.68	44.35
Suspension in water,	-	17 minutes.	-
Suspension in filtered lime water,	-	48 minutes.	-

Both greens contained an excess of cupric oxide and acetic acid, and may have been hydrolyzed somewhat by washing with

¹ Determined by the entomological department of this station.

the formation of a basic acetate. Sample B showed a considerable amount of impurities. Any hypothetical combination of the various constituents that might be offered would be decidedly arbitrary, and a discussion seems inadvisable at this time. A careful study of the results would indicate that the slow process green, exclusive of moisture, was at least 96 per cent. pure. To be of standard quality Paris green should contain not less than 50 per cent. of arsenous oxide combined with copper, and not more than 3.50 per cent. of arsenous oxide soluble in water. The poisonous character of Paris green is dependent on the arsenic content, but the form in which the arsenic exists largely fixes its value as an insecticide. Adulteration is seldom practiced under the inspection laws now in force.

Paris green is a dry, impalpable powder that readily passes a 100-mesh sieve, and to the touch resembles flour. A microscopical examination is required to determine the size, shape and uniformity of particles as well as the general character and amount of impurities. The latter may consist of Scheele's green that was not transformed or by-products such as arsenic, sodium sulfate, sodium acetate and possibly other compounds not intentionally added but present in the original chemicals. The sample of instantaneous green under examination was of a pale green color, and consisted of very small, irregular, angular particles with considerable impurity. It was cohesive, had a poor "flow," and the film test¹ on glass appeared whitish. The slow process green, on the other hand, had a brilliant green color of metallic luster, and was composed of minute green spheres of various sizes, together with a small amount of crystalline and fragmentary matter. It had an excellent "flow," and the film test on glass was green. The size of the particles is affected by the concentration, temperature and amount of agitation at the time of formation. The smaller the globules with retention of perfect form and similar size, the more desirable the product.

Paris green has a high specific gravity and a low power of suspension. In the station laboratory suspension was determined² in a foot column containing the insecticide at the proportion of 1 gram of dry salt to 1,000 cubic centimeters of

¹ C. W. Woodworth, Cal. Exp. Sta., Bul. No. 126, p. 13 (1899).

² Modification of the California method. G. E. Colby, Cal. Exp. Sta., Bul. No. 151, pp. 33-35 (1903).

water. The mixture in a closed cylinder was thoroughly agitated, and the reading, in minutes, taken with a horizontal microscope, using a 1-inch eyepiece and 1/2-inch objective, when movement of the particles midway of the column (6 inches down) was no longer apparent. The slow process green gave a reading of seventeen minutes in water and forty-eight minutes in filtered lime water. As lime tends to flocculate the particles of Paris green, the test should be performed immediately after mixing.

Although copper aceto-arsenite is termed insoluble in water, decomposition readily takes place under certain conditions; therefore, the determination of so-called "free" and "loosely combined" arsenic is closely related to stability of product and should be considered in that connection.

Solubility.

	Instan- taneous Green.	Slow Process Green.
Manufacturer,	A	B
Water (per cent.), . . . . .	.78	1.46
Sodium acetate soluble "free arsenic" (Avery and Beans Method):—		
Cupric oxide,	Trace.	Trace.
Arsenic trioxide (per cent.),	1.45	.74
Copper acetate soluble:—		
Arsenic trioxide (per cent.),	1.09	.45
Water soluble "free and loosely combined arsenic" (Hilgard Method):—		
Cupric oxide,	None.	Trace.
Arsenic trioxide, (per cent.)	2.06	.86
Solids (per cent.),	3.08	1.95
Lime water soluble:—		
Cupric oxide,	None.	—
Arsenic trioxide (per cent.), . . . . .	.97	1.52
Ammonia insoluble (per cent.),	—	.11

Neither of the greens contained an excessive amount of free or of free and loosely combined arsenic, judging by the standard, although the slow process was decidedly the better in that respect. This was to be expected, as the finely divided angular particles of the instantaneous green offered greater surface and apparently less resistance to a solvent than the nearly perfect

spheres of the slow process. The copper acetate soluble results are of uncertain value. Filtered lime water, with .12 per cent. calcium oxide, contained insufficient lime to prevent solution of the arsenic. Ammonia dissolves Paris green and the normal by-products concomitant with its manufacture, such as copper arsenite, arsenous oxide, sodium sulfate and sodium acetate; the residue, .11 per cent. in case of the slow process green, was organic and other insoluble materials.

To ascertain the solvent action of various substances in solution on Paris green, a series of tests were conducted with the slow process sample. The green in stoppered flasks was treated with water and with solutions of the respective compounds at the rate of 1 gram to 1,000 cubic centimeters for twenty-four hours at laboratory temperature, with occasional agitation during the working day.

Solubility Tests, Slow Process Green.

SOLVENT.	Amount of Solvent in a Liter of Water (Grams).	Soluble As_2O_3 (Per Cent.).	Copper.	Remarks.
Distilled water,	-	.84	None.	- -
Water saturated with CO_2 ,	- ¹	6.16	Much.	- -
Ammonium hydroxide (concentrated).	1	.86	None.	- -
Ammonium hydroxide (concentrated).	5	13.49	Much.	Residue darker green.
Ammonium carbonate,	1	6.83	Much.	Blue solution.
Ammonium carbonate,	5	55.93	Excessive.	Blue, nearly complete solution.
Ammonium chloride,	1	2.41	Considerable.	- -
Ammonium nitrate,	1	2.03	Trace.	- -
Ammonium nitrate,	5	4.70	Much.	- -
Ammonium nitrite solution,	1	.36	- -	- -
Ammonium nitrite solution,	5	.36	- -	- -
Ammonium sulfate,	1	4.20	Considerable.	- -
Sodium carbonate (anhydrous),	1	3.15	None.	- -
Sodium bicarbonate,	1	.84	Very slight trace.	- -
Sodium chloride,	1	.96	None.	- -
Sodium nitrate,	1	.86	None.	- -
Sodium nitrite,	1	.88	- -	- -
Sodium sulfate (anhydrous),	1	1.67	Very slight trace.	- -
Boiling water, one hour,	-	14.93	Much.	Change in color of residue.

¹ About 5 gallons of gas used, water pressure.

Cold water dissolved a small amount of arsenic, boiling water very much more. The green appeared to resist hot water for a considerable time after which the change was noticeable. If the boiling had been continued all the arsenic would probably have passed into solution. The .10 per cent. ammonium salts, exclusive of nitrite, dissolved on the average 58 per cent.¹ more arsenic than the corresponding sodium salts. In both instances the carbonate was the most active, followed respectively by the sulfate, chloride and nitrate. Sodium bicarbonate was apparently inactive under the conditions employed. Free carbonic acid was effective and so was ammonia when in sufficient amount to overcome the resistance of the green, and jointly, carbonic acid and ammonia dissolved the most arsenic.

It is evident from what has been stated that carbonic acid and ammonia of the atmosphere in conjunction with dew, fogs or light rains and high temperature will materially increase the dissociation of Paris green. Data more or less contradictory have been offered by various investigators relative to the influence of weather conditions on the effect of arsenic on foliage. While more or less problematical, certain deductions seem warranted: conditions favoring a rapid drying of the green and its continuance in a dry state are propitious. For instance, a relatively high temperature, low humidity and a good circulation of air at the time of application, followed by warm, dry weather should tend toward a minimum of arsenical injury. On the other hand, factors conducive to solubility of the arsenic and its passage by osmosis into the substance of the leaf are detrimental; as, for example, warm, "muggy" weather or warm weather accompanied by fogs or heavy dews. Rains are not necessarily injurious if of sufficient quantity to remove the soluble arsenic from its sphere of influence. The addition of milk of lime to Paris green tends to reduce arsenical injury by forming, with the free arsenic, arsenite of lime insoluble in the presence of excess lime. As lime flocculates the particles of green, it is not advisable to prepare the spray mixture until shortly before application.

In conclusion, it may be said that Paris green contains a fairly high per cent. of arsenic, is nominally insoluble in water

¹ Direct comparison.

but unstable, hydrolyzing readily under favorable conditions. It has a low power of suspension though its fineness permits of reasonable distribution. It is a poor indicator without lime of the leaf surface covered, but possesses fair adhesive qualities.

B. CALCIUM ARSENITE.

Historical.

Early attempts to use arsenous oxide as an insecticide by Riley ¹ in 1869 and Saunders and Reed ² in 1871 were unsatisfactory. John Smith ³ in 1868 appears to have been more successful, applying it in water, but the practice proved too hazardous to warrant its continuance, although freshly prepared mixtures have been applied in numerous instances without injury. The relatively high cost of Paris green and London purple, and the necessity of adding lime to neutralize the free arsenic, led to the production of lime arsenite. So far as known this has always been a farm preparation and not a commercial product.

Kilgore ⁴ recommended adding 1 pound of white arsenic to 2 pounds of lime in 2 to 5 gallons of water and boiling thirty minutes. Taft ⁵ advised adding 2 pounds of freshly slaked lime to 1 pound of arsenic in 2 gallons of water and boiling forty minutes. Kedzie ⁶ suggested dissolving the arsenic in a solution of sal soda and offered the formula which bears his name. Boil 2 pounds of arsenic with 8 pounds of sal soda in 2 gallons of water until dissolved. Slake 2 pounds of lime, add to 40 gallons of water and stir in 1 pint of the arsenic solution. Stewart ⁷ evidently noted the undue amount of sal soda in the Kedzie formula and reported better results, using equal parts, 2 pounds of arsenic and 2 pounds of sal soda. E. L. Smith ⁸ recommended 2 pints of Kedzie mixture to 6 to 10 pounds of lime in 50 gallons of water, and claimed that the additional lime increased safety and adhesiveness.

¹ Potato Pests, p. 60 (1876).

² Can. Ent., 3, pp. 45-47 (1871).

³ Western Pomologist, 2, p. 125 (1871). Cited by Lodeman.

⁴ N. Car. Exp. Sta., Bul. No. 77b, pp. 7-8 (1891).

⁵ Mich. Bd. Agr. Rept., 35, p. 119 (1897). In Rept. 37, p. 466 (1899), the amount of lime was increased 8 pounds on application.

⁶ Mich. Farmer, 31, p. 132 (1897).

⁷ Penn. Exp. Sta., Bul. No. 99, p. 11 (1910).

⁸ Cal. Exp. Sta., Bul. No. 126, p. 24 (1899).

Authorities differ as to the arsenite that results from the union of lime and arsenic. Prescott and Johnson¹ state that the arsenites of the alkaline earth are usually ortho compounds, Merck & Co.² and Gooch and Walker³ give neutral orthoarsenite of lime, while Comey⁴ and Watts' Dictionary⁵ recognize the ortho, $\text{Ca}_3(\text{AsO}_3)_2$, the meta, $\text{Ca}(\text{AsO}_2)_2$, and the pyro, $\text{Ca}_2\text{As}_2\text{O}_5$, salts. The latter is designated a mixture of basic salts with 1 molecule of water, $2\text{CaO} \cdot \text{As}_2\text{O}_3 \cdot \text{H}_2\text{O}$. So far as noted the formula acknowledged by experiment station workers has been that of the neutral ortho salt, although the subject has been given little attention.

As determined by Colby⁶ the suspension, in 1 foot column, of arsenite of lime made according to directions published by Taft was forty-four minutes, and by Kedzie formula fifty-seven minutes. Headden⁷ noted that arsenite of lime was almost entirely soluble in water and in dilute solutions of sodium sulfate and sodium chloride.

Experimental Results.

For the preparation of a high-grade arsenite of lime required for the work in view, precipitation from soluble salts of lime and of arsenic, while more costly, promised a more definite and uniform product. As lime arsenite is noncrystallizable, precipitation from perfect solutions insured better combination and greater freedom from admixtures. The comparative insolubility of lime, CaO , necessitated the use of a soluble salt. Lime salts of strong oxidizing acids were deemed objectionable on account of possible action on the arsenite and were excluded. The acetate of organic compounds and the chloride of the halogens were selected for trial, but after several tests the chloride was considered preferable. The fused salt was almost invariably employed. It should be free from other bases forming insoluble compounds with arsenic. The direct use of arsenous oxide is not advisable with a lime salt, not only for

¹ Qual. Chem. Anal., 6th edition, p. 57 (1905).

² Merck's 1907 Index, p. 113.

³ Outlines of Inorg. Chem. Pt. 2, p. 184 (1905).

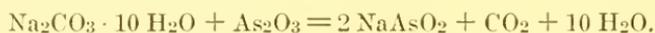
⁴ Dict. of Chem. Sol., p. 41 (1896).

⁵ Watts' Dict. of Chem., 3d edition, 1, p. 306 (1893).

⁶ Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).

⁷ Cal. Exp. Sta., Bul. No. 131, p. 22 (1908).

the reason that ordinary porcelainous arsenic in pulverulent condition is difficult to moisten and of low solubility, but more particularly because it would induce a secondary reaction from lack of base to satisfy the acid that was previously combined with the lime. Sodium arsenite, NaAsO_2 , is readily soluble and proved a satisfactory source of arsenic. A salt of fair quality can be procured on the market, or is easily prepared by adding 1 part of arsenous oxide to a boiling solution of 1.45 parts of sal soda, or an equivalent amount of soda in the form of anhydrous carbonate, bicarbonate or hydroxide. A slight excess of arsenic is required to insure complete volatilization of the carbonic acid.



The resulting arsenite should be free from arsenates, carbonates, sulfates or other acids forming insoluble compounds with lime.

Any decision as to concentration of solutions is naturally more or less arbitrary; dilution tends to make difficult precipitation with considerable loss of salt, and the opposite an unwieldy precipitate with greater occlusion. As a compromise solutions of $\frac{1}{2}$ molecular strength (M/2) were finally adopted. Another factor studied was the influence of temperature of solutions on the resulting precipitate, ranging from that of the laboratory to nearly boiling point at the moment of precipitation. Room temperature with two hours' standing gave a product of practically the same composition, and of probably better physical characteristics, than the higher temperatures and was considered more desirable.

As the alkalinity of the soda in sodium arsenite is not destroyed by the arsenous acid, it should be run into the calcium chloride solution slowly with constant agitation in order to prevent any precipitation of calcium hydroxide. An excess (10 per cent.) of sodium arsenite was found desirable to perfect the salt. After standing several hours the liquor was removed by means of a Buchner funnel, and the lime arsenite washed rapidly with cold water until nearly free from chlorides. A centrifuge or filter press might give equally good or better results provided the work was done rapidly. Undue washing was avoided, as it was thought safer to retain a small amount

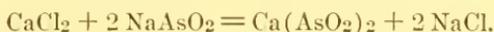
of sodium chloride than to take chances on *possible* hydrolysis and decomposition of the arsenite, an action readily inferred from the behavior of Paris green under similar conditions. The above method of preparation was employed in all subsequent work unless otherwise noted. Minor changes were attempted in some instances from which no apparent benefit was derived.

As previously stated there was considerable uncertainty as to the composition of the lime precipitate. To ascertain whether the resulting product was a definite compound and, if so, its composition, salts were produced from an excess of sodium arsenite into calcium chloride and *vice versa*, observing the usual precautions as to dilution, precipitation of calcium hydroxide, oxidation of the arsenic, etc. Incomplete analyses of a few laboratory samples are given.

Calcium Arsenite produced in the Laboratory (Per Cent.).

	EXCESS NaAsO_2 INTO CaCl_2 .			EXCESS CaCl_2 INTO NaAsO_2 . Precipitated Hot.
	Precipitated Hot.	Precipitated at 90° C.	Precipitated and held at 90° C. for Two Hours.	
Water, . . . . .	.12	.12	-	.12
Arsenic trioxide,	77.01	77.04	76.75	76.80
Insoluble matter,	-	-	-	.03

The small samples were of uniform composition, indicating a definite compound of about 77 per cent. arsenic content. This amount of arsenic exceeds the requirements of the ortho and pyro salts, and substantially conforms to that of the meta compound with a theoretical content of 77.92 per cent. The following equation illustrates the reaction that must have occurred:—



Attention has been called on pages 180, 181 and 182 to 5 samples of lime arsenite supplied by several firms for the investigation. Manufacturer C was furnished directions deduced from experimental work in the station laboratory. A and B evidently employed a different method.

Calcium Arsenite from Chemical Manufacturers.

	AS RECEIVED.					IN DRY MATTER.	THEORETICAL.
	A	B	C ₁	C ₂	C ₃		
MANUFACTURER,	A	B	C ₁	C ₂	C ₃	C ₃	-
Character of product,	Dry, granular.	Moist powder.	Dry, granular.	Gritty ² paste.	Smooth paste.	-	-
Color,	White.	White.	Slightly pink.	Pink. ²	Nearly white.	-	-
Water (per cent.), . . . . .	.67	16.27	.80	-	67.87	-	-
Calcium oxide (CaO) (per cent.),	-	-	21.63	-	6.78	21.10	22.08
Arsenic trioxide (As ₂ O ₃) (per cent.),	29.30	29.30	76.31	-	23.87	74.28	77.92
Arsenic pentoxide (As ₂ O ₅) (per cent.),	-	-	-	-	.09	.28	-
Magnesium oxide (MgO) (per cent.),	-	-	-	-	.05	.16	-
Chlorine (Cl) (per cent.),	-	-	-	-	.80	2.49	-
Sodium oxide (estimated) (Na ₂ O) (per cent.),	-	-	-	-	.70	2.18	-
Insoluble matter (per cent.),	5.63	.20	.02	-	.01	.03	-
Less oxygen equivalent to chlorine (per cent.),	-	-	-	-	100.17	100.52	100.00
Arsenic (As) (per cent.),	-	-	-	-	.18	.56	-
Suspension in lime water, hours,	-	-	-	-	99.99	99.96	-
Suspension in lime water after drying, hours,	-	-	-	-	18.14	56.46	59.02
Suspension in lime water, hours,	-	-	-	-	56	-	-
Suspension in lime water after drying, hours,	-	-	-	-	48	-	-

¹ A, B and C refer to individual manufacturers, the numerals to different samples.

² Gritty on account of compressed air being used to agitate and pink due to the presence of manganese.

Sample C₁ and C₃ confirmed the former analyses as to arsenous oxide, and the molecular ratio of calcium oxide to arsenous oxide was almost theoretical for calcium metarsenite. It would, therefore, appear safe to assume that lime arsenite precipitated from soluble salts of lime and of arsenic is invariably the meta salt.

Sample C₃ was employed in spraying, although in the process of manufacture it had been imperfectly washed, contained a small amount of magnesia and showed a slight oxidation of arsenic. Any arrangement of constituents is of doubtful value; still, the following may be suggested:—

Calcium Arsenite employed in Spraying.

Manufacturer,	C ₃
Water (per cent.),	67.87
Calcium orthoarsenate ($\text{Ca}_3(\text{AsO}_4)_2 \cdot 3 \text{H}_2\text{O}$) (per cent.), . . . . .	.18
Magnesium metarsenite ($\text{Mg}(\text{AsO}_2)_2$) (per cent.), . . . . .	.30
Calcium metarsenite ($\text{Ca}(\text{AsO}_2)_2$) (per cent.),	30.31
Sodium chloride (NaCl) (per cent.),	1.32
Insoluble matter (per cent.), . . . . .	.01
	99.99

The above analysis would indicate a purity, on a water-free basis, of 94.34 per cent.

Calcium metarsenite, prepared according to the directions given, is a smooth white gelatinous mass or jell of very fine, adhesive particles. The power of suspension which has to be determined in lime water to prevent partial solution is extremely high but lessened by drying. Sample C₃ gave phenomenal results, though the actual figures are indicative rather than absolute. A moist paste of arsenite of lime proved unstable, gradually changing to arsenate with the separation of free arsenic (As). Calcium arsenite is probably the most soluble arsenical insecticide in use as shown by the following results:—

Solubility.

MANUFACTURER,	A	B	C ₁	C ₂	C ₃
Water (per cent.),	.67	-	.80	-	67.87
Calcium acetate soluble:—					
Arsenic trioxide (per cent.),	27.55	-	11.62	-	-
Water soluble (Hilgard Method):—					
Calcium oxide (per cent.),	-	-	10.98	-	3.14
Arsenic trioxide (per cent.),	24.78	-	40.88	-	11.58
Solids (per cent.),	64.90	-	53.48 ¹	-	16.54
Lime water soluble:—					
Arsenic trioxide (per cent.),	.14	-	.17	-	.05

The calcium acetate soluble appeared to have no particular significance, and the test was eventually dropped. The water soluble results are only approximate, as slight variations in temperature or agitation caused marked differences. Solubility is apparently not a result of hydrolysis, as proportionally the lime passed into solution almost as rapidly as the arsenic. If hydrolysis played any part it would seem to be inappreciable. Lime arsenite was nearly insoluble in lime water. In order to secure additional data relative to the solubility of lime arsenite, 1 gram of sample C₃, after drying, was subjected to the action of various solvents for twenty-four hours in stoppered flasks with occasional agitation, the results of which are stated below:—

Solubility Tests, Sample C₃ Dried.

SOLVENT.	Amount of Solvent in a Liter of Water (Grams).	Soluble As ₂ O ₃ (Per Cent.).	Lime.	Remarks.
Distilled water,	-	38.45	Present.	-
Water saturated with CO ₂ ,	- ²	62.22	Present.	-
Ammonium hydroxide (concentrated),	1	36.66	Present.	-
Ammonium carbonate,	1	64.36	Trace.	-
Ammonium chloride,	1	53.40	Present.	-
Ammonium nitrate,	1	51.97	Present.	-
Ammonium nitrite solution,	1	43.06	Present.	-
Ammonium sulfate,	1	52.71	Present.	-
Sodium carbonate (anhydrous),	1	59.32	None.	-
Sodium bicarbonate,	1	62.19	None.	-
Sodium chloride,	1	41.20	Present.	-
Sodium nitrate,	1	40.53	Present.	-
Sodium nitrite,	1	40.72	Present.	-
Sodium sulfate (anhydrous),	1	41.08	Present.	-
Boiling water, 1 hour,	-	58.63	Much.	-

¹ Contained .39 per cent. of ferric and aluminum oxides and .08 per cent. of magnesium oxide.

² About 5 gallons of gas used, water pressure.

Calcium metarsenite was fairly soluble in cold water, but much more so in boiling water. The ammonium salts, exclusive of nitrite, dissolved about 19 per cent.¹ more arsenic than the corresponding sodium salts. The carbonate in both instances proved very effective, followed by the chloride, sulfate and nitrate with only slight differences between the latter. An interchange of bases must have resulted in many instances to permit the high solubility recorded. Carbonic acid, combined and free, was the most active of any single agent, consequently excess lime should afford one of the best methods of protection under atmospheric conditions. Ammonium hydroxide depressed slightly the solubility of the arsenic.

Calcium metarsenite contains the highest per cent. of arsenic of all the common insecticides, and is quite soluble except in presence of excess lime; the fineness of its particles and the high power of suspension insure uniform distribution; the white film readily indicates the surface covered; and its adhesiveness provides protection for a reasonable period under average weather conditions.

C. LEAD ARSENATES.

Historical.

F. C. Moulton,² chemist for the Massachusetts Gypsy Moth Commission, was the first to prepare arsenate of lead for insecticidal purposes. He employed lead acetate and sodium arsenate. The work was continued by F. J. Smith,³ who studied the composition of the chemicals used, the reactions and other matters pertaining to the manufacture. He stated that ordinary spray material was not a single salt, but a mixture of neutral and acid arsenates, and believed that the relative amount of each depended principally upon the source of the soluble lead salt, although temperature and concentration at the moment of precipitation affected the results; in other words, that acetate of lead had a tendency, other factors being equal, to yield the neutral salt and the nitrate the acid arsenate.

An electrolytic process for making arsenate of lead was patented by C. D. Vreeland in 1907, using lead, sodium arsenate

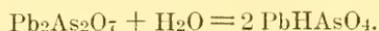
¹ Direct comparison.

³ *Ibid.*, 45, pp. 357-371 (1898).

² Mass. Bd. Agr. Rept., 41, p. 282 (1894).

and an electrolyte of sodium nitrate. Patents have also been taken out on various other methods of manufacture, references to which are found in technical journals. I. W. Drummond patented a dry preparation of lead nitrate, sodium arsenate and corn starch to be mixed with water when applied.

Most authorities recognize neutral orthoarsenate of lead, $Pb_3(AsO_4)_2$, and acid arsenate, $PbHAsO_4$, and a few mention pyroarsenate, $Pb_2As_2O_7$. W. H. Volck¹ claims the latter salt may occur in commercial pastes, though Lefevre² states that it is decomposed by cold water. Pyroarsenate differs from 2 molecules of the acid salt by 1 molecule of water.



So far as noted, the presence of pyroarsenate in insecticides has not been proved.

The low specific gravity of lead arsenate, 1.00668 according to Smith³ (salt not specified), results in a high power of suspension as shown by Colby,⁴ from nitrate one hundred and thirty minutes and from acetate two hundred and forty minutes. Investigators have found lead arsenates comparatively little affected by hot water or carbonic acid. Dilute solutions of sodium carbonate, sodium chloride and sodium sulfate have an appreciable action as shown by Headden⁵ and others. The acid salt has invariably proved the more unstable. Volck⁶ noted that under alkaline conditions it tends to decompose with the formation of the ortho salt and arsenic acid, and he states that this reaction appears to take place in the orchards of the Pacific coast as a result of the continuous fogs and heavy dews. P. J. O'Gara⁷ also claims that the acid salt is very injurious under certain climatic conditions. Haywood⁸ recommended the addition of lime to arsenate of lead to prevent injury to delicate foliage.

¹ Science, 33, p. 868 (1911).

² Cited by A. M. Comey, Dict. of Chem. Sol., p. 35.

³ Mass. Bd. Agr. Rept., 45, p. 355 (1898).

⁴ Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).

⁵ Col. Exp. Sta., Bul. No. 131, p. 22 (1908); Bul. No. 157, pp. 29, 30 (1910).

⁶ *Loc. cit.*

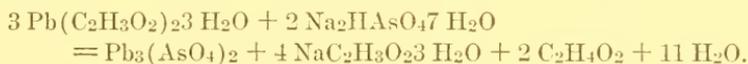
⁷ Science, 33, p. 900 (1911).

⁸ Bur. Chem., Bul. No. 131, p. 49 (1910).

Experimental Results.

In the production of lead arsenates pure chemicals are a prime requisite for a high-grade product. The lead salts should be free from other bases forming insoluble arsenates, and the sodium arsenate ($\text{Na}_2\text{HAsO}_4 \cdot 7\text{H}_2\text{O}$) from arsenites, carbonates, chlorides and sulfates. Acetate of lead is objectionable as a source of lead in that it readily carbonates on exposure to air. As to concentration of solutions, our experience has shown that for salts of such high molecular weight dilute solutions not exceeding $\frac{1}{5}$ molecular ($M/5$) are preferable. At that dilution, laboratory temperature gives a very finely divided precipitate which is highly desirable from the standpoint of suspension. The arsenate should be run into the lead salt *very slowly* with thorough agitation in order to prevent precipitation of lead hydroxide due to the alkalinity of the sodium salt. The reverse precipitation, lead into the arsenic, proved less satisfactory both as to formation and behavior of the precipitate. While arsenic acid is stronger than arsenous, it neutralizes only about one-half the alkalinity of the soda in disodium hydrogen arsenate.

Neutral Lead Arsenate. — After many attempts, employing di and tri sodium and ammonium arsenates, salts containing arsenic and lead in proper molecular ratio were finally produced according to the following equation: —



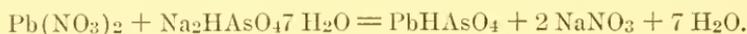
To obtain these results it was necessary to prepare the disodium arsenate in order to exclude carbonic acid which was present in the commercial salts purchased. The principal difficulties, however, arose from failure to add the strongly alkaline sodium arsenate slowly and with sufficient agitation to prevent the precipitation of lead hydroxide and to maintain an excess of at least 5 per cent. of lead to prevent the formation of the acid salt. The usual precautions as to concentration, temperature and thoroughness of washing were carefully observed. The following analyses of two samples show the material to be practically of theoretical composition: —

Neutral Lead Arsenate produced in the Laboratory.

Sample number,	31	32
Water 100° C. (per cent.), . . . . .	.75	.70
Arsenic pentoxide (per cent.),	25.10	25.18
Lead oxide (per cent.),	73.15	73.20
Water occluded (per cent.), . . . . .	.98	.82
	99.98	99.90

The lead salt invariably contained a small amount of water probably held by occlusion which is not volatilized at 100° C.

Acid lead arsenate is readily prepared from nitrate of lead and sodium arsenate provided dilute solutions are employed and the sodium salt added carefully in excess (10 per cent.).



By this method of procedure no difficulty was experienced in producing salts of theoretical composition. The acetate can be used as a source of lead, but is less satisfactory.

Six samples of lead arsenate were supplied by three manufacturers for the spraying tests. Manufacturer C was furnished full directions as outlined above for making the acid salt. The detailed process for preparing the neutral salt was not deduced until later.

Lead Arsenates from Chemical Manufacturers.

	SUPPLIED AS —					
	UNKNOWN.	NEUTRAL.		ACID.		Theoret- ical.
			Theoret- ical.		In Dry Matter.	
MANUFACTURER. ¹	A	B ₁	C ₁	B ₂	C ₂	C ₃
Character of product,	Dry, granular.	Dry, powder.	Dry, slightly granular.	Dry, powder.	Dry, powder.	Smooth paste.
Color,	Yellowish.	Dirty white.	White.	White.	White.	White.
Water (per cent.),	.34	.34	6.39	.66	.35	46.99
Lead oxide (PbO) (per cent.),	66.11	66.11	69.74	63.63	65.39	34.58
Arsenic pentoxide (As ₂ O ₅) (per cent.),	—	29.47	22.75	29.50	30.92	17.11
Water in combination (per cent.),	—	—	—	—	1.06	1.33
Chlorine (Cl) (per cent.),	—	—	—	—	—	.04
Insoluble matter (per cent.),	—	.36	.01	.08	.00	.01
Less oxygen equivalent to chlorine (per cent.),	—	—	—	—	—	100.06
	—	—	—	—	—	100.11
	—	—	—	—	—	.02
	—	—	—	—	—	100.09
Arsenic (As) (per cent.),	—	—	—	—	—	11.16
	—	—	—	—	—	21.05
Suspension in water, minutes,	—	—	—	—	—	81
Suspension in water after drying, minutes,	—	—	—	—	—	42

¹ A, B and C refer to individual manufacturers, the numerals to different samples.² Sample rejected.

Neutral and acid arsenates of lead are quite insoluble, although both salts will undoubtedly yield arsenic slowly to continuous percolation, the acid salt decomposing the more readily.

Solubility.

	SUPPLIED AS —					
	NEUTRAL.			ACID.		
Manufacturer,	A	B ₁	C ₁	B ₂	C ₂	C ₃
Water (per cent.),	— ¹	.34	6.39	.66	.35	46.99
Water soluble (Hilgard method):—						
Lead oxide (per cent.),	—	None.	.01	None.	.14	.06
Arsenic pentoxide (per cent.),	—	.48	.05	.16	.02	.03
Solids (per cent.),	—	2.33	1.13	4.21	2.10	.30

The acid salt C₃ was practically insoluble under the conditions tested, and nearly free from soluble by-products.

The legal standard² for commercial lead arsenate in form of paste specifies not more than 50 per cent. of water nor less than 12.50 per cent. of arsenic pentoxide and not more than .75 per cent. of arsenic pentoxide soluble in water. Sample C₃, acid salt, which was used in experimental work, exceeded standard requirements in all particulars. A careful study of the analytical results, C₃, might warrant the following combination:—

Acid Lead Arsenate employed in Spraying.

	Per Cent.
Water,	46.99
Acid lead arsenate (PbHAsO ₄),	51.61
Lead chloride (PbCl ₂), . . . . .	.16
Lead hydroxide (2 PbO · H ₂ O),	1.34
Insoluble matter, . . . . .	.01
	100.11

Exclusive of water, the purity was approximately 97.36 per cent. There was a small amount of lead chloride, but the most objectionable feature appeared to be the precipitated lead hydroxide due to careless preparation.

¹ Sample rejected.

² The insecticide act of 1910, section 7.

There is evidently a difference in stability between acid and neutral lead arsenates as measured by boiling ammoniacal solutions, but, contrary to general belief, it is apparently only a matter of degree. Both salts are decomposable, yielding soluble arsenic acid.

Neutral arsenate, sample 31, page 204, after being twice heated with ammonia and washed, gave a residue which was practically stable and tested as follows:—

	Per Cent.
Water, . . . . .	.44
Arsenic pentoxide,	23.84
Lead oxide,	75.02
Occluded water, . . . . .	.64
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/>
	99.94

Stability was apparently the result of a reversible reaction, ammonia setting arsenic acid free, and lead hydroxide, when present in sufficient excess (10 per cent.), completely reprecipitating it. Similar results were obtained by adding freshly precipitated lead hydroxide, litharge and lime to neutral arsenate, the excess base preventing the separation of arsenic acid.

If properly made, neutral and acid arsenates of lead are smooth, white pastes of very fine particles, low specific gravity, excellent suspension and exceptional adhesiveness. The power of suspension is injured by drying. The readings reported for sample C₃ are not the maximum, but were taken when no movement of particles was perceptible, although the mixture continued milky for a considerable period thereafter.

Both acid and neutral lead arsenates are slow-acting poisons of low arsenic content, and that in the form of pentoxide. They are practically insoluble in water and fairly stable. The fineness of the particles and low specific gravity insure a high power of suspension and uniform distribution. The white mixture readily indicates the leaf surface covered and dries to a film which adheres with great persistence.

THE NATURAL FERTILITY OF CRANBERRY BOGS.

BY F. W. MORSE, M.S.C.

Years of experience by practical men have shown that cranberries are best grown on a peat bog the surface of which has been covered with a thin layer of sand. Furthermore, the best results with this soil are obtained only when there is an abundance of water by which at times the land may be flooded and at other times irrigated; and at the same time there must be opportunities for thoroughly draining the land at some stages of growth. This combination of peat subsoil, sandy surface and varying amounts of water is unusual in any other line of crop production, and most of the present methods pursued in cranberry culture are wholly empirical in their character.

One important problem now puzzling the cranberry grower is that of fertilization; is it necessary or unnecessary? The potential fertility of a true peat soil, that is, the amount of the elements of plant nutrition contained in its dry matter, is known to be high. Hopkins¹ states that a peat soil contains in the upper layer (6 $\frac{3}{4}$ inches thick) of 1 acre, 35,000 pounds of nitrogen, 2,000 pounds of phosphorus and 2,900 pounds of potassium, while a layer 40 inches deep over 1 acre contains 197,000 pounds of nitrogen, 8,600 pounds of phosphorus and 21,400 pounds of potassium. He further states² that but little of this enormous store of material is in an actively available form, and estimates that a corn crop can get at not more than 7 pounds of potassium per acre, while in an experiment on a poorly drained field, corn was benefited by the addition of nitrogen.³ The sand on the surface of the peat may be disregarded as a source of plant nutrients, but it is an important agent in making availa-

¹ Hopkins, C. G., *Soil Fertility*, Ginn & Co., 1910, pp. 83-87.

² *Ibid.*, p. 471.

³ *Ibid.*, p. 472.

ble the elements contained in the peat. The water used in flooding and irrigating may be regarded in a similar way, since it is as pure as the average public water supply and often purer.

Analyses of the cranberries and cranberry vines reveal an unusually low proportion of nitrogen and ash constituents, especially in the fruit which, as a rule, is all that is removed from the bog.

TABLE I. — *Composition of Cranberries and Vines.*

	Water.	Ash.	Nitro- gen.	Phos- phoric Acid.	Potash.	Lime.	Mag- nesia.
Berries, Massachusetts, ¹	89.40	0.195	0.07	0.025	0.08	0.03	-
Berries, New Jersey, ²	-	0.175	0.05	0.020	0.07	0.01	0.009
Vines, Massachusetts, ¹	13.07	2.450	0.77	0.270	0.33	0.40	0.250
Vines, New Jersey, ²	-	2.070	0.64	0.180	0.24	0.49	0.190
Vines, New Jersey, ²	-	2.100	0.65	0.310	0.40	0.50	0.190

A crop of 100 barrels of cranberries per acre, weighing 10,000 pounds, will contain only 7 pounds of nitrogen, 3 pounds of phosphoric acid and 8 pounds of potash. One ton of dried vines would contain 15 pounds of nitrogen, 6.2 pounds of phosphoric acid and 8 pounds of potash. These figures show clearly that the cranberry crop will never exhaust the potential fertility of the bog; but it is equally plain that it has become accustomed to a scanty nourishment, and they do not answer the question, "Shall fertilizers be used?"

There are on record only three series of fertilizer tests on the cranberry crop. They are somewhat empirical and throw little light on the problem.

An experiment in New Jersey was reported in 1895.³ A complete fertilizer gave the best results, with the next best from the nitrogen with phosphorus and nitrogen with potash. This was indicative of the actual need of nitrogen; but the soil was described as a black sand somewhat too dry for a good bog.

In Wisconsin Whitson began a series of fertilizer tests in 1904,⁴ the last detailed report of which was published in 1907.⁵

¹ Mass. State Exp. Sta. Rept., 1889, p. 274; 1893, pp. 330, 370.

² N. J. Agr. Exp. Sta. Rept., 1898, pp. 122, 123.

³ Ann. Rept., N. J. Agr. Exp. Sta., 1895, p. 110.

⁴ Whitson, A. R., Ann. Rept., Wis. Agr. Exp. Sta., 1905, pp. 291 and 292.

⁵ Ann. Rept., Wis. Agr. Exp. Sta., 1907, p. 305.

The largest increase in fruit was from the use of sodium nitrate with acid phosphate, and the next best yield was from the nitrate with potash salts, while nitrate of soda alone was more effective than either of the other substances used singly. The actual character of the soil to which the fertilizers were applied is not stated, but from the general description of the bog it is inferred that the soil was a deep peat with the usual surface layer of sand.

In Massachusetts Brooks began a fertilizer test in 1906.¹ Three years later he reported² that nitrate of soda greatly promoted the growth of vines, and seemed to be favorable to fruitfulness, but when used in excess of 100 pounds per acre the growth of vines was liable to be too luxuriant. High-grade sulfate of potash was decidedly favorable, and the maximum yield was obtained from a heavy dressing of this salt supplemented by a moderate application of nitrate of soda and acid phosphate. The soil of the Massachusetts bog was not a deep peat, but a sand colored with peat as shown by a chemical analysis which revealed less than 2 per cent. of organic matter. In this instance there is evidence of a low potential fertility, which does not help clear up the problem of the use of fertilizers on a true peat soil.

When peat soils have been well drained and planted to common farm crops like corn, they have not been found to require nitrogen, but have been noticeably improved by the addition of potash salts and phosphates.³ The conditions required by corn and staple farm crops differ, however, very much from those required by the cranberry. In the former conditions drainage is maintained continuously as a rule, while in the latter case the soil is saturated and even flooded through nearly three-fourths of the year. In the former case nitrification is favored, but in the latter case it is hindered, which may account for the agreement of all three fertilizer tests in showing an increase of fruit upon applications of nitrate of soda.

A consideration of the methods followed by cranberry growers in regulating the water supply of their bogs is helpful in connec-

¹ Brooks, Wm. P., Ann. Rept., Mass. Agr. Exp. Sta., 1908, p. 17.

² Ann. Rept., Mass. Agr. Exp. Sta., 1910, p. 32.

³ Hopkins, C. G., Soil Fertility, Ginn & Co., 1910, pp. 471-472; Whitson, A. R., Ann. Rept., Wis. Agr. Exp. Sta., 1905.

tion with a study of the natural fertility of the soil. Where conditions permit the bog is completely overflowed from some time in November until May, sometimes until the latter part of this month. During this period the changes within the soil must be limited to solution of matter in the water and putrefactive decomposition in the vegetable matter. Both will be at the lowest point because of the winter temperature. In the spring, when the sluices are opened, there is a rapid run-off from the surface followed finally by seepage into the ditches. The water table falls in the soil to a point a little higher than the level maintained in the drains. It is only above this water table that the activities of useful bacteria can occur, and while it is not definitely known how deep the cranberry roots penetrate, it is probable that they do not extend below the permanent water table. Through a large part of the growing season the water is maintained in the ditches at a level 12 to 15 inches below the surface of the soil. This permits oxidation changes and free root development in a soil depth of not more than 1 foot.

Moist sand is a well known medium for aerobic bacterial action, and the same is true of peat when it contains the optimum amount of water. Sewage filters are constructed of both types of soils, while several proposed processes for production of nitrates are based on the rapid nitrification known to take place in peat under favorable conditions.

During the summer season there must be a movement of water upward from the level of the water table into the surface peat and sand. This upward current is produced mainly by the transpiration of water from the plants, as they cover the surface so completely that actual evaporation must be small. But this makes little difference since it has been shown that transpiration follows the same laws as evaporation from a free surface.¹ Botanists have also observed that bog plants, for some reason, take on the character of desert plants and resist transpiration. The peat which is continually saturated or submerged must be constantly yielding soluble material to the enveloping water, and the solution must be nearly saturated. This soluble matter is poisonous to plants of many families, but

¹ Montgomery, Proc. Am. Soc. Agronomy, 1911, pp. 261, 283.

its influence on cranberry vines is not known. In the aerated surface soil, however, it will be transformed into the beneficial highly oxidized compounds, as nitrates and sulfates.

The present use of water on cranberry bogs is empirical, but a consideration of the conditions under which soil changes occur leads me to believe that water should be withdrawn from the surface at the earliest possible moment in the spring consistent with safety from frost, and held at the lowest possible level at which the vines can secure sufficient moisture for free growth during dry and hot weather. By this arrangement the period of active soil change, and the volume of soil in which it can take place, will be at a maximum, with a consequent increase in the amount of available nutrients for the plants. Flooding the bogs followed by the spring draining undoubtedly causes some loss of soluble fertility, and, on account of the close approach to saturation of the soil during the summer, heavy rains will also result in loss through seepage into the ditches.

This experiment station has begun an investigation of the problem of cranberry-bog fertility, and Director Brooks has devised a series of 30 miniature bogs described by him in a recent article.¹ Each bog is constructed in a 24-inch tile, 48 inches deep, and connected with it is a 6-inch tile that corresponds to the ditch on a large bog, by which the bog can be drained or irrigated. Analyses of the drainage water during the past two summers throw some light on the development of soluble material in the peat and its transformation into active nutrients for the vines. The first analyses were made on samples collected July 14, 1910. Other samples were analyzed at intervals until October 19. During most of this period frequent additions of water were required by the bog because the rainfall was abnormally small. All the water was applied to the surface of the bogs in order to promote diffusion into the small drainage cylinders.

There was much variation in the composition and also in the color of the different samples, which continued until the collection of September 12. There was, however, a steady progress toward uniformity. A few days previous to September 12, viz., on the 8th, there was an exceptionally heavy rainfall which

¹ Brooks, Wm. P., Proc. Soc. Promotion Agr. Sci., 1911, pp. 23-28.

flooded the bogs, covering the surface with an inch of water. The percolation which followed forced the bog water into the drainage cylinders. The water from nearly every bog on September 12 was a dark coffee color, whereas before this date there had been a wide range of tints from dark coffee to light amber. The total solids, and particularly the volatile solids, had now reached a maximum in all but two or three samples, and the amounts were of the same order of magnitude. When sampled for the last time in 1910, on October 19, there was another noticeable change in the water. Nearly all the samples were now a greenish black in color, and opaque and inky in appearance. They also were filtered with difficulty. All the samples collected during the season had been filtered through dry paper filters to remove suspended matter and sand. The water ran rapidly through the paper and in the earlier collections left little or no stain behind. As the colors deepened the later collections stained the filters more and more. The last series deposited a colloidal film on the paper which hindered the passage of the water through the pores and caused the filtration to occupy several hours, in some cases nearly twenty-four hours, while the filtered water had lost its inky appearance and was as a rule a light coffee color. This behavior, together with the appearance of a maximum point in the total solids and volatile solids, points conclusively to a saturated solution with respect to the organic constituents of the peat.

TABLE II.—*Inorganic Solids in Bog Waters, 1910.*

[Parts in 100,000.]

BOG NUMBER.	July 14.	July 27.	August 22.	September 12.	October 19.
1,	11.8	34.8	53.0	62.4	59.6
2,	19.8	56.2	67.6	58.6	64.0
3,	31.4	49.8	76.6	64.6	63.8
4,	83.2	60.4	62.0	64.6	50.0
5,	73.6	69.4	70.0	53.8	59.6
6,	11.0	23.6	40.2	54.6	62.8
15,	11.2	—	52.0	73.4	68.0
16,	11.4	—	39.0	63.0	78.8
17,	54.6	49.4	51.4	63.0	—
18,	50.8	53.8	56.8	49.8	—
22,	63.4	56.2	58.6	49.0	—
25,	23.8	41.0	55.0	52.0	53.0

TABLE III. — *Organic Solids in Bog Waters, 1910.*

[Parts in 100,000.]

BOG NUMBER.	July 14.	July 27.	August 22.	September 12.	October 19.
1,	5.8	12.8	18.6	94.0	73.6
2,	8.2	25.8	37.6	107.4	80.2
3,	10.4	16.4	28.0	112.6	94.0
4,	25.0	66.2	78.0	106.6	67.2
5,	44.8	62.6	70.4	131.2	101.2
6,	5.8	11.8	20.4	114.8	96.0
15,	3.2	-	22.0	102.8	104.2
16,	4.6	-	15.4	65.8	64.4
17,	54.4	89.2	101.6	93.8	-
18,	70.6	108.2	113.2	92.0	-
22,	48.6	60.2	118.0	96.6	-
25,	-	21.6	32.0	93.2	88.8

The inorganic solids were more or less influenced by the cement used in the construction of the cylinders.

The samples of 1911 are best considered in two groups, one of which represents the bog water in the spring, while the other shows its composition at the end of the summer. The first group consisted of two series of samples which were taken from 10 of the bogs on the 10th and 12th of May, before the flood water was drained off. The samples therefore represented the results of six months of solution, diffusion and precipitation on the organic and inorganic matter in the bogs. One set of samples was filtered through dry paper filters before they were analyzed, while the other set was allowed to stand over night to settle, and then used without filtering. The samples were inky in appearance when taken and changed but little on standing. Filtration required from twenty-four to forty-eight hours and a change of filter papers, because their surfaces were soon covered with a dark slime which rendered them nearly impervious. The filtered water was much lighter in color than the original sample. The material removed by the filters was largely organic in its nature, since the organic solids in the filtered water were lower proportionally than the inorganic

solids when compared with the corresponding figures for the unfiltered water.

TABLE IV. — *Average Composition of Bog Waters, May 10-12, 1911.*

	Organic Solids.	Inorganic Solids.
Unfiltered,	63.0	48.0
Filtered,	38.8	34.0

The behavior of the samples in filtering, their opaque appearance before it, and the lower solids compared with the results of the previous season, point toward a saturation of the water in the bogs by the soluble material in the soil.

On June 2 chemical fertilizers were added to 22 of the 30 bogs, and the bogs were renumbered in pairs; 1A, 1B to 15A, 15B, and each cylinder of a pair was a duplicate of the other.

TABLE V. — *Scheme for Fertilizers on Bogs, 1911.*

BOG NUMBER.	Nitrate Soda (Grams).	Acid Phosphate (Grams).	Sulfate Potash (Grams).	Calcium Hydrate (Grams).
1A, 1B,	3.25	—	—	—
2A, 2B,	—	13	—	—
3A, 3B,	—	—	6.5	—
4A, 4B,	3.25	13	—	—
5A, 5B,	3.25	—	6.5	—
6A, 6B,	—	—	—	—
7A, 7B,	—	13	6.5	—
8A, 8B,	3.25	13	6.5	—
9A, 9B,	6.50	13	6.5	—
10A, 10B,	—	—	—	—
11A, 11B,	—	—	—	—
12A, 12B,	3.25	26	6.5	—
13A, 13B,	3.25	13	13.0	—
14A, 14B,	—	—	—	—
15A, 15B,	3.25	13	6.5	65

NOTE. — Area of bogs, $\frac{1}{14,000}$ of an acre.

After the fertilizers were added all irrigation of the bogs was executed by adding water to the drainage cylinders instead

of to the surface of the bogs. The rainfall was scanty during the summer, and frequent additions of water were necessary to maintain the water level within 14 to 16 inches of the surface. Beginning in the latter part of August, and continuing throughout September and October, frequent rains, some very heavy, caused copious percolation and resulted in considerable overflow from the drainage cylinders. Numerous samples were collected during this period and form the second group already mentioned. About two-thirds of these samples were analyzed after subsidence of sediment without filtration, and one-third were filtered through porcelain filter tubes under a pressure of 40 to 45 pounds per square inch. The character and appearance of the samples were like those of the May group. They were inky in color until filtered, and were then transparent and of varying shades of coffee color. The amount of solids was remarkably uniform and a little higher in the unfiltered water than was found in May, but much lower than the figures obtained the previous year. It is pretty conclusive that the peat had now become a stable bog soil, and the bog water had reached a stage of equilibrium with its soil environment.

TABLE VI. — *Organic Solids in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	September 5.	September 11.	September 20.	October 3.	October 25.
1,	75.2	—	—	—	—
2,	84.6	—	—	—	—
3,	—	—	71.6	—	—
4,	—	—	87.2	89.2	—
5,	78.0	—	74.2	82.4	—
6,	—	—	—	—	86.4
7,	—	—	64.2	71.4	—
8,	80.0	79.0	—	79.0	86.4
9,	—	69.4	74.2	65.4	82.0
10,	—	—	—	64.6	89.1
11,	—	69.8	60.8	—	—
12,	82.8	—	—	64.8	88.6
13,	—	—	—	82.0	92.4
14,	63.4	79.2	75.8	77.0	92.0
15,	94.2	—	85.2	92.8	97.6

TABLE VII. — *Inorganic Solids in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	September 5.	September 11.	September 20.	October 3.	October 25.
1,	50.4	-	-	-	-
2,	71.6	-	-	-	-
3,	-	-	68.8	-	-
4,	-	-	63.6	56.2	-
5,	61.4	-	63.8	51.6	-
6,	-	-	-	-	48.8
7,	-	-	58.6	48.6	-
8,	54.6	52.6	-	47.0	51.0
9,	-	50.6	47.8	41.0	49.4
10,	-	-	-	58.0	55.6
11,	-	63.8	56.9	-	-
12,	66.4	-	-	45.8	50.8
13,	-	-	-	43.0	51.0
14,	70.6	58.4	63.4	53.0	50.0
15,	68.6	-	66.2	54.4	65.2

TABLE VIII. — *Organic and Inorganic Solids in Bog Waters, Filtered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	ORGANIC.			INORGANIC.		
	August 24.	September 11.	October 25.	August 24.	September 11.	October 25.
1,	-	35.8	-	-	41.4	-
5,	29.8	-	-	36.6	-	-
6,	-	-	27.4	-	-	33.8
7,	20.0	-	-	21.4	-	-
8,	-	32.4	30.8	-	39.2	38.0
9,	14.4	28.0	35.0	20.4	34.2	44.8
10,	21.6	-	32.2	19.8	-	37.6
12,	-	-	47.2	-	-	43.6
13,	-	-	38.2	-	-	35.6
14,	-	37.4	33.6	-	47.1	32.2
15,	-	-	46.0	-	-	40.0

Since the primary object of the cranberry experiment is to ascertain the needs of the crop for fertilizers and the fate of

the fertilizing materials added to the soil, numerous determinations of the total nitrogen, free ammonia and nitrates were made on samples of water from the drainage cylinders between July 14 and Oct. 25, 1911. Nitrates were invariably found, but in insignificant amounts, and there was no practical difference between the water from bogs treated with nitrates and from those without them. Twenty-nine samples from bogs with nitrates contained 0.0299 part of nitric nitrogen in 100,000 parts of water, while 23 samples from bogs without nitrates contained 0.0298 part in 100,000. Free ammonia was much more prominent than nitrates and formed about one-third of the total nitrogen. There was a slight difference in favor of the fertilized bogs, since 34 samples from bogs fertilized with nitrate of soda contained 1.358 parts of ammonia in 100,000 parts of water, while 21 samples from bogs receiving no nitrates contained 1.227 parts of ammonia in 100,000. This slight difference indicates a possible denitrification and loss of nitrates in the form of ammonia. In determining total nitrogen about one-third of the samples were filtered through porcelain tubes before making the analysis. The slimy precipitate thus removed contained nearly two-fifths of the nitrogen present in the unfiltered waters. Forty-eight samples of unfiltered water contained 3.296 parts of nitrogen in 100,000 parts of water, while 27 samples of filtered water contained 2.058 parts of nitrogen in 100,000 parts of water.

TABLE IX. — *Total Nitrogen in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

Bog No.	FERTILIZER.	Septem-ber 5.	Septem-ber 11.	Septem-ber 21.	October 3.	October 9.	October 25.
1	Nitrate,	2.993	—	—	—	—	—
2	No nitrate,	3.977	—	—	—	—	—
3	No nitrate,	—	—	3.485	—	—	—
4	Nitrate,	—	—	4.100	3.767	—	—
5	Nitrate,	3.485	—	3.362	3.362	3.726	—
6	Nothing,	—	—	—	—	—	3.198
7	No nitrate,	2.911	—	2.993	2.788	3.280	—
8	Nitrate,	—	3.034	3.157	2.952	3.485	3.378
9	Double nitrate,	—	3.034	3.034	2.911	3.378	3.075
10	Nothing,	—	—	—	3.280	3.526	3.075
11	Nothing,	—	3.017	2.788	—	—	—
12	Nitrate,	3.485	—	—	3.280	3.526	—
13	Nitrate,	—	—	—	3.198	3.485	3.321
14	Nothing,	3.280	3.157	3.362	3.485	3.567	3.034
15	Nitrate,	3.977	—	3.936	3.854	—	3.485

Average nitrogen in 27 samples from nitrate bogs, 3.399 parts.

Average nitrogen in 18 samples from no nitrate bogs, 3.233 parts.

TABLE X. — *Total Nitrogen in Bog Waters, Filtered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	August 9.	August 14.	August 24.	September 11.	October 25.
1,	-	-	-	2.583	-
4,	-	1.312	-	-	-
5,	-	1.476	1.722	-	-
6,	-	-	-	-	2.173
7,	-	0.820	1.107	-	-
8,	-	-	2.419	2.419	2.337
9,	-	-	-	2.337	2.419
10,	-	-	1.148	-	2.173
11,	-	0.984	-	-	-
12,	2.337	-	2.720	-	-
13,	2.173	-	-	-	2.337
14,	2.378	-	2.214	2.706	2.173
15,	2.665	-	2.829	-	2.747

In 1910 total nitrogen was determined in the waters from all the bogs on September 12, at the time of maximum total solids. The 29 samples of that date averaged 3.260 parts nitrogen in 100,000 parts of water, or practically like the average for 1911 in the unfiltered water.

A few determinations of phosphoric acid and potash were made in 1911 in the unfiltered waters. Samples were taken from bogs receiving fertilizers and from those without. The results were too nearly alike to justify any statements about the two groups, and only averages will be used to show the composition of the bog water. Eighteen samples representing 7 pairs of bogs contained an average of 1.772 parts of phosphoric acid in 100,000 parts of water. Sixteen samples representing 6 pairs of bogs contained an average of 5.15 parts of potash in 100,000 parts of water. A few analyses of filtered samples showed that the potassium compounds in the water were completely soluble and passed through the filters with the water; but practically all the phosphoric acid in the unfiltered water was removed by the filter with the slime. Since the slime when burned showed marked evidence of iron in the residue, it is probable that any phosphoric acid which dissolves in the bog

water soon becomes iron phosphate, which is well known as a highly gelatinous precipitate when formed in dilute solutions.

Summarizing the composition of the bog water from the analyses of September and October, 1911, we have the following figures as the average composition of the water standing in contact with the peat in a saturated condition.

TABLE XI. — *Average Composition of Bog Water.*

[Parts in 100,000.]

	Unfiltered.	Filtered.
Organic matter,	79.2400	31.8600
Inorganic matter,	55.6500	35.3600
Total nitrogen,	3.2960	2.0580
Free ammonia,	1.4500 ¹	1.4500
Nitrogen in nitrates,	0.0417 ¹	0.0417
Phosphoric acid,	1.7720	Traces.
Potash,	5.1500	5.1500

This preliminary study does not throw much light on the problem of fertilizing cranberry bogs. It points, however, to certain conditions worthy of consideration in the use of fertilizers. The cranberry crop does not draw heavily on the soil. Its period of growth is, however, comparatively short, especially if the flood water is retained late, and its soil volume is relatively small when the water level is maintained near the surface. Bog conditions do not favor nitrification and oxidation on account of the saturated soil and low temperature, hence the bog water is low in active fertilizing constituents, especially in nitrates. Therefore it is probable that small amounts of soluble chemicals applied in the late spring would be effective in stimulating growth.

¹ Ammonia and nitrates averaged somewhat higher during this period than for the season as a whole.

TYPES OF CORN SUITED TO MASSACHUSETTS CONDITIONS.

BY P. H. SMITH AND J. B. LINDSEY.

INTRODUCTION.

Since 1903 experiments have been in progress with corn to determine, if possible, those varieties, or rather types, best suited to Massachusetts conditions. With this end in view the total yield of dry matter per acre, the digestibility, the relative proportions, and in some cases the composition, of the various parts of the plant (stalk, leaf, ear and husk), and the relation of the stage of development to the relative proportion of different parts as affecting the food value have been carefully studied.

Soil, Cultivation, Size of Plots, Fertilizers used.

With the exception of the Eureka and Pride of the North, varieties tested in 1904, the corn was grown upon one-twentieth acre plots (30 by 73 feet), rows running east and west. The soil consisted of a light sandy loam such as might be considered satisfactory corn land. Each plot was liberally and uniformly fertilized.

1906. — Varieties: Leaming and Pride of the North.

Fertilizers used per acre: —

200 pounds high-grade sulfate of potash, equivalent to about 100 pounds potash.

300 pounds acid phosphate, equivalent to about 45 pounds available phosphoric acid.

200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.

200 pounds dry ground fish, equivalent to about 16 pounds organic nitrogen.

The corn planted in 1906 produced an exceptionally fine crop. This was evidently due to very favorable weather con-

ditions. The yield may also have been favored to some extent by the growth of medium green soy beans on the same plots the preceding year.

1907. — *Varieties: Leaming and Pride of the North.*

Fertilizers used per acre: —

- 200 pounds high-grade sulfate of potash, equivalent to about 100 pounds potash.
- 500 pounds phosphatic slag, equivalent to about 75 pounds available phosphoric acid.
- 200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
- 300 pounds dry ground fish, equivalent to 24 pounds organic nitrogen.

1908. — *Varieties: Sanford, Longfellow, Rustler, Early Mastodon, Klondike, Red Cob Silage and White Cap Yellow.*

Fertilizers used per acre: —

- 300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
- 500 pounds acid phosphate, equivalent to about 75 pounds available phosphoric acid.
- 200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
- 500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

1909. — *Varieties: Twitchell's, Rustler, Brewer's, Early Mastodon, White Cap Yellow, Wing's Improved White Cap.*

Fertilizers used per acre: —

- 300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
- 700 pounds acid phosphate, equivalent to about 105 pounds available phosphoric acid.
- 200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
- 500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

1910. — *Varieties: Rustler, Brewer's, Longfellow, Eureka.*

Fertilizers used per acre: —

- 300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
- 700 pounds acid phosphate, equivalent to about 105 pounds available phosphoric acid.
- 200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
- 500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

A larger amount of fertilizer was added during the last few years of the experiment in order to insure the maximum development of the crop. The yield of corn when planted on the same land for several successive years is likely to decrease, and it was thought that the additional amount of plant food applied would in a measure check this probable shrinkage.

The chemicals were mixed, sown broadcast and harrowed in just before the corn was planted. While the application of commercial fertilizer was liberal, it is believed that larger yields might have been secured, in some cases at least, if more organic matter had been added to the soil either through the medium of barnyard manure or as a cover crop to be ploughed under in the spring.

The Pride of the North and Eureka corn grown in 1904 were not planted on the twentieth-acre plots, but were grown on one-half acre plots in an adjoining field. It was fertilized with cow manure at the rate of six cords to the acre and the land well fitted. In this case the rows ran north and south and the corn was sown in drills and thinned to one plant to the foot at the time of hoeing.

The corn grown on one-twentieth acre plots was planted in hills $3\frac{1}{2}$ by $3\frac{1}{2}$ feet, and thinned to four plants at the time of hoeing. It was seeded May 20–25 and harvested September 15, which is about as late as it is advisable to allow corn to stand and be safe from frosts.

Description of Varieties.

Twitchell's. — A small growing yellow flint bred in Maine. On account of its early maturing qualities (with us in the vicinity of August 20) it may be grown as far north as corn culture can be considered profitable. It has a short stalk of small diameter and a good-sized ear, in some cases two ears being noted on each stalk. It cannot be considered well suited for forage or silage where larger varieties will mature.

Sanford White. — A white flint corn, quite like Longfellow in general appearance, size of plant and time of ripening.

Longfellow. — An old established yellow flint variety extensively grown in Massachusetts. It is one of the best of the yellow flint varieties.

Pride of the North. — One of the earliest and apparently most satisfactory yellow dent varieties for Massachusetts. It does not usually make as large a growth as the Leaming, but in an average season will reach maturity.

Rustler Minnesota Dent. — A white dent corn believed to have been first raised in Massachusetts, on the Agricultural College farm, from seed procured in Minnesota. It has given uniformly good results and can be considered a satisfactory dent variety in spite of the fact that the ears do not usually develop well at the tip. It is believed that this corn can be greatly improved by careful breeding.

Leaming. — Yellow dent. Somewhat like the *Pride of the North*, but makes a larger growth and matures a little later. It is extensively grown for silage in Massachusetts, and, unless the season is unusually backward, will mature sufficiently for this purpose.

Brewer's. — Yellow dent. This is believed to be a western dent variety improved by N. H. Brewer of Hockanum, Conn. Mr. Brewer has raised enormous crops by following an intensive system of fertilization and cultivation. We have not been successful in ripening it on the station farm. At the time of cutting (September 15) the ears were hardly in milk, and consequently not suitable to harvest for grain. It evidently needs a somewhat longer growing season than is usually experienced in the vicinity of Amherst.

Early Mastodon. — Yellow dent. Bred by C. S. Clark of Ohio. A large growing variety evidently rather too late for grain in Massachusetts.

Klondike. — Yellow dent. Quite like the *Early Mastodon* in appearance, but noticeably later and unsuited to New England conditions.

Red Cob Silage. — White dent. Medium late.

White Cap Yellow Dent. — Resembles *Leaming* in size, but matures rather later. Fairly satisfactory for silage.

Wing's Improved White Cap. — Originated by J. E. Wing of Ohio. Some of the stalks bore two ears. It would probably form a very satisfactory variety in the middle western States, but the season is not sufficiently long to enable it to reach maturity in New England.

Eureka White Dent. — A large growing southern variety. It reaches a height of some 13 or more feet and has very coarse stalks. It has never matured in Amherst. The ears set very high on the stalk and the kernels are forming by September 15.

Yield Per Acre of Entire Corn Plant (Pounds).

Year.	VARIETY.	Condition.	Total Yield.	Dry Matter.
1909	Twitchell's,	Mature,	13,800	4,236
1908	Sanford White,	Mature,	28,400	8,148
1908	Longfellow,	Mature,	34,960	8,981
1910	Longfellow,	Mature,	25,400	6,480
1904	Pride of the North,	Fairly ripe, kernels glazing,	27,800	6,253
1906	Pride of the North,	Mature,	42,600	11,664
1907	Pride of the North,	In milk, not quite ripe,	28,500	5,141
1908	Rustler,	Mature,	23,067	7,843
1909	Rustler,	Mature,	27,100	5,328
1910	Rustler,	Mature,	22,400	6,772
1906	Leaming,	Mature,	51,560	12,307
1907	Leaming,	In milk, not quite ripe,	28,200	5,144
1909	Brewer's,	In milk, green,	35,100	6,286
1910	Brewer's,	In milk, green,	28,100	7,226
1908	Early Mastodon,	In milk to dent stage, green,	39,320	9,488
1909	Early Mastodon,	In milk to dent stage, green,	36,220	6,436
1908	Klondike,	Green and poorly eared,	37,340	9,069
1908	Red Cob Silage,	In milk to dent stage, green,	43,500	11,210
1908	White Cap Yellow,	In milk to dent stage, green,	35,300	11,038
1909	White Cap Yellow,	In milk to dent stage, green,	24,900	5,784
1909	Wing's Improved White Cap,	In milk, green,	28,300	5,671
1904	Eureka,	Immature, kernels scarcely formed,	40,800	6,671
1910	Eureka,	Immature, ears just forming,	43,800	9,044

The preceding table shows the total yield per acre as cut and also the total yield of dry matter. The entire crop for each one-twentieth acre plot was cut and immediately hauled to the barn and weighed. The dry matter was determined by taking a representative sample at the time of harvesting, running it through a cutter, subsampling, placing the subsample in a glass-stoppered jar and drying at 100° C.

Twitchell's corn was well matured in spite of the unfavorable season, and although the 4,236 pounds of dry matter

were much less than for any of the other varieties, it probably represented a fair average yield of its kind.

The yields of Longfellow and Sanford, both grown in favorable seasons, may be considered normal in amount. The season of 1908 was rather better than 1910, which would probably account for the larger yield of Longfellow corn in the former year.

Pride of the North was grown during three seasons. The seasons of 1904 and 1907 were both unfavorable, while 1906 was especially satisfactory, and in this year it yielded approximately twice as much dry matter as was secured in the average crop of the other two seasons.

Rustler, also grown for three seasons, showed a reasonably uniform dry matter content with the highest yield in the more favorable season (1908).

Leaming, grown in a favorable and unfavorable season, yielded over twice as much dry matter in the favorable year.

Brewer's dent, which evidently needs a longer growing season for its maturity than the average in Massachusetts, did not show a very decided variation between the two years.

Early Mastodon and White Cap Yellow, both grown in 1908 and 1909, showed the larger yields in 1908, the more favorable year.

Klondike and Red Cob Silage were both grown in 1908, a favorable year. Neither ripened satisfactorily, but showed good yields of dry matter. The former was noticeably immature when harvested.

Wing's Improved White Cap — grown in 1909, a poor corn year — did not yield well, and evidently needs a longer growing season.

Eureka, grown in 1909 and 1910, showed the better yield in 1910. In neither case was the corn well matured, nor did it show a larger yield of dry matter than some of the smaller varieties that showed a very much larger percentage of mature ears.

The total yield of dry matter, rather than the green material, gives a much better indication of the value of the crop for feeding purposes. A green, immature crop will often furnish a large apparent yield, but it contains an excessive amount of

water. This fact is especially evidenced by the Eureka and Klondike which, while they gave high yields of green material, did not show the highest production of dry matter.

Morrow,¹ as a result of four years' observations, states that in no year was there more than half the total amount of dry matter when the plant had reached its full height, and not more than 75 per cent. of the maximum when the ears were in dough stage. Ladd,² as a result of a two years' experiment, found the greatest weight of green fodder to be between the period of full silking and milky stage of kernel, and that while the total weight diminished after this date the total dry matter increased. Our own results, corroborated by those of other investigators, indicate that such varieties as the Twitchell, Sanford, Longfellow, Pride of the North (in one case) and Rustler can be considered as having reached a maximum weight in dry matter under the conditions in which they were grown. The remaining varieties, with the exception of the Eureka, would surely have increased in dry matter and decreased in total weight had their growing season been longer, while the Eureka would probably have increased in both total weight and dry matter. On account of their high water content and less mature condition the last 8 varieties in the preceding table cannot be considered as valuable pound for pound as the more mature types.

Effect of Season on Yield.

The following data, taken from the Massachusetts Crop Report, will show the weather conditions for the years during which the corn was grown: —

- 1904.** Season, as a whole, cool and dry which made corn unusually late and poorly ripened.
- 1906.** Season, as a whole, warm, especially in July and August. Good rainfall in June and July, hot and humid weather in August, with warm, dry weather the first part of September. The weather conditions were very favorable for corn and the crop ripened exceedingly well.
- 1907.** Season, as a whole, hot and dry. August being the hottest month for thirty-six years. A late spring, together with succeeding dry weather, hindered the development of the crop which was below normal.

¹ Bul. No. 25, Ill. Exp. Sta., p. 200.

² Eighth Ann. Rept., N. Y. Exp. Sta., p. 90.

- 1908.** Season variable, with high temperature and rainfall at opportune times. July hot with little rain till the last part. August cool with plenty of rain. The early part of September dry and warm which hastened the development of the crop that was exceptionally good.
- 1909.** Season, as a whole, dry and cool. The crop germinated well, but the growth was checked by drought and cool weather to such an extent that in many cases the ears did not ripen in spite of no killing frosts until late.
- 1910.** Season, as a whole, hot and dry. Rain at such times as to greatly benefit crop, which was above normal and well matured.

The most striking feature brought out by the preceding table is the extreme variation in yield, not only between different varieties, but between the same varieties grown in different years. This point is well illustrated by *Pride of the North*, grown in 1904, 1906 and 1907, the yield being a third more for 1906, a very favorable corn year. Morrow¹ found this to be the case in experiments conducted in Illinois, and states that the rain and heat were more influential on the rate of growth than the difference in the variety of corn. It is believed that the total yield of dry matter can be affected by climatic conditions in two ways: a lack of rain at critical periods may cause the corn to ripen before it has obtained its maximum growth, while a cold, wet season will retard the growth of the crop so that it does not reach maturity in the growing season.

The data in the above table make especially clear that:—

1. The small varieties as represented by the *Twitchell*, because of the relatively low yield of total dry matter, are not economical for Massachusetts conditions.

2. The flint varieties, such as *Longfellow* and *Sanford* and the medium dents—*Rustler* and *Pride of the North*—are quite well suited for grain and also serve fairly well for silage.

3. The larger medium dents—including the *Leaming*, *White Cap Yellow*, *Red Cob* and *Early Mastodon*—give a very good yield of dry matter, and in average season bring their ears to the milk stage. All conditions considered, these varieties are rather preferable for silage purposes.

4. The coarse, late maturing varieties as represented by the

¹ Bul. No. 31, Ill. Exp. Sta., p. 363.

Klondike, Wing's Improved, Brewer's, and particularly the Eureka, while yielding a fair average amount of dry matter are not satisfactory because of their failure to mature; the resulting silage has been repeatedly shown by other observers as being watery, sour and of less nutritive value.

5. The season has a marked influence upon the yield of the corn crop, the same variety of corn under otherwise identical conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

Composition of Different Varieties of Corn Fodder (Entire Plant) (Per Cent.).

[As harvested.]

Number of Analyses.	VARIETY.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1	Twitchell's,	69.11	3.03	.94	20.21	5.34	1.37
1	Sanford White,	71.31	1.97	.75	19.03	5.78	1.16
1	Longfellow,	74.31	2.30	.60	16.38	5.03	1.38
6	Pride of the North,	75.33	2.02	.60	15.74	5.18	1.13
3	Rustler,	71.62	2.17	.68	18.36	5.94	1.23
4	Leaming,	76.85	1.77	.47	14.21	5.60	1.10
2	Brewer's,	81.35	1.82	.27	10.90	4.72	.94
3	Early Mastodon,	77.77	1.86	.41	13.77	5.14	1.05
1	Klondike,	75.71	1.31	.42	14.09	6.98	1.49
1	Red Cob Silage,	74.23	1.58	.40	15.69	6.93	1.17
2	White Cap Yellow Dent,	72.75	2.17	.50	17.38	6.02	1.18
2	Wing's Improved White Cap,	80.39	1.72	.32	12.06	4.53	.98
1	Eureka,	82.58	1.63	.27	9.26	4.78	1.08

Composition of Different Varieties of Corn Fodder (Entire Plant) (Per Cent.).

[Dry Matter.]

Number of Analyses.	VARIETY.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1	Twitchell's,	9.82	3.05	65.43	17.28	4.42
1	Sanford White,	6.85	2.61	66.36	20.13	4.05
1	Longfellow,	8.96	2.34	63.77	19.56	5.37
6	Pride of the North,	8.18	2.43	63.08	21.01	4.58
3	Rustler,	7.66	2.39	64.68	20.94	4.33
4	Leaming,	7.63	2.01	61.40	24.19	4.77
2	Brewer's,	9.75	1.43	58.43	25.33	5.06
3	Early Mastodon,	8.37	1.85	61.97	23.10	4.71
1	Klondike,	5.43	1.72	57.99	28.74	6.14
1	Red Cob Silage,	6.12	1.57	60.87	26.90	4.54
2	White Cap Yellow Dent,	7.98	1.83	63.78	22.10	4.33
2	Wing's Improved White Cap,	8.75	1.65	61.48	23.10	5.02
1	Eureka,	9.34	1.54	55.52	27.41	6.19

The varieties of corn given in the preceding tabulation can be divided into four different groups according to their period of ripening.

1. Mature (dents and flints): Twitchell's, Sanford White, Longfellow, Pride of the North and Rustler.

2. Medium mature (coarse dents): Leaming, Early Mastodon, Red Cob Silage and White Cap Yellow Dent.

3. Immature (very coarse dent): Brewer's, Klondike and Wing's Improved White Cap.

4. Very immature (very coarse dent): Eureka.

The average water content of the four groups was as follows: —

	Per Cent.
Mature,	74.34
Medium mature,	75.40
Immature,	79.15
Very immature,	82.58

While there is a gradual diminution in the water content from the time that the ears are formed until maturity, as shown by this table, the total dry matter gradually increases to maturity.¹

It is not believed that, owing to individual variations, conclusions can be readily drawn relative to the chemical composition of the different varieties. By averaging the four groups previously given the following results are obtained: —

Dry Matter (Per Cent.).

	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Mature,	8.29	2.56	64.81	19.78	4.55
Medium mature,	7.52	1.82	62.09	24.07	4.59
Immature,	7.97	1.60	59.30	25.72	5.41
Very immature,	9.34	1.54	55.52	27.41	6.19

The very green, immature corn contains a larger relative percentage of protein, but more of it in the amido form.² The fat, and particularly the nitrogen-free extract matter, increase the more mature the variety. This is to be expected, for the corn is a carbohydrate plant, and stores up large amounts of starch in the latter stages of its growth. As the starch increases the percentage of fiber and ash relatively decrease. The ash is always at its highest point in the early stages of development.

¹ Ladd, N. Y. Exp. Sta., Rept., 1889.

² Eighth Ann. Rept. N. Y. Exp. Sta., p. 90.

The preceding facts are substantiated by the investigations of Schweitzer,¹ Jordan,² Ladd³ and others.

The general conclusion can be drawn that the changes in chemical composition which the plant undergoes in its development are such that its maximum feeding value exists at its maturity.

DIGESTIBILITY OF THE PLANT.

The digestibility of 7 representative varieties of the entire plant was determined with sheep. The method followed in conducting such experiments is illustrated and described in detail elsewhere.⁴ The entire data of the several experiments have been presented in previous reports; only the digestion coefficients, therefore, are given in this connection. As only four sheep were available, but two duplicate digestion trials could be completed in a single season. The method of procedure was as follows: each experiment was begun about September 5th, when the sheep received their first feeding. The corn was allowed to stand in the field, sufficient being cut for only two consecutive days. The entire digestion period lasted fourteen days, the first seven of which were preliminary. The corn was cut in 2-inch pieces before being fed. Two days' feeding were weighed out in advance, and samples taken for dry-matter determinations and for complete chemical analysis. The difference between the amount and chemical composition of the fodder fed and the amount and chemical composition of the feces excreted served as a basis for computing the amount digested and utilized by the animals.

¹ Bul. No. 9, Mo. Exp. Sta.

² Ann. Rept. Me. Exp. Sta., 1893.

³ Eighth Ann. Rept. N. Y. Exp. Sta., 1899.

⁴ Eleventh Rept. of the Mass. State Agr. Exp. Sta., pp. 126-149; also 22d Rept. of the Mass. Agr. Exp. Sta., p. 84.

*Digestion Coefficients.*¹
[Per Cent. Dry Matter digested.]

VARIETY CORN.	Condition of Crop at Time of Harvest.	DIGESTION COEFFICIENTS.					
		Dry Matter.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Pride of the North, . . .	In dough to denting, . .	71	63	76	77	65	34
Pride of the North, . . .	In dough to denting, . .	77	63	84	84	66	36
Rustler,	In dough to denting, . .	69	43	76	78	59	28
Leaming,	Corn in late milk, . . .	70	60	76	77	61	36
Brewer's,	Corn in milk,	72	69	68	77	69	46
Early Mastodon,	Corn in milk,	72	57	81	79	60	36
Wing's Improved White Cap,	Corn in milk,	70	63	70	76	65	39
Eureka,	Kernels just forming, . .	67	67	66	72	60	42
Pride of the North stover, .	- - -	54	45	64	54	60	31
Eureka stover,	- - -	54	48	67	53	59	45

A study of the above coefficients shows no wide variations in the relative digestibility of the several varieties. Naturally the larger the percentage of ear present the higher should be the digestibility of the entire plant, the grain having a much higher digestibility than the stalk. This in a general way is made clear by classifying the results according to the stage of growth. Corn that is immature and with ears partially formed may show nearly as high an absolute digestibility as a mature variety because of the soft, incompletely developed stalks. If it had been possible to determine the net available energy of each variety according to the method employed by Kellner,² those varieties having the mature ears would unquestionably have shown a much larger amount of energy than the less mature varieties.

Attention may also be called to the variation in the percentage of nitrogen-free extract of the several varieties. With one exception³ the digestibility varies to a limited extent inversely

¹ For figures in detail see supplement.

² The Scientific Feeding of Animals, pp. 48-50.

³ In case of Rustler Dent rather more was fed than the animals could well utilize, which explains the low coefficient for this variety.

with the percentage of nitrogen-free extract, or, otherwise explained, the larger the percentage of extract or starchy matter present, the higher the digestibility of the corn plant.

A division and tabulation of the results according to the stage of growth of the varieties gives us the following results: ¹ —

Dry Matter.

	Average Yield per Acre.	Per Cent. digested.	Pounds per Acre digested.
Mature,	7,686	74	5,688
Medium mature,	8,344	71	5,924
Immature,	6,394	71	4,540
Very immature,	7,858	67	5,265

It would appear from the above that the larger growing varieties, such as Leaming, Red Cob, Early Mastodon and White Cap, will produce rather more dry and digestible matter than do the medium dent or flints as typified in the Longfellow or Rustler, and the former varieties, on the whole, are to be given the preference for silage purposes. It is questionable, however, if they furnish any more final nutritive effect (net available energy) than do the varieties that will thoroughly mature by the middle of September. The percentage of dry matter digested, on the other hand, is in favor of the mature varieties. The extremely late varieties, such as the Eureka and Klondike, are not at all suited to New England conditions.

Experiments were made with a sample of Pride of the North and a sample of Eureka corn stover during the year of 1904, the two lots proving to be equally digestible. The former variety of stover contained 18.13 per cent. of water when sampled (December 27), and the latter contained 59.92 per cent. (February 29). Both samples had been stored in the barn since late autumn. When drawn from the field the former contained 37.84 per cent. and the latter 68.92 per cent. of water. The Eureka stover, because of its coarse, immature condition, retained the moisture to a much greater extent than did the fully matured corn.

¹ Omitting coefficients for Rustler Dent from the mature varieties.

*Proportions and Composition of Parts.**(a) Proportions at Time of Cutting (100 Pounds).*

Year.	VARIETY.	Stalks.	Leaves.	Husks.	Ears.
1909	Twitchell's,	27	26	10	37
1908	Sanford White,	45	20	11	24
1908	Longfellow,	43	21	10	21
1910	Longfellow,	38	25	9	28
1901	Pride of the North,	47	20	11	22
1906	Pride of the North,	40	17	12	31
1907	Pride of the North,	52	16	14	18
1908	Rustler,	46	19	7	28
1909	Rustler,	41	14	15	30
1910	Rustler,	40	19	9	32
1906	Leaming,	48	19	11	22
1907	Leaming,	52	17	12	19
1909	Brewer's,	51	17	13	19
1910	Brewer's,	53	17	10	20
1908	Early Mastodon,	52	19	9	20
1909	Early Mastodon,	50	18	12	20
1908	Klondike,	62	19	9	10
1903	Red Cob Silage,	53	17	12	18
1908	White Cap Yellow,	46	19	11	24
1909	White Cap Yellow,	50	16	12	22
1909	Wing's Improved White Cap,	52	19	10	19
1904	Eureka,	64	22	7	7
1910	Eureka,	62	21	7	10

(b) Proportions in Dry Matter (100 Pounds).

Year.	VARIETY.	Stalks.	Leaves.	Husks.	Ears.
1909	Twitchell's,	15	21	9	55
1908	Sanford White,	35	20	10	35
1908	Longfellow,	34	18	9	39
1910	Longfellow,	23	21	7	49
1904	Pride of the North,	37	18	9	36
1906	Pride of the North,	28	14	9	49
1907	Pride of the North,	50	19	11	20
1908	Rustler,	33	19	7	41
1909	Rustler,	32	13	12	43
1910	Rustler,	30	17	8	45
1906	Leaming,	41	19	9	31

(b) Proportions in Dry Matter (100 Pounds) — Concluded.

Year.	VARIETY.	Stalks.	Leaves.	Husks.	Ears.
1907	Leaming,	48	20	10	22
1909	Brewer's,	51	20	12	17
1910	Brewer's,	47	20	10	23
1908	Early Mastodon,	44	19	9	28
1909	Early Mastodon,	47	21	11	21
1908	Klondike,	59	22	7	12
1908	Red Cob Silage,	50	19	11	20
1908	White Cap Yellow,	38	19	10	33
1909	White Cap Yellow,	47	19	11	23
1909	Wing's Improved White Cap,	52	23	9	16
1904	Eureka,	63	25	6	6
1910	Eureka,	59	28	6	6
	Average,	42	20	9	29

Condition of Crop when cut and Character of Season.

- 1904.** *Poor Corn Year.* — Varieties grown: Pride of the North and Eureka. In spite of the unfavorable season, Pride of the North was fairly ripe when cut and contained a fair proportion of ear. The Eureka was quite immature, with ears just forming.
- 1906.** *An Exceptionally Favorable Corn Year.* — Varieties grown: Pride of the North and Leaming. Both matured, gave a large total yield and showed a noticeably large proportion of ears.
- 1907.** *Poor Corn Year.* — Varieties grown: Pride of the North and Leaming. Neither variety did as well as in 1906 and the proportion of ear was much less.
- 1908.** *Satisfactory Corn Year.* — Varieties grown: Sanford White, Longfellow, Rustler, Early Mastodon, Klondike, Red Cob Silage and White Cap Yellow. Of these the first three were fully developed when cut, and showed a larger development of ear than did the last four, which were in the milk-to-denting stage. White Cap Yellow was the best developed of the last-named varieties, and showed a fair proportion of ear.
- 1909.** *Poor Corn Year.* — Varieties grown: Twitchell's, Rustler, Brewer's, Early Mastodon, White Cap Yellow, Wing's Improved White Cap. The first two varieties matured. The Twitchell, a very small variety, has a short stalk with a long ear setting low on the stalk. It showed the largest proportion of ear of any variety raised. The last three varieties were in milk when cut.

1910. *Favorable Corn Year.* — Varieties: Longfellow, Rustler, Brewer's, Eureka. The first two varieties were mature when cut. Brewer's was in milk and the ears just forming on the Eureka.

It will be observed that in many cases the proportion of the several parts differ in the green stage and on the dry-matter basis. Thus Twitchell's shows 27 per cent. of stalk when cut and only 15 per cent. when all of the water is eliminated. Sanford White shows 24 per cent. of ears when cut and 35 per cent. in dry matter.

The remarks which follow refer to the proportions of the parts on the basis of dry material. In general it may be said that there is a wide difference between the proportion of stalks and ears; the difference between the leaves and husks is less marked.

A decided difference is noted between the *same variety* grown in *different* years. This variation is evidently due, to some extent, to the stage of maturity of the plant when cut and also to unfavorable conditions, which checked the development of the ear. *The stalks and ears form practically 70 per cent. of the dry matter of the plant. The leaves and husks 30 per cent.* From the data at hand the inference can be drawn that this is an inherent characteristic of the maize plant. While other investigators¹ have determined the relative proportions of the plant, it is believed that this fact has not before been noticed.

Those coarse varieties maturing late naturally have less ear and a correspondingly larger proportion of stalk. Note the mature varieties, including the Longfellow with an average of 28 per cent. of stalk and 44 per cent. of ears; the Pride of the North with an average of 38 per cent. of stalk and 35 per cent. of ears; the Rustler with 32 per cent. of stalk and 35 per cent. of ears, against the later maturing varieties, such as the Brewer's with 49 per cent. of stalk and 19 per cent. of ears; the Leaming with 44 per cent. of stalk and 26 per cent. of ears; and finally the Eureka with 61 per cent. of stalk and 6 per cent. of ears. On the whole, the proportion of leaves and husks does not vary widely in any of the varieties, averaging 20 per cent. for the leaves and 9 per cent. for the husks. The Eureka shows rather

¹ Schweitzer, Bul. No. 9, Mo. Exp. Sta., Caldwell, Bul. Nos. 7-11; Rept. of 1890, pp. 30-43, Pa. Exp. Sta.; Bul. No. 21, Iowa Exp. Sta.

more leaf and correspondingly less husk than the other varieties; in fact, this variety as cut was largely stalk and leaf.

The following general conclusions can be drawn:—

1. The stalks and ears form substantially 70 per cent. of the entire maize plant.

2. The small, early maturing varieties of which the Twitchell is a type show an exceptionally large proportion of ears.

3. The mature medium varieties average 33 per cent. of stalk and 37 per cent. of ears.

4. The coarser, less mature varieties show 45 per cent. of stalk and 26 per cent. of ears.

5. The very coarse, immature varieties (excepting Eureka) show 52 per cent. of stalks and 17 per cent. of ears.

6. Most of the varieties have in the vicinity of 20 per cent. of leaves and 10 per cent. of husks.

The above conclusions are for corn grown in Massachusetts and cut about September 15. These conclusions might not hold, especially for the larger immature varieties, had they been ripe at the time of cutting.

Average Composition of Parts (Per Cent.).

Number of Analyses.	VARIETY.	Water.	DRY MATTER.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
<i>Stalks.</i>							
2	Pride of the North, . . .	79.84	4.04	.89	56.52	32.91	5.64
2	Leaming,	80.97	3.91	.94	58.94	31.56	4.65
1	Eureka,	83.08	4.80	1.07	52.94	35.77	5.42
<i>Leaves.</i>							
2	Pride of the North, . . .	76.28	13.99	3.39	48.89	24.06	9.67
2	Leaming,	76.53	13.65	3.03	48.89	25.16	9.27
1	Eureka,	81.17	14.53	2.43	45.63	28.43	8.98
<i>Husks.</i>							
2	Pride of the North, . . .	77.49	5.14	1.36	62.23	27.98	3.29
2	Leaming,	81.87	6.77	1.50	61.69	26.74	3.30
1	Eureka,	85.35	8.66	1.46	62.22	24.64	3.02
<i>Ears.</i>							
2	Pride of the North, . . .	56.54	9.53	3.73	75.50	9.46	1.78
2	Leaming,	71.77	9.56	2.90	71.48	13.82	2.24
1	Eureka,	86.91	12.00	1.44	63.84	19.47	3.25

While the analyses are not sufficient in number to enable one to draw any positive conclusions, attention may be called to a few of the more striking facts.

Stalks. — A comparatively low percentage of both protein and fat is noted in the stalks of all the several kinds. The proportion of extract matter is lowest in the Eureka and the fiber percentage the highest.

Leaves. — The protein percentage is highest in the leaves. Naturally, the fiber percentage is less in the leaves than in the stalks, while the percentage of ash is noticeably high and quite constant for the three types. The leaves of the three varieties analyzed resemble each other quite closely in the proportion of all of the several groups of constituents.

Husks. — The one noticeable difference in the case of the husks of the several varieties consists in the low protein content in the Pride of the North and the high protein content of the Eureka. This is, of course, due to the fact that the ears of the latter were in the formative stage, while those of the former had matured and the protein had entered into the kernel. The fiber content of the Pride of the North was somewhat higher than that contained in the Eureka, which is explained on similar grounds.

Ears. — The composition of the ears of the three varieties indicate a very immature condition on the part of the Eureka, — high protein and fiber and low carbohydrates and fat, — and a reasonably mature condition of the ears yielded by the Pride of the North and Leaming.

RELATIVE PROPORTIONS OF GRAIN AND COB.

Ten representative ears of corn were selected at the time of husking from the crops of 1908 and 1909 and preserved for analysis. The corn and cob were weighed separately at the time of shelling, dry-matter determinations made, and percentage of cob and kernel determined.

Weights of Ten Average Ears with Proportion of Kernel and Cob in Dry Matter.

VARIETY.	Condition when cut.	DRY MATTER (POUNDS).			DRY MATTER (PER CENT.).	
		10 Ears.	Kernel.	Cob.	Kernel.	Cob.
Twitchell's,	Mature.	3.37	2.93	.44	86.9	13.1
Sanford White,	Mature.	3.37	2.65	.72	78.6	21.4
Longfellow,	Mature.	3.53	2.95	.58	83.6	16.4
Rustler,	Mature.	4.71	4.08	.63	86.6	13.4
Rustler,	Mature.	4.87	4.23	.64	86.9	13.1
Average,		3.97	3.37	.60	84.5	15.5
Brewer's,	In milk.	4.29	3.57	.72	83.2	16.8
Early Mastodon,	In milk.	4.05	3.37	.68	83.2	16.8
Early Mastodon,	In milk.	5.48	4.55	.93	83.0	17.0
Klondike,	In milk.	3.60	2.66	.94	73.9	26.1
Red Cob Silage,	In milk.	4.37	3.59	.78	82.2	17.8
White Cap Yellow,	In milk.	3.70	3.12	.58	84.3	15.7
White Cap Yellow,	In milk.	3.71	3.11	.60	83.8	16.2
Wing's Improved White Cap,	In milk.	4.14	3.39	.75	81.9	18.1
Average,		4.17	3.42	.75	81.9	18.1

Wide variations were noted depending upon stage of ripeness. The Twitchell, a long eared and early maturing flint, showed the smallest percentage of cob (13.1), and the Klondike, a quite immature dent, the largest amount of cob (26.1). The average of the several mature types was 15.5 per cent. cob, and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 for cob and 81.9 for kernel. If the less mature varieties had been grown in a climate favorable to their complete maturity, it is probable that they would have shown equally as favorable a proportion of cob and kernel.

The weight of the Massachusetts legal bushel in case of shelled corn is 56 pounds, and for a bushel of ears 70 pounds. This allows 14 pounds, or 20 per cent., for the cob. With but two exceptions the samples tested contained less than 20 per cent. cob in dry matter. Assuming that the standard of 70 pounds per bushel for corn was based upon the average of a large number of trials, is it not possible that the corn crop has

been improved since the time that such a standard was adopted, and that corn is now being grown that contains relatively less cob and more kernel than formerly?

The results of these trials are substantiated by work done by the author in connection with corn grown for the Bowker prize in 1910. The proportions of corn and cob in dry matter in 10 representative ears of 9 varieties were determined with the following results:—

	Grain (Per Cent.).	Cob (Per Cent.).
1. Flint,	83.7	16.3
2. Flint,	84.8	15.2
3. Flint,	85.8	14.2
4. Flint,	78.7	21.3
5. Flint,	83.6	16.4
6. Flint,	84.6	15.4
Average,	83.5	16.5
7. Dent,	85.0	15.0
8. Dent,	80.7	19.3
9. Dent,	83.9	16.1
Average,	83.2	16.8

COMPOSITION OF GRAIN AND COB.

During the seasons of 1908 and 1909 samples of corn kernels were analyzed with the following results:—

Analyses of Grain (Per Cent.).

[Dry Matter.]

Year.	VARIETY.	Condition.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Starch.
1909	Twitchell's,	Mature.	11.30	5.12	80.49	1.58	1.51	67.54
1908	Sanford White,	Mature.	10.92	5.22	80.83	1.53	1.50	71.35
1908	Longfellow,	Mature.	10.80	5.46	80.72	1.43	1.59	70.86
1908	Rustler,	Mature.	9.55	4.44	82.79	1.77	1.45	72.84
1909	Rustler,	Mature.	9.56	4.55	82.33	1.41	1.52	70.00
1909	Brewer's,	In milk.	9.64	3.97	81.99	2.70	1.70	67.27
1908	Early Mastodon,	In milk.	9.22	4.62	82.29	2.33	1.54	72.98
1909	Early Mastodon,	In milk.	9.69	4.36	82.06	2.21	1.68	68.39
1908	Klondike,	In milk.	10.81	4.40	80.73	2.27	1.79	71.48
1908	Red Cob Silage,	In milk.	10.69	3.61	81.80	2.33	1.57	72.70
1908	White Cap Yellow,	In milk.	10.30	3.93	82.13	2.09	1.55	73.13
1909	White Cap Yellow,	In milk.	9.06	4.42	82.77	2.24	1.51	69.16
1909	Wing's Improved White Cap,	In milk.	10.21	4.35	81.18	2.52	1.74	67.90

A study of the analytical results shows very slight variations in composition. The protein of the first varieties is

rather in excess of the Rustler Dent. The protein of the coarse, less mature dents would probably have been somewhat less had they been more completely matured. The fiber percentage is noticeably less in the mature lots, 1.54 as against 2.34 for the immature types. A high fiber is believed to be characteristic of immature corn. The percentages of starch are remarkably uniform.

While corn has been bred in an experimental way which bore decidedly different chemical characteristics (namely, high protein, high starch and high fat), such corn has not come into general use; when, therefore, the grain is grown primarily as a food for stock it is believed that the farmer can do no better than to grow the variety that will in his experience produce the largest number of bushels of mature corn per acre. This fact is borne out not only by the analyses herein reported, but also by others made by the author. Chemical composition cannot, at the present time, be considered a factor in the selection of seed corn where the crop is used for the sustenance of live stock.

An evident effect of the season upon the starch content is shown in the case of Rustler, Early Mastodon and White Cap Yellow, all grown in two successive years. In each case the starch content was slightly lower for 1909, an unfavorable year.

Analysis of Corn Cob (Per Cent.).

[Dry Matter.]

Year.	VARIETY.	Condition.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1908	Sanford White, . . .	Mature.	1.97	.27	58.21	38.01	1.54
1908	Longfellow, . . .	Mature.	1.98	.30	59.11	36.91	1.70
1908	Rustler, . . .	Mature.	1.70	.44	62.15	34.12	1.59
1908	Early Mastodon, . . .	In milk.	1.84	.32	60.79	35.49	1.56
1908	Klondike, . . .	In milk.	2.21	.38	61.80	33.86	1.75
1908	Red Cob Silage, . . .	In milk.	2.09	.38	60.07	35.75	1.75
1908	White Cap Yellow Dent,	In milk.	2.17	.34	60.08	35.98	1.49
	Average, . . .	-	1.99	.33	60.32	35.73	1.63

The above analyses represent the product of several varieties of cob produced during the season of 1908. One notes com-

paratively little variation in the composition. The cob is characterized by its very low protein and fat content and its high extract matter and fiber. It is doubtful if the cob from any number of different varieties would show substantial variations from the figures reported above. Lindsey and Holland¹ have shown the cob to contain over 30 per cent. of pentosans which have a digestibility of 63 per cent., and, further,² that the total dry matter of the cob has a digestibility of 59 per cent. So far as known, further studies of the chemical character of the extract matter have not been made. It is evident that the chief feeding value of the cob is to be found in its 59 per cent. of digestible carbohydrates.

On the basis of the work done by Kellner,³ the net available energy in 100 pounds of cob containing 11 per cent. water is 40.2 therms, as against 85.5 therms in a like amount of corn meal; or 100 pounds of corn cob has 47 per cent. of the energy value of corn meal.

The practical feeder, therefore, cannot afford to pay grain prices for the cob when used as an adulterant of wheat-mixed feed, hominy meal or the like. Its use, however, is warranted when produced upon the farm and ground together with the kernel as a food for farm animals.

SUMMARY.

Yield. — The small, early maturing types of corn are not economical for Massachusetts conditions; the medium dent and flint varieties that will mature in the average season are quite well suited for grain, and also serve fairly well for silage. The larger medium dent varieties that in an average season bring their ears to the milk stage are, all conditions considered, rather preferable for silage purposes, while the coarse, late maturing varieties, which never ripen seed in this locality, are not satisfactory because of the less net available energy produced (actual food value).

The season has a marked influence upon the yield of the corn crop, the same variety of corn under otherwise identical

¹ Fifteenth Rept. of the Hatch Exp. Sta., pp. 73-79.

² Eighteenth Rept. of the Hatch Exp. Sta., p. 243.

³ Die Ernährung die Landw. Nützhire, fünfte Auflage, pp. 159-169, also p. 601.

conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

Composition of the Corn Plant. — The general conclusion can be drawn that the changes in chemical composition which the plant undergoes in its development are such that its maximum feeding value exists at its maturity.

Digestibility of the Corn Plant. — Digestion experiments conducted with the entire corn plant showed no wide variation in the digestibility of the several varieties, the range being from 67 to 77 per cent. With one exception the digestibility appeared to depend upon the percentage of nitrogen-free extract. The higher the percentage of extract or starchy matter present, the higher the digestibility.

Proportion and Composition of Parts. — The stalks and ears form practically 70 per cent. of the dry matter of the plant, the leaves and husks 30 per cent.

Relative Proportion of Grain to Cob. — The percentage of grain to cob varies widely, depending to some extent upon the maturity of the plant when cut. The average for the several mature types was 15.5 per cent. cob and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 per cent. cob and 81.9 per cent. kernel. In either case the percentage of cob was less than that of the Massachusetts legal bushel, which in the case of shelled corn is 56 pounds, and for ear corn 70 pounds, thus allowing 14 pounds, or 20 per cent., for cob.

Composition of Grain and Cob. — The grain analyzed showed only slight variations in composition. Chemical composition cannot at the present time be considered a factor in the selection of seed corn where the crop is used for the sustenance of live stock.

There appears to be very little variation in the composition of the corn cob. The net available energy in 100 pounds of cob, after the method of calculation suggested by Kellner, is 40.2 therms as against 85.5 therms in a like amount of corn meal; hence on this basis ground corn cob would have 47 per cent. of the energy value of corn meal.¹

¹ The Kellner method of calculation is the best we have for making comparative estimates of relative values.

THE DIGESTIBILITY OF CATTLE FOODS.

BY J. B. LINDSEY AND P. H. SMITH.

The digestion experiments herein reported were made during the autumn, winter and early spring of 1906-07, 1908-09 and 1909-10, and form part of what are known as Series XII., XIV. and XV. The experiments made in these series and not here included have been published in previous reports.

The usual method was employed and has been fully described elsewhere.¹ The full data are here presented, with the exception of the daily production of manure and the daily water consumption, in which cases, to economize space, averages only are given. The periods extended over fourteen days, the first seven of which were preliminary, collection of feces being made during the last seven. Ten grams of salt were given each sheep daily with water *ad libitum*.

SERIES XII.

Three lots of Southdown wethers were employed and were known as Old Sheep, Young Sheep and Paige Sheep. The former were fully seven years of age, and the latter two lots four to five years old.

The hay used in connection with the several experiments consisted of fine-mixed grasses, and contained a large proportion of June grass. The digestion coefficients of this hay as applied to the experiments in this series were obtained in 1905, and were as follows:—

¹ Eleventh report of the Mass. State Agr. Exp. Sta., pp. 146-149; also the 22d report of the Mass. Agr. Exp. Sta., p. 84.

Digestion Coefficients used in these Experiments.¹

[English Hay.]

	Old Sheep II. and III.	Young Sheep I., II. and III.	Paige Sheep IV. and V.
Dry matter,	67.87	65.92	65.48
Ash,	49.17	51.95	44.60
Protein,	62.31	61.98	61.53
Fiber,	76.30	72.87	73.81
Nitrogen-free extract,	66.39	64.66	64.46
Fat,	52.37	54.23	50.20

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

	Ash.	Protein.	Fiber.	Nitro- gen-free Ex- tract.	Fat.
Pride of the North corn fodder (entire plant),	4.07	7.69	17.96	67.62	2.66
Leaming corn fodder (entire plant),	4.69	7.80	22.42	62.94	2.06
English hay,	6.75	12.23	33.45	44.67	2.90
Biles Union grains,	6.67	27.11	10.55	47.45	8.22
Schumacher's stock feed,	4.44	11.73	11.70	67.31	4.82
Protena dairy feed,	7.28	19.56	20.16	49.92	3.05
Buffalo Creamery feed,	4.68	21.87	13.58	55.32	4.55
Waste, Paige Sheep, IV., Period I.,	3.77	8.70	14.28	69.92	3.33

Composition of Feces (Per Cent.).

[Dry Matter.]

Old Sheep II.

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitro- gen-free Ex- tract.	Fat.
I.	Pride of the North corn fodder,	10.21	11.74	27.77	48.65	1.63
VI.	Biles Union grains,	13.30	17.90	21.39	43.81	3.60

Old Sheep III.

II.	Leaming corn fodder,	9.67	10.90	28.21	49.49	1.73
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¹ Made in 1905.

Composition of Feces (Per Cent.) — Concluded.

[Dry Matter.]

Young Sheep I.

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
VIII.	Schumacher's stock feed, . . .	11.58	13.62	24.06	47.40	3.34
XIII.	Buffalo Creamery feed, . . .	10.07	13.59	25.17	47.61	3.56

Young Sheep II.

IX.	Biles Union grains,	11.32	17.33	22.28	45.71	3.36
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Young Sheep III.

VIII.	Schumacher's stock feed, . . .	11.63	12.95	25.14	46.91	3.37
XIII.	Buffalo Creamery feed, . . .	10.03	13.62	25.14	47.87	3.34

Paige Sheep IV.

I.	Pride of the North corn fodder, . . .	12.89	12.75	24.61	47.65	2.10
XII.	Protana dairy feed,	11.72	14.49	27.15	43.42	3.22

Paige Sheep V.

II.	Leaming corn fodder,	10.23	10.30	29.40	48.50	1.57
XII.	Protana dairy feed,	11.24	13.77	28.24	43.67	3.08

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Old Sheep II.

PERIOD.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protana Dairy Feed.	Waste.	Feces.
I.	-	29.50	-	-	-	-	-	-	89.78
VI.	88.20	-	-	-	-	90.91	-	-	92.15

Old Sheep III.

II.	-	-	24.52	-	-	-	-	-	89.92
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Young Sheep I.

VIII.	89.82	-	-	90.78	-	-	-	-	92.79
XIII.	90.65	-	-	-	90.55	-	-	-	94.48

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.)—Concluded.

Young Sheep II.

PERIOD.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protens Dairy Feed.	Waste.	Feces.
IX.	89.82	-	-	-	-	92.57	-	-	92.34

Young Sheep III.

VIII.	89.82	-	-	90.78	-	-	-	-	92.97
XIII.	90.65	-	-	-	90.55	-	-	-	94.26

Paige Sheep IV.

I.	-	29.50	-	-	-	-	-	36.26	90.19
XII.	90.45	-	-	-	-	-	91.36	-	94.55

Paige Sheep V.

II.	-	-	24.52	-	-	-	-	-	90.76
XII.	90.45	-	-	-	-	-	91.36	-	94.42

Average Daily Amount of Manure excreted and Water drunk (Grams).

Old Sheep II.

Period.	CHARACTER OF FOOD OR RATION.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Pride of the North corn fodder,	1,008	31.84	937
VI.	Biles Union grains,	751	25.63	1,899

Old Sheep III.

II.	Leaming corn fodder,	795	28.64	893
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Young Sheep I.

VIII.	Schumacher's stock feed,	540	24.96	1,936
XIII.	Buffalo Creamery feed,	545	25.68	2,286

Young Sheep II.

IX.	Biles Union grains,	770	25.41	2,271
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Average Daily Amount of Manure excreted and Water drunk (Grams)
— Concluded.

Young Sheep III.

Period.	CHARACTER OF FOOD OR RATION.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
VIII.	Schumacher's stock feed,	528	25.32	2,185
XIII.	Buffalo Creamery feed,	551	25.32	2,179

Paige Sheep IV.

I.	Pride of the North corn fodder,	613	20.03	1,401
XII.	Protena dairy feed,	823	26.36	1,364

Paige Sheep V.

II.	Leaming corn fodder,	1,143	29.91	1,050
XII.	Protena dairy feed,	769	27.03	1,764

Weights of Animals at Beginning and End of Period (Pounds).¹

Old Sheep II.

Period.	CHARACTER OF FOOD OR RATION.	Beginning.	End.
I.	Pride of the North corn fodder,	110.0	111.0
VI.	Biles Union grains,	108.5	103.5

Old Sheep III.

II.	Leaming corn fodder,	113.5	125.5
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Young Sheep I.

VIII.	Schumacher's stock feed,	102.0	101.5
XIII.	Buffalo Creamery feed,	102.0	100.0

Young Sheep II.

IX.	Biles Union grains,	93.5	89.0
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Young Sheep III.

VIII.	Schumacher's stock feed,	94.5	92.5
XIII.	Buffalo Creamery feed,	92.0	93.0

¹ The weights of the sheep in several cases vary much more widely than would be expected, and it is possible that errors were made in recording them. In order to guard against this, weights for two consecutive days are now made at the beginning and end of each trial.

Weights of Animals at Beginning and End of Period (Pounds) — Concluded.

Paige Sheep IV.

Period.	CHARACTER OF FOOD OR RATION.	Beginning.	End.
I.	Pride of the North corn fodder,	121.5	116.5
XII.	Protena dairy feed,	124.5	122.5

Paige Sheep V.

II.	Leaming corn fodder,	108.0	110.0
XII.	Protena dairy feed,	119.0	112.0

Pride of the North Corn Fodder, Period I.

Old Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3,600 grams Pride of the North corn fodder fed daily.	1,062.00	43.22	81.67	190.74	718.12	28.25
318.41 grams manure excreted,	285.87	29.19	33.56	79.39	139.08	4.66
Grams digested,	776.13	14.03	48.11	111.35	579.04	23.59
Per cent. digested,	73.08	32.46	58.91	58.38	80.63	83.50

Paige Sheep IV.

3,600 grams Pride of the North corn fodder fed daily.	1,062.00	43.22	81.67	190.74	718.12	28.25
335.4 grams waste,	121.62	4.59	10.58	17.37	85.04	4.05
Amount consumed,	940.38	38.63	71.09	173.37	633.08	24.20
200.26 grams manure excreted,	180.61	23.28	23.03	44.45	86.06	3.79
Grams digested,	759.77	15.35	48.06	128.92	547.02	20.41
Per cent. digested,	80.79	39.74	67.60	74.36	86.41	84.34
Average per cent. for both sheep,	76.94	36.10	63.26	66.37	83.52	83.92

Leaming Corn Fodder, Period II.

Old Sheep III.

3,600 grams Leaming corn fodder fed,	882.72	41.40	69.65	197.91	555.58	18.18
286.43 grams manure excreted,	257.56	24.91	28.07	72.66	127.47	4.46
Grams digested,	625.16	16.49	41.58	125.25	428.11	13.72
Per cent. digested,	70.82	39.83	59.70	63.29	77.06	75.47

Leaming Corn Fodder, Period II—Concluded.

Paige Sheep V.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3,600 grams Leaming corn fodder fed,	882.72	41.40	69.65	197.91	555.58	18.18
299.08 grams manure excreted,	271.45	27.77	27.96	79.81	131.65	4.26
Grams digested,	611.27	13.63	41.69	118.10	423.93	43.92
Per cent. digested,	69.25	32.92	59.86	59.67	76.30	76.57
Average per cent. for both sheep,	70.04	36.38	59.78	61.48	76.68	76.02

Biles Union Grains, Period VI.

Old Sheep II.

650 grams English hay fed,	573.30	38.70	70.11	191.77	256.09	16.63
250 grams Biles Union grains fed,	227.28	15.16	61.62	23.98	107.84	18.68
Amount consumed,	800.58	53.86	131.73	215.75	363.93	35.31
256.76 grams manure excreted,	236.60	31.47	42.35	50.61	103.65	8.52
Grams digested,	563.98	22.39	89.38	165.14	260.28	26.79
Minus hay digested,	389.10	19.03	43.69	146.32	170.02	8.71
Biles Union grains digested,	174.88	3.36	45.69	18.82	90.26	18.08
Per cent. digested,	76.94	22.16	74.15	78.48	83.70	96.79

Biles Union Grains, Period IX.

Young Sheep II.

600 grams English hay fed,	538.92	36.38	65.91	180.27	240.74	15.63
200 grams Biles Union grains fed,	185.14	12.35	50.19	19.53	87.85	15.22
Amount consumed,	724.06	48.73	116.10	199.80	328.59	30.85
254.10 grams manure excreted,	234.86	26.59	40.70	52.33	107.35	7.89
Grams digested,	489.20	22.14	75.40	147.47	221.24	22.96
Minus hay digested,	355.26	18.90	40.85	131.36	155.66	8.48
Biles Union grains digested,	133.94	3.24	34.55	16.11	65.58	14.48
Per cent. digested,	72.35	26.23	68.84	82.49	74.65	95.14

Schumacher's Stock Feed, Period VIII.

Young Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
550 grams English hay fed,	494.01	33.35	60.42	165.25	220.67	14.33
250 grams Schumacher's stock feed fed,	226.95	10.08	26.62	26.55	152.76	10.94
Amount consumed,	720.96	43.43	87.04	191.80	373.43	25.27
249.61 grams manure excreted,	231.64	26.82	31.55	55.73	109.80	7.74
Grams digested,	489.32	16.61	55.49	136.07	263.63	17.53
Minus hay digested,	325.65	17.33	37.45	120.42	142.69	7.77
Schumacher's stock feed digested,	163.67	—	18.04	15.65	120.94	9.76
Per cent. digested,	72.12	—	67.77	58.95	79.17	89.21

Young Sheep III.

Amount consumed as above,	720.96	43.43	87.04	191.80	373.43	25.27
253.20 grams manure excreted,	235.40	27.38	30.48	59.18	110.43	7.93
Grams digested,	485.56	16.05	56.56	132.62	263.00	17.34
Minus hay digested,	325.65	17.33	37.45	120.42	142.69	7.77
Schumacher's stock feed digested,	159.91	—	19.11	12.20	120.31	9.57
Per cent. digested,	70.46	—	71.79	45.95	78.76	87.48
Average per cent. for both sheep,	71.29	—	69.78	52.45	78.97	88.35

Protena Dairy Feed, Period XII.

Paige Sheep IV.

600 grams English hay fed,	542.70	36.63	66.37	181.53	242.42	15.74
200 grams Protena dairy feed fed,	182.72	13.30	35.74	36.84	91.21	5.63
Amount consumed,	725.42	49.93	102.11	218.37	333.63	21.37
263.57 grams manure excreted,	249.21	29.21	36.11	67.66	108.21	8.02
Grams digested,	476.21	20.72	66.00	150.71	225.42	13.35
Minus hay digested,	355.36	16.34	40.84	133.99	156.26	7.90
Protena dairy feed digested,	120.85	4.38	25.16	16.72	69.16	5.45
Per cent. digested,	66.14	32.93	70.40	45.39	75.83	96.80

Protina Dairy Feed, Period XII—Concluded.

Paige Sheep V.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Amount consumed as above,	725.42	49.93	102.11	218.37	333.63	21.37
270.27 grams manure excreted,	255.19	28.68	35.14	72.07	111.44	7.86
Grams digested,	470.23	21.25	66.97	146.30	222.19	13.51
Minus hay digested,	355.36	16.34	40.84	133.99	156.26	7.90
Protina dairy feed digested,	114.87	4.91	26.13	12.31	65.93	5.61
Per cent. digested,	62.87	36.92	73.11	33.41	72.29	99.64
Average per cent. for both sheep,	64.51	34.93	71.76	39.40	74.06	98.22

Buffalo Creamery Feed, Period XIII.

Young Sheep I.

600 grams English hay fed,	543.90	36.71	66.52	181.93	242.96	15.77
200 grams Buffalo Creamery feed fed,	181.10	8.48	39.61	24.59	100.18	8.24
Amount consumed,	725.00	45.19	106.13	206.52	343.14	24.01
256.84 grams manure excreted,	242.66	24.44	32.98	61.08	115.53	8.64
Grams digested,	482.34	20.75	73.15	145.44	227.61	15.37
Minus hay digested,	358.54	19.07	41.23	132.57	157.10	8.55
Buffalo Creamery feed digested,	123.80	1.68	31.92	12.87	70.51	6.82
Per cent. digested,	68.36	19.81	80.59	52.34	70.38	82.77

Young Sheep III.

Amount consumed as above,	725.00	45.19	106.13	206.52	343.14	24.01
253.23 grams manure excreted,	238.69	23.94	32.51	60.01	114.26	7.97
Grams digested,	486.31	21.25	73.62	146.51	228.88	16.04
Minus hay digested,	358.54	19.07	41.23	132.57	157.10	8.55
Buffalo Creamery feed digested,	127.70	2.18	32.39	13.94	71.78	7.49
Per cent. digested,	70.55	25.71	81.77	56.69	71.65	90.90
Average per cent. for both sheep,	69.46	22.76	81.18	54.52	71.02	86.84

Summary of Coefficients (Per Cent.).

Food.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.	
Pride of the North corn fodder,	{ Old Sheep II.,	73.08	32.46	58.91	58.38	80.63	83.50	
	{ Paige Sheep IV.,	80.79	39.74	67.60	74.36	86.41	84.34	
	Average,	-	-	76.94	36.10	63.26	66.37	83.52	83.92
Leaming corn fodder,	{ Old Sheep III.,	70.82	39.83	59.70	63.29	77.06	75.47	
	{ Paige Sheep V.,	69.25	32.92	59.86	59.67	76.30	76.57	
	Average,	-	-	70.04	36.38	59.78	61.48	76.68	76.02
Biles Union grains,	{ Old Sheep II.,	76.94	22.16	74.15	78.48	83.70	96.79	
	{ Young Sheep II.,	72.35	26.23	68.84	82.49	74.65	95.14	
	Average,	-	-	74.65	24.20	71.50	80.49	79.18	95.97
Schumacher's stock feed,	{ Young Sheep I.,	72.12	-	67.77	58.95	79.17	89.21	
	{ Young Sheep III.,	70.46	-	71.79	45.95	78.76	87.48	
	Average,	-	-	71.29	-	69.78	52.45	78.97	88.35
Protena dairy feed,	{ Paige Sheep IV.,	66.14	32.93	70.40	45.39	75.83	96.80	
	{ Paige Sheep V.,	62.87	36.92	73.11	33.41	72.29	99.64	
	Average,	-	-	64.51	34.93	71.76	39.40	74.06	98.22
Buffalo Creamery feed,	{ Young Sheep I.,	68.36	19.81	80.59	52.34	70.38	82.77	
	{ Young Sheep III.,	70.55	25.71	81.77	56.69	71.65	90.90	
	Average,	-	-	69.46	22.76	81.18	54.52	71.02	86.84

Discussion of the Results.

The most important results obtained from the experiments reported in the previous pages are discussed under the following headings:—

Pride of the North Corn Fodder.—The fodder used was of excellent quality and exceptionally well cared. The one-twentieth acre plot on which it was grown yielded at the rate of slightly over 21 tons to the acre and contained 49 per cent. of ears in dry matter. The unusually high percentage of ears naturally increased the digestibility of the fodder. The corn was cut from the field every two days, the first cutting being September 5, and the last September 19. The entire plant was finely cut before being fed, dry matter determinations being made of each single cutting.

Summary of Coefficients, Period I. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep II.,	1	1	73.08	32.46	58.91	58.38	80.63	83.50
Paige Sheep IV.,	1	1	80.79	39.74	67.60	74.36	86.41	84.34
Average,	1	2	76.94	36.10	63.26	66.37	83.52	83.92
Average of all experiments, mature dent corn fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

Paige Sheep IV. gave higher results than did Old Sheep II., probably due in part to the fact that the former left a portion of the tougher and less digestible part. The present experiment shows in a fairly satisfactory manner the digestibility of a variety of dent corn that will mature in Massachusetts, and also emphasizes the fact that a fodder containing a higher percentage of ears is noticeably more digestible than one containing relatively fewer ears and a larger percentage of stalk.

Leaming Corn Fodder. — The fodder used was fed at the same time and handled in the same manner as was the preceding variety. The one-twentieth acre plot yielded at the rate of 25½ tons per acre. The crop contained 31 per cent. of ears in dry matter. The stalks are rather larger than the Pride of the North, and in the average season the Leaming matures a little later.

Summary of Coefficients, Period II. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep III.,	1	1	70.82	39.83	59.70	63.29	77.06	75.47
Paige Sheep V.,	1	1	69.25	32.92	59.86	59.67	76.30	76.57
Average,	1	2	70.04	36.38	59.78	61.48	76.68	76.02
Average all experiments, mature dent corn fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

The sheep consumed the entire ration fed. The coefficients for both sheep agreed closely, not only with each other, but also with the average of all experiments with dent fodder. The Leaming is shown to be rather less digestible than the Pride of the North, due to its rather coarser stalks and to its relatively less ear production. It is believed, however, that this variety of dent fodder is quite well suited for silage in Massachusetts.

Biles Union Grains. — Biles Union Grains is a proprietary feed consisting principally of a mixture of distillers' dried grains and malt sprouts, together with some corn and wheat products, cottonseed meal and salt. The amount of its several components is likely to vary more or less from time to time, depending upon the feeding stuffs available and their cost. This variation in composition varies its digestibility within narrow limits. It is intended, when fed with home-grown roughage, to constitute a balanced ration for dairy stock.

Summary of Coefficients, Periods VI. and IX. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep II.,	1	1	76.94	22.16	74.15	78.48	83.70	96.79
Young Sheep II.,	1	1	72.35	26.23	68.84	82.49	74.56	95.14
Average,	1	2	74.65	24.20	71.50	80.49	79.18	95.97

The coefficients agree fairly well, although the Young Sheep II. did not appear to digest the nitrogen-free extract as well as did Old Sheep II. The feed can be considered fairly digestible.

Schumacher's Stock Feed. — This material consists of a mixture of corn, oat and barley residues resulting from the manufacture of human foods from these cereals. It contains about 10 per cent. protein, 3.50 per cent. fat and 9 per cent. fiber. It is extensively advertised as a food for horses and dairy stock.

Summary of Coefficients, Period VIII. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Young Sheep I.,	1	1	72.12	-	67.77	58.95	79.17	89.21
Young Sheep II.,	1	1	70.46	-	71.79	45.95	78.76	87.48
Average,	1	2	71.29	-	69.78	52.45	78.97	88.35
Oats, unground, for comparison,	2	6	70.00	-	77.00	31.00	77.00	89.00

The coefficients obtained for both sheep with the exception of that for fiber agree satisfactorily. The digestibility as well as the composition of this feed resembles that of oats, for which it is often substituted in feeding horses. When used for this purpose it would be advisable to moisten it because of its fine and dry condition.

Protena Dairy Feed. — This material is no longer found in the Massachusetts market. It was composed of ground alfalfa as a basis, together with cottonseed meal, wheat by-products and salt.

Summary of Coefficients, Period XII. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Paige Sheep IV.,	1	1	66.14	32.93	70.40	45.39	75.83	96.80
Paige Sheep V.,	1	1	62.87	36.92	73.11	33.41	72.29	99.64
Average,	1	2	64.51	34.93	71.76	39.40	74.06	98.22

The presence of so much alfalfa gave it a relatively high fiber content, and a low fiber digestibility. The digestibility of the entire foodstuff is decidedly below the minimum desired for a high-grade concentrate, due also to the large amount of alfalfa used.

Buffalo Creamery Feed. — This is a proprietary mixture containing about 20 per cent. protein, 5 per cent. fat and 9 per

cent. fiber. According to the manufacturer's guarantee it contains corn, wheat middlings, oat hulls, hominy feed, cottonseed meal and gluten feed.

Summary of Coefficients, Period XIII. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Young Sheep I.,	1	1	68.36	19.81	80.59	52.34	70.38	82.77
Young Sheep III.,	1	1	70.55	25.71	81.77	56.69	71.65	90.90
Average,	1	2	69.46	22.76	81.18	54.52	71.02	86.84

The coefficients agree closely, and the feed approaches the minimum degree of digestibility (70 per cent.) for a concentrate. Its protein digestibility is fairly satisfactory. Its economy as a dairy feed would naturally depend upon its cost. Feeds of this character are likely to cost more than the ingredients of which they are composed.

SERIES XIV.

Eleven experiments were made in this series, all of which, with the exception of the 4 that follow, were carried out with Porto Rico molasses and are published elsewhere. The digestion coefficients for the hay used in periods VIII. and X. were those obtained in period XI. The 4 sheep used in this experiment were yearling Shropshires of substantially uniform weight.

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
English hay,	6.82	7.67	30.35	52.79	2.37
Early Mastodon Dent corn fodder.	4.31	7.38	19.40	66.74	2.17
Rustler White Dent corn fodder,	4.38	6.87	19.46	66.96	2.33
Unicorn dairy ration,	3.60	29.61	9.76	50.11	6.92
Waste, Sheep IV., period II., . . .	2.85	3.37	29.12	63.58	1.08

Composition of Feces (Per Cent.).

[Dry Matter.]

Sheep I.

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
I.	Early Mastodon Dent corn fodder,	9.52	11.12	27.34	50.57	1.45
VIII.	Unicorn dairy ration,	10.55	15.61	24.37	46.56	2.91
X.	Unicorn dairy ration,	11.64	13.63	25.18	46.47	3.08
XI.	English hay,	11.16	10.65	27.78	46.91	3.50

Sheep II.

I.	Early Mastodon Dent corn fodder,	10.16	11.41	27.70	49.17	1.56
VIII.	Unicorn dairy ration,	11.01	14.66	25.32	46.14	2.87
XI.	English hay,	10.45	10.17	29.55	46.65	3.18

Sheep III.

II.	Rustler White Dent corn fodder, .	9.77	12.07	26.62	49.87	1.67
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Sheep IV.

II.	Rustler White Dent corn fodder, .	11.17	14.11	25.11	47.61	1.99
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Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Sheep I.

PERIOD.	English Hay.	Early Mastodon Dent Corn Fodder.	Rustler White Dent Corn Fodder.	Unicorn Dairy Ration.	Waste.	Feces.
I.,	-	24.80	-	-	-	89.08
VIII.,	89.45	-	-	91.11	-	93.36
X.,	90.22	-	-	92.46	-	93.52
XI.,	90.05	-	-	-	-	93.41

Sheep II.

I.,	-	24.80	-	-	-	88.92
VIII.,	89.45	-	-	91.11	-	93.27
XI.,	90.05	-	-	-	-	93.49

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.)—Concluded.

Sheep III.

PERIOD.	English Hay.	Early Mastodon Dent Corn Fodder.	Rustler White Dent Corn Fodder.	Unicorn Dairy Ration.	Waste.	Feces.
II.,	-	-	31.46	-	-	88.51

Sheep IV.

II.,	-	-	31.46	-	94.05	88.64
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Average Daily Amount of Manure excreted and Water Drunk (Grams).

Sheep I.

Period.	CHARACTER OF FOOD OR RATION.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Early Mastodon Dent corn fodder,	594	18.62	404
VIII.	Unicorn dairy ration,	1,060	21.97	2,325
X.	Unicorn dairy ration,	751	23.97	2,493
XI.	English hay,	633	24.55	2,292

Sheep II.

I.	Early Mastodon Dent corn fodder,	733	18.99	416
VIII.	Unicorn dairy ration,	891	21.85	2,500
XI.	English hay,	722	26.62	2,251

Sheep III.

II.	Rustler White Dent corn fodder,	929	26.67	1,889
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Sheep IV.

II.	Rustler White Dent corn fodder,	1,184	24.15	904
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Weights of Animals at Beginning and End of Period (Pounds).

Sheep I.

Period.	CHARACTER OF FOOD OR RATION.	Beginning.	End.
I.	Early Mastodon Dent corn fodder,	89.0	89.0
VIII.	Unicorn dairy ration,	86.5	87.5
X.	Unicorn dairy ration,	86.0	88.0
XI.	English hay,	90.0	88.5

Sheep II.

I.	Early Mastodon Dent corn fodder,	86.5	86.0
VIII.	Unicorn dairy ration,	87.5	87.0
XI.	English hay,	90.5	88.5

Sheep III.

II.	Rustler White Dent corn fodder,	85.5	90.0
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Sheep IV.

II.	Rustler White Dent corn fodder,	97.0	95.0
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Early Mastodon Dent Corn Fodder, Period I.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,400 grams Mastodon corn fodder fed,	595.20	25.67	43.93	115.47	397.21	12.92
186.21 grams manure excreted (air-dry),	165.88	15.79	18.45	45.35	83.88	2.41
Grams digested,	429.32	9.88	25.48	70.12	313.33	10.51
Per cent. digested,	72.13	38.49	58.00	60.73	78.88	81.35

Sheep II.

2,400 grams Mastodon corn fodder fed,	595.20	25.67	43.93	115.47	397.21	12.92
189.90 grams manure excreted (air-dry),	168.86	17.16	19.27	46.77	83.03	2.63
Grams digested,	426.34	8.51	24.66	68.70	314.18	10.29
Per cent. digested,	71.63	33.15	56.13	59.50	79.10	79.64
Average per cent. for both sheep,	71.88	35.82	57.07	60.12	78.99	80.50

Rustler White Dent Corn Fodder, Period II.

Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extrac.	Fat.
2,400 grams Rustler corn fodder fed, . . .	755.04	33.07	51.87	146.93	505.56	17.59
266.74 grams manure excreted (air-dry), . . .	236.09	23.07	28.50	62.85	117.72	3.93
Grams digested,	518.95	10.00	23.37	84.08	387.84	13.66
Per cent. digested,	68.73	30.24	45.05	57.22	76.71	77.66

Sheep IV.

2,400 grams Rustler corn fodder fed, . . .	755.04	33.07	51.87	146.93	505.56	17.59
37.86 grams waste,	35.61	1.01	1.20	10.37	22.65	.38
Amount consumed,	719.43	32.06	50.67	136.56	482.91	17.21
241.53 grams manure excreted,	214.09	23.91	30.21	53.76	101.95	4.26
Grams digested,	505.34	8.15	20.46	82.80	380.96	12.95
Per cent. digested,	70.24	25.42	40.38	60.63	78.89	75.25
Average per cent. for both sheep,	69.49	27.83	42.72	58.93	77.80	76.46

Unicorn Dairy Ration, Period VIII.

Sheep I.

500 grams English hay fed,	447.35	30.51	34.31	135.77	236.21	10.55
200 grams Unicorn dairy ration fed,	182.22	6.56	53.96	17.78	91.31	12.61
Amount consumed,	629.57	37.07	88.27	153.55	327.52	23.16
219.65 grams manure excreted (air-dry),	205.07	21.63	32.01	49.98	95.48	5.97
Grams digested,	424.50	15.44	56.26	103.57	232.04	17.19
Minus hay digested,	277.36	12.81	16.81	90.97	153.54	5.17
Unicorn dairy ration digested,	147.14	2.63	39.45	12.60	78.50	12.02
Per cent. digested,	80.74	40.09	73.11	70.87	85.97	95.32

Sheep II.

Amount consumed as above,	629.57	37.07	88.27	153.55	327.52	23.16
218.50 grams manure excreted (air-dry),	203.79	22.44	29.87	51.60	94.03	5.85
Grams digested,	425.78	14.63	58.40	101.95	233.49	17.31
Minus hay digested,	277.36	12.81	16.81	90.97	153.54	5.17
Unicorn dairy ration digested,	148.42	1.82	41.59	10.98	79.95	12.14
Per cent. digested,	81.45	27.74	77.07	61.75	87.55	96.27
Average per cent. for both sheep,	81.10	33.92	75.09	66.31	86.76	95.80

Unicorn Dairy Ration, Period X.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
600 grams English hay fed,	541.32	36.92	41.52	164.29	285.73	12.86
150 grams Unicorn dairy ration fed,	138.69	4.98	41.07	13.54	69.50	9.60
Amount consumed,	680.01	41.90	82.59	177.83	355.23	22.46
239.67 grams manure excreted (air-dry),	224.14	26.09	30.55	56.44	104.16	6.90
Grams digested,	455.87	15.81	52.04	121.49	251.07	15.56
Minus hay digested,	335.62	15.51	20.34	110.07	185.72	6.30
Unicorn dairy ration digested,	120.25	.30	31.70	11.42	65.35	9.26
Per cent. digested,	86.70	6.02	77.19	84.34	94.03	96.46

English Hay, Period XI.

Sheep I.

700 grams English hay fed,	630.35	44.82	48.85	205.74	315.24	15.70
245.46 grams manure excreted (air-dry),	229.28	25.59	24.42	63.69	107.56	8.02
Grams digested,	401.07	19.23	24.43	142.05	207.68	7.68
Per cent. digested,	63.63	42.91	50.01	69.04	65.88	48.92

Sheep II.

700 grams English hay fed,	630.35	44.82	48.85	205.74	315.24	15.70
266.16 grams manure excreted (air-dry),	248.83	26.00	25.31	73.53	116.08	7.91
Grams digested,	381.52	18.82	23.54	132.21	199.16	7.79
Per cent. digested,	60.53	41.99	48.19	64.27	63.18	49.62
Average per cent. for both sheep,	62.08	42.45	49.10	66.66	64.53	49.27

Summary of Coefficients (Per Cent.).

FOOD.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Early Mastodon Dent corn fodder,	{ Sheep I.,	72.13	38.49	58.00	60.73	78.88	81.35
	{ Sheep II.,	71.63	33.15	56.13	59.50	79.10	79.64
	Average,	71.88	35.82	57.07	60.12	78.99	80.50
Rustler White Dent corn fodder,	{ Sheep III.,	68.73	30.24	45.05	57.22	76.71	77.66
	{ Sheep IV.,	70.24	25.42	40.38	60.63	78.89	75.25
	Average,	69.49	27.83	42.72	58.93	77.80	76.46
Unicorn dairy ration,	{ Sheep I.,	80.74	40.09	73.11	70.87	85.97	95.32
	{ Sheep I.,	86.70	6.02	77.19	84.34	94.03	96.46
	{ Sheep II.,	81.45	27.74	77.07	61.75	87.55	96.27
	Average,	82.96	24.62	75.79	72.32	89.18	96.02
English hay,	{ Sheep I.,	63.63	42.91	50.01	69.04	65.88	48.92
	{ Sheep II.,	60.53	41.99	48.19	64.27	63.18	49.62
	Average,	62.08	42.45	49.10	66.66	64.53	49.27

Discussion of the Results.

Early Mastodon Dent Corn Fodder. — This is a large growing yellow dent variety bred by C. S. Clark of Ohio. It is evidently rather too late for the average Massachusetts season. At the time of cutting (September 5–19) it was in the milk-to-denting stage, and could not be considered ripe enough to be cut for the grain. It yielded about 20 tons to the acre of green fodder which contained 28 per cent. of ears in dry matter.

Summary of Coefficients, Period I. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	72.13	38.49	58.00	60.73	78.88	81.35
Sheep II.,	1	1	71.63	33.15	56.13	59.50	79.10	79.64
Average,	1	2	71.88	35.82	57.07	60.12	78.99	80.50
Average of all experiments, dent fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

The results obtained in this trial were very satisfactory. They also agreed quite closely with the average for all trials for dent corn.

Rustler White Dent Corn Fodder. — So far as known this variety of corn originated in Minnesota; it was first grown at the Massachusetts Agricultural Experiment Station, where it has given excellent satisfaction. At the time of cutting (September 5–19) it was dented and glazing and ready to harvest. It yielded about 12 tons of green fodder which contained 41 per cent. of ears in dry matter. The yield was not so large as on other fields nearby. The tendency of this variety is to mature in our latitude and yield a fair amount of stalk with a relatively high grain percentage.

Summary of Coefficients, Period II. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep III.,	1	1	68.73	30.24	45.05	57.22	76.71	77.66
Sheep IV.,	1	1	70.24	25.42	40.38	60.63	78.89	75.25
Average,	1	2	69.49	27.83	42.72	58.93	77.80	76.46
Average of all experiments, dent fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

While the coefficients obtained in this experiment agreed closely, the digestibility was not as great as would naturally be expected, considering the percentage of ears and degree of maturity. This may be due, in part at least, to the fact that this corn was comparatively dry when cut, and the animals were fed rather more dry matter than was intended; in fact, more than they could readily care for. Sheep IV. left a part of the daily ration. With a smaller amount of dry matter in the ration, the coefficients might have been somewhat higher.

Unicorn Dairy Ration. — This is a proprietary mixture consisting of corn, distillers' grains, cottonseed meal, hominy feed, barley feed and sprouts and wheat bran. It contained on a natural moisture basis about 26 per cent. protein, 6 per cent. fat and 9 per cent. fiber.

Summary of Coefficients, Periods VIII. and X. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	80.74	40.09	73.11	70.87	85.97	95.32
Sheep II.,	1	1	81.45	27.74	77.07	61.75	87.55	96.27
Sheep I.,	1	1	86.07	6.02	77.19	84.34	94.03	96.46
Average,	1	2	81.10	33.92	75.09	66.31	86.76	95.80

The results secured in case of Sheep I. in period X. are noticeably above those for the other two trials, and it is thought best not to include them in the average. The reason for this variation cannot be explained. The coefficients for Sheep I. and II. in period VIII. agree fairly well, and show this proprietary feed to have a high digestibility. These results, together with its high protein and a low fiber content, indicate a high-grade protein dairy feed.

English Hay.—The hay used in this period consisted of mixed grasses with June grass predominating. It was cut while in blossom, well cured and in good condition. Before feeding it was cut fine by running it through a feed cutter, and thoroughly mixed to insure uniformity through the entire lot.

Summary of Coefficients, Period XI. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	63.63	42.91	50.01	69.04	65.88	48.92
Sheep II.,	1	1	60.53	41.99	48.19	64.24	63.18	49.62
Average,	1	2	62.08	42.45	49.10	66.66	64.53	49.27
Average of all trials, similar hay for comparison.	21	73	61.00	47.00	57.00	62.00	62.00	50.00

The coefficients obtained in this trial agree closely. With the exception of the coefficient obtained for protein they also

agree closely with the average of all results obtained with similar hay.

SERIES XV.

This series of experiments was conducted during the fall and winter of 1909-10. Those not reported concerned the effect of lactic acid and calcium lactate upon digestibility, and will be published at a later date. The sheep used were the same as for the preceding year.

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract Matter.	Fat.
I.	Brewer's Dent corn fodder,	5.32	9.84	23.94	59.40	1.50
II.	Wing's Improved White Dent corn fodder,	4.85	9.36	22.58	61.64	1.57
III.	Alfalfa hay, first cutting, third-year growth,	7.55	16.62	30.16	43.78	1.89
IV.	Alfalfa hay, second cutting, third-year growth,	6.70	15.31	38.03	38.67	1.29
V.	Alfalfa hay, first cutting, first-year growth,	7.63	16.49	35.28	39.10	1.50
VI.	Clover, second cutting,	8.96	15.28	29.76	44.12	1.88
VII.	Clover, first cutting,	11.22	17.82	28.30	40.70	1.96

Composition of Feces (Per Cent.).

Sheep I.

I.	Brewer's Dent corn fodder,	10.00	11.27	25.93	51.17	1.63
III.	Alfalfa hay, first cutting, third-year growth,	10.13	11.35	43.90	31.33	3.29
V.	Alfalfa hay, first cutting, first-year growth,	10.41	11.01	45.14	30.87	2.57
VII.	Clover hay, first cutting,	12.26	18.09	30.28	36.75	2.62

Sheep II.

I.	Brewer's Dent corn fodder,	10.50	10.87	27.75	49.08	1.80
III.	Alfalfa hay, first cutting, third-year growth,	10.70	10.74	44.82	30.74	3.00
V.	Alfalfa hay, first cutting, first-year growth,	10.34	11.04	44.99	30.86	2.77
VII.	Clover hay, first cutting,	12.14	17.23	32.45	35.68	2.50

Sheep III.

II.	Wing's Improved White Cap corn fodder,	9.96	11.66	28.33	48.54	1.51
IV.	Alfalfa hay, second cutting, third-year growth,	9.47	10.23	48.09	29.78	2.43
VI.	Clover hay, second cutting,	9.87	14.78	40.15	33.19	2.01

Composition of Feces (Per Cent.) — Concluded.

Sheep IV.

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract Matter.	Fat.
II.	Wing's Improved White Cap corn fodder, .	9.99	11.73	25.08	51.55	1.65
IV.	Alfalfa hay, second cutting, third-year growth.	9.50	9.68	48.46	29.79	2.57
VI.	Clover hay, second cutting,	9.73	15.56	38.93	33.63	2.15

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Sheep I.

PERIOD.	Brewer's Dent Corn Fodder.	Wing's Improved Dent Corn Fodder.	Alfalfa Hay, First Cutting, Third-year Growth.	Alfalfa Hay, First Cutting, First-year Growth.	Alfalfa Hay, Second Cutting, Third-year Growth.	Clover Hay, First Cutting.	Clover Hay, Second Cutting.	Feces.
I., . . .	19.39	-	-	-	-	-	-	89.59
III., . . .	-	-	85.42	-	-	-	-	91.53
V., . . .	-	-	-	86.97	-	-	-	93.88
VII., . . .	-	-	-	-	-	88.65	-	93.12

Sheep II.

I., . . .	19.39	-	-	-	-	-	-	89.71
III., . . .	-	-	85.42	-	-	-	-	91.62
V., . . .	-	-	-	86.97	-	-	-	93.87
VII., . . .	-	-	-	-	-	88.65	-	93.22

Sheep III.

II., . . .	-	19.18	-	-	-	-	-	89.17
IV., . . .	-	-	-	-	86.75	-	-	93.51
VI., . . .	-	-	-	-	-	-	88.10	93.05

Sheep IV.

II., . . .	-	19.18	-	-	-	-	-	89.72
IV., . . .	-	-	-	-	87.90	-	-	93.37
VI., . . .	-	-	-	-	-	-	88.10	93.21

Average Daily Amount of Manure excreted and Water drunk (Grams).

Sheep I.

Period.	CHARACTER OF FOOD OR RATION.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Brewer's Dent corn fodder,	403	29.21 ¹	262
III.	Alfalfa hay, first cutting, third-year growth,	563	22.21	1,737
V.	Alfalfa hay, first cutting, first-year growth,	906	33.06	2,451
VII.	Clover hay, first cutting,	807	27.05	2,646

Sheep II.

I.	Brewer's Dent corn fodder,	407	30.91 ¹	224
III.	Alfalfa hay, first cutting, third-year growth,	749	26.03	1,969
V.	Alfalfa hay, first cutting, first-year growth,	724	29.83	2,475
VII.	Clover hay, first cutting,	721	28.48	2,656

Sheep III.

II.	Wing's Improved White Cap fodder,	560	32.42 ¹	157
IV.	Alfalfa hay, second cutting, third-year growth,	944	31.80	2,261
VI.	Clover hay, second cutting,	972	31.85	2,562

Sheep IV.

II.	Wing's Improved White Cap fodder,	372	31.11 ¹	95
IV.	Alfalfa hay, second cutting, third-year growth,	779	28.60	1,841
VI.	Clover hay, second cutting,	675	29.26	2,453

Weights of Animals at Beginning and End of Periods (Pounds).

Sheep I.

Period.	CHARACTER OF FOOD OR RATION.	Beginning.	End.
I.	Brewer's Dent corn fodder,	94.50	93.25
III.	Alfalfa hay, first cutting, third-year growth,	99.50	97.25
V.	Alfalfa hay, first cutting, first-year growth,	101.25	100.00
VII.	Clover hay, first cutting,	97.25	100.00

¹ One-fifth of daily amount excreted.

Weights of Animals at Beginning and End of Periods (Pounds)
— Concluded.

Sheep II.

Period.	CHARACTER OF FOOD OR RATION.	Beginning.	End.
I.	Brewer's Dent corn fodder,	95.25	93.00
III.	Alfalfa hay, first cutting, third-year growth,	101.75	96.25
V.	Alfalfa hay, first cutting, first-year growth,	97.75	98.75
VII.	Clover hay, first cutting,	102.50	96.50

Sheep III.

II.	Wing's Improved White Cap fodder,	78.50	77.75
IV.	Alfalfa hay, second cutting, third-year growth,	93.25	89.50
VI.	Clover hay, second cutting,	93.75	91.75

Sheep IV.

II.	Wing's Improved White Cap fodder,	107.75	106.75
IV.	Alfalfa hay, second cutting, third-year growth,	112.75	110.50
VI.	Clover hay, second cutting,	113.75	111.50

Brewer's Dent Corn Fodder, Period I.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,500 grams Brewer's Dent corn fodder fed,	484.75	25.79	47.70	116.05	287.94	7.27
146.04 grams manure excreted,	130.84	13.08	14.75	33.93	66.95	2.13
Grams digested,	353.91	12.71	32.95	82.12	220.99	5.14
Per cent. digested,	73.01	49.28	69.08	70.76	76.75	70.70

Sheep II.

2,500 grams Brewer's Dent corn fodder fed,	484.75	25.79	47.70	116.05	287.94	7.27
154.56 grams manure excreted,	138.66	14.56	15.07	38.48	68.05	2.50
Grams digested,	346.09	11.23	32.63	77.57	219.89	4.77
Per cent. digested,	71.40	43.54	68.41	66.84	76.37	65.61
Average per cent. for both sheep,	72.21	46.41	68.75	68.80	76.56	68.16

Wing's Improved White Cap Dent Corn Fodder, Period II.

Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,500 grams White Cap Dent corn fodder fed,	479.50	23.26	44.88	108.28	295.56	7.52
162.08 grams manure excreted,	144.53	14.40	16.85	40.95	70.15	2.18
Grams digested,	334.97	8.86	28.03	67.33	225.41	5.34
Per cent. digested,	69.86	38.09	62.46	62.18	76.27	71.01

Sheep IV.

2,500 grams White Cap Dent corn fodder fed,	479.50	23.26	44.88	108.28	295.56	7.52
155.55 grams manure excreted,	139.56	13.94	16.37	35.00	71.95	2.30
Grams digested,	339.94	9.32	28.51	73.28	223.61	5.22
Per cent. digested,	70.89	40.07	63.52	67.68	75.66	69.41
Average per cent. for both sheep,	70.38	39.08	62.99	64.93	75.97	70.21

Alfalfa Hay, First Cutting, Third-year Growth, Period III.

Sheep I.

750 grams alfalfa hay fed,	640.65	48.37	106.46	193.22	280.49	12.11
222.06 grams manure excreted,	203.25	20.59	23.07	89.22	63.68	6.69
Grams digested,	437.40	27.78	83.39	104.00	216.81	5.42
Per cent. digested,	68.27	57.43	78.33	53.82	77.30	44.76

Sheep II.

750 grams alfalfa hay fed,	640.65	48.37	106.46	193.22	280.49	12.11
260.33 grams manure excreted,	238.51	25.52	25.62	106.89	73.32	7.16
Grams digested,	402.14	22.85	80.84	86.33	207.17	4.95
Per cent. digested,	62.77	47.24	75.93	44.68	73.86	40.88
Average per cent. for both sheep,	65.52	52.34	77.13	49.25	75.58	42.82

Alfalfa Hay, Second Cutting, Third-year Growth, Period IV.

Sheep III.

750 grams alfalfa hay fed,	650.63	43.59	99.61	247.43	251.61	8.39
318.04 grams manure excreted,	297.40	28.16	30.42	143.02	88.57	7.23
Grams digested,	353.23	15.43	69.19	104.41	163.04	1.16
Per cent. digested,	54.29	35.40	69.46	42.20	64.79	13.83

Alfalfa Hay, Second Cutting, Third-year Growth, Period IV—Concluded.

Sheep IV.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
750 grams alfalfa hay fed,	659.25	44.17	100.93	250.71	254.94	8.50
285.99 grams manure excreted,	267.03	25.37	25.85	129.40	79.55	6.86
Grams digested,	392.22	18.80	75.08	121.31	175.39	1.64
Per cent. digested,	59.49	42.56	74.39	48.39	68.80	19.29
Average per cent. for both sheep,	56.89	38.98	71.93	45.30	66.80	16.56

Alfalfa Hay, First Cutting, First-year Growth, Period V.

Sheep I.

800 grams alfalfa hay fed,	605.76	53.09	114.73	245.46	272.04	10.44
330.56 grams manure excreted,	310.33	32.31	34.17	140.07	95.80	7.98
Grams digested,	385.43	20.78	80.56	105.39	176.24	2.46
Per cent. digested,	55.40	39.14	70.22	42.94	64.78	23.56

Sheep II.

800 grams alfalfa hay fed,	695.76	53.09	114.73	245.46	272.04	10.44
298.29 grams manure excreted,	280.00	28.95	30.91	125.97	86.41	7.76
Grams digested,	415.76	24.14	83.82	119.49	185.63	2.68
Per cent. digested,	59.76	45.47	73.06	48.68	68.24	25.67
Average per cent. for both sheep,	57.58	42.31	71.64	45.81	66.51	24.62

Clover Hay, Second Cutting, Period VI.

Sheep III.

800 grams clover hay fed,	704.80	63.15	107.69	209.75	310.96	13.25
318.54 grams manure excreted,	296.40	29.25	43.81	119.00	98.38	5.96
Grams digested,	408.40	33.90	63.88	90.75	212.58	7.29
Per cent. digested,	57.94	53.68	59.32	43.27	68.36	55.02

Sheep IV.

800 grams clover hay fed,	704.80	63.15	107.69	209.75	310.96	13.25
292.57 grams manure excreted,	272.70	26.53	42.43	106.17	91.71	5.86
Grams digested,	432.10	36.62	65.26	103.58	219.25	7.39
Per cent. digested,	61.31	57.99	60.60	49.38	70.51	55.77
Average per cent. for both sheep,	59.63	55.84	59.96	46.33	69.44	55.40

Clover Hay, First Cutting, Period VII.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams clover hay fed,	709.20	79.57	126.38	200.70	288.65	13.90
270.50 grams manure excreted,	251.89	30.88	45.57	76.27	92.57	6.60
Grams digested,	457.31	48.69	80.81	124.43	196.08	7.30
Per cent. digested,	64.48	61.19	63.94	62.00	67.93	52.52

Sheep II.

800 grams clover hay fed,	709.20	79.57	126.38	200.70	288.65	13.90
234.76 grams manure excreted,	265.45	32.23	45.74	86.14	94.70	6.64
Grams digested,	443.75	47.34	80.64	114.56	193.95	7.26
Per cent. digested,	62.57	59.49	63.81	57.08	67.19	52.23
Average per cent. for both sheep,	63.53	60.34	63.88	59.54	67.56	52.38

Summary of Coefficients (Per Cent.).

FOOD.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Brewer's Dent corn fodder,	Sheep I.,	73.01	49.28	69.08	70.76	76.75	70.70
	Sheep II.,	71.40	43.54	68.41	66.84	76.37	65.61
	Average,	72.21	46.41	68.75	68.80	76.56	68.16
Wing's Improved White Cap Dent corn fodder.	Sheep III.,	69.86	38.09	62.46	62.18	76.27	71.01
	Sheep IV.,	70.89	40.07	63.52	67.68	75.66	69.41
	Average,	70.38	39.08	62.99	64.93	75.97	70.21
Alfalfa hay,	Sheep I.,	68.27	57.43	78.33	53.82	77.30	44.76
	Sheep I.,	55.40	39.14	70.22	42.94	64.78	23.56
	Sheep II.,	65.52	52.34	77.13	49.25	75.58	42.82
	Sheep II.,	59.76	45.47	73.06	48.68	68.24	25.67
	Sheep III.,	54.29	35.40	69.46	42.20	64.79	13.83
	Sheep IV.,	59.49	42.56	74.39	48.39	68.80	19.29
Average,	60.46	45.39	73.77	47.55	69.92	28.32	
Clover hay,	Sheep I.,	64.48	61.19	63.94	62.00	67.93	52.52
	Sheep II.,	62.57	59.49	63.81	57.08	67.19	52.23
	Sheep III.,	57.94	53.68	59.32	43.27	68.36	55.02
	Sheep IV.,	61.31	57.99	60.60	49.38	70.51	55.77
	Average,	61.58	58.09	61.92	52.93	68.50	53.89

Discussion of the Results.

Brewer's Dent Corn Fodder. — This is a yellow dent corn believed to have been first bred in the middle west and improved by N. H. Brewer of Connecticut, who has raised enormous crops by following an intensive system of fertilization and cultivation. We have not been successful in ripening it on the station farm. At the time of cutting (September 5–19) the ears were hardly in milk, and consequently not suitable to harvest for grain. It evidently needs a somewhat longer growing season than is usually experienced in the vicinity of Amherst. It produced at the rate of about 18 tons of green fodder per acre, and yielded about 17 per cent. of ears in dry matter.

Summary of Coefficients, Period I. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	73.01	49.28	69.08	70.76	76.75	70.70
Sheep II.,	1	1	71.40	43.54	68.41	66.84	76.37	65.61
Average,	1	2	72.21	46.41	68.75	68.80	76.56	68.16
Average of all trials, immature dents for comparison.	5	14	68.00	42.00	66.00	65.00	71.00	68.00

The coefficients obtained in this trial are somewhat higher than the average for immature corn. While the percentage of ears was low, the high digestibility can probably be accounted for by the soft, incompletely developed stalks, the fiber showing a relatively high digestibility.

Wing's Improved White Cap Dent Corn Fodder. — This variety of corn was originated by J. E. Wing of Ohio. It would probably form a very satisfactory variety in the middle west, but the season is not sufficiently long to enable it to reach maturity in New England. Two partially developed ears were frequently noticed on a stalk. When cut (September 5–19) it was in milk and still green. It yielded at the rate of about 14 tons of green fodder per acre, and contained 16 per cent. of ears in its dry matter.

Summary of Coefficients, Period II. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep III.,	1	1	69.86	38.09	62.46	62.18	76.27	71.01
Sheep IV.,	1	1	70.89	40.07	63.52	67.68	75.66	69.41
Average,	1	2	70.38	39.08	62.99	64.93	75.97	70.21
Average of all trials, immature dents for comparison.	5	14	68.00	42.00	66.00	65.00	71.00	68.00

This corn is of substantially the same type as the one immediately preceding. It appeared to be slightly less digestible, although the difference may have been partly due to the individuality of the two lots of sheep.

Alfalfa Hay.—The alfalfa hay used in these experiments was grown on the college farm. It was cut while in early blossom, and was quite free from weeds and grass. Period III. represented the first cutting of the third-year growth, period IV. the second cutting of the third-year growth, and period V. the first cutting of the first-year growth. Owing to different weather conditions which prevailed at the time of cutting, and which necessitated different methods of handling, the amount of leaves lost in curing was not uniform; hence a strictly fair comparison could not be made between the different cuttings. The results are therefore reported together, and the average given for the several lots. In order to draw accurate conclusions between cuttings, the crop should either be fed green or cured under uniform conditions. Owing to frequent weather changes this is often not possible in New England.

Summary of Coefficients, Periods III., IV. and V. (Per Cent.).

SHEEP.	Cutting.	Number of Different Lots,	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1 ¹	1	1	68.27	57.43	78.33	53.82	77.30	44.76
Sheep I.,	1 ²	1	1	55.40	39.14	70.22	42.94	64.78	23.56
Sheep II.,	1 ¹	1	1	62.77	47.24	75.93	44.68	73.86	40.88
Sheep II.,	1 ²	1	1	59.76	45.47	73.06	48.68	68.24	25.67
Sheep III.,	2 ¹	1	1	54.29	35.40	69.46	42.20	64.79	13.83
Sheep IV.,	2 ¹	1	1	59.49	42.56	74.39	48.39	68.80	19.29
Average,	—	3	6	60.00	44.54	73.57	46.79	69.63	28.00
Average of all trials, alfalfa hay for comparison.	—	42	80	62.00	50.00	74.00	46.00	72.00	40.00
Average of all trials, red clover for comparison.	—	12	25	58.00	36.00	58.00	54.00	65.00	56.00

Unfortunately an exact record of the conditions during the curing process of the several lots was not kept. It would appear that the first cutting of the *third-year growth* was cured without the loss of a great deal of leafy matter. This is shown by the relatively low fiber percentage and the high digestibility. The second cutting of the *third-year growth* evidently lost a considerable portion of its leaves, as indicated by its high fiber percentage and lessened digestibility. The first cutting of the *first-year growth* also must have lost an excess of leaves, as it also shows excessive fiber and low digestion coefficients. It is possible that the tags of the first cutting, third-year growth and the first cutting first-year growth, were reversed, although we have not the slightest evidence to that effect.

While the coefficients obtained vary considerably the average is about the same as the average for all trials, except that the coefficient for fat is somewhat lower. It is believed that the average coefficients obtained in our several trials show fairly the digestibility of eastern grown alfalfa under the adverse conditions due to the loss of leaves in the process of curing.

Red Clover Hay. — The clover was seeded in early August the year previous. It yielded well, was in early blossom when

¹ Third-year growth.

² First-year growth.

cut, and was cured in cocks. The first cutting did not cure out well, owing to a rainy spell during the curing process. It had a black appearance when taken to the barn, and later had to be spread in the sun for further drying. It did not lose its leaves to any extent. The lot was lacking in a satisfactory odor and was slightly musty. The conditions during the curing of the second cutting were more favorable. Both lots were rich in protein (15.28 and 17.82 per cent. in dry matter) and comparatively low in fiber (29.76 and 28.30 per cent. in dry matter).

Summary of Coefficients, Periods VI. and VII. (Per Cent.).

SHEEP.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	1	64.48	61.19	63.94	62.00	67.93	52.52
Sheep II.,	1	1	1	62.57	59.49	63.81	57.08	67.19	52.23
Sheep III.,	2	1	1	57.94	53.68	59.32	43.27	68.36	55.02
Sheep IV.,	2	1	1	61.31	57.99	60.60	49.38	70.51	55.77
Average,	-	2	4	61.58	58.09	61.92	52.93	68.50	53.89
Average alfalfa hay (our trials).	-	3	6	60.46	45.39	73.77	47.55	69.92	28.32
Average of all trials, clover hay for comparison.	-	12	25	58.00	36.00	58.00	54.00	65.00	56.00
Average of all trials, alfalfa hay for comparison.	-	42	80	62.00	50.00	74.00	46.00	72.00	40.00

The most noticeable difference in the four single trials with clover hay consists in the variation in the digestion coefficients obtained for the fiber (43-62). This is evidently due, in part at least, to the individuality of the several animals. The fiber in the second cutting was apparently not as digestible as in the first cutting. The other coefficients — excepting the ash, which is found to vary widely in most all experiments — may be considered fairly uniform. The coefficients secured by us are higher than the average for all experiments, probably due to the early cuttings of the crop. When the clover coefficients are compared with our reported experiments for alfalfa, it is noted that in case of the total dry matter, the former shows to advantage, although the reverse is true in a comparison of the

experiments reported for all trials. The protein in the clover is shown to be substantially 12 per cent. less digestible than in the alfalfa; the coefficients vary 16 per cent. in case of the average for all trials. In case of the fiber the conditions are reversed, differences of from 5 to 8 points being noted in favor of the clover. The comparative digestibility of the extract matter is about the same, although the average figures show 7 points in favor of the alfalfa. In making a comparison of the two plants from the standpoint of digestibility, two important differences are noted: (1) the protein in the alfalfa is noticeably more digestible than in the clover (12 to 16 points), and (2) the fiber from 5 to 8 points less so. In total digested the two plants approach each other, showing an average of about 60 per cent. as against 55 per cent. for timothy, 60 per cent. for early cut fine hay, 65 per cent. for rowen, 70 per cent. for the entire corn plant, and 85 per cent. for corn meal.

It is evident that the relative value of the two crops cannot be determined from their digestibility alone; other important factors to be considered are cost of production, yield and adaptability to Massachusetts conditions. Taking all the evidence into consideration, it would appear that although the cost of seed and preparation of land is somewhat against the alfalfa, yet its much greater length of life, its larger average annual yield, and its rather superior nutritive value are all in its favor. The conditions governing its successful cultivation must be carefully studied by all interested in its production. To the lack of attention to these conditions by the average farmer is due in no small measure the failures reported.

INDEX.

INDEX.

	PAGE
Agriculturist, report of,	37
Field experiments, 1911, results from,	37
Alfalfa hay, digestibility of,	274
Alfalfa hay <i>v.</i> red clover hay,	276
Analysis of fertilizers, summary of,	58
Analysis of soils, mechanical, new method,	115
Analysis of water,	67
Asparagus experiments,	25
Bacterial growth, influence of soil decoctions from sterilized and unsterilized soils upon,	126
Bacterial flora of soils, protozoa as a factor in,	132
Conclusions,	134
Discussion and methods used,	126
Tables showing:—	
Comparison of amounts of ammonia,	130
Comparison of number of bacteria,	128, 132
Growth of soy bean,	129
Mechanical analysis of soils used,	126
Benefits of soil sterilization,	122
Blossoms, fertilization of cranberry,	23
Botanist, report of,	70
Bovine tuberculosis, research concerning transmission of,	78
Branches, electrical resistance of,	156
Breeding experiment, asparagus,	26
Buildings, improvements and repairs of,	33
Calcium arsenite,	194
Comparison of samples,	198
Experimental results,	195
History of,	194
Preparation of,	195
Solubility,	200
Solubility tests,	200
Cattle foods, digestibility of,	244
Changes in staff,	11
Chemistry of arsenical insecticides,	177
Calcium arsenite,	194
Comparison of samples,	198
Experimental results,	195
History of,	194
Preparation of,	195
Solubility,	200
Solubility tests,	200
Introduction,	177
Use of insecticides, development of,	178
Investigation, plan of,	180

	PAGE
Chemistry of arsenical insecticides— <i>Concluded.</i>	
Lead arsenates,	201
Comparison of samples,	205
Experimental results,	203
Acid lead arsenate,	204
Natural lead arsenate,	203
History of,	201
Solubility,	206
Paris green,	183
Atmospheric effects on use,	193
Experimental results,	187
Free arsenic, presence of,	185
History of,	183
"Instantaneous" and "slow" green, comparison of,	189
Manufacture, methods of,	184
Properties of,	190
Solubility of,	191
Solubility tests,	192
Chemist, report of,	46
Chemical analyses made, number of,	46
Correspondence,	46
Feed and dairy section, report of,	63
Dairy law,	64
Dairy inspection, summary of,	65
Creameries and milk depots visited, tables of,	66
Summary, eleven years, table of,	65
Feed law,	63
New law, proposed,	63
Violations of,	63
Free examination of milk, cream and feeds,	67
Miscellaneous work,	67
Testing pure-bred cows,	68
Water analysis,	67
Fertilizer section, report of,	48
Activities of the year, review of,	48
Fertilizers analyzed,	51
Fertilizers collected,	50
Fertilizers licensed,	50
Grades of fertilizer,	55
Average composition of high, medium and low grades, table of,	56
Comparative cost of nitrogen, potash and phosphoric acid, table of,	57
Results of analyses, summary of,	58
Miscellaneous fertilizers,	62
Quality of plant food,	60
Nitrogen,	60
Phosphoric acid,	61
Potash,	62
Trade value of ingredients,	51
Unmixed fertilizer materials,	52
Nitrogen compounds,	53
Phosphoric acid,	54
Potash,	53
Research section, work of,	47
Control work; dairy, feed and fertilizers laws,	28
Corn, cob analyses of (see types of corn),	241
Composition of parts of,	237

	PAGE
Corn, cob analyses of (see types of corn)— <i>Concluded.</i>	
Digestibility of plant,	231
Effect of season on yield of,	227
Proportions and composition of parts,	234
Relative proportions of grain and cob,	238
Varieties, description of,	223
Suited to Massachusetts conditions, types of,	221
Corn fodder, digestibility of varieties of:—	
Brewer's Dent,	273
Early Mastodon,	263
Leaming,	254
Pride of the North,	253
Rustler White dent,	264
Wing's Improved White Cap,	273
Correlation of garden peas,	93
Cranberry bogs, natural fertility of,	208
Cranberry substation,	14
Crop, 1911,	16
Fertilizer experiments,	16
Investigations, 1910,	17
Fungi,	19
Insects,	17
Cranberry girdler,	19
Fruit worm,	17
New pest,	19
Investigations, 1911,	19
Blossoms, fertilization of,	23
Fungus diseases,	22
Insects, fruit worm and fire worm,	20
Irrigation, Skinner system,	25
Varieties, prolificness of,	25
Weather observations,	23
Plant, additions to,	14
Flooding areas,	15
Skinner system installation,	16
Cranberries and vines, composition of,	209
Cranberry bog water, average composition of,	220
Dairy inspection, summary of,	65
Diagnosis work, veterinary,	79
Digestibility of cattle foods,	244
Digestion experiments, series XII., data relative to,	244
Coefficients, summary of,	253
Results, discussion of,	253
Biles Union Grains,	255
Buffalo Creamery Feed,	256
Leaming corn fodder,	254
Pride of the North corn fodder,	253
Protena Dairy Feed,	256
Schumacher's Stock Feed,	255
Digestion experiments, series XIV., data relative to,	257
Coefficients, summary of,	263
Results, discussion of,	263
Early Mastodon dent corn fodder,	263
English hay,	265
Rustler White dent corn fodder,	264
Unicorn Dairy Ration,	264

	PAGE
Digestibility of cattle foods— <i>Concluded.</i>	
Digestion experiments, series XV., data relative to,	266
Coefficients, summary of,	272
Results, discussion of,	273
Alfalfa hay,	274
Brewer's Dent corn fodder,	273
Red clover hay,	275
Wing's Improved White Cap dent corn fodder,	273
Digestibility of corn plant,	231
Director, report of,	11
Asparagus substation, work of,	25
Breeding experiments,	26
Fertilizer experiments,	26
Buildings, improvements and repairs of,	33
Changes in staff,	11
Control work; dairy, feed and fertilizer laws,	28
Cranberry substation, work of (see Cranberry),	14
General experiments,	12
Information, dissemination of,	29
Correspondence,	32
Lectures, etc.,	33
Mailing lists,	32
Publications,	29
Available, list of,	30
Circulation of,	31
Lines of work,	12
Research,	12
Electrical charges on seeds and seedlings, effects of positive and negative,	135
Discussion and summary,	141
Growth, effects on (illustrations),	138
Stimulating effects, tables of,	136
Electrical resistance of trees,	144
Conclusions,	175
Experiments with cut branches,	156
Experiments with small plants,	160
Lightning discharges,	165
Path of current,	165
Relation of resistance to flow of sap,	162
Resistance of different tissues,	163
Tables showing:—	
Curve of resistance and temperature of elm,	169
Curve of resistance and temperature of maple,	170
Daily records of elm,	146
Daily records of maple,	145, 150, 153
Hourly records of maple,	155
Maximum and minimum resistances,	153
Resistance of tobacco plant,	161
Temperature conditions,	151
Three months' records, elm,	148
Three months' records, maple,	147
Entomologist,	72
Adams fund projects,	75
Correspondence,	72
Insects, collection of,	73
Spray materials, testing of,	74
Feed and dairy section, report of,	63

	PAGE
Feed law, newly proposed,	63
Fertilizer section, report of,	48
Fertilizers, grades of,	55
Fertilizers, trade values of ingredients,	51
Foods, cattle, digestibility of,	244
Experimental results, discussion of:—	
Alfalfa hay,	274
Biles Union Grains,	255
Brewer's Dent corn fodder,	273
Buffalo Creamery Feed,	256
Early Mastodon corn fodder,	263
English hay,	265
Leaming corn fodder,	254
Pride of the North corn fodder,	253
Protena Dairy Feed,	256
Red clover hay,	275
Rustler's White dent corn fodder,	264
Schumacher's Stock Feed,	255
Unicorn Dairy Ration,	264
Wing's Improved White Cap dent corn fodder,	273
Frost cracks in trees,	110
Discussion,	110
Variation in width, table of,	111
Garden peas, heredity, correlation and variation of,	82
Correlation,	93
Correlation of vine length and weight of seed, table of,	88
Heredity,	84
Heredity coefficients, tables of,	85, 87
Investigations, purposes of,	82
Results, discussion of,	100
Variation,	94
Variation in vine length and productiveness, table of,	95
Grain and cob, composition of,	240
Relative proportions of,	238
Hay, digestibility of:—	
Alfalfa,	274
English,	265
Red clover,	275
Heredity of garden peas,	84
Horticulturist, report of,	44
Plant breeding, progress of,	44
Introduction,	5
Lead arsenates,	201
Comparison of samples,	205
Experimental results,	203
Acid lead arsenate,	204
Neutral lead arsenate,	203
History of,	201
Solubility,	206
Lightning discharges, path of, etc.,	165
Mechanical analysis of soils, new method of,	115
Method, details of,	116
Results from "long method" and new method, table of,	119
Natural fertility of cranberry bogs,	208
Analysis of drainage water,	212

	PAGE
Natural fertility of cranberry bogs — <i>Concluded.</i>	
Fertilizer experiments,	209
Need of fertilizers,	208
Relation of water to bogs,	211
Tables: —	
Average composition of bog water,	220
Cranberries and vines, composition of,	209
Fertilizer scheme,	215
Inorganic solids in bog water, 1910,	213
Inorganic solids in bog water, unfiltered, 1911,	217
Organic and inorganic solids in bog water, filtered, 1911,	217
Organic solids in bog water, 1910,	214
Organic solids in bog water, unfiltered, 1911,	216
Total nitrogen in bog water, filtered, 1911,	219
Total nitrogen in bog water, unfiltered, 1911,	218
Organization list,	9
Paris green,	183
Atmospheric effects on use,	193
Experimental results,	187
Free arsenic, presence of,	185
History of,	183
“Instantaneous” and “slow” green, comparison of,	189
Manufacture, methods of,	184
Properties of,	190
Solubility of,	191
Solubility tests,	192
Path of electrical discharges,	165
Plant breeding, progress of,	44
Plants, small, electrical resistance of,	160
Proprietary cattle feeds, digestibility of: —	
Biles Union Grains,	255
Buffalo Creamery Feed,	256
Protena Dairy Feed,	256
Schumacher's Stock Feed,	255
Unicorn Dairy Ration,	264
Proportions and composition of parts of corn plant,	234
Red clover hay, digestibility of,	275
Red clover hay <i>v.</i> alfalfa hay,	276
Report of: —	
Agriculturist,	37
Botanist,	70
Chemist,	46
Feed and dairy section,	63
Fertilizer section,	48
Director,	11
Changes in staff,	11
Control work,	28
Information, dissemination of,	29
Entomologist,	72
Horticulturist,	44
Treasurer,	35
Veterinarian,	77
Research, Adams fund problems,	13
Resistance, electrical, of cut branches,	156
Of different tissues,	163
Influence of temperature,	167

	PAGE
Resistance, electrical — <i>Concluded.</i>	
Of small plants,	160
Of trees,	144
Rust on Vinca,	108
Sap flow, relationship of electrical resistance to,	162
Seeds and seedlings, effects of electrical charges on,	135
Seed work for year 1911,	102
Tables with discussion of:—	
Number samples and pounds tested,	106
Number tests for twelve years,	104
Onion, tobacco and celery germination,	105
Seed germination records,	102
Seed separation records,	103
Soils:—	
Bacterial flora, protozoa as a factor in,	132
Mechanical analysis of, new method,	115
Sterilized and unsterilized, bacterial growth of,	126
Soil sterilization, present status of,	121
Benefits of,	122
Substations:—	
Asparagus, Concord,	25
Cranberry, East Wareham,	14
Testing pure-bred cows,	68
Trade values of fertilizer ingredients,	51
Treasurer, report of,	35
Trees, electrical resistance of,	144
Cut branches, experiments with,	156
Different tissues, resistance of,	163
Flow of sap, relation to resistance,	162
Path of current,	165
Small plants, experiments with,	160
Types of corn suited to Massachusetts conditions,	221
Cob, analyses of,	241
Composition of parts, conclusions as to,	237
Condition of crop when cut and character of season,	235
Details of experiment,	221
Digestion coefficients,	232
Digestibility of plant,	231
Grain, analyses of,	240
Grain and cob, composition of,	240
Grain and cob, from ten average ears, weights and proportion of,	239
Grain and cob, relative proportions of,	238
Proportions and composition of parts,	234
Season on yield, effect of,	227
Summary,	242
Varieties, description of,	223
Yields per acre,	225
Variation of garden peas,	95
Veterinarian, report of,	77
Correspondence,	80
Diagnosis work,	79
Research work,	77
Bovine tuberculosis, transmission of,	78

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MASSACHUSETTS AGRICULTURAL
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PART II.,

BEING PART IV. OF THE FORTY-NINTH ANNUAL REPORT OF
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PART II.

GENERAL REPORT OF THE EXPERIMENT STATION.

CONTENTS.

PART II.

	PAGE
Summary of leading conclusions,	7
Alfalfa co-operative experiments,	10
Types of corn best suited to Massachusetts,	14
Complete analyses of corn grown in competition for the Bowker prize,	16
Methods of selection for plant improvement,	21
Experiments to determine the nitrogen absorption capacity of several well known chemicals,	26
Chemical methods for the preservation of manure,	31
Gypsum or land plaster,	32
Precipitated gypsum,	33
Gypsum-superphosphate and superphosphate,	33
Sulfuric acid,	33
Kainit,	34
Tobacco injury due to malnutrition or overfertilization,	35
Digestion experiments with cattle feeds,	47
Corn fodders (varieties),	48
Proprietary grain mixtures,	49
Alfalfa hay,	50
Red clover hay,	52
Bronzing of maple leaves,	54
Coarse nozzle versus mist nozzle spraying,	56
Experiments with rose soils,	60
A notable elm tree,	69
Some observations on the growth of elm trees,	72
Do we need a seed law in Massachusetts?	75
Diseases more or less common during the year,	78
Insects of the year 1911 in Massachusetts,	82

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION
OF THE
MASSACHUSETTS AGRICULTURAL COLLEGE,
AMHERST, MASS.

TWENTY-FOURTH ANNUAL REPORT.
PART II.

SUMMARY OF LEADING CONCLUSIONS.

WM. P. BROOKS, DIRECTOR.

A number of the papers included in this part of the annual report are themselves summaries of articles which will be found in Part I. of the report. It is impossible, therefore, to summarize them further. All the articles are brief and concise and should be read in full by those interested in the subjects discussed. Especial attention is called to the following conclusions: —

1. A majority of those who have tried co-operative experiments with alfalfa have attained either complete or partial success, and the results indicate that the crop can be grown profitably in many parts of the State.

2. The most profitable varieties of corn for ensilage are those which bring their ears to the milk stage in an average season.

3. The total yield of grain affects the value of a variety of field corn in greater degree than variation in chemical com-

position, and a large proportion of kernel to cob is a character of much importance.

4. Great improvement in yield of crops can be made by careful selection, and in the case of self-fertilized plants by pollinating from superior individuals.

5. Laboratory experiments indicate that the loss of nitrogen from manure cannot economically be prevented by use of chemicals. The best method of preservation appears to be to keep the manure moist and well packed.

6. Among the different chemicals tested sulfate of magnesia appears to be one of the best nitrogen absorbents, while gypsum (sulfate of lime), although most commonly used in farm practice, is one of the least active absorbents.

7. Tobacco injury, due to malnutrition or overfertilization, usually occurs on land that is underlaid with an impervious subsoil and poorly drained, as increased evaporation brings such an excess of plant food to the surface that normal growth is checked. Deficiency in rainfall may also have some influence. The remedy consists in breaking up the subsoil or in under-drainage, and also planting the land for a year or two to corn or grass.

8. Alfalfa has been shown to be rather superior in nutritive value to clover hay, and while it is a more costly crop to establish, its much greater length of life and larger annual yield render it preferable to clover wherever it can be grown.

9. The bronzing of maple leaves is not caused by pathogenic organisms. It occurs on very hot, dry days in periods of severe drouth, and is purely functional in nature.

10. From the standpoint of cost and efficiency the high-pressure coarse nozzle is superior to the low-pressure mist nozzle, especially for work on large trees. The nozzles at present in use can undoubtedly be greatly improved.

11. The soil best adapted to roses is one which contains from 8-12 per cent. of clay, and is well supplied with silt and the finest grades of sand. The proportion of these three classes of material should exceed 75 per cent.

12. The elm is greatly affected by the texture of the soil in which it grows. If this is right it is usually free from disease and attains enormous size and great beauty.

13. Elms thrive better in pastures and lawns than in mowings, and they are usually benefited by application of fertilizers and by cultivation.

14. The reasons why a seed law framed upon existing models would be unsatisfactory in Massachusetts are presented; the difficulties which must be met are discussed and the conclusion is reached that, for the present at least, while reasonable guarantees as to germination and purity should be required, it seems best to depend chiefly upon inspection and publicity.

ALFALFA CO-OPERATIVE EXPERIMENTS.

WM. P. BROOKS AND H. J. BAKER.

In the late summer of 1910 a number of farmers agreed to co-operate with the experiment station in determining the possible success of growing alfalfa in this State. The experiments have been made in 10 different counties. Northern grown seed treated with "Farmogerm" for inoculation with nitrogen-fixing bacteria was used. The following directions, which are believed to give a satisfactory method of preparing for the crop, were sent to all those taking part in the experiment:—

1. Plow in spring just as soon as possible after the ground can be worked.
2. Apply lime at the rate of about $1\frac{1}{2}$ tons to the acre and disk in at once.
3. About ten days later apply the following mixture per acre: basic slag meal, 1,500 pounds, high-grade sulfate of potash, 400 to 500 pounds, and disk in.
4. Thereafter harrow about once in ten to twelve days, until you are ready to sow the seed, which should not be later than about July 27.
5. When ready to sow the seed, apply per acre: nitrate of soda, 100 pounds, basic slag meal, 300 pounds, mixing them and harrowing in lightly.
6. Sow 30 pounds of seed per acre, in showery weather if possible, and cover as you would grass seed.

The fall months were exceedingly dry and, therefore, somewhat unfavorable; but in most cases the crop made an excellent start and was in good condition before winter began, having made sufficient growth to afford the needed protection. The winter was a rather hard one for alfalfa. In the spring circular letters were sent to the growers asking for information relative to the condition of the crop. Most of the growers sent in a very favorable report. The crop had winter killed to some

extent, though in most cases this occurred on poorly drained portions of the field, and in some instances it was due to standing water and ice. Under such conditions it would naturally be expected to winter kill, since it is a crop which demands good drainage. Standing water and ice during the winter are fatal to it. Most of the growers reported about the middle of May. At that time the crop was from 8 to 12 inches in height.

The experiments have been classified under three headings: successful, partially successful and failures. The number under each heading follows:—

Successful,	. . . . .	13
Partially successful,	. . . . .	9
Failures,	. . . . .	7
		—
Total,	. . . . .	29

Causes for Failures. — From the reports of the 7 experiments which failed entirely, one or more of the following conditions are given as the cause of failure:—

1. Winter killing.
 - (a) Due in most cases to poor drainage, standing water and ice.
 - (b) Planted too late so that there was not sufficient growth for winter protection.
2. Excessively dry weather so that the crop did not get a good start the first season before winter set in.
3. Weeds and grasses have come in. (This occurred mainly on fields that did not get a good start in the beginning and in places that winter killed.)

Condition as affected by Drouth. — The growing seasons of 1910 and 1911 are noted as excessively dry. The crop in many instances was affected by this long-continued drouth. Alfalfa, however, stood this excessive drouth well, and in several instances better than other farm crops. During this extremely dry time a grower on Nantucket wrote: "It is practically the only green thing on my farm." Another grower said: "It has stood the drouth fully as well as timothy, redtop and clover."

Condition as affected by Frost. — Some of the growers reported that it had heaved to some extent, but in practically all cases this appears to have occurred on land that was not thoroughly drained. Several growers reported that the crop did not heave.

Yield. — The range of yields on the successful experiments, as reported by the growers, is from $1\frac{1}{2}$ to 6 tons per acre. The average yield per acre of 14 growers who reported definite yields is $2\frac{1}{2}$ tons. In most cases the crop was cut three times and had sufficient growth for winter protection. The dates of cutting appear to have been about as follows: —

1. June 1 to June 30.
2. August 3 to August 20.
3. September 1 to October 1.

Opinions of Growers. — Following is a list of farmers who are co-operating in this work and their opinion as to the value of this crop for the section of the State in which they live: —

C. M. CUDWORTH (Cumington). — If land well prepared and planted on the dryest land it should be a good crop for two years at least.

JOHN H. BARTLETT (Nantucket). — Don't see any reason why it can't be raised with success. Have put in $2\frac{1}{2}$ acres more.

LOVETT BROTHERS (Oxford). — Believe it to be a valuable crop.

C. W. PRESCOTT (Concord). — Results very encouraging. Fed green to horses, hogs, cattle and hens with great profit.

F. E. TATREAU (Framingham). — Not promising, which is partly due to extremely dry season.

FRANK S. WALKER (Dudley). — I feel sure crop will be very valuable.

EDWARD KIRKHAM (Holliston). — So far I am not discouraged. Its value depends upon length of time it will remain in sod.

LYMAN P. THOMAS (Rock). — Can form better estimate next fall. Made a mistake in pasturing too late.

CHARLES L. CLAY (North Dana). — My land is sandy and it was so dry in June and July that it did better than I expected. It seems to be just the grass for this sandy valley.

PAUL CUNNINGHAM (Bolton). — From results obtained do not think crop will be valuable.

H. A. PARSONS (North Amherst). — Results indicate crop to be valuable.

CYRUS S. BARDWELL (Shelburne). — Will be valuable if blight can be controlled, otherwise, clover more valuable.

G. B. TROWBRIDGE (South Weymouth). — From results obtained believe it to be a valuable crop.

J. B. SAWYER (Bradford). — Highly satisfactory. Have planted 1½ acres more. Neighbors are planting it.

In conclusion I would say that the results of these experiments up to the present time indicate that alfalfa can be grown profitably when planted on land that has thorough surface and under-drainage, has been well prepared, and properly fertilized.

If the leaves show much "spot" or blight the crop should be cut at once. The reports of growers make it apparent that many failed to act on this plan.

In not a few instances the first and second crops were cut too late. The best time for cutting is indicated by the formation of buds at the base of the stems. These usually appear about the time blooming begins.

TYPES OF CORN BEST SUITED TO MASSACHUSETTS.¹

P. H. SMITH AND J. B. LINDSEY.

Since 1903 experiments have been in progress with corn to determine those types best suited to Massachusetts conditions. The total yield of dry matter per acre, digestibility, relative proportions, in some cases the composition of the various parts of the plant (stalk, leaf, ear and husk), and the relation of stage of development to the relative proportion of different parts as affecting the food value, have been carefully studied. The following varieties have been tested: Twitchell's Early Flint, Sanford White, Longfellow, Pride of the North, Rustler Dent, Leaming, Brewer's, Early Mastodon, Klondike, Red Cob Silage, White Cap Yellow, Wing's Improved White Cap, and Eureka.

The results of the study may be summarized under the following headings:—

1. The stalks and ears form substantially 70 per cent. of the entire maize plant; most varieties showed about 20 per cent. leaves and 10 per cent. husks.

2. The Twitchell, a small early maturing variety, showed an exceptionally large proportion of ears (55 per cent.), but it is not economical for Massachusetts conditions. The medium dent and flint varieties (Pride of the North, Rustler, Longfellow, Sanford White) averaged 33 per cent. of stalk and 37 per cent. of ears, and are quite well suited for grain, and serve fairly well for silage. The larger medium dent varieties that in an average season bring their ears to the milk stage, yield about 45 per cent. stalk and 26 per cent. ears, and are rather preferable for silage purposes (Leaming,

¹ The entire article with full data is to be found in Part I. of this report.

White Cap Yellow, Brewer's,¹ Early Mastodon¹). The very coarse late-maturing varieties which never ripen seed in this locality are not satisfactory for silage purposes.

3. As is well known, the season has a marked influence on the yield of the corn plant, the same variety under otherwise identical conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

4. The changes in chemical composition which the corn plant undergoes in its development are such that its maximum feeding value exists at its maturity.

5. Numerous digestion experiments have shown no wide variations in the digestibility of the several varieties, the range being from 67 to 77 per cent. with an average of approximately 70 per cent. The general statement can be made that the higher the percentage of extract or starchy matter present (the larger the percentage of ears) the higher the digestibility and resulting feeding value.

6. The percentage of grain to cob varies widely, depending, to some extent, upon the maturity of the plant when cut. The average for the several mature types was 15.5 per cent. cob and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 per cent. cob and 81.9 per cent. kernel. In either case the percentage of cob was less than that of the legal Massachusetts bushel, which in case of shelled corn is 56 pounds and in case of ear corn 70 pounds, thus allowing 14 pounds or 20 per cent. for cob.

7. The grain showed only slight variations in composition. It is believed that chemical composition cannot be considered an important factor in the selection of seed corn when the crop is to be used for the sustenance of live stock.

8. But little variation was noted in the composition of the corn cob. The net available energy in 100 pounds of cob is 40.2 therms, as against 85.5 therms in a like amount of corn meal; hence the cob has 47 per cent. of the value of the meal for feeding purposes.²

¹ Do better in southern New England.

² This is calculated on the basis of the method suggested by Kellner, and is the most satisfactory method available for the estimation of relative energy values.

COMPLETE ANALYSES OF CORN GROWN IN COMPETITION FOR THE BOWKER PRIZE.

BY P. H. SMITH.

The analyses which follow were made from samples grown in competition for the Bowker corn contest for the year 1910.¹ In this contest the production values of the several food ingredients as well as the total yield were considered, which necessitated a complete fodder analysis of the corn. Of the 27 samples sent to the station to be tested 22 were flint and 5 dent varieties. The analyses are figured to a uniform water content of 12 per cent., which is considered a fair average for crib-dried corn.

So far as we have been able to ascertain, all of the flint varieties were fully matured when harvested. Information is not at hand in regard to the stage of maturity of the dent varieties grown by John P. Bowditch and Butler Bros. Silver King, grown by the Middlebrook farm, and Brewer's dent, grown by E. W. Capen, were not fully matured when cut. Early Huron, grown by M. H. Williams, was ripe when harvested.

¹ For complete data see Book of the Bowker Contest, issued by the Bowker Fertilizer Company, 48 Chatham Street, Boston, Mass.

Table of Analyses.

[12 per cent. water basis.]

GROWER.	Variety.	Protein (Per Cent.).	Fat (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fiber (Per Cent.).	Ash (Per Cent.).
<i>Flints.</i>						
John P. Bowditch, Framingham, Mass.,	Stickney, . . .	10.03	4.88	70.42	1.23	1.44
Nathaniel I. Bowditch, Framingham, Mass.,	Stickney, . . .	10.09	4.66	70.79	1.17	1.29
Samuel Carr, Northborough, Mass., . . .	Stickney, . . .	10.58	4.85	70.01	1.26	1.30
Martin A. Carey, Brockton, Mass., . . .	Dibble, . . .	8.97	4.71	72.10	1.14	1.08
Paul Cunningham, Bolton, Mass., . . .	Stickney, . . .	11.59	4.95	68.83	1.17	1.46
Perley E. Davis, Granby, Mass., . . .	Davis Improved,	10.32	4.51	70.51	1.28	1.38
Arthur S. Felton, Bolton, Mass., . . .	Stickney, . . .	10.72	4.89	69.78	1.18	1.43
George H. Fish, North Appleton, Me., . . .	Yellow Flint, . . .	9.50	4.11	71.12	1.67	1.60
W. C. Ford, Whitefield, Me., . . .	Yellow Flint, . . .	9.55	4.45	70.31	2.44	1.25
A. J. Guptil & Sons, Berwick, Me., . . .	Ordway, . . .	10.21	4.77	70.52	1.22	1.28
Arthur T. Hathaway, Monmouth, Me., . . .	Early Canada, . . .	9.74	4.73	71.08	1.17	1.28
Joseph Howland, Taunton, Mass., . . .	Yellow Flint, . . .	10.33	4.55	70.48	1.27	1.37
Hathorn J. Libby, Charleston, Me., . . .	Yellow Flint, . . .	10.09	4.29	70.39	1.69	1.54
L. W. Peet, Middlebury, Vt., . . .	White Australian,	10.30	4.65	70.49	1.17	1.39
Burton L. Robinson, Monmouth, Me., . . .	Yellow Flint, . . .	9.21	4.80	71.50	1.20	1.29
William E. Sarle, Shawomet, R. I., . . .	Longfellow, . . .	10.67	4.73	69.94	1.30	1.36
George E. Stickney, Newburyport, Mass., . . .	Stickney, . . .	9.30	4.64	71.68	1.13	1.25
Edward P. West, Hadley, Mass., . . .	Yellow Flint, . . .	10.42	4.61	70.53	1.14	1.30
L. S. White, Collinsville, Conn., . . .	White Flint, . . .	9.65	4.53	71.06	1.36	1.35
James E. Phelps, Millbury, Mass., . . .	Yellow Flint, . . .	10.91	4.78	69.73	1.17	1.41
John G. Francis, Bridgewater, Mass., . . .	Early Canada, . . .	10.33	4.88	70.29	1.11	1.39
J. E. Hamilton, Garland, Me., . . .	Yellow Flint, . . .	11.20	4.81	68.65	1.70	1.64
Average, . . . . .	. . . . .	10.17	4.67	70.46	1.33	1.37
<i>Dents.</i>						
John P. Bowditch, Framingham, Mass., . . .	Funk Bros., . . .	9.07	3.73	71.84	2.12	1.24
Middlebrook farm, Dover, N. H., . . .	Silver King, . . .	9.55	4.29	71.10	1.75	1.31
M. H. Williams, Sunderland, Mass., . . .	Early Huron, . . .	9.44	4.30	71.23	1.65	1.38
E. W. Capen, Monson, Mass., . . .	Brewer's, . . .	8.84	3.47	72.43	2.01	1.20
Butler Bros., Montello, Mass., . . .	Diamond Joe, . . .	9.77	3.33	71.63	1.94	1.33
Average, . . . . .	. . . . .	9.33	3.82	71.67	1.89	1.29

The corn showed the following ranges in analysis:—

	<i>Flint.</i>	
	High (Per Cent.).	Low (Per Cent.).
Protein,	11.59	8.97
Fat,	4.95	4.11
Nitrogen-free extract,	72.10	68.65
Fiber,	2.44	1.11
Ash,	1.64	1.08
	<i>Dent.</i>	
Protein,	9.77	8.84
Fat,	4.30	3.33
Nitrogen-free extract,	72.48	71.10
Fiber,	2.12	1.65
Ash,	1.38	1.20

From the data obtained it is evident that chemical composition cannot be considered an important factor in the selection of seed corn where the crop is used for the sustenance of live stock. For such a purpose that variety should be selected which is suited to the locality where it is grown and which will produce the largest amount of shelled corn to the acre.

The variation in the analyses of the different samples is evidently due largely to the relative size of the several parts of the kernel (hull, gluten layer, starch and germ).

Additional Data.

[Relative proportions of kernels and cob.]

GROWER.	Variety.	WEIGHT OF TEN EARS (OUNCES).		AVERAGE WEIGHT PER EAR (OUNCES).		Weight of Kernels from Ten Ears, Water Free (Ounces).	Weight of Cob from Ten Ears, Water Free (Ounces).	PER CENT. KERNEL AND COB IN DRY MATTER.	
		Air Dry.	Water Free.	Air Dry.	Water Free.			Kernel.	Cob.
<i>Flints.</i>									
Samuel Carr, Northborough, Mass.,	Stickney,	83.4	77.9	8.3	7.8	65.2	12.7	83.6	16.4
Perley E. Davis, Granby, Mass.,	Yellow Flint,	78.5	73.0	7.9	7.3	61.9	11.1	84.8	15.2
W. C. Ford, Whitefield, Me.,	Yellow Flint,	89.6	83.6	9.0	8.4	65.8	17.8	78.7	21.3
A. J. Gupta & Sons, Berwick, Me.,	Ordway,	68.9	64.0	6.9	6.4	53.6	10.4	83.8	16.2
Arthur T. Hathaway, Monmouth, Me.,	Early Canada,	61.0	57.0	6.1	5.7	48.9	8.1	85.8	14.2
L. S. White, Collinsville, Conn.,	White Flint,	53.7	50.1	5.4	5.0	42.4	7.7	84.6	15.4
Average, . . . . .	. . . . .	72.5	67.6	7.3	6.8	56.3	11.3	83.6	16.4
<i>Dents.</i>									
Middlebrook farm, Dover, N. H.,	Silver King,	84.0	78.3	8.4	7.8	65.7	12.6	83.9	16.1
M. H. Williams, Sunderland, Mass.,	Early Huron,	93.8	87.2	9.4	8.7	74.1	13.1	85.0	15.0
E. W. Capen, Monson, Mass.,	Brewer's,	86.5	79.9	8.7	8.0	64.5	15.4	80.7	19.3
Average, . . . . .	. . . . .	88.1	81.8	8.8	8.2	68.1	13.7	83.2	16.8

Ten representative ears of 6 of the flint and 3 of the dent varieties were secured from the growers, and the relative proportion of corn to cob determined. With but two exceptions the differences were not marked. The yellow flint corn grown by W. C. Ford consisted of 21.3 per cent. of cob and 78.7 per cent. kernel. This corn had an exceptionally large ear with a bulging butt, and the kernels were quite shallow, a condition which would affect adversely the total yield of grain. Brewer's dent corn, grown by E. W. Capen of Monson, consisted of 80.7 per cent. kernel and 19.3 per cent. cob. This corn was quite immature when cut and would have shown a larger percentage of kernel had it reached maturity.

In the selection of seed corn the relative proportion of kernel to cob should be carefully considered. If seed corn is purchased rather than home grown, it is advisable to obtain ear corn, test its vitality by approved germination tests, and finally determine the proportion of kernels and cob. This is easily done by weighing separately the kernels and cob and calculating the percentage of each. The ear should not contain over 17 per cent. of cob. It is a significant fact that the prize corn in this contest contained only 15.2 per cent. of cob.

METHODS OF SELECTION FOR PLANT IMPROVEMENT.

BY J. K. SHAW.

The fact that plants are unlike lies at the foundation of all plant improvement. Sometimes it is first attempted to bring about increased unlikeness by hybridization or otherwise, but the great part of the work is the choice of desirable plants and by repeated selection securing and maintaining the desired standard. Selection of desirable plants is generally followed by more or less positive results, but not uniformly so; sometimes the results seem to be negative, or at any rate not as satisfactory as might be desired.

The plant is much the subject of its environment; variation in the nature and amount of the available food supply, and the varying conditions of weather and climate, affect it strongly, and selection of plants whose desirable qualities are thus brought about must obviously be less effective than selection of differences that arise from causes within the plant, and which persist from generation to generation. In a collection of varying plant individuals some of the differences are environmental and are inherited in small degrees if at all, while others are innate with the plant and persist from generation to generation. The task of the man who would improve his stock of beans or corn is to distinguish between these two sorts of variation, and select and hold to that which is not due to environment but is inherited by succeeding generations.

Certain investigations that have been carried on by the department of horticulture during the past four years with garden peas bear directly on this. This work is fully reported in Part I. of this report (p. 82), to which the reader may refer for detailed information. It is the purpose of this article to set

forth the application of results there indicated to practical methods of plant improvement. The methods used have served to distinguish between those differences that are due to soil and weather conditions and those peculiar to the plant which are inherited and therefore of greatest interest to the practical plant grower. The results which are in harmony with those of other investigations indicate that our common varieties of garden peas are composed of subvarieties or, more properly, strains, which differ from each other in varying degrees, this difference, however, being relatively fixed and permanent.

A planting of Excelsior peas proved to contain two strains, one of which exceeded the other in productiveness by about 15 per cent. in an average of four years crops. While this difference is a pronounced one, it would have been totally hidden by differences in yield due to environment had the two strains not been planted separately and in large numbers. The separation of this more prolific strain should prove advantageous to the gardener.

According to the generally accepted belief, the selection of superior individuals within this strain should result in further improvement. This is doubtful. It is probable that if any real progress can be made by this method it will be small and of doubtful permanency. We do not regard this as a proven fact, but only as a strong probability. The efforts of the gardener should then be directed to the isolation of their superior strains where they exist in our common varieties.

We may now outline a simple method of accomplishing this.

The first step is to secure the best available stock of a variety suited to the purpose of the grower. This should be planted and cared for in the best possible manner. The most uniform plot of ground available should be selected. The grower should study the plants carefully and select those which appear the most desirable, particularly as regards yield. The seed from each plant should be gathered separately and given a number. All shrunken or otherwise imperfect seeds should be thrown out.

The next spring the seeds from the several plants should be planted, each in a row by itself, under the most uniform con-

ditions possible as to space for the plants and soil, and given good care as before. The grower should study them carefully during the growing period and make a note of the rows showing desirable characters. As yield is a most important character, it may be well to provide for a careful record of the yield of equal length of row of the different selections. In the fall the seed from the most successful rows should be saved as before. If one cares to take the trouble to select from the better plants within the row it will do no harm, but it seems doubtful if it will do any good, and it will delay the increase of the stock to a point when it is sufficient for the general crop. The superior rows chosen will each yield seed enough, after rejecting the imperfect seeds by sifting or other convenient method, to plant a longer row or a small plot, thus providing for the growing of the selected strains in greater quantity and enabling one to judge their comparative value better. This operation may be repeated a third time, and this should result in the final selection of the best that the original selection contained.

Fig. 1 will serve to make this method of selection perfectly clear. Twelve plants are chosen from a field plot and sown the

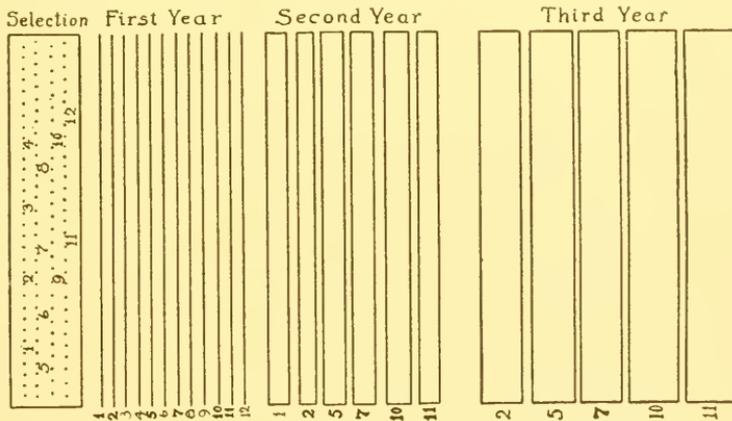


FIG. 1.

first year in 12 rows. The ones with the heavy-faced figures prove the better and are sown the second year in small plots. One of these is rejected and 5 are retained for a third year. Of these number 7 proves the most desirable and is retained for field sowing. If possible a larger number of plants than

indicated should be chosen at the start, thus increasing the chances of securing the very best that the variety affords. Experience has shown most conclusively that the character of an individual plant is small indication of the value of its progeny, and the selection that proves finally to be the best may very likely come from one of the less promising plants of the original selection.

The foregoing has been written as applicable to the garden peas alone, for our own investigations along this line have been confined to that plant. The question now arises whether the same methods may be applied to other plants as well.

Our common garden peas are almost invariably self-pollinated, and there is reason to believe that the same general method will succeed equally well with all self-pollinated plants; with naturally cross-pollinated plants some modification will be necessary. Among our common garden and field crops the following are believed to be almost always self-pollinated; peas, beans, tobacco, wheat, oats, barley. Most others are often or generally crossed in the field, and for such the method must be modified to make sure that the pollen for the improved races comes from the best possible plant.

Assuming that naturally cross-fertilizing plants are made up of slightly differing strains, as seems to be the case with peas, a field of plants will be made up largely of individuals that are crosses between the several strains; consequently the task of separating superior strains becomes a complicated one. Furthermore, it is probable that with some, and perhaps many, naturally crossed fertilized plants, crossing between distinct strains or varieties results in the first generation, in greater vigor and more productive plants. Thus is the problem of securing the very best still further complicated.

Nevertheless, great improvement can be made by following substantially the scheme outlined for self-fertilized plants, but taking into consideration the pollen parent, and pollinating from superior individuals either by hand or planting individuals which are desired as parents together in an isolated location. The latter method is often used with corn and other wind-pollinated plants. In any event it is always of the utmost

importance to judge the value of any strains by the average of the largest possible number of individuals belonging to it, and if the test can be extended over a period of several years, three or four at least, the estimate of value will be more dependable.

With cross-fertilized plants it may prove best to use for field seeding the first generation hybrid between certain strains which are known to give desirable progeny when so crossed, and repeating the same cross for succeeding years, growing only the first generation of the cross as the benefits derived from crossing tend to disappear in succeeding generations.

We are only beginning to realize the improvement, especially in yield, that may be realized by proper methods of breeding, and great progress is being made in working out these methods. Their general application by practical plant growers will effect most substantial increase in the value of crops. It is, perhaps, not too much to say that the general application in this Commonwealth of our present knowledge of breeding would result in an increase of 20 per cent. in the value of its crops.

It is hoped that the farmers and gardeners of Massachusetts may become more interested in plant improvement, and the department of horticulture of the experiment station will be glad to co-operate with any one desiring further information or specific suggestions.

EXPERIMENTS TO DETERMINE THE NITROGEN ABSORPTION CAPACITY OF SEVERAL WELL-KNOWN CHEMICALS.

BY HENRI D. HASKINS.

Some years since a series of tests was instituted to show the nitrogen-absorbing capacity of several of the better known chemicals, more commonly used as fixers or absorbers of nitrogen in the form of ammonia, resulting from the decomposition of barnyard manure. Four hundred and fifty grams of manure were employed in each test, and 100 grams of each of the following chemicals were used:—

1. Sulfate of magnesia.
2. Sulfate of lime (gypsum).
3. Sulfate of potash-magnesia.
4. Kainit.
5. High-grade sulfate of potash.

The chemicals were all tested for nitrogen with negative results. An analysis of the several manures which are represented by the numbers from 1 to 5, as in case of the chemicals, showed the following percentages of moisture and nitrogen.

Table 1.

NUMBER.	Moisture.	Nitrogen.	NUMBER.	Moisture.	Nitrogen.
1,	70.37	.62	4,	71.77	.61
2,	73.75	.58	5,	72.86	.59
3,	73.29	.61	Average, . . .	72.40	.602

The tests were conducted in the following manner: 450 grams of manure were placed in like-sized crystallization dishes,

and a large pipestem triangle was placed across the top of each dish upon which was set a smaller crystallization dish containing, in each case, 100 grams of one of the absorbents. Each crystallization dish thus arranged was set on a ground-glass plate and enclosed within a bell glass, which was made air-tight by the use of tallow and sealed with melted paraffine. The tests were conducted side by side in a room of ordinary temperature (70° to 75° F.) and covered a period of six weeks. At the close of the experiment all of the chemicals were subjected to a chemical analysis, and showed the following content of nitrogen:—

Table 2. — Weight of Nitrogen in Manure and Nitrogen absorbed by Each Chemical.

	Grams Nitrogen in 450 Grams Manure.	Grams Nitrogen absorbed.	Per Cent. Nitrogen absorbed.
Sulfate of magnesia,	2.79	.018409	.66
Kainit,	2.61	.016553	.63
Sulfate of potash-magnesia,	2.75	.006884	.25
High-grade sulfate of potash,	2.75	.003483	.13
Sulfate of lime (gypsum),	2.66	.000851	.03

From the above table of comparative results it will be seen that magnesium sulfate absorbed the greatest amount of nitrogen, and that gypsum, the absorbent more commonly used in general farm practice, had the lowest nitrogen absorption power of any of the chemicals under trial. The percentage of nitrogen absorbed, however, in proportion to the amount contained in the manure was so small (less than 1 per cent.) as to indicate that but little decomposition took place. This is not to be wondered at when it is recalled that the manure was placed in an air-tight dish.

To obtain further data as to the nitrogen-absorbing capacity of the different chemicals during the process of decomposition of barnyard manure, another test was instituted, beginning on the same date as the above-described experiments and continuing through a period of six weeks. Four hundred and fifty

grams of manure (analyzing .65 per cent. of nitrogen and 68.57 per cent. of moisture) were placed in a glass vessel and enclosed within a bell glass similar to the ones used in the above tests, with the exception that the bell jar was provided with glass tubes for the ingress and egress of air. The air passing into the bell jar was made to pass through a solution of sulfuric acid to remove any traces of ammonia which might be present in the atmosphere. Upon leaving the bell jar the air was made to pass through a standard solution of half normal hydrochloric acid, which was to absorb any ammonia which might be given off in the process of decomposition of the manure. The exit tube from the flask of standard hydrochloric acid was attached to an aspirator to provide a steady current of air through the apparatus. The apparatus was made perfectly airtight by sealing, so that no air could enter the bell jar except by first passing through the sulfuric acid arranged to remove all traces of ammonia. An analysis of the standard solution of hydrochloric acid at the end of the experiment showed the following amount of nitrogen, expressed in fractions of a gram .001709. The infinitesimal amount of nitrogen liberated may be due to the fact that the steady current of dry air which was constantly passing through the bell jar removed the greater part of the moisture from the manure, thus retarding and preventing its natural decomposition.

For the purpose of verifying the results of the foregoing experiments a series of tests was instituted similar to those previously described, with the exception that 50 grams of each fixer were used and the experiment covered a much longer period of time, beginning March 21, 1901, and continuing through the spring and summer, concluding Feb. 1, 1902.

In the following table the first column shows the amount of nitrogen contained in 450 grams of the manure. The second column shows the nitrogen given off during the experiment, both in grams and percentage, as determined by a chemical analysis of the manure samples before and after the experiment. The third column shows the nitrogen absorbed as determined by a chemical analysis of each fixer at the conclusion of the experiment.

Table 3.

ABSORBENT.	NITROGEN PRESENT IN MANURE.	NITROGEN GIVEN OFF.		NITROGEN ABSORBED (BASIS OF GRAMS IN MANURE).	
	Grams.	Grams.	Per Cent.	Grams.	Per Cent.
Sulfate of magnesia,	2.30	.13449	5.85	.05229	2.27
Kainit,	2.28	.16811	7.37	.04653	2.04
Sulfate of potash-magnesia,	2.39	.11768	4.92	.04031	1.69
High-grade sulfate of potash,	2.46	.31961	12.99	.03660	1.49
Sulfate of lime,	2.35	.26217	11.16	.00179	.08

TABLE 4. — *Showing the Order of Excellence of the Different Chemicals used as Fixers and the Percentage of Liberated Nitrogen which each Fixer absorbed.*

ORDER OF EXCELLENCE OF THE ABSORBENTS.	Per Cent. of Liberated Nitrogen absorbed.
1. Sulfate of magnesia,	38.88
2. Sulfate of potash-magnesia,	34.25
3. Kainit,	27.67
4. High-grade sulfate of potash,	11.45
5. Sulfate of lime (gypsum), . . . . .	.68

The above tables show that the 5 different samples of manure, of 450 grams each, contained from 2.28 to 2.46 grams of nitrogen, and of these amounts from 5.85 per cent. to 12.99 per cent. were liberated. Of the relatively small amounts liberated the sulfate of magnesia absorbed 38.88 per cent., and was followed by the other chemicals as indicated in Table 4. How much more nitrogen as ammonia would have been absorbed by the different chemicals had the manure undergone a more normal fermentation it is impossible to state. The above tests strongly indicate sulfate of magnesia and sulfate of potash-magnesia to be decidedly preferable to gypsum as ammonia absorbents.

If the above, however, were typical of actual farm conditions we should have the following results: nitrogen in 1 ton of barnyard manure, 37.2 pounds; per cent. absorbed by sulfate

of magnesia (being, of course, a part of the nitrogen set free as ammonia), 1.87, which is equal to .67 pound of nitrogen. In other words, less than 1 pound of nitrogen would be actually saved from a ton of manure, which, of course, is of no practical account. It is probable, however, that much more nitrogen in different forms would be liberated than the amounts secured in the above experiment, and that probably somewhat more would be absorbed.

Extensive investigations by German authorities indicate that the value of the nitrogen saved by chemical absorbents is quite out of proportion to the cost of the chemicals and the labor involved. See the results of their investigations in the paper following, entitled, "Chemical Methods for the Preservation of Manure."

CHEMICAL METHODS FOR THE PRESERVA- TION OF MANURE.

BY J. B. LINDSEY.

Barnyard manure is composed (*a*) of the undigested part of the food, represented by the solid matter or feces; (*b*) the end products of the protein digestion largely diluted with water, namely, the urine; and (*c*) such materials as straw, sawdust and the like, which are used for bedding. The solid part, or feces, is mixed with more or less of the digestive fluids, such as the bile of the liver, the intestinal juices and minute pieces of the skin or lining of the intestines. The nitrogen-containing matter of the urine of herbivorous or plant-eating animals is composed chiefly of urea, together with such mineral matter as is no longer of use in the blood (potash, soda, phosphates, etc.). A considerable portion of the soluble nitrogenous part of the manure is likely to be lost, both by volatilization and leaching. The loss through volatilization, and in part through leaching, is brought about by the action of bacteria, of which manure contains an innumerable number and a great variety of species.

Briefly stated there are four groups of bacteria which act upon the nitrogenous matter of the manure:—

1. *Putrefactive bacteria*, which attack both the insoluble part of the nitrogenous matter and also the urea or soluble part, and convert them into carbonate of ammonia, which is volatile.

2. *Nitrifying bacteria*, which act upon the ammonia compounds and convert them into nitrites and nitrates. In order to be active they must have plenty of oxygen, and hence act near the surface of the manure pile.

3. *Denitrifying bacteria*, which have the power to take the oxygen from the nitrates, thus decomposing it and setting the

unbound nitrogen free. These bacteria act when the air is excluded, deriving their supply of oxygen both from the nitrates and from the protein and carbohydrates of the manure.

4. *Protein-forming bacteria.* In order for bacteria to live and multiply they must have as a food a certain amount of nitrogen-containing matter. This they take from the ammonia and nitrates (soluble compounds), and convert it again into the insoluble proteid matter, which naturally does not become again available, and then only gradually, until the bacteria cease to live. Certain molds also act in a similar way.

Bacteria, therefore, destroy the nitrogenous matter of the manure by converting it into the volatile ammonia compounds and nitrates, and then reconvert a small portion of the ammonia and nitrates back into protein; they also destroy the nitrates and set the elementary nitrogen free.

If manure is allowed to remain in loose piles exposed to the air for months, about 35 per cent. of its total nitrogen is likely to be lost. The extremes are said to be from 20 to 50 per cent. Fully one-third of the total nitrogen lost has been ascertained to be in the elementary form, *i.e.*, uncombined. No method is known for preventing the loss of the uncombined nitrogen.

Various chemical methods have been tried to catch that portion of the nitrogen which escapes in the form of ammonia. The results of the numerous experiments may be summarized as follows:¹

GYPSUM OR LAND PLASTER.

As early as 1860 ordinary land plaster or calcium sulfate was recommended, particularly by the German investigator, Grouven, as a substance suitable to catch and hold the volatile ammonia. Later the French investigators, Müntz and Girard, by means of carefully conducted experiments, demonstrated that such material was of no particular value for such a purpose. The reports of other investigators confirmed this and showed that the plaster actually hastened the decomposition of the manure.

¹ After A. Stutzer, *Behandlung und Anwendung der Stalldüngers.*

PRECIPITATED GYPSUM.

About 1870 the manufacture of double superphosphate was undertaken. The method consisted of extracting the raw phosphate with dilute sulfuric acid, and this solution was used again for extracting another portion of the phosphoric acid. This method left behind a large amount of gypsum which contained about 1 per cent. of citrate soluble phosphoric acid. This residue was sold to farmers at a low price, and was used to check the escape of the ammonia from the manure. Experiments by several investigators, particularly by Hansen, showed it to be of no particular value for such a purpose.

GYPSUM-SUPERPHOSPHATE AND SUPERPHOSPHATE.

In Germany low-grade raw phosphates were treated with sulfuric acid, and a product was secured containing 4-6-8 per cent. of soluble phosphoric acid, and this was called gypsum-superphosphate. It was found that this material, if used in sufficient amount, held fast the ammonium carbonate present in the manure and checked the further action of the bacteria. This was due to the action of the free phosphoric acid. Sulfuric acid and ordinary superphosphate had a similar effect. Because of the cost of such materials, however, their use was not advised.

SULFURIC ACID.

After the use of superphosphate had been discontinued numerous experiments were made with quite dilute sulfuric acid. A 2 per cent. solution of the sulfuric acid was sprinkled over the manure before throwing it out, and also in the gutters after its removal. The dilute acid was also mixed with peat and sand before distributing it. Experiments by Maereker and Pfeiffer showed that such treatment made the manure sour, checked the loss of ammonia, and better results were secured temporarily in the field due to the conserved nitrogen. It was found, however, that one had to be very careful, otherwise the feet and udder of the animal would be injured; and, furthermore, that the resulting manure had a bad effect upon the physical character of heavy soils which required the addi-

tion of lime to correct. These disadvantages, together with the cost of the acid, rendered the use of the sulfuric acid inadvisable.

KAINIT.

As early as 1860 kainit was recommended as a desirable material for the preservation of manure; it was supposed that the sulfate of magnesia in this salt would act even better than the gypsum. Holderfleiss recommended 5 pounds, and later 2 pounds, of kainit to every 100 pounds of manure. Numerous other investigators experimented with the kainit and came to the conclusion that it was of no particular value for the purpose.

German workers, therefore, have come to the conclusion that there is no economy in attempting to check the loss of nitrogen in manures by chemicals, and advise in their place the following simple method of treatment:—

Halt ihn feucht und tritt ihn feste,
Das ist für den Mist das beste.

Keep the manure moist and well packed,
That is the best method of preservation.

TOBACCO INJURY DUE TO MALNUTRITION OR OVERFERTILIZATION.

BY H. D. HASKINS.

During the past four or five years the experiment station has received occasional inquiries from tobacco growers concerning certain peculiar conditions which affect the young tobacco plant, and which usually manifest themselves soon after transplanting. The young plants may make a small growth in the field during the first week, after which differences in growth are observed. The plants growing on low places or hollows, which receive drainage from the surrounding soil, seem to be more affected and show a more stunted growth than do those on the more elevated portions of the field. It was thought at first that the trouble was due to some fungus disease, but a careful microscopical examination failed to reveal the presence of fungi which could be held accountable for the trouble. An examination of the roots showed that the tap root had been destroyed; that the plant, in its endeavor to recover from the injury, had thrown new secondary roots, which in turn had become injured or destroyed so that it was unable to make any appreciable growth. It was the opinion of Dr. G. E. Stone, the vegetable pathologist, that the trouble was due to overfertilization, the roots having all of the characteristic symptoms of fertilizer burning. The absence of fungi also indicated that some abnormal soil condition was responsible for the trouble.

Samples of the surface soil were, therefore, carefully taken from a field where the trouble was noticed. Numbers 1, 2 and 3 were taken from portions of the field where the trouble was most conspicuous, number 4 from an elevated portion of the field, showing practically a fairly normal growth, and number

5 from the tobacco bed which furnished the plants for setting the field. Exact quantitative determinations of nitrogen, potash, phosphoric acid and lime were made, using 1.115 specific gravity hydrochloric acid as a solvent. For the sake of comparison the results have been calculated to a normal moisture soil condition, namely, 20 per cent. The results have also been expressed in pounds per acre, it being assumed that an acre of the average tobacco soil 1 foot deep would weigh about 3,000,000 pounds.

TABLE 1. — *Showing Constituents soluble in Hydrochloric Acid Solution.*

	SOIL No. 1, ABNORMAL.		SOIL No. 2, ABNORMAL.		SOIL No. 3, ABNORMAL.		SOIL No. 4, NORMAL.		SOIL No. 5, TOBACCO BED.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.000	—	20.000	—	20.000	—	20.000	—	20.000	—
Organic matter,	6.456	193,680	6.576	197,280	6.304	189,120	7.304	219,120	5.144	154,320
Nitrogen, . . . . .	.182	5,472	.221	6,624	.210	6,312	.246	7,380	.092	2,760
Phosphoric acid, . . . . .	.164	4,920	.110	3,312	.165	4,944	.196	5,880	.478	14,328
Potassium oxide, . . . . .	.182	5,472	.156	4,680	.110	3,288	.127	3,816	.211	6,336
Calcium oxide, . . . . .	.640	19,200	.506	15,168	.769	23,064	.568	17,040	1.096	32,880

As may be seen from the table of analysis, it was not possible to account for the trouble from a chemical analysis showing the total amount of the several elements of plant food present, soluble in the acid solution. The soil producing a normal plant showed a *larger amount* of nitrogen and phosphoric acid than the three abnormal soils producing a stunted growth; also in one instance a *larger amount* of potash and lime.

It seemed at least possible that any injurious effect to the growing plant might be due to the *water soluble portion* of the various fertilizer constituents contained in the soil. A given weight (200 grams) of each soil was, therefore, successively washed with the same volume of hot water (1,000 cubic centimeters), the water being allowed to percolate through the soil contained within a separatory funnel, cylindrical in shape. The water solution was evaporated to dryness, carefully weighed, and a chemical analysis was made of the saline residue. The results have been calculated on the basis of 20 per cent. moisture in the soil, and have also been computed to show the pounds of the various constituents per acre.

TABLE 2. — Showing Constituents soluble in Hot Water, Results figured to Parts in 100 Parts of Soil, the Latter showing a Moisture Content of 20 Per Cent.

	SOIL No. 1, ABNORMAL.		SOIL No. 2, ABNORMAL.		SOIL No. 3, ABNORMAL.		SOIL No. 4, NORMAL.		SOIL No. 5, TOBACCO BED.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids (largely saline residue), . . . . .	.2000	6,000.0	.2096	6,288.0	.1384	4,152.0	.1072	3,216.0	.0800	2,400.0
Water soluble nitrogen, . . . . .	.0210	631.0	.0229	868.0	.0108	324.0	.0099	298.0	.0068	204.0
Water soluble potash, . . . . .	.0238	715.0	.0219	658.0	.0199	598.0	.0069	206.0	.0073	218.0
Water soluble phosphoric acid,	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Water soluble calcium oxide, . . . . .	.0344	1,032.0	.0275	825.0	.0271	814.0	.0144	431.0	.0202	605.0
Water soluble sodium oxide, . . . . .	.0146	438.0	.0148	444.0	.0188	564.0	.0144	431.0	.0159	478.0
Water soluble magnesium oxide, . . . . .	.0094	282.0	.0180	540.0	.0073	219.0	.0144	431.0	.0046	137.0
Water soluble iron and aluminum,	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.
Water soluble sulfates calculated as SO ₃, . . . . .	.0272	816.0	.0210	639.0	.0147	443.0	.0158	475.0	.0082	247.0
Water soluble chlorine,	Trace.	.3	Trace.	.7	Trace.	.3	Trace.	.2	Trace.	.1
Acidity,	Trace.	.4	Trace.	.4	Trace.	.4	Trace.	.4	Trace.	.4

The results shown by this table tell quite a different story than do the analyses in the first table. Note the comparatively small amount of total solids, nitrogen, potash and, in fact, of most all of the water soluble constituents in soil No. 4, which showed a normal growth of tobacco, and No. 5, taken from tobacco bed. The soils giving abnormal results showed an increase of over 70 per cent. in total soluble solids, over 85 per cent. in water soluble nitrogen, and over 219 per cent. in water soluble potash. To have supplied the water soluble nitrogen found in soil No. 2, it would have required an application of 3,445 pounds of nitrate of soda per acre; to have supplied the water soluble potash found in soil No. 1 it would have required an application of 1,112 pounds of high-grade sulfate of potash per acre.

It was subsequently discovered that the field was underlaid with a hard impervious subsoil furnishing very poor drainage facilities, the soil had been used for the cultivation of tobacco continuously for more than thirty years. These facts, taken in connection with the very large amount of soluble plant food present, seemed to indicate strongly that the trouble was due to the accumulation of soluble saline constituents, probably originating in the fertilizers which had been applied in very liberal quantities for many years. It is a reasonable assumption that, had the soil been underlaid by an open porous subsoil, the condition would never have occurred, as the soluble salines would have passed out in the drainage water. This is borne out by the fact that all of the soils which have given this trouble have had imperfect drainage. In this connection it seemed of interest to procure several typical, well-drained tobacco soils which had been used continuously for thirty or forty years for tobacco culture. Three samples of soil and subsoil were, therefore, carefully taken from the farms of well known tobacco growers in various parts of the Connecticut valley. The soil was taken to a depth of 1 foot, the subsoil to a depth of 1 foot below the surface soil.

The following table shows the composition of the several soils and subsoils. Hydrochloric acid, specific gravity 1.115, was used as a solvent. The results are expressed on a 20 per cent. moisture basis, also in pounds per acre.

TABLE 3. — *Averages of Normal Surface Soils used for Over Thirty Successive Years for the Cultivation of Tobacco.*

	SOIL No. 1.		SOIL No. 2.		SOIL No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.0000	—	20.0000	—	20.0000	—
Nitrogen, . . . . .	.0970	2,910	.0810	2,430	.0604	1,812
Phosphoric acid, . . . . .	.2341	7,023	.1535	4,605	.0810	2,430
Potassium oxide, . . . . .	.1940	5,820	.2020	6,060	.1691	5,073
Calcium oxide, . . . . .	.2131	6,393	.3300	9,900	.3450	10,350
Sodium oxide, . . . . .	.1291	3,873	.2340	7,020	.1192	3,576
Magnesium oxide, . . . . .	.0410	1,320	.0291	873	.0880	2,640

TABLE 4. — *Analyses of Subsoils taken from Field used for Over Thirty Successive Years for the Cultivation of Tobacco.*

	SOIL No. 1.		SOIL No. 2.		SOIL No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.0000	—	20.0000	—	20.0000	—
Nitrogen, . . . . .	.0251	753	.0183	549	.0220	660
Phosphoric acid, . . . . .	.0880	2,610	.0482	1,446	.0810	2,430
Potassium oxide, . . . . .	.1530	4,590	.1690	5,070	.1370	4,110
Calcium oxide, . . . . .	.3770	11,310	.3610	10,830	.2790	11,370
Sodium oxide, . . . . .	.1280	3,840	.1610	4,830	.1630	4,890
Magnesium oxide, . . . . .	.0723	2,169	.0580	1,740	.0733	2,199

Two hundred grams of each soil and subsoil were also washed with 1,000 cubic centimeters of hot water. The solution was evaporated to dryness and a chemical analysis was made of the soluble residue. The results are computed on the basis of 20 per cent. moisture in the soils; they are also expressed in terms of pounds per acre of the various ingredients.

TABLE 5. — *Water Soluble Constituents contained in Normal Surface Soils used for Over Thirty Successive Years for the Cultivation of Tobacco. Underlying Subsoil Open and Porous, furnishing Good Facilities for Drainage.*

	SOIL No. 1.		SOIL No. 2.		SOIL No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids, . . . . .	.0881	2,643	.0937	2,811	.0509	1,527
Water soluble nitrogen, . . . . .	.0092	276	.0079	237	.0093	279
Water soluble potash, . . . . .	.0150	450	.0153	459	.0054	162
Water soluble phosphoric acid, . . . . .	.0029	87	.0030	90	Trace.	Trace.
Water soluble calcium oxide, . . . . .	.0091	273	.0107	321	.0098	294
Water soluble sodium oxide, . . . . .	.0087	261	.0105	315	.0074	222
Water soluble magnesium oxide, . . . . .	.0046	138	.0034	102	.0030	90
Water soluble sulfuric acid (SO ₃), . . . . .	.0088	264	.0108	324	.0117	351

TABLE 6. — *Water Soluble Constituents contained in Subsoils. Samples taken from Field used for Over Thirty Successive Years for the Cultivation of Tobacco. Subsoils of a Sandy Character, Open and Porous, insuring Good Drainage.*

	SOIL No. 1.		SOIL No. 2.		SOIL No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids, . . . . .	.0321	963	.0286	858	.0289	867
Water soluble nitrogen, . . . . .	.0092	276	.0043	129	.0033	99
Water soluble potash, . . . . .	.0062	186	.0072	216	.0025	75
Water soluble phosphoric acid,	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Water soluble calcium oxide, . . . . .	.0055	165	.0041	123	.0038	114
Water soluble sodium oxide, . . . . .	.0051	153	.0064	192	.0066	198
Water soluble magnesium oxide, . . . . .	.0018	54	.0010	30	.0006	18
Water soluble sulfuric acid (SO ₃), . . . . .	.0109	327	.0092	276	.0092	276

For the sake of comparison a table has been prepared giving the average composition of the three normal soils including both the active hydrochloric acid and water solutions, and like-

wise the average of the several abnormal soils which have shown strong indication of overfertilization. Results calculated to 20 per cent. moisture basis on soils.

TABLE 7. — *Amounts dissolved by Hydrochloric Acid (Specific Gravity 1.115).*

	AVERAGE ANALYSIS OF 4 NORMAL TOBACCO SOILS.		AVERAGE ANALYSIS OF 3 ABNORMAL TOBACCO SOILS.	
	Parts per 100 Parts of Soil.	Pounds per Acre.	Parts per 100 Parts of Soil.	Pounds per Acre.
Moisture,	20.0000	—	20.000	—
Nitrogen, . . . . .	.1211	3,633	.204	6,120
Phosphoric acid, . . . . .	.1661	4,983	.146	4,380
Potassium oxide, . . . . .	.1731	5,193	.149	4,470
Calcium oxide, . . . . .	.3640	10,920	.638	19,140
Sodium oxide, . . . . .	.1608	4,824	—	—
Magnesium oxide, . . . . .	.0537	1,611	—	—

TABLE 8. — *Water Soluble Constituents in Average Normal and Abnormal Tobacco Soils.*

	AVERAGE ANALYSIS OF 5 NORMAL TOBACCO SOILS.		AVERAGE ANALYSIS OF 4 ABNORMAL TOBACCO SOILS.	
	Parts per 100 Parts of Soil.	Pounds per Acre.	Parts per 100 Parts of Soil.	Pounds per Acre.
Total solids, . . . . .	.1043	3,129	.1981	5,943
Nitrogen, . . . . .	.0109	327	.0193	579
Potassium oxide, . . . . .	.0122	366	.0205	615
Phosphoric acid, . . . . .	.0013	39	.0002	6
Calcium oxide, . . . . .	.0148	444	.0326	978
Sodium oxide, . . . . .	.0102	306	.0161	483
Magnesium oxide, . . . . .	.0063	189	.0116	348
Sulfuric acid (SO ₃), . . . . .	.0118	354	.0209	627
Total salines,	—	1,698	—	3,057

The results of analysis of the different soils indicate that the injurious effect upon the growing plants, if due to the accumulation of plant food elements, must have resulted from

the water soluble salines present. The soluble matter in the three normal soils was very much less than in the soils which had given trouble, although the normal soils had been used for the continuous growing of tobacco for as long a term of years, and had been as liberally fertilized, as the soils giving poor results.

It is impossible to say just how large an accumulation of soluble constituents may take place before the plants will be injuriously affected. The data at hand, however, would indicate that a relatively wide latitude may be allowed on at least some of the constituents. It is believed that the combined effect of the total *soluble mineral constituents* in the soil is responsible for the injurious effect on the growing plants rather than an accumulation of any *one* of the soluble elements. It is probable, also, that the rainfall has an important influence in this connection, plenty of rain having a tendency to keep the soluble matter well below the surface, while the absence of a normal rainfall would tend to draw the soluble salts to the surface.

It will be seen from Table 8, giving the average composition of the two types of soil, that nearly twice the amount of soluble salines was found in the abnormal solids as was present in the normal ones. A tobacco soil examined but not reported here has shown as high as .18 per cent. water soluble salines (equivalent to 5,448 pounds per acre), and yet has produced a fair crop of tobacco. On the other hand, serious injury to the crop has been noted on soil which tested only .14 per cent. soluble salines (equivalent to 4,152 pounds per acre). Another fact should not be lost sight of, namely, that the abnormal soils in all cases were underlaid with an impervious or hardpan subsoil which prevented the free circulation of the soil water. It seems probable, therefore, that the trouble is due to, or is most likely to occur on, soils underlaid with hardpan and in the absence of a normal rainfall, the accumulated soluble saline matter being brought to the surface.

The investigation brings out one fact of unusual interest, namely, the large amount of water soluble potash as compared with the total potash content of the abnormal soil. The

average total acid soluble potash present in the three abnormal soils was .149 per cent., of which .0205 per cent. (or nearly 14 per cent. of the total amount) was present in water soluble form. The writer is aware that these facts are not in accordance with the usual teachings, it being generally held that potash does not remain in solution for any great length of time, but is soon fixed as basic compounds in the soil, only to be liberated gradually by chemical action. It does not seem improbable that the concentration of the soluble salines may in a measure be responsible for the large proportion of soluble potash present, and possibly even tends to dissolve greater quantities of the fixed potash. The proportion of water soluble potash in the normal tobacco soils bears out this theory, as out of a total of .1731 per cent., only .0122 per cent. (about 7 per cent. of the total amount) was present in water soluble form.

The results in Table 8 are of interest in connection with the question of the proper concentration of soil solutions most favorable to plant development. Numerous investigators have demonstrated that one part of mineral matter in 1,000 parts of water furnishes the best conditions.¹ The average analysis of the five normal soils shows the presence of 1.04 parts per 1,000, whereas in the abnormal soils nearly twice this amount was present. It is well known that some plants stand a greater concentration of soil solutions than others; for instance, corn and grass showed a wonderful development on soils which were so unfavorable for tobacco. Onions, on the other hand, seem to be quite as susceptible to injury as is tobacco. The same difference has been noticed in connection with the accumulation of soluble mineral constituents in greenhouse soils. Soil solutions too concentrated for cucumbers seem to be quite favorable for tomatoes. Little data is available in connection with this whole subject of the concentration of soil solutions, and further study with different plants is needed before any sweeping conclusions can be drawn. It is not improbable that if the amounts of the various soluble constituents in the soil are present in certain proportions the plant may be able to with-

¹ Pfeffer, Vol. 1, p. 420; Stockbridge, *Rocks and Soils*, p. 206.

stand a more concentrated soil solution. Pfeffer, in speaking of the concentration of cultural solutions, says, "The concentration of the cultural fluid is always important, for when its osmotic concentration passes a certain limit growth becomes impossible, though no poisonous effect is exercised, while when the fluid is too dilute, *or when a single essential salt is present in insufficient amount, the development of the plant is retarded.*"

As a remedy for the trouble under consideration the rotation of crops is advised. Corn seems to be a good hoed crop to be grown on soils in this condition. It requires a liberal amount of potash and other plant food constituents, and it appears to withstand the effect of the concentrated soil solution. The writer has known of some tremendous yields of corn, grown on tobacco soils evidently suffering from overfertilization, without the addition of any fertilizer whatever. Grass can follow corn with satisfactory results, and after three or four years of such treatment the soil can be used again for tobacco.

It is needless to say that if possible such land as has been described would be greatly benefited by underdraining, and it is strongly advised.

DIGESTION EXPERIMENTS WITH CATTLE FEEDS.

BY J. B. LINDSEY.

The term "digestibility" refers to that portion of food that an animal can actually make use of for nutritive purposes; the undigested portion is represented by the solid manure (feces) which is excreted by the animal as so much worthless material.

The unit of measurement is termed "digestion coefficient." Thus, experiments have shown that out of 100 pounds of bran 62 pounds, or 62 per cent., are digestible, and this figure is termed the digestion coefficient for bran. Again, experiments have shown that 77 per cent. of the protein and only 39 per cent. of the fiber in bran are digestible, and these two figures represent, respectively, the digestion coefficients for the protein and fiber in bran. Coefficients are used in figuring out balanced rations and in determining the relative nutritive values of different feedstuffs. A single illustration as to the method employed in calculating the actual digestible material in a food-stuff may suffice:—

One Hundred Pounds Timothy Hay.

	CONTAINS (Per Cent.).	Per Cent. Di- gestible (Coefficient).	Pounds Digestible.
Water,	15.00	-	-
Ash,	4.30	-	-
Protein,	6.30	48	3.0
Fiber,	28.40	58	16.5
Starchy matter,	43.60	63	27.5
Fat,	2.40	61	1.5
Total,	100.00	-	48.5

It thus appears that 100 pounds of hay contain 48.5 pounds of material available for the purposes of nutrition. In case of corn meal 76.2 pounds are available, so that a definite amount of the latter food is more valuable than a like amount of the former.

In Part I. of this report detailed data of numerous digestion experiments with a variety of cattle foods are presented. In this article a résumé only is given of the results secured.

1. CORN FODDERS (VARIETIES).

(a) Pride of the North, a medium dent that will mature its ears in Massachusetts.

(b) Rustler white dent, a corn of medium growth that will mature its ears in this State.

(c) Leaming, a dent that usually is not quite mature by September 15, in many sections of Massachusetts.

(d) Early Mastodon, a large growing dent that brings its ears to the milk stage by September 15.

(e) Brewer's dent, a large growing dent that may mature its ears in southern and southeastern Massachusetts in a favorable corn year.

(f) Wing's improved white dent, a large growing variety that is spoken of highly in Ohio, but will not mature with us.

Results secured.

	COEFFICIENTS.					
	Dry Matter.	Ash.	Protein.	Fiber.	Extract or Starchy Matter.	Fat.
Pride of the North,	77	36	63	66	84	84
Rustler Dent,	69	27	43	59	78	76
Leaming,	70	36	60	61	77	76
Early Mastodon,	72	36	57	60	79	80
Brewer's Dent,	72	46	69	69	77	68
Wing's Improved,	70	39	63	65	76	70
Average,	72	37	59	63	78	76
Average all trials, mature dents, . .	69	34	54	59	75	75
Average all trials, immature dents,	68	42	66	65	71	68

The results of the several experiments as expressed in the above coefficients when studied by themselves, without taking into consideration the chemical composition of the plant, would not reveal much of interest.

In general it may be said that those varieties that will bring their ears to maturity will have a higher degree of digestibility than those coarser, less mature varieties. This is due to the relatively larger proportion of grain to stalk. The Pride of the North shows a total digestibility of 77 as against 72 for the average of the others. It is not entirely clear why the Rustler dent did not show approximately as high a degree of digestibility as the Pride of the North. This may be due to the fact that the animals were fed rather more than they could eat, and probably did not digest quite as thoroughly as though they had received a less amount. The last four — Leaming, Mastodon, Brewer's and Wing's — representing the less mature dent varieties, show about the same degree of digestibility.

Mature dents (whole plant) will have a digestibility of from 70 to 75 per cent., while in case of the less mature dents the digestion coefficient will fall somewhat below that figure.

2. PROPRIETARY GRAIN MIXTURES.

The highest grades of unmixed concentrates have the following digestion coefficients:—

	Dry Matter.	Ash.	Protein.	Fiber.	Extract or Starchy Matter.	Fat.
Corn meal,	88	-	67	-	92	90
Gluten feed,	88	-	85	87	90	81
Cottonseed meal,	79	-	84	35	78	94

In experiments conducted with a number of proprietary mixtures the following coefficients were secured:—

	Dry Matter.	Ash.	Protein.	Fiber.	Starchy or Extract Matter.	Fat.
Schumacher's stock food,	71	-	70	52	79	88
Biles union grains,	75	24	71	80	79	96
Buffalo creamery feed,	69	23	81	55	71	87
Unicorn dairy ration,	83	25	76	72	89	96

It will be seen that the sample of Unicorn dairy ration had a relatively high total digestibility. Biles union grains were also well digested, while Schumacher's stock food and Buffalo creamery feed were fairly well utilized. None of these feeds had what would be termed a relatively low degree of digestibility. From a nutritive standpoint, therefore, the feeder could safely purchase these mixtures and feel that he was not buying inferior articles, provided, of course, that the manufacturers continued to maintain the standards represented by those samples. The questions of cost and suitability for definite purposes would also have to be considered before purchasing. These items are discussed in our annual feed bulletins.

3. ALFALFA HAY.

The alfalfa hay used in these experiments was grown on the college farm. It was cut while in early blossom and was quite free from weeds and grass. Owing to different weather conditions which prevailed at the time of cutting, and which necessitated different methods of handling, the amount of leaves lost in curing was not uniform; hence a strictly fair comparison could not be made between the different cuttings. The results of the several trials are therefore reported, and the average given for the several lots. In order to draw accurate conclusions between cuttings, the crop should either be fed green or cured under uniform conditions. Owing to frequent weather changes this is often not possible in New England.

Summary of Coefficients (Per Cent.), Periods III., IV. and V.

SHEEP.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1 ¹	1	1	63.27	57.43	78.33	53.82	77.30	44.76
Sheep I.,	1 ²	1	1	55.40	39.14	70.22	42.94	64.78	23.56
Sheep II.,	1 ¹	1	1	62.77	47.24	75.93	44.68	73.86	40.88
Sheep II.,	1 ²	1	1	59.76	45.47	73.06	48.68	68.24	25.67
Sheep III.,	2 ¹	1	1	54.29	35.40	69.46	42.20	64.79	13.83
Sheep IV.,	2 ¹	1	1	59.49	42.56	74.39	48.39	68.80	19.29
Average,	-	3	6	60.00	44.54	73.57	46.79	69.63	28.00
Average of all trials, alfalfa hay for comparison,	-	42	80	62.00	50.00	74.00	46.00	72.00	40.00
Average of all trials, red clover for comparison,	-	12	25	58.00	36.00	58.00	54.00	65.00	56.00

¹ Third-year growth.

² First-year growth.

Unfortunately an exact record of the weather conditions during the curing process of the several lots was not kept. It would appear that the first cutting of the *third year growth* was cured without the loss of a great deal of leafy matter. This is shown by the relatively low fiber percentage and the high digestibility. The second cutting of the *third year growth* evidently lost a considerable portion of its leaves, as indicated by its high fiber percentage and lessened digestibility. The first cutting of the *first year growth* also must have lost an excess of leaves, as it also shows excessive fiber and low digestion coefficients. It is possible that the markings of the first cutting third-year growth and the first cutting first-year growth were reversed, although we have not the slightest evidence to that effect.

While the coefficients obtained vary considerably the average is about the same as the average for all trials, except that the coefficient for fat is somewhat lower. It is believed that the average coefficients obtained in our several trials show fairly the digestibility of eastern-grown alfalfa under the adverse conditions due to the loss of leaves in the process of curing.

4. RED CLOVER HAY.

The clover was seeded in early August. It yielded well, was in early blossom when cut, and was cured in cocks. The first cutting did not cure out well, owing to a rainy spell during the curing process. It had a black appearance when taken to the barn, and later had to be spread in the sun for further drying. It did not lose its leaves to any extent; the lot was lacking in a satisfactory odor and was slightly musty. The conditions during the curing of the second cutting were more favorable. Both lots were rich in protein (15.28 and 17.82 per cent. in dry matter), and comparatively low in fiber (29.76 and 28.30 per cent. in dry matter).

Summary of Coefficients (Per Cent.), Periods VI. and VII.

SHEEP.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	1	64.48	61.19	63.94	62.00	67.93	52.52
Sheep II.,	1	1	1	62.57	59.49	63.81	57.08	67.19	52.23
Sheep III.,	2	1	1	57.94	53.68	59.32	43.27	68.36	55.02
Sheep IV.,	2	1	1	61.31	57.99	60.60	49.38	70.51	55.77
Average,	-	2	4	61.58	58.09	61.92	52.93	68.50	53.89
Average alfalfa hay (our trials),	-	3	6	60.46	45.39	73.77	47.55	69.92	28.32
Average of all trials, clover hay for comparison,	-	12	25	58.00	36.00	58.00	54.00	65.00	56.00
Average of all trials, alfalfa hay for comparison,	-	42	80	62.00	50.00	74.00	46.00	72.00	40.00

The most noticeable difference in the four single trials with clover hay consists in the variation in the digestion coefficients obtained for the fiber (43 to 62). This is evidently due in part, at least, to the individuality of the several animals. The fiber in the second cutting was apparently not as digestible as in the first cutting. The other coefficients—excepting the ash, which is found to vary widely in most all experiments—

may be considered fairly uniform. The coefficients secured by us are higher than the average for all other experiments, probably due to the early cutting of the crop.

When the average of the clover coefficients is compared with the average of our reported coefficients for alfalfa, it is noted that in case of the total dry matter the former shows to advantage, although the reverse is true in a comparison of the experiments reported for all trials. The protein in the clover is shown to be substantially 12 per cent. less digestible than in the alfalfa; in case of the average for all trials the difference is 16 per cent. In case of the fiber the conditions are reversed, — differences of from 5 to 8 points being noted in favor of the clover. The comparative digestibility of the extract matter is about the same, although the average figures show 7 points in favor of the alfalfa. In making a comparison of the two plants from the standpoint of digestibility, two important differences are noted: (1) the protein in the alfalfa is noticeably more digestible than in the clover (12 to 16 points), and (2) the fiber from 5 to 8 points less so. In total digestibility the two plants approach each other, showing an average of about 60 per cent. as against 55 per cent. for timothy, 60 per cent. for early cut fine hay, 65 per cent. for rowen, 70 per cent. for the entire corn plant, and 85 per cent. for corn meal.

It is evident that the relative value of the two crops cannot be determined from their digestibility alone; other important factors to be considered are cost of production and yield and adaptability to Massachusetts conditions. Taking all the evidence into consideration it would appear that although the cost of seed and preparation of land is somewhat against the alfalfa, yet its much greater length of life, its larger average yearly yield, and its rather superior nutritive value are all in its favor. The conditions governing its successful cultivation must be carefully studied by all interested in its production. To the lack of attention to these conditions by the average farmer is due, in no small measure, the failures reported.

BRONZING OF MAPLE LEAVES.

G. E. STONE.

A somewhat common and peculiar effect on rock maple leaves, especially noticeable in very hot and dry summers, was brought to our attention this past summer. We have noticed this trouble many times before, particularly on rock maples growing in certain characteristic soils or habitats. It is most commonly seen on maples growing in dry soil where there is insufficient soil-moisture during periods of extreme drought.

The trouble is characterized by an absence of the typical maple leaf green. The leaves are more or less rigid, and in color are light, with a reddish brown tinge. An examination of the surface of the leaf with a hand lens, or even with the naked eye plainly shows that many of the cells of the leaf blade or lamina are dead and reddish brown in color. These dead cells are confined to certain areas of the laminae, mainly between the minute veinlets, whereas those cells near the veinlets are green and alive.

Repeated examination of the leaves has demonstrated that the trouble is caused by no pathogenic organism, but is purely functional in nature. On the other hand, it is quite distinct from the so-called sun scorch so commonly affecting the rock maple, although both are induced by similar conditions. The typical sun scorch is characterized by more or less irregular blotches of dead tissue more often on the edges of the leaves, which are usually more susceptible to the scorching and are often lacerated severely. This sun scorch, like the "bronzing," also affects maples growing in very dry soil, on dry, windy days, when the roots cannot supply the foliage with sufficient water. Since transpiration under such conditions is very active and root absorption limited, wilting and death of the leaf tissues result.

Sun scorch is common to many plants, and is referred to under different names such as "topburn" in lettuce, "tip-burn" of potatoes, "leaf burn," "wilt," etc. It may result from the presence of certain chemical substances in the soil, or from some individual peculiarity in the root-absorptive capacity of the organism. The peculiar drying and reddening of the cells of the maple leaves which we have previously referred to as "bronzing" is not necessarily caused by wind; the principal factors necessary being a soil deficient in moisture, and excessive transpiration.

As already stated, "bronzing" occurs on very hot, dry days, in periods of severe drought, and this last summer we have succeeded in producing many excellent examples of it in the greenhouse. The trouble was very common this season, our attention often being called to it, and we have been observing very severe cases of it in certain maple trees for many years.

COARSE NOZZLE VERSUS MIST NOZZLE SPRAYING.

G. E. STONE.

At the present time much thought is being given to the general technique of spraying. The subject is an important one and is by no means settled, either as regards equipment or methods. Our own State has done its share in this respect since the important economic problems involved in handling the gypsy and brown-tail moths have made it necessary to originate and utilize the most modern and efficient spraying machinery.

For the perfection of modern spraying on a large scale great credit should be given to Mr. A. H. Kirkland, a graduate of this college and former superintendent of the Gypsy Moth Commission, whose handling of economic problems of this nature has been unexcelled, and particularly to Mr. L. H. Worthley, the present superintendent. The former methods of spraying advocated and used by the old commission were considered revolutionary in those days, and great credit should be given to Mr. E. C. Ware, the mechanic associated with the former commission, for developing an improved outfit and for originating the best fine mist nozzle as yet devised. The old method, however, has been practically discarded, since the modern method is much cheaper and about as effective.

This makes use of the powerful high pressure machine and coarse nozzle, which is capable of throwing a stream to a great height, this breaking up into a more or less fine mist. The first attempt to use engines in spraying dates back some years.¹ Most of the devices were very crude in construction. Mr. J.

¹ L. O. Howard, Year Book, Department of Agriculture, 1895, pp. 361-394, and 1896, pp. 69-88.

W. Pettigrew, superintendent of the Boston park system, was one of the first to construct a really effective spraying equipment provided with high-pressure gasoline engines and modern coarse spray nozzles. This was used with much satisfaction some years ago in spraying woodlands for the gypsy moth and for park work, and on this model were constructed the later and more improved types of machines. In 1896 he employed a more or less cumbersome outfit for spraying in the public parks of Brooklyn, N. Y., consisting of an ordinary road sprinkler and a 10-horse power portable steam boiler fitted to a large pump. He made use of a $\frac{3}{4}$ -inch hose provided with $\frac{3}{16}$ or $\frac{1}{4}$ inch nozzle.

About the same time Mr. Christopher Clark, the veteran city forester of Northampton, Mass., made use of a similar machine for spraying elm trees. Mr. Clark's equipment consisted of a small steam boiler which used coal for fuel, and a Duplex pump mounted on a truck. The pressure he obtained from this equipment was something over 100 pounds. He used an ordinary garden hose nozzle of $\frac{1}{8}$ -inch aperture and obtained a coarse spray, not in any way comparable, however, with that obtained from the use of modern equipment. Other make-shifts, which used steam for power, were employed here and there about the same time, but these were all crude affairs compared with the modern outfit.

Those who have had opportunity to make extensive comparisons of the high-pressure, coarse-nozzle spraying and the fine mist spray under low pressure are generally convinced that, considering the cost and efficiency, the former method is far superior to the latter for certain work. The question therefore arises to-day whether or not high-pressure coarse-nozzle spraying cannot be applied to orchards with the same results that have followed its use in other ways. Recent experiments made in Virginia¹ have shown that for the control of the codling moth the high-pressure, coarse-nozzle spray has proved superior to the low-pressure mist spray. The best high-power sprayers in use at the present time have reached a high degree of perfection, especially the machines manufactured for and

¹ Spraying for the Codling Moth, West Vir. Agr. Exp. Sta., Bul. No. 127.

used by the Gypsy Moth Commission. But there are many others, of both high and low power, which are thrown together in an altogether haphazard fashion. A machine which is to develop and maintain 250 pounds pressure with a 1-inch hose and 1.8 and 3.16 inch nozzle should be provided with an engine which will develop 5 or 6 horse power at the least. A machine of this type would be suitable for small towns where it is necessary to spray only 500 or 1,000 trees each year, or it would be suitable for large orchardists. When the spraying to be done is extensive, however, the larger machines, at least 10 or 15 horse power, are the more economical in the end, even if the first cost is greater, since some allowance should be made for deterioration and loss of power in any machine.

It is a question whether we are using the best methods in some of our spraying work. A 5 or 6 horse power pressure machine can be depended upon to handle a stream of from 40 to 60 feet high, and this is sufficient if a ladder is used; but if it is necessary to throw the spray 100 feet, or to the tops of the trees, larger machines must be used.

At the present time less attention is being given to nozzles than to machines, and in our opinion there is ample room for improvement on the nozzles in use to-day. The various mist-spray nozzles are good for short distances, and those in use at the present time are an improvement over the old spray nozzles. But we need wide-angled spray nozzles that will give a spray of uniform density which will throw a relatively fine mist at least 20 or 30 feet. To obtain such a spray high pressure is one of the necessities, and a new type of nozzle another. By the use of nozzles adapted to high-pressure machines which can be adjusted to different distances we are of the opinion that the spraying of orchards can be done as effectively and more cheaply than at present. Instead of employing 70 pounds pressure and forcing the spray through $\frac{1}{2}$ -inch hose provided with a mist nozzle with a limited carrying capacity, we shall come to the use of high pressure and larger hose provided with nozzles of great carrying capacity. In our opinion spraying will be developed along these lines in the future, since the process will be rendered cheaper and practically as effective

as at the present time by the use of high pressures and nozzles of better carrying power.

The writer has devised a number of spray nozzles adapted to high-pressure machines, some of which have been constructed and tested. The aim has been in constructing the nozzles to get a good carrying power, and still to maintain a fairly fine mist.

EXPERIMENTS WITH ROSE SOILS.

G. E. STONE.

Although requiring exceptional skill, the management of green-houses has reached such a high degree of perfection in the United States that it seems somewhat presumptuous for an amateur to attempt serious experimentation with the idea of its being of value to the remarkably trained men who make a profession of growing roses and carnations under glass. Nevertheless, for two years we experimented with roses, and during this time freely consulted the best experts in the line. The experiments were undertaken largely to determine the effects of different soil textures on the growth of roses, to study their diseases, and in general to ascertain the limitations of the plant under different methods of treatment. Such crops as lettuce, tobacco, roses and others are quite susceptible to differences in soil texture, which often produce quite different types of tissues and of growth. Tobacco, for example, will bring \$0.30 a pound when grown in certain soils, while the same plants, when grown in other soils even by the same grower, will often not be worth \$0.10 a pound. Likewise lettuce grown in the light, porous soils about Boston is quite different from that grown in the heavy, inland soils.

For the best growth of roses it is essential that the soil have a more or less definite texture, and in these experiments it was our purpose to observe the effect of different soils on the development of roses. We selected the American Beauty rose for the experiments, as it is considered the most susceptible to soil texture. It has even been maintained that a soil suitable for its growth is rare in this State, whereas in Pennsylvania the soils appear to be ideal for this variety.

Mechanical analyses of some of the best rose soils in this country demonstrate that they contain a large percentage of

finer particles, clay, etc., than is generally found here in our soils. In our experiments we selected soils which resembled as much as possible the best types. Some of the soils in the Connecticut valley seemed to be excellent substitutes for the real rose soils, and these were tested in order to obtain some idea of their relative value. Most of the Connecticut valley soils run low in coarser materials and high in the finer materials such as very fine sand, and occasionally silts predominate. These fine sands and silts give a compact character to the soil, with a large water retaining capacity. Very fine sand predominates in many of these soils, as high as 75 per cent. being found in some samples, but nearer the river we often find samples in which the coarser silt predominates.

These experiments were continued for two years in a greenhouse provided with 5 beds, one-half of each bed containing a typical Amherst loam which had been used for some years in growing cucumbers, tomatoes and melons, and to which no commercial fertilizer had been added, although horse manure had been applied freely. The other half of each bed was filled with specially selected soil of different textures for the purpose of comparison. These benches were 1 foot deep and the bottoms were filled with brick placed on end, leaving about 7 inches depth of soil in each bed. Seventeen plants were used in each section, or in the whole house a total of 170 plants. Since five of these sections contained soil of the same types, only five were used for other types, and these were all different.

TABLE 1. — *Showing Mechanical Analysis of Soils used in Rose Experiments.*

NUMBER.	Section.	Bed.	PER CENT. OF ORGANIC MATTER, GRAVEL, SAND, SILT, AND CLAY IN 20 GRAMS OF SOIL.								
			Organic Matter.	Gravel (2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.).	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay. (.005-.0001 mm.).
20,	I.	A	8.22	0.10	9.45	1.44	4.35	40.01	29.67	0.46	5.65
69,	I.	B	18.21	1.45	4.40	3.85	12.93	38.13	1.50	0.51	12.26
68,	I.	C	6.58	0.99	1.48	1.53	12.51	28.02	14.51	14.11	10.41
67,	I.	D	8.96	3.51	3.25	3.87	9.75	45.42	14.49	0.99	3.86
66,	I.	E	9.80	0.69	3.86	3.63	6.51	36.53	14.27	12.25	9.43
71,	II.	A-E	7.54	1.24	3.62	3.48	11.64	49.01	10.85	1.55	1.71

The mechanical analysis of the soils used in our experiments with roses is shown in the preceding table. Five of the beds in section II., beds A to E, contained soils represented by No. 71, which is a fairly typical Amherst loam, the analysis being made from a composite sample taken from each of the five beds, and contains 1.71 per cent. of clay. The remaining five beds, section I., were filled with selected soil of different textures. These were all obtained from the vicinity of the experiment station, but were different in texture and appearance from our typical loams. All were thoroughly mixed with about one-third cow manure. The character of the soils in beds A to E, section I., was as follows:—

Soil No. 70, bed A, was obtained from near the banks of the Connecticut River, and was higher in clay than No. 71. Silt and very fine sand, however, predominated in this type.

Soil No. 69, bed B, was obtained from a forest near by and was rich in vegetable matter as a result of many years' accumulation of decayed roots, leaves and twigs, and was very dark in appearance. It was characterized by considerable amounts of clay and very fine sand, which was the result of wash from higher elevations.

Soil No. 68, bed C, procured 6 feet below the surface, was very compact, containing little organic matter, and would be designated as hardpan. Very fine sand predominated in this soil, which also contained 10 per cent. of clay.

Soil No. 67, bed C, was a modified local soil obtained from what was originally a muck meadow which at one time was overflowed with water, but later reclaimed. It had received some wash in times past, was dark in appearance, and more or less compact. For some years it had been growing excellent crops of grass, but the year before we obtained it had been ploughed up and reseeded. Our sample was taken from the surface and contained the old and new seeded soil, well decomposed. Fine sand and silt predominated and the soil contained a little more clay than No. 71.

Soil No. 66, bed E, was the same as No. 68, except that besides the one-third cow manure, one-third finely pulverized sod was added.

All of the soils in section I. contained more clay than our

regular greenhouse soils shown in section II., the clay ranging from 3.86 per cent. to 12.26 per cent. The plants were set out in October and removed the following June. Besides the above treatment all of the beds were freely supplied every week or two with liquid cow manure. The steam pipes were painted with sulphur and oil, and there was little or no mildew or black spot. The plants were quite free from diseases caused by pathogenic organisms, although much variation occurred in the vigor and growth of the plants in the different soils, as was anticipated from the dissimilar conditions. In most cases they were not what would be called vigorous. The following table gives the height of the plants at two different periods in their growth; viz., at March 17 and June 19.

TABLE 2. — *Showing the Average Height in Inches of Rose Plants grown in Different Soils, in Beds A to E, Section I.*

	BEDS.				
	A.	B.	C.	D.	E.
Soil number,	70	69	68	67	66
Average height of plants March 17 (inches),	37	38	22	46	36
Average height of plants June 19 (inches),	50	68	39	72	66

The average height of plants in section I., beds A to E, which contained a variety of new soils, was 36 inches for March 17, and 29 inches for corresponding plants in section II., beds A to E. At the second period of measurement, June 19, the average height of the plants in beds A to E, section I., was 59 inches, while that for beds A to E, section II., was only 34 inches, showing that the new soils produced plants of greater average height than the old greenhouse soil. If we take the averages of the final measurements made on June 19 of the plants grown in new soils, that is, in beds A to E, section I., we find that the highest average growth in height is shown by soil No. 67, or in bed D. (See Table 2.) Soil No. 67 contained nearly 4 per cent. of clay and considerable fine sand and silt, and constituted one of the best soils for roses in the house. Soil No. 69, bed B, produced the next highest average of plants, but they were abnormal, developing small leaves and

a spindling growth. The soil in this case was very dark colored and rich in organic matter.

The plants in soil No. 66, bed E, closely resembled in height those in the preceding one. The soil in this case was heavy and compact, but contained besides the cow manure considerable pulverized sod. Soil No. 70 in bed A and No. 68 in bed C gave the lowest average growth in height. The latter soil was the same as No. 66, bed E, except that it contained no pulverized sod. This soil contained the least organic matter of any, was heavy and compact, and contained 10 per cent. of clay. When pulverized sod was added, as in No. 66, far better results were obtained. No. 70 was also lacking in organic matter. The heavier, more compact soil developed better leaves and blossoms than the lighter soil. Soil No. 67 produced the best developed plants, while the most slender canes were produced by soil No. 69.

The largest number of flowers developed on the plants which made the best growth, but the quality was the best in No. 67. The most normally developed plants were grown in soils No. 67 and No. 66, the latter being the only soil to which was added pulverized sod, and the former contained a fairly good supply of well decomposed sod incorporated with the soil when brought from the field into the greenhouse. The addition of sod to some of the other soils would no doubt have given better results. The superior plants produced by soil No. 67 were undoubtedly due to the large amount of well decomposed sod it contained; in other words, the humus was in a condition to make it more available, whereas in soil No. 66 this was not so, as the sod was applied fresh and was not in the least decomposed, and in Nos. 70 and 68 there was too little humus. Soil No. 69, obtained from the woods and containing large amounts of decomposed roots, leaves and branches of shrubs and other plants, was not suitable for growing stocky plants, although rich in humus.

The soil in the different beds remained undisturbed during the summer, and a second crop of roses was set out the following fall. However, before setting out the plants each bed in both sections received a fairly good application of cow manure, this being thoroughly incorporated in the soil. The new plants

during the second year started very poorly, became sickly, and in the course of three months half of them died. This experiment was conducted purposely along this line, although we knew we were violating the customs of the best growers. Nevertheless, we wished to learn what the result would be. The sickly plants showed no indications of being affected by pathogenic fungi or eel worms, but the roots were abnormal, indicating that the trouble was in the soil. We therefore flooded each bed while the plants were "in situ" for a period of two hours, washing out the soil very thoroughly. The first water that came through the soil was exceptionally turbid, but that which came through later was very clear. The percolated water was collected at intervals and chemical tests made of it for acidity, etc. These tests gave surprising results, as they showed that the soil was in very abnormal condition for root growth. These soils had been given, the year before, the customary treatment, consisting of a liberal supply of cow manure, both in the solid and liquid form, but this had so filled up the soils with injurious chemical compounds as to prevent root development. Rose growers have found by experience that good results can be obtained only by changing their soils each year, and this experiment verifies the wisdom of the practice.¹ On the other hand, lettuce growers seldom if ever change their soil, experience showing that for lettuce the older the soil the better. In the former case cow manure is used, and in the latter, horse manure, mixed with a large percentage of straw, is used exclusively, the effects on the soil being quite different.

Carnation soils are treated in the same way as rose soils, the soil being changed each year. Roses and carnations, therefore, require a new soil each year, while most market garden crops are grown year after year in the same soil enriched with horse manure and straw. Repeated applications of horse manure improve such soils, and there is little danger of over manuring; whereas cow manure has a quite different effect and cannot be used in the same way, as there is danger of root injury and malnutrition.

¹ At the present time rose growers use Manetti stock for grafting and do not change the soil more than once in two or three years. This stock is said to be more immune to eel worms.

Most of the lettuce soils in the greenhouses in this State have never been changed, and some of them are very old. The older such soils are the better for lettuce and market-garden crops in general although tomatoes do the best when the soil is changed occasionally.

After the rose soils were washed out no further dying of the plants occurred; on the other hand, they developed quite rapidly and the crop matured. The trouble was with the roots and was caused by an abnormal chemical condition of the soil. When this occurs, as it does quite commonly in greenhouses, washing out the soil is a corrective. Sometimes the trouble can be remedied by placing a new layer of soil on top of the bed, in which case new roots will form in the top layer of soil.

The development of the plants in the second crop was not as good as in the first, but the same characteristic growth in the different beds was noticeable. The washing out of the soil improved the condition of the plants to quite a remarkable degree, especially in soil No. 69, which appeared to be more acid than that in the other beds. The plants in soil No. 67, however, as in the preceding experiments, showed the best development.

At this point it might be well to compare the texture of other rose soils with that of those with which we experimented. The following table gives the results of the analyses of some of the best and most typical rose soils found in the eastern States.

TABLE 3. — *Showing Mechanical Analysis of some of the Best Rose Soils obtainable from the Rose Houses of the Eastern United States*

STATES.	Number.	PER CENT. OF ORGANIC MATTER, GRAVEL, SAND, SILT, AND CLAY IN 20 GRAMS OF SOIL.								
		Organic Matter.	Gravel (2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.).	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay (.005-.0001 mm.).
New Hampshire,	109	4.58	0.13	0.16	0.25	6.62	36.80	16.34	12.74	9.11
	110	7.90	1.35	1.25	2.22	3.72	13.18	32.25	23.59	13.73
New York,	105	4.69	0.41	0.13	0.49	0.89	14.05	29.46	15.36	29.28
	106	4.69	0.74	0.73	2.09	8.57	32.25	26.84	12.76	8.53
	108	3.15	0.21	0.13	0.56	2.82	43.15	14.56	19.40	10.15
Pennsylvania,	107	7.28	2.87	1.73	3.33	9.55	39.44	20.09	3.37	6.73
	118	5.12	5.10	2.62	4.52	12.09	26.20	31.04	3.52	6.42
	111	4.60	0.62	0.60	2.04	3.98	23.15	25.52	19.10	11.01
	112	5.19	0.35	0.42	1.34	2.48	32.26	5.15	36.10	11.80

TABLE 4. — *Showing the Percentage of Coarse and Fine Material in Rose Soils.*

BED.	Number of Soil.	PERCENTAGE OF SOIL CONSTITUENTS IN—	
		Gravel through Fine Sand.	Very Fine Sand through Clay.
A,	70	15.34	75.70
B,	69	22.63	52.40
C,	68	16.51	67.05
D,	67	20.38	64.76
E,	66	14.69	72.48
A-E,	71	19.98	63.12
	109	71.17	74.98
	110	8.54	82.75
	105	1.92	88.15
	106	12.13	80.38
	108	3.72	87.26
	107	17.48	69.63
	118	24.33	67.18
	111	7.24	78.78
	112	4.59	85.31
Average,	70-66	17.91	66.49
Average,	109-112	9.63	79.36

All the soils shown in this table are from locations where roses are grown to perfection. A casual glance, however, at the mechanical analyses of these soils given in Tables 3 and 4 shows that they are somewhat higher in the finer particles than most of the Massachusetts soils. The clay runs from 6 to 29 per cent. in the soils shown in Table 3, while the very fine sand, silt and clay run from 67.18 to 88.15 per cent. The gravel, coarse and medium and fine sand run from 1.92 to 24.33 per cent. (See Table 4.) In our experiment soil the very fine sand, silt and clays run from 52.40 to 75.79 per cent., while the coarse particles, namely the gravel, coarse, medium and fine sand, run from 14.69 to 22.63 per cent. In most of the types the silts run higher than in our typical Massachusetts soils, although in some cases the very fine sand and silt are less than those found in some Connecticut valley soils.

The average percentage of coarse particles is 19.98 in our experiment soils, and 9.68 in typical rose soils, while the average for the finer particles is 66.49 in our soils and 79.36 for the typical rose soils; in other words, the percentage of coarse material averages highest in the soils with which we experimented, and the percentage of finer particles averaged less than in the typical rose soils. The average percentage for silt is 14.88, and for fine silt 5.66 in our experiment soils, while the typical rose soils give 22.36 for the silt and 16.21 for the fine silt, the typical rose soils showing a larger percentage of silts than our experiment soils. This also holds true for the clays. We are of the opinion that the larger percentage of silt and very fine sand makes a compact soil of good water-retaining capacity. Our experiments were not carried on extensively enough to determine, except in a general way, the textural effect on roses, and it would require considerable experimenting to determine the specific effects of each group of soil particles on the development of this plant. Numerous mechanical analyses of a large number of our best rose soils which have been made for many years throw some light on the problem of soil texture, but the problem, like many others, is complicated by the undoubted presence of other factors which may play a part here in the development of a crop.

The best rose soils appear to be those which possess from 8 to 12 per cent. or more of clay, and which are well supplied with other grades of the finer particles. The percentage of very fine sand, silt and clay should exceed 75 per cent.

Our experiments with roses were not continued as long as we should have liked, and the results have a limited value. Neither were our soils treated with fresh pulverized sod, as is customary, except in one case, where the addition of sod proved a great benefit. The presence of organic matter is important, and our best soil was the one in which the organic matter was well incorporated and decomposed. The soils which produced the most normal growth were those of a compact nature, and the freshly prepared soils gave better results than the old ones which had been used for growing various crops.

A NOTABLE ELM TREE.

G. E. STONE.

The American elm, as found growing in New England, is a tree unsurpassed in grace and beauty. It reaches its highest state of perfection in the river valleys where the soil conditions are well suited to its growth, and especially in the Connecticut valley, where the soil is largely composed of very fine sand and silt, and has considerable water-retaining capacity. The elm, however, will grow in very moist soil, although requiring for its best development a well-drained surface soil. While it makes good growth in almost any type of Connecticut valley soil, it reaches its best development in a soil in which coarse silt predominates rather than very fine sand. Our many years' observations on the elm have convinced us that it is quite susceptible to soil texture, and its freedom from various troubles is equally marked when growing under ideal conditions.

A somewhat notable elm growing near the college was recently cut down, and the opportunity was taken advantage of to make careful observations in regard to its age and growth. This tree is illustrated in the third edition of Emerson's "Trees and Shrubs of Massachusetts," published in 1878, and was at that time considered an exceptionally large and symmetrical tree. At the time of its removal, in 1911, it had lost none of its beauty and symmetry.

Measurements of the tree after it was cut down showed it to be 19 feet in circumference 1 foot above the ground; 17 feet 4 feet from the ground, and 8 feet above the ground, at a point just below the larger branches, it measured 21 feet 7 inches. Fourteen feet from the ground it measured 25 feet 5 inches.

The age of the tree, obtained by counting the annual rings, was found to be one hundred and thirty-one years, and the height, which was estimated after the tree was felled, was between 115 and 125 feet. The south and east radii showed the greatest development. This is not surprising, since the light conditions are 10 or 15 per cent. more favorable in the morning than in the afternoon, and there naturally occurs more photosynthetic activity and therefore more growth on the south-east side of the tree than on any other side. Careful measurements were made of the annual rings in decades by Sumner C. Brooks, and the results of these measurements, showing the grand period of growth, are shown in Fig. 1. By studying the

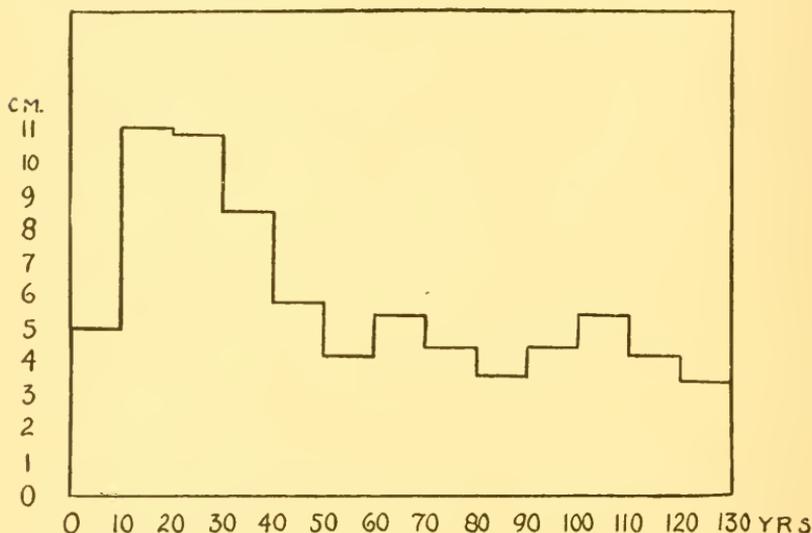


FIG. 1. — Showing grand period of growth of elm tree, *Ulmus Americana*, L. The figures on the ordinates represent centimeters, and those in the abscissæ, years.

curve it will be seen that the maximum period of growth occurred between the tenth and thirtieth years, following which there is a gradual decline in the decade growth, as might be expected. Even between the one hundred and twentieth and one hundred and thirtieth year the growth in thickness of the trunk indicated considerable vigor and was about two-thirds that which occurred between the first and tenth year.

There were a few small, dead branches on the tree, and a

small split in one of the crotches of the larger branches. One of the largest branches also showed a more or less decayed interior resulting from lack of proper treatment, which should have been given years before; but the tree was practically intact at the time of its removal, and providing its root system was normal it was certainly capable of growth for many years to come, as was shown by its vigor at the time it was cut down. By the aid of modern tree surgery what few defects the tree possessed could easily have been remedied.

Table showing the Growth in Thickness of an Elm Tree, Ulmus Americana, L. Measurements represent the Growth of the Annual Rings in Decades.

DECADES.	Growth in Centimeters.	DECADES.	Growth in Centimeters.
0-10,	5.0	70-80,	4.4
10-20,	11.0	80-90,	3.6
20-30,	10.8	90-100,	4.4
30-40,	8.5	100-110,	5.4
40-50,	5.8	110-120,	4.2
50-60,	4.2	120-130,	3.4
60-70,	5.4		76.1

SOME OBSERVATIONS ON THE GROWTH OF ELM TREES.

G. E. STONE.

Trees like most plants, make different growths in soils of different natures, and many of them respond noticeably to cultivation. While no extensive experiments have been made to determine the effects of specific fertilizers on shade trees, it is well known that many varieties respond to such treatment. The elm is especially susceptible to variations in soil texture, requiring certain conditions for its best development. Dry, gravelly soil causes a spindling growth, and it is very often difficult to make young trees live in soils of this nature. Mowings are not at all favorable locations for elm trees, as the grass robs them of considerable moisture; and here young trees often succumb in the struggle for existence.

There are many elm trees on the college grounds which have been for the most part set out by the different classes, and in this immediate vicinity we have for some years had opportunity to carefully observe the growth these elms have made. For some time we have been making series of measurements at frequent intervals to determine the rate of growth under various conditions, and the results of some of these observations are presented here.

In two rows of elm trees running north and south and growing in soils of similar texture we find quite marked differences in the rate of growth. On one side of the road the trees have been in mowing land ever since they were set out, about thirty-two years ago, and on the other side they have been growing in lawn conditions for the same length of time. As the road was not very wide the roots of both rows of trees extended into the roadway, giving some of the roots similar conditions.

The rate of growth in circumference 4 feet from the ground of the trees growing on the lawn side of the road was 9 per cent. greater than of those on the mowing side for the same period, thirty-two years.

In another case, where the roadway was wider and the trees smaller, the difference was 36 per cent. in favor of the trees on the lawn for a period of twenty-two years. Here the soil was much drier than in the preceding instance, and the trees showed the effects of occasional applications of fertilizer to the lawn. However, there was a marked difference not only in the growth, but in the color and amount of foliage in the two groups of elms. The difference between lawn and mowing conditions is more prominent in dry than in moist soil, although it is possible for elms to receive too much water, as is proved by the following instance:—

Two rows of elms running north and south on either side of a wider highway were under practically the same conditions, except that one row was in a good soil underdrained and the other in a wet soil where the drainage was very insufficient. The difference in the growth in circumference of these 4 feet from the ground for a period of thirty years was 10 per cent. It should also be noted that the soil with the poor drainage had been cultivated a few times, while the other had not, but the drainage in the former soil was so poor that the trees made little growth and were stunted in appearance.

Elms growing in wet soils are invariably poorly formed, and seldom develop into good ornamental or street trees.

Exposure to light, as might be expected, materially affects the growth of trees. A row of trees located in mowing soil on either side of a narrow roadway running southeast, in thirty-two years showed a difference of 11 per cent. in their circumference 4 feet from the ground, in favor of the south or sunny side of the radii. No differences would occur with small trees when first set out, but when they grow large enough to shade each other there are differences in the rate of growth. Since these trees were planted close together and the roadbed is narrow, they shade each other at the present time, and have for some years past.

Trees grow in proportion to the amount of foliage they develop, as well as to the amount of light they receive. Those growing on the east side of mountains develop most on the east side, and those on the west side will develop most on that side of the trunk. We found 28 per cent. difference in favor of the east radii of some stumps growing on the east side of a mountain, and 8 per cent. difference between the east and west radii of trees growing on the west side of mountains. The growth of trees differs greatly according to the exposure; as, for example, on the edge of forests the growth is greater than in the middle of the forest, proving that light affects growth materially.

In the case of the trees on the east and west sides of mountains, they will receive sunlight during only part of the day, and their development will coincide with the amount of light they receive, as well as depending also on the side of the tree exposed. Since morning light is more intense than afternoon light, the east side of a tree will show the greatest growth, and a great many measurements of trees and of light intensity at different times during the day have shown us that the growth of the tree in one direction or another is directly in proportion to the light they receive.

In conclusion we might repeat that elms thrive better in pastures where the grass is likely to be scant, than in mowings, and lawn conditions are more or less favorable. They also respond to cultivation and treatment with fertilizers like any other crop.

DO WE NEED A SEED LAW IN MASSACHUSETTS?

G. E. STONE.

There has been considerable agitation during the past two or three years over a seed law for the State, interest in which has been shown by farmers and citizens in general. Some States have passed laws relating to seeds and have established standards for seed germination and purity, while others are seriously considering the matter of purity of seeds, and are attempting to establish laws to this end. The standards for purity and germination adopted by our different States are similar, but are so high that it is impossible for any seed dealer or extensive importer to live up to the law under the present system of handling seeds. The presence of laws on our statute books which no one can live up to is conducive to the best interests of no one; nor is it wise to bring seed dealers before the courts for selling as good quality seeds as can be obtained, and brand them as criminals or law-breakers. A law which cannot be enforced is worse than none, since it has a tendency to breed contempt for all law. A seed law which cannot be conformed to is bound to be broken, as certain crops have to be grown whether the seed complies with some arbitrary standard or not.

It is most unfortunate that the majority of the laws are drawn up from the seed analyst's point of view and not from that of the dealer or retailer. Too rigid seed laws are bound to prove very unsatisfactory in the end to seed importers and dealers, and if strictly enforced will prove of great disadvantage to the farmer. The best process of cleaning seed is not known, and it is also a difficult matter to grow clean seed.

The germination of seeds is greatly influenced by climatic

conditions, and the percentage is by no means a constant factor from year to year. It is often impossible to obtain seeds anywhere in the world that will come up to the standard required for germination by these arbitrary laws, and the question is, "What are the farmer and seedsman going to do in such cases?" We are strongly of the opinion that the time is not ripe for a severe seed law, at least in this section, and we question whether it would not be better at present to restrain by publicity the dealer who persists in selling poor seeds rather than hold him to a standard impossible to comply with.

The seed situation in a nutshell is this: the purchaser has a right to know what he is buying, therefore the seedsman should give some guarantee of what he is selling. The sale of adulterated seeds should be prohibited by law, and if all packages of the more important varieties of seeds containing over 5 pounds were to have a guarantee label, and if samples were tested each year and the results made public through some official publication, the moral effect would be good.

Many of the State seed laws which have been adopted at the present time appear to us to be failures. A glance at the results of official analyses of seeds of various States which have these laws shows that a very large percentage do not come up to the standard, many being far from it, and prosecutions in these States are so rare that it is difficult to find them. We question very much whether the purity of seeds or the standard of germination have been very much improved in those States where these laws have been passed. If some of these laws were strictly enforced it would drive most of the seed dealers out of business, and many of them are of course very reliable and honest men. A great many, as we know from personal experience, take the greatest pains in selecting the best and highest grade seeds on the market, although of course there are many dealers who care little about the grade of seed they sell. They buy the poorest seed obtainable, catering to the farmer who wants to get seed as cheaply as possible, regardless of its quality. Here the farmer is largely to blame.

The seed laws passed up to this time expressly emphasize seed purity and germination. It is well known that these are

by no means the most essential factors, and cannot be compared with such important considerations as strain, etc. The seed of a certain strain, even if it contains 10 per cent. impurities, is better than one that is pure and of an inferior variety.

The writer has studied the seed question from various points of view, — from that of the seed importer, the seed dealer and the farmer, — and is well aware that there are a great many difficulties associated with the seed problem which cannot be overcome by legislation. The importer, retailer and farmer are interested in the seed question, and the reliable dealer is anxious to put on the market as good seed as possible. We are of the opinion, however, that the matter is a delicate one, and whatever is accomplished in the line of legislation must be done cautiously and in a spirit of co-operation.

As already stated, the collecting of seed samples in the open market or from dealers each year would greatly improve conditions if these samples were analyzed and tested for purity and germination and the results published. A law requiring an approximate guarantee concerning the germination and purity of certain seeds, especially those sold in packages of over 5 pounds, would also have a salutary effect. We repeat that we do not consider it wise to load our statute books, however, with impractical laws; any restrictions relating to the sale of seed should conform to common sense. We cannot compel nature, by any form of legislation, to produce a definite quality of seeds each year; neither have we the right to ask dealers to accomplish what is impossible. Publicity, in our opinion, would constitute the best corrective for abuses.

DISEASES MORE OR LESS COMMON DURING THE YEAR.

G. E. STONE.

Like the preceding one the past summer has been exceptionally dry, and the heat has been intense at times. This drought, coming as it did after three or four previous dry seasons has affected vegetation to a considerable extent, and will result in later injury, especially to trees.

Some of the diseases which have been more or less common during the summer are as follows: black rot of cabbage and cauliflower (*Pseudomonas*), asparagus rust (*Puccinia*), bean Anthracnose (*Colletotrichum*) and celery rot. The cucumber *Fusarium* wilt described in our last report has caused much damage to greenhouse cucumbers, in many cases destroying the whole crop, and is serious at the present time. Experiments relating to the control of this disease are now being carried on, but the nature of the trouble makes considerable study necessary. A similar disease of tomatoes is also becoming troublesome, but it does not cause so much damage to the tomato as to cucumbers.

A new disease of tomatoes characterized by bacterial infection of the leaves has recently been brought to our attention, but at present we have found only one variety of tomatoes affected.

Many dahlias made a stunted growth this summer, and others were deficient in flower production. From our observations we should say that this condition was not associated with attacks of either fungi or insects, but was due to some abnormal feature causing a slow and stunted growth.

A peculiar instance of malnutrition was observed on corn. This was caused either by too heavy applications of fertilizer

or wrong methods of applying it; or it may possibly have occurred from lack of rain needed to dilute or wash out the fertilizer; at any rate, the plants were yellow and sickly and the tissues were abnormally gorged with nitrates.

The epidemic of rust which has prevailed generally over the country during the past few years and which has affected plants usually immune in this region was not so severe this year. However, beans were affected to some extent, as were quinces and Vinca. The apple, ash and some other species were practically free from the trouble.

Some apple troubles have been somewhat common, while others have been less common than usual. The Baldwin fruit spot, which has been with us for so many years, and which has never been associated with pathogenic organisms, has apparently been superseded by a similar but more prominent and disastrous spot termed the "fruit spot." This has been very common not only on Baldwins but on Greenings and other varieties. The latter is characterized by much more conspicuous spots than the former, and a fungus termed *Cylindrosporium* is usually found associated with it. In one of the best orchards in the State we were able to find only two or three apples on a tree affected with this spot. In some other cases, however, it was much more common. On the whole, this trouble has proved rather serious this year, and as it appears to be controlled by spraying it may become necessary to resort to this in order to control it. Both spots seem to be associated with drought.

Many cases of sun scald were observed on apple trees during the year, both large and small trees being affected. Much of the scalding noticed was on the trunk near the ground. In some orchards which have been severely pruned, and the trees ploughed around and fertilized, more or less sun scalding occurred. This was noticed on unusually vigorous young shoots which are characteristic of trees handled in this way, and was due to the nonripening of the wood.

Potatoes were affected by the drought and to some extent by early blight. The severe fall rains caused attacks from late blight, and in some cases potato stem rot was reported.

Trees in general were affected to an unusual extent by a series of troubles.

Burning of conifers, including our native white pine, and various evergreens such as rhododendrons, arbor vitæ and others was the worst experienced in years. The loss to nursery-men and others from this cause was large, and it was very difficult to meet the demand for nursery stock of this class. Sun scorch was also common on the rock maple, and the young growth was generally affected by winter killing.

The chestnut disease, which has been with us now for four or five years, is spreading in some localities, but it should be borne in mind that every chestnut tree which appears sickly or dying is not necessarily affected with the so-called "blight." There are, in fact, many sickly chestnut trees as well as others which are showing no indications of blight, a feature which Dr. G. P. Clinton, of New Haven, has noted in Connecticut. The chestnut disease is the worst at present in the Connecticut valley so far as we can observe, and the question of preventive measures seems wellnigh hopeless, although not less so than the possibility of extermination in other ways. There is, however, some reason to believe that it will not prove as severe as further south.

Other trees, such as the elm, maple, some oaks and ashes, are at present in bad condition throughout the State. The large number of dying trees, particularly elms, which may be seen here and there is surprising even to a casual observer. The elm, to be sure, has many enemies, such as the leopard moth and elm-leaf beetle, but there are other causes responsible for their present condition. It is questionable whether it is advisable at the present time to plant elms as shade trees, and a number of other varieties are doubtful, but after many years of close observation on trees we have found one species which has stood the effects of drought, winter killing and other troubles better than all others, and that is the red oak. Prof. C. S. Sargent of the Arnold Arboretum has recommended this for many years as a shade tree, and although little used there are a great many reasons why it should be used more than it is. Under good conditions the red oak will grow as

rapidly as the elm and maple, and its habit of retaining its leaves, which it shares with other oaks, gives it a rugged and picturesque appearance in winter.

In conclusion we might repeat that the past few years have been very hard on vegetation. The summers have been dry and the falls wet. Vegetation needs water the most during the growing season, and a superabundance in the fall is a menace rather than a benefit, as it has a tendency to develop tender shoots and prevent the ripening of the tissue. When the wood of trees does not ripen properly and is subjected to even ordinary cold, it sun scalds or winter kills, with disastrous results. The exceptionally dry summer and rather wet fall which we have just experienced have furnished ideal conditions for winter injury this coming winter.

INSECTS OF THE YEAR 1911, IN MASSACHUSETTS.

H. T. FERNALD.

No unusual destruction by insects has been observed in Massachusetts during the year which has just closed. On the other hand, many different kinds have contributed toward the loss which has been experienced, and several not usually met with have been in evidence.

The unusually hot, dry summer was of course favorable to the rapid increase of plant lice and the San José scale. Cutworms were also very abundant and did much damage, and the elm-leaf beetle was unusually destructive, though in most towns this pest is now quite well kept in check by spraying. It was first found in Nantucket this summer in small numbers, on five or six elms, near the center of the town, not, as perhaps might have been expected, on the trees nearest the wharves.

The leopard moth, *Zeuzera pyrina* L., is now present almost everywhere in eastern Massachusetts near the coast, and has even reached Nantucket. It does not seem to have worked its way far inland, however, and, as in other States, its injuries are most pronounced in the cities and larger towns.

The 12-spotted asparagus beetle, *Crioceris 12-punctata* L., which has been working its way northward, was taken at Concord and Roslindale near Boston in 1909. It was not observed at Amherst until last summer, which might indicate a more rapid dispersal along the coast than inward.

The cottony maple scale, *Pulvinaria innumerabilis* Rathv., has been unusually abundant in the Connecticut valley this year, many of the soft maples being so thoroughly covered with

it as to have made little or no growth. This is the first time for several years that this insect has attracted any attention in the State.

In 1910 the white birches throughout New England were attacked by the birch-leaf skeletonizer, *Bucculatrix canadensella* Chamb., and almost without exception the leaf tissues were entirely consumed. As scrub birch is so abundant everywhere in this part of the country much attention was directed to this insect, and many inquiries as to the likelihood of the destruction of the trees were received. During the past fall the insect was again in evidence, but to a less degree, only a small portion of the foliage being destroyed, and as a whole the greatest injury appears to have been in localities where the pest was least abundant last year.

The cut-leaved birches, so much favored as ornamental trees, have had a different experience. They have suffered equally with the native varieties, but in addition, for the last three years in the Connecticut valley at least, they have also been attacked by the bronze birch borer, *Agrilus anxius* Gory, and in nearly every case where this insect has entered a tree the death of the latter has followed, while the native birches have thus far appeared to be exempt.

The latter part of May some large chestnut trees in Amherst were reported as dying. An examination showed that they had been nearly girdled close to the ground, and full grown larvæ, pupæ, and adults of *Leptura zebra* Oliv. were found in the burrows.

For several years the elm-leaf miner, *Kaliosyphinga ulmi* Sund., has been present in considerable abundance. Last year this insect was less noticeable than in 1909, but during the past summer its work on Camperdown and European elms has been very noticeable. In many cases the parenchyma of all the leaves of the trees has been almost entirely consumed, and the trees have made little or no growth. Some facts which have been noted would seem to indicate that there are two generations a year of this sawfly in Massachusetts.

The work of the maple-leaf stem sawfly, *Priophorus acericaulis* MacGill., was quite noticeable in some parts of the State

last spring. It had previously been noticed, but has evidently become much more abundant during the last year or two.

A specimen of the roach *Panchlora hyalina* Sauss. was taken near Amherst in a field at least half a mile from the nearest store. It is of course to be presumed that it came in on some tropical fruit, but it is evidently liable to fly some distance, and may therefore be met with almost anywhere.

During June the members of an elementary class in entomology at the college, interested in collecting insects, obtained a trolley car headlight with the requisite apparatus, and took it to a point where the local car line passes through a densely wooded area. There they established connections with the feed wire of the line and used the headlight to attract insects. The resulting catch included about twenty *lunas*, several *polyphemus* and *io* moths, besides a large number of smaller Lepidoptera, in a little over an hour. Several trials of this method gave extremely good results, and suggest the possibility of using electricity at places where moths are most abundant when trolley lines are properly located for this purpose.

On the 5th, 10th and 23d of June blister beetles were received from correspondents in Stockbridge and Williamstown which were evidently of the genus *Pomphopæa*, and which were kindly identified by Mr. Charles Schaeffer of the Brooklyn Museum as *Pomphopæa sayi* Lec. This insect has never before been received by the experiment station, and the data sent with the insects were of such interest as to be worthy of record. The Williamstown correspondent, under date of June 5, writes: "On the mountain ash tree where they were found there were about a quart." One of the Stockbridge correspondents wrote, June 10:—

Yesterday morning on entering my garden I found that these beetles had taken possession of the place. Every flower stalk had been eaten down and the iris and roses were fast being devoured. Lupins seemed to be the favorite and not one was left. The beetles seem to be drunk with the nectar, for they stuck to the flowers and we could easily cut the stalk and drop it in a pail of kerosene. We caught hundreds in this way. Later, in the afternoon, they seemed to have taken flight. There was a flight of about 300 on June 12, eating lupin, roses, syringas,

iris, etc., eating the flowers and not the foliage. They appeared suddenly, over night. There was no special wind or other climatic conditions noticed. They were exterminated by hand, and after a heavy rain at night none appeared next day.

The other Stockbridge correspondent, on June 23, wrote: —

Three days ago I found these beetles eating the roses in the garden. They lighted, half a dozen or so, on one rose and devoured it rapidly. They were either so sluggish or so hungry that they were easily caught and the gardener drowned several hundred in an hour. Since then I have seen only a few scattered individuals. They seem tenacious of life, as specimens have lived three days in a box.

INDEX.

INDEX.

	PAGE
Alfalfa co-operative experiments,	10
Cultural directions, etc.,	10
Drought, effects of,	11
Failures, causes for,	11
Growers, opinions of,	12
Yields,	12
Bowker prize, complete analyses of corn grown in competition for,	16
Bronzing of maple leaves,	54
Cause,	54
Sun scorch,	55
Chemical methods for the preservation of manure,	31
Bacteria affecting nitrogenous content,	31
Gypsum or land plaster,	32
Kainit,	34
Precipitated gypsum,	33
Sulfuric acid,	33
Superphosphate,	33
Chemicals, nitrogen absorption, capacity of,	26
Coarse nozzle <i>versus</i> mist nozzle spraying,	56
Coarse spraying, development of,	56
Power spraying,	58
Conclusions, summary of leading,	7
Corn best suited to Massachusetts, types of,	14
Results, summary of,	14
Varieties tested,	14
Corn grown in competition for the Bowker prize, complete analyses of,	16
Analyses, table of,	17
Kernel and cob, relative proportion of,	19
Ranges in analysis,	18
Digestion experiments with cattle feeds,	47
Introduction,	47
Red clover and alfalfa hay, comparison of,	53
Results with:—	
Alfalfa hay,	50
Corn fodders,	48
Proprietary grain mixtures,	49
Red clover hay,	52
Diseases more or less common during the year,	78
Apple troubles,	79
Shade trees,	80
Elm trees, observations on growth of,	72
Experiments, alfalfa co-operative,	10
Experiments to determine the nitrogen absorption capacity of several well-known chemicals,	26
Experiments with cattle feeds, digestion,	47

	PAGE
Experiments with rose soils,	60
Mechanical composition of best rose soils, discussion of,	68
Objects,	60
Plants, growth of, etc.,	63
Renewal of soils,	66
Results of the second year,	65
Rose soils, mechanical analysis of,	61, 66
Soils used, notes on,	62
Feeds, digestion experiments with,	47
Alfalfa hay,	50
Corn fodders,	48
Proprietary grain mixtures,	49
Red clover hay,	52
Insects of the year 1911 in Massachusetts,	82
Blister beetles,	84
Malnutrition or overfertilization, tobacco injury due to,	35
Soil solutions, concentration of,	45
Soluble mineral constituents, discussion of,	44
Manure, chemical methods for the preservation of,	31
Maple leaves, bronzing of,	54
Methods of selection for plant improvement,	21
Need of seed law in Massachusetts,	75
Nitrogen absorption capacity of several well-known chemicals, experiments to determine the,	26
Chemicals used,	26
Methods,	27
Nitrogen absorbed, tables,	29
Notable elm tree,	69
Age and growth, data on,	70
Observations on the growth of elm trees,	72
Growth under different conditions, rate of,	73
Light on growth, effects of,	73
Plant improvement, methods of selection for,	21
Cross-fertilized plants, consideration of,	24
Introduction,	21
Superior strains, simple method of selecting,	22
Preservation of manure, chemical methods for,	31
Rose soils, experiments with,	60
Mechanical texture of,	61, 66, 68
Objects,	60
Seed law in Massachusetts,	75
Publicity as a remedy,	77
Seed laws, nature of,	76
Selection for plant improvement, methods of,	21
Soils, experiments with rose,	60
Spraying, coarse nozzle <i>versus</i> mist nozzle,	56
Tobacco injury due to malnutrition or overfertilization,	35
Analyses of soils, tables of,	37, 39, 41
Hot water soluble constituents, discussion of,	40
Injury, description of,	35
Rotation remedy,	46
Soil solutions, concentration of,	45
Soluble mineral constituents, discussion of,	44
Water soluble potash, discussion of,	44





