Frontispiece.— The Original Station Building.

State of New York—Department of Agriculture

TWENTY-SIXTH ANNUAL REPORT

OF THE

New York Agricultural Experiment Station

PART III

TWENTY-FIFTH ANNIVERSARY REPORT

1882--1907

ALBANY
J. B. LYON COMPANY, STATE PRINTERS
1908

1882–1907.

ORGANIZATION OF THE STATION.

MEMBERS OF BOARD OF CONTROL.

Governor Alonzo B. Cornell, Ex-officio	Albany	1881–1882
Robert J. Swan	Geneva	1881–1887
N. M. Curtis	Ogdensburg	1881–1891
Patrick Barry	Rochester	1881–1889
W. A. Armstrong	Elmira	1881–1890
James McCann	Elmira	1881–1893
S. W. Clark	Spencerport	1881–1882
Daniel Batchelor	Utica	1881–1893
Jabez S. Woodward	Lockport	1881–1888
A. V. Mekeel	North Hector	1881–1885
Governor Grover Cleveland, Ex-officio	Albany	1883–1884
John O'Donnell	Jamaica	1883–1887
David B. Hill, Ex-officio	Albany	1885–1890
Charles C. B. Walker	Corning	1885–1888
William W. Wright	Geneva	1887–1889
Charles Jones	Geneseo	1887–1896
Gerrit S. Miller	Peterboro	1888–1893
George F. Mills	Fonda	1888–1895
William C. Barry	Rochester	1889–1900
Philip N. Nicholas	Geneva	1890–1896
Adrian Tuttle	Watkins	1890–1896
Governor Roswell P. Flower, Ex-officio	Albany	1891–1894
Stephen H. Hammond	Geneva	1891–
William D. Barns	Middle Hope	1893–1896
Martin V. B. Ives	Potsdam	1893–1900
Luman D. Olney	Watertown	1893–1896
Governor Levi P. Morton, Ex-officio	Albany	1895–1896
Austin C. Chase	Syracuse	1895–1902
Governor Frank S. Black, Ex-officio	Albany	1896–1898
Frank O. Chamberlain	Canandaigua	1896–1902
Fred C. Schraub	Lowville	1896–1905
Nicholas Hallock	Queens	1896–1902
Lyman P. Haviland	Camden	1896–
G. Howard Davison	Millbrook	1896–1900
Governor Theodore Roosevelt, Ex-officio	Albany	1899–1900
Edgar G. Dusenbury	Portville	1900–
Oscar H. Hale	North Stockholm	1900–1903

Martin L. Allen	Fayette	1900–1903
Governor Benjamin B. Odell, Ex-officio	Albany	1901–1904
Jens Jensen	Binghamton	1902–1905
Thomas B. Wilson	Halls Corners	1902–
Edward A. Callahan*	Albany	1902.
Milo H. Olin	Perry	1903–1907
Irving Rouse	Rochester	1903–
Charles W. Ward	Queens	1903–1906
Commissioner Charles A. Wieting, Ex-officio	Cobleskill	1904–
Governor Frank W. Higgins, Ex-officio	Albany	1905–1906
Alfred G. Lewis	Geneva	1906–
Governor Charles Evans Hughes, Ex-officio	Albany	1907–
Willis G. Johnson*	New York City	1907.

TREASURERS.

Robert J. Swan..........1882–1885
William Slosson..........1885–1886

SECRETARY AND TREASURER.

William O'Hanlon.........1887–

MEMBERS OF STATION STAFF.

DIRECTORS.

E. Lewis Sturtevant.......1882–1887
Peter Collier..............1887–1895
Lucius L. Van Slyke, acting.1895–1896
Whitman H. Jordan.......1896–

AGRICULTURIST.

G. W. Churchill...........1884–

ANIMAL HUSBANDRY.

Henry H. Wing, assistant..1882–1884
Charles S. Plumb, asst....1884–1887
William P. Wheeler, asst..1896–

BOTANISTS.

Joseph C. Arthur..........1884–1887
Fred C. Stewart...........1895–

ASSISTANT BOTANISTS.

Frederick H. Blodgett.....1899–1900
G. Talbot French..........1906–
Harry J. Eustace..........1902–1906
John G. Grossenbacher.....1907–

CHEMISTS.

S. Moulton Babcock.......1882–1887
Lucius L. Van Slyke.......1890–
Edwin F. Ladd............1888–1889

* Died before expiration of term.

ASSOCIATE CHEMISTS.

Edwin B. Hart............1904–1906
Alfred W. Bosworth.......1907–

ASSISTANT CHEMISTS.

Edwin F. Ladd............1884–1888
William H. Whalen.......1889–1891
William I. Tibballs........1890–1891
Paul H. Seymour..........1890–1891
Robert B. Armstrong......1890–1891
Roy D. Young............1890–1891
Christian G. Jenter........1891–1905
Abram L. Knisely.........1891–1897
Shinichi Ando.............1891–1892
William H. Andrews......1891–1892
William H. Andrews.......1895–1905
Benjamin L. Murray.......1891–1894
William B. Cady...........1892–1895
Amasa D. Cook...........1892–1901
John T. Sheedy...........1892–1893
Harry H. Seeley..........1894–1896
J. Arthur LeClerc.........1896–1902
Fred D. Fuller............1897–1905
Edwin B. Hart............1897–1904
Firman Thompson.........1897–1899
Charles W. Mudge.........1899–1905
Andrew J. Patten..........1900–1905
Frank A. Urner...........1903–1905
Alfred W. Bosworth.......1905–1907
William E. Tottingham....1905–1906
Arthur W. Clark..........1905–
Ernest L. Baker...........1905–
Anton R. Rose............1906–
Morgan P. Sweeney........1907–
James T. Cusick...........1907–
Otto McCreary............1907–
Percy W. Flint............1907.

BACTERIOLOGIST.

Harry A. Harding.........1899–

ASSISTANT BACTERIOLOGISTS.

Lore A. Rogers............1900–1902
John F. Nicholson.........1902–1903
Martin J. Prucha..........1903–
James K. Wilson..........1906–

DAIRY EXPERT.

George A. Smith..........1898–

EDITOR AND LIBRARIAN.

Frank H. Hall............1897–

ENTOMOLOGISTS.

F. Atwood Sirrine........1894–1902
Victor H. Lowe...........1894–1903
Percival J. Parrott........1903–

ASSISTANT ENTOMOLOGISTS.

Percival J. Parrott........1900–1902
Howard O. Woodworth....1902–1903
Harold E. Hodgkiss.......1904–
William J. Schoene........1906–

HORTICULTURISTS.

Emmett S. Goff..........1882–1889
Charles E. Hunn, acting...1889–1892
Spencer A. Beach.........1891–1905
Ulysses P. Hedrick........1905–

ASSISTANT HORTICULTURISTS.

Antoine deB. Lovett.......1883–1884
Milton H. Beckwith.......1885–1888
Charles E. Hunn 1892–1893
Wendell Paddock..........1893–1900
Charles P. Close...........1896–1899
Heinrich Hasselbring......1900–1901
Nathaniel O. Booth........1901–1902
Nathaniel O. Booth........1904–
Vinton A. Clark...........1902–1904
Richard Wellington........1906–
Maxwell J. Dorsey........1907–

MISCELLANEOUS.

Oscar E. Liess............1884–1885
Stephen D. Anderson......1885–1886
William P. Wheeler,
First assistant...........1888–1896
Frank E. Emery,
Supterintendent of farm.1888–1890
George W. Churchill,
Acting pomologist.......1890–1892
Orrin M. Taylor,
Foreman in horticulture..1902–
F. Atwood Sirrine,
Special Agent...........1902–

STUDENT ASSISTANTS.

Fred M. Rolfs............1899.
Lore A. Rogers............1899–1900
Harry J. Eustace..........1901–1902
Henry J. Ramsey..........1905.
William J. Schoene........1905–1906

STENOGRAPHERS.

Robert Watson............1882–1884
Frank E. Newton..........1884–
Jennie Terwilliger.........1897–
George A. Menard.........1906.
Willard F. Patchin........1906–

CLERKS.

A. H. Horton,
Computer and mailing clk. 1890–
Julia A. Hoey, junior clerk.1905–

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ANNIVERSARY EXERCISES

NEW YORK AGRICULTURAL EXPERIMENT STATION

ANNIVERSARY FIELD DAY

August 29, 1907

Program

President of the day

Hon. T. B. Wilson.................. President Board of Control

10:00 A. M.

Greetings

Hon. A. P. Rose............................ Mayor of Geneva

Addresses

Hon. Charles Evans Hughes.............. Governor of New York
Hon. Sereno E. Payne..................... Member of Congress
Hon. Sherman Moreland............ Member of N. Y. Legislature
Hon. G. L. Flanders............ N. Y. Department of Agriculture

2:00 P. M.

Addresses

Hon. F. W. Godfrey............ Master New York State Grange
Hon. Jabez S. Woodward..............................
Member First Board of Control of Station
Dr. William Oxley Thompson........ Pres. Ohio State University
"National and State Aid to Investigation"
Dr. L. H. Bailey, Dean New York State College of Agriculture
"Lessons of the Day"

INTRODUCTORY.*

Ideal weather marked the day set apart for the exercises celebrating the twenty-fifth anniversary of the establishment of the New York Agricultural Experiment Station. A clear blue sky, bright but not dazzling sunlight, and an exhilarating atmosphere made the prospect of a day upon the green lawns of the Station an inviting one; and thousands of farmers and other friends of the institution accepted the invitation to join with Board and Staff in celebrating the day. As preliminary to the exercises at the grounds, the city of Geneva united with the Station in welcoming Governor Charles Evans Hughes, upon his arrival from the east on the 9:01 A. M. train of the New York Central railroad. Waiting the Governor's coming were the Mayor and other officials and dignitaries of the city, members of the Board of Control and Staff of the Station, many invited guests of the day, the Geneva City Band and Company B of the New York National Guard. Under this escort the Governor was conducted to the Armory, where a short informal reception was held. After the reception, automobiles were provided for the leading members of the party for a ride through many of the principal streets of the city and visits to the Country Club and the White Springs farm. The owners of many automobiles in the city placed their machines at the disposal of the Experiment Station for the purpose, and the line of machines decorated with flags made an interesting and picturesque sight, which was enjoyed by the citizens and residents along the route who were out in the highways, on the streets or on the porches of their house to see the vehicles with their distinguished visitors pass.

There were ten cars in the procession, which were occupied by the following:

Car 1, Lewis — Governor Hughes, Colonel Treadwell, T. B. Wilson, W. H. Jordan, Mayor Rose, Mr. Lewis.

Car 2, Fast — Mr. Payne, Senator Raines, Mr. Moreland, Colonel Wilson.

Car 3, Jordan — Dr. Thompson, Dr. Brown, Dr. True, Prof. Downing.

Car 4, Burrall — Dr. Arthur, Prof. Wing, Dr. Babcock.

Car 5, Clark — Mr. Flanders, Mr. Godfrey, Mr. W. K. Payne.

Car 6, Chew — Prof. Bailey, Prof. Davis, Mr. Barry.

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* This account of the exercises is taken, in part, from the description given in the *Geneva Daily Times* of August 29, 1907.

Car 7, Truslow — Mr. Ives, Mr. Schraub, Mr. Nicholas.
Car 8, Chase — Mr. Johnson, Mr. Dusenbury, Mr. Rouse.
Car 9, Dey — Captain Stacey, William O'Hanlon, W. A. Gracey.
Car 10, Blaine — Mr. Haviland, Mr. Woodward, Mr. Hallock, Mr. Henderson.

BIG TENT CROWDED.

On arrival at the Experiment Station the visitors found the large tent filled with people to its utmost capacity, probably three thousand being assembled within the canvas covering. People from the city were there as well as farmers and residents of the adjacent rural sections. The Experiment Station by its association and relation to the farming and rural communities naturally in its field day attracted to its celebration many of that constituency.

GREETING TO THE GOVERNOR.

As Governor Hughes walked into the tent, followed by the other distinguished visitors, the entire assemblage rose to greet him. Hats were thrown into the air and handkerchiefs were waved on every side. The audience remained standing until the Governor and party had taken their seats on the platform. The exercises were called to order by Hon. T. B. Wilson, president of the Board of Control of the Experiment Station, who acted as president of the day. Mr. Wilson first introduced Mayor A. P. Rose, who gave a greeting in the following words:

MAYOR ROSE'S GREETING.

"Gentlemen, Friends and Guests.—Geneva esteems it an honor to welcome a company of such eminent and distinguished men. New York State cannot equal, in its productions, the cotton of the south nor the corn of the west, but to-day this little city claims the pre-eminence over the whole country for its magnificent collection of able, distinguished, learned and practical agriculturists, and men eminent in science and statesmanship, gathered here from the length and breadth of the land, to do honor to our Experiment Station. This Station is not a local affair but belongs to the whole State, and yet, on account of its location, we Genevans cannot but consider that it belongs to us in a special sense, and you must permit us to take a special pride in it. We trust that when you leave our city you will go away convinced that no mistake was made when this Station was located here twenty-five years ago. And the pride that we take in it as a local institution will be doubled when we remember that it had the power, as a magnet, to draw within our borders you, our eminent and distinguished guests. And, therefore, welcome, thrice welcome."

Dr. W. H. Jordan, Director of the Station, then gave the following address, reviewing briefly the history and work of the Station:

STATION HISTORY.

W. H. JORDAN.

LADIES AND GENTLEMEN.— In the name of my associates I give you a cordial greeting and a hearty welcome to these grounds. You have come to visit what is your own. The ostensible reason for asking you here is that this Experiment Station has passed its twenty-fifth birthday. But this institution is not old — it is young, and has not even attained its full stature and vigor, and the real reason for your invitation to pay us a visit lies deeper than the mere matter of age. The underlying purpose of this occasion is that you may pause for a moment and give us your attention and interest.

JUST A PUBLIC SERVANT.

An institution like this, standing apart from a college or university, appoints few feasts. It has no family of devoted sons that it can call home annually to give cheer and inspiration — indeed it has no calendar of special days. It is just a public servant with its assigned duties, duties that if well met will be performed quietly and without ostentation. Real scientific investigation has few elements of popularity.

SOME MAIN FACTS.

It would be ungrateful, however, on such an occasion as this for me to withhold a generous recognition of some of the main factors that have been efficient in the upbuilding of this Experiment Station.

Something more than ten years ago I wrote: "It is a matter for congratulation that the Station is well located, both agriculturally and socially. It is in the midst of one of the most fertile and prosperous farming regions of the State, which has an almost world-wide reputation for its production of nursery stock and fruit.

"Moreover, the Station has a desirable social environment. The village of Geneva is one of the oldest in the State, and has long been the home of cultivated people who have received the Station as an institution in which they have a peculiar and abiding interest. This is fortunate, because the prosperity and efficiency of any work which calls together a body of educated men is greatly enhanced by a loyal local support and agreeable social relations."

I have seen no reason for revising these statements and to-day I desire to express again, for myself and associates, our sense of obligation to the people among whom our lot is cast.

FREEDOM FROM PARTISANSHIP.

The main element in the life of any public institution is its board of management. It behooves me to refer to my superior officers with due and becoming deference and discretion, but I make bold to place on record this one statement, which is, that during the eleven years that I have been connected with the Station I have not heard from any member of the Board, either in the meetings of the Board or outside, a single suggestion that savored of personal or partisan advantage. No further comment from me is necessary as an evidence of the singleness of purpose that has animated this Board.

INTIMATE RELATIONS WITH FARMERS.

Our work and influence have been greatly strengthened with the people and brought much closer to farm practice through the intimate relations we sustain with the State Bureau of Farmers' Institutes. The Station staff and the institute lecturers meet annually for several days' discussion of the newer phases of knowledge, a conference that is unquestionably of great mutual advantage.

My acknowledgments would not be complete if I neglected to mention gratefully the cordial and helpful attitude toward us of the New York State College of Agriculture; and last, but not least, of the agencies with which we have joined hands, are the agricultural organizations of the State. Chief among these, and most comprehensive, is the Grange, to whose unwavering support we owe much. No less should be said of the fruit growers' organizations and other special groups of farmers whose confidence and support are invaluable.

HISTORY OF THE STATION.

Doubtless there may have been an expectation that on this occasion the history of the Station and the results it has accomplished would be presented more or less in detail. The history of the Station may best be read in what the institution now is and what it stands for, and its results in common with those of similar institutions are exemplified in the greatly increased application of exact knowledge to agricultural practice. Nevertheless a few facts may be interesting and pertinent:

The Station began its operations on the first day of March, 1882. The building equipment then consisted of a mansion house and an ordinary set of farm buildings; we now have fifteen buildings devoted to our use with five more assured and others whose perspective is definitely outlined in the field of hopeful expectation. The sum annually available for maintenance for the first few years was $20,000; it is now nearly $90,000. The staff at first numbered five persons; it now numbers thirty-one. In the beginning there was here no laboratory or other equipment — now we have seven laboratories equipped for work of a special character, to say nothing of barns and other buildings of a modern type. These are the material evidences of growth.

VAGUE IDEAS AT FIRST.

The essential fact to consider is the touch we have with agricultural practice. I once asked a member of the first Board of Control what that Board expected the Station would do. His answer was, "We did not have very clear ideas." Not only were the internal conceptions of the Station's functions dimly outlined at first, but the public, while expectant, was to a large degree suspicious that the new effort was fanciful in its origin and would be impractical in its results. In the earlier days there were those who lost no opportunity to criticise. A Buffalo editor wrote of an early report something like this: "It is said that figures do not lie. If this be true, the report of the New York Agricultural Experiment Station contains a tremendous pile of truth."

CALLED IT A HUMBUG.

The able and versatile paper, *The Sun*, published an editorial in March, 1887, in which the following language occurs: "It is enough to make an earnest American despair of the future of democracy in America to see the ease with which a few men, hating to work for their own living and determined to live on the Government, succeeded in putting a law through our Legislature to set them up, with $22,000 a year income, in the fraudulent business of conducting agricultural experiments to improve New York farming. From top to bottom, the bill, the Station, and its operations have been a fraud on our farmers and taxpayers. The contrivers of the Station had no more care of our farmers than the Washington claim agents had for the heroes who died in battle to save the Union when they put through Congress their pauper pension bill for the benefit of themselves and the relatives of deserters and non-combatants." The editorial ends with this: "In the name of New York's insulted farmers and in the name of good government, we demand of the Legislature to abolish the Geneva Agricultural Experiment Station. It is a humbug." So much for the *Sun* whose dyspeptic utterances were expressive of a sentiment then somewhat prevalent, but whose editor evidently donned the mantle of a false prophet.

CHANGES OF 25 YEARS.

What a change a quarter of a century has wrought! The agricultural scientist now feels that his right to live and labor is recognized. Members of the staffs of our college and two stations very nearly man the programs of our larger agricultural conventions; they are listened to with respect and confidence from the farmers' institute platform; there is evidence that the bulletins they write are sometimes carefully read; and their advice is freely sought concerning troublesome farm problems.

A COMPARISON.

I wish that in a word I could, by way of comparison, throw before you in perspective the agriculture of fifty or even twenty-five years ago and the agriculture of to-day. Within a half century farm practice, in many of its features, has passed from under the sway of tradition and superstition into the domain of exact knowledge. We now know in part why soils are infertile; we are able to trace the income and outgo of fertility and so conserve the National fundamental resources; the processes of nutrition are now not altogether a mystery and more or less rational systems of feeding man and beast are possible; commercial standards are established in dairying and have displaced the unbusinesslike and unfair measurements of former days; milk sanitation is an accomplished fact than which nothing is of greater importance to the dwellers in our cities; boundaries have been set to the depredations of many fungus and insect pests that otherwise would devastate orchard and garden, and best of all the new basis of agricultural practice demands a high order of intelligence on the part of the practitioner. The supreme test of any movement that we call progress is the quality of its reaction upon men and women and nothing will permanently elevate and dignify agriculture that does not uplift the intellectual and moral status of those who dwell in the open country. Surely the changes that have come to agriculture will bear this test and I am glad to believe that this institution has had some small part in what has been accomplished.

Permit me a word concerning the policy around which the Station's activities are centered. A prominent newspaper in commenting on this occasion stated that our Station "has done its work in a quiet way." I am grateful that this institution has so impressed itself upon an observing editorial mind. Some of us have little respect for science with a brass band attachment, for it savors of sensationalism and chicanery. We place our faith rather in those who abide in the atmosphere of conservative scholarship, who, working in a patient and truth-loving spirit, find their satisfying reward in advancing knowledge.

THE REAL FUNCTION.

But what do we regard as the real function of this institution? The State undertakes to do three things for agriculture, investigate, teach and enforce law. In co-operation with our sister station at Ithaca, it is for us to investigate, but what we should do is often seriously handicapped by what we are asked to do. Just now we are in danger that investigation will be displaced by popular demonstration. A strenuous and widespread movement is now in progress for the exploitation of agricultural knowledge, sometimes, I fear, without proper discrimination as to what knowledge is soundly ripened. It is a question, too, whether in this movement we are always recognizing the boundaries of individual initiative and responsibility. Whatever is done for the farmer or any other class should have as its chief end the cultivation of individual grasp and power and governmental aid should go no farther than to secure this result. But because of this trend of effort it requires courage, sometimes it seems hardly possible, for us to put aside these activities that most quickly react upon the public minds, and by so doing,

Plate I.— Station Buildings in 1882.

Plate II.— Station Buildings in 1907.

MAP SHOWING LOCATION OF PRINCIPAL BUILDINGS

N. Y. AGRICULTURAL EXPERIMENT STATION

as some fear, endanger our popular support. It is real menace to research work that the worth to agriculture of the men of the colleges and stations is so largely judged by popular efforts. I do not know how it is with Director Bailey's associates, but if the members of the Station staff were to meet all the calls they have for speaking and for visitation to different localities in the State, dust would settle on the crucible and the microscope. We do not complain because we are asked to do these things but we want you to feel with us, that if this institution is to remain true to its real function, we must be allowed to spend a generous share of our time behind the closed doors of observation and reflection, whether in the field or laboratory. This, then, is the policy of this Station as I undersstand it, to hold mainly to the work of real investigation and leave teaching and popular demonstration largely to other agencies.

GOVERNOR HUGHES INTRODUCED.

In closing his remarks Dr. Jordan introduced Governor Hughes in the following words:

"Ladies and Gentlemen.— I appreciate the patience with which you have listened to me; for you are anxious to greet the speakers who are to come. Agriculture and this institution are greatly honored by the presence here of the Chief Executive of our State. Our Governor stands to-day in the forefront of public attention not only in this State but in the Nation. There is now going on a far-reaching adjustment of our political and governmental relations, a readjustment which has the support of a lively public sentiment. Such times, that are always more or less critical, demand, not opportunism, but constructive statesmanship. We welcome Governor Hughes here to-day because he is exhibiting the qualities of leadership that the times demand and that the people admire, and because, in common with other trusted leaders who are with us, he stands for the application of the simple principles of common honesty to all the affairs in which the people are interested. We deem it a privilege to felicitate our distinguished guest upon his personal and official honors. Ladies and gentlemen, I have the honor to present Governor Hughes."

CHEERS FOR THE GOVERNOR.

When Governor Hughes arose to speak there was another demonstration. The audience again arose and Senator Raines proposed three cheers for the Governor, which were given with a zest that manifested a genuine enthusiasm. After addressing the president of the day the Governor spoke as follows:

ADDRESS OF GOVERNOR CHARLES EVANS HUGHES.

"Ladies and Gentlemen.— It is very agreeable to visit Geneva upon this congenial errand. As I have been driven through the streets of your city and along your beautiful lake, where so much is presented to charm the eye and so many manifestations are found of thrift and intelligence, of prosperity and contentment,I have not only been interested in the exhibition of a model city but I have been surprised at the extraordinary self-restraint which was shown in the control of the pride which those who were displaying the advantages of Geneva must have felt. You may well be proud, Genevans, proud of a location almost matchless, proud of a city of beautiful homes, proud of a situation in a country so beautiful, proud of your prosperity, and to-day we assemble to express as citizens, not of Geneva, but of the Empire State, our pride in a great institution doing efficient work and having a noble aim.

RESULTS OF SPLENDID EFFORT.

"I like no part of my work better than the visiting of the institutions of the State. To me they represent, not acres, not buildings, not equipment, but human efforts for the benefit of mankind. We think too much of institutions in an impersonal way. We think too much of the physical manifestations of the activities, we pay too little attention to the hard, steady work which makes them successful, and whatever need there may be throughout this State of here and there correcting an error of administration, of here and there perfecting an adjustment or obtaining a more efficient service, and doubtless there is need of it, no one can see the activities of the government of this great State in its varied institutions without thanking God for the splendid efforts of our citizenship for the benefit of all the people. (Applause.)

HONORS UNHERALDED.

"To-day I think not so much of the Geneva Experiment Station as a sort of entity, which has achieved its twenty-fifth birthday. I rather think of the line of patient, quiet it may be, but effective investigators who have been living their lives here, doing their work through these years, honorable, careful work, in order that one of the great and important activities of our State should be further advanced. Oh, it is a noble thought to think of the men whose names are not heralded abroad, whose acts do not furnish headlines for the newspapers, but who in their different fields of activity are making this the Empire State, so all honor to the twenty-five years of honorable and careful effort at Geneva. (Applause.)

FARMER NOT OBJECT OF CHARITY.

"Now I do not believe that the farmer regards himself an object for State charity. (Applause.) So far as I have observed the farmer is a pretty independent citizen. He generally has a mind of his own. In fact I do not know what our fund of intelligence and rationalism would amount to if we did not draw upon the farmers for a continual renewal of the supply. (Applause.)

"When you get out where a man has a little elbow room and a chance to develop, he has thoughts of his own. His thinking is not supplied to him every night and every morning and he is less of a machine and more of a man, so that I do not think that the farmers need to be looked upon or want to be looked upon as dependents of the State. They do not come to the State government asking alms; they are self-reliant, they are intelligent. What we want in connection with agriculture is what we want in connection with every other field of noble effort; we want training, we want intelligence, we want scientific method, we want direction, we want the way shown and then the man in a way can walk in it. (Applause.) There is no reason why the same care and attention and skill and scientific consideration should not be devoted to agriculture as to industry and the technical trades. The men who are running away from the farms too frequently make a mistake; and some day in New York,— and the day is rapidly approaching — many a young man will wake up to the fact that he has a pretty good chance on the farm and that he may be more of a man and to a greater degree independent and happy in life, if he stays where his happy lot was cast in connection with his father's farm or another which he may be able to procure.

"Dr. Jordan has said that there is not much popularity in scientific method, or with relation to the scientific method. Well, of course, they do not go around, so far as the scientific method is concerned, with quite the same parade that attaches to some other activities, but I tell you if your test of popularity is what people are thinking in their minds and what the average American citizen wants, the scientific method is the only thing that is popular, whether it is in agriculture or in government. (Applause.)

NARROWING THE FIELD OF FAILURE.

"We are constantly trying to narrow the field of failure. We are constantly trying to increase the opportunities for success in every line of knowing. Knowledge is power. I remember that Wendell Phillips, in one of his impassionate addresses (I do not know as I can quote the exact words at this moment) said something like this: 'The age of bullets is over, the day of men armored in mail has passed, but the day of thinking men has come.' And when the farmers of New York are all intelligent, thinking men in regard to their own particular work, and taking advantage of the results of experimentation and availing themselves of agricultural education, New York will regain the place which it once had, and which some years ago it lost, of being the first agricultural state in the United States. (Applause.) It is first to-day in many important departments, first with reference to its dairy products, first in reference to hay and apples, first with reference to other matters. It is not first with reference to the value of farm property, but were the same intelligence and earnestness applied in that direction as has been applied in industry and engineering, it cannot fail to attain the supremacy. Scientific method; what is it? Why, the scientific method is nothing but a patient, careful, persistent pursuit of truth, that is all. The man who is content with anything but the truth, the man who will be desirous of obtaining anything that does not square with the verities of the situation, he is not a scientist, he has not the noble ambition of the scientist. The scientist is the man that will go through any danger and will endure any amount of toil and will pursue unfailing the one ambition of his life, the attainment of truth in his line. That is what we need regarding agriculture. We don't want it in a haphazard way. It is impossible for one individual farmer in connection with his farm, to conduct a variety of experiments which will enable him to know what the advantages of this or that particular training might be. I do not know whether this is true, or not, but I should assume, from acquaintance with other lines that if the farmers of the State had pursued many of the experiments of our friend, Dr. Jordan, for the last few years, they might have been wiped out before they got through with the experiments. You have got to experiment and

Plate III.— Chemical Laboratory.

take your failures in order that you may have your successes, and the State says with reference to agriculture, ' We will have a place where we can find out the truth in regard to matters pertaining to the interests of large numbers of our citizens. We will have men there that will work until they can see what things can be accomplished in certain ways; how these destroyers themselves can be destroyed; how fertility can be increased; how particular advantages can be gained, and then when they have reached the truth, we will provide for its dissemination and meanwhile we will provide an opportunity for educating young men who are going onto the farm, broadening their outlook and giving them a proper perspective, I love that word perspective. We have got to have things in their true relations and a man's happiness in life is more dependent on his perspective than on anything else. Some men hold a little thing, not of much importance in itself, so close to their eyes that the whole world outside is hidden. If we can only see things in their true relations how happy would be those who have the good fortune to be farmers. How many of those there are who are now suffering from ills that could easily be gotten rid of, if they only saw things in their true relations.

SCIENCE IN GOVERNMENT.

"What I want to say in conclusion is that this same scientific method, which we admire in the work of this Experiment Station, which promises so much for the agricultural interests in our State, we want to see applied everywhere through the administration of government. We cannot, as I said the other day, as human beings dealing with the affairs and interests of human beings, have things done with exact regard to scientific formulae and I tell you, my friends, what you want, what the citizens of this State want, more than anything else, in connection with their government is the ascertainment of the truth, the dealing with things in a true and honorable way, the standing for the truth and the readiness to account to the people according to the truth."

ADDRESS OF CONGRESSMAN PAYNE.

After the protracted applause which followed the Governor's address, Dr. Jordan introduced as the second speaker of the morning, Hon. Sereno E. Payne, of Auburn, Member of Congress. Mr. Payne said in part:

"I am glad that Governor Hughes has discovered Geneva with its beauty and evidences of prosperity. He is a great discoverer. As you know he has discovered some things down at Albany which have not been thought of before. There is one thing about Governor Hughes that when he makes a discovery he generally acts. Now that he has discovered Geneva and the Experiment Station I am sure that you will hear from Albany more loudly than before. After hearing him speak I have begun to feel that he too is a farmer or at least an agriculturist, and the farmer is the greatest man in the country especially at election time.

"The farmers comprise more than half of the people of the United States. As so large a part of his family belongs to this class Uncle Sam has spent considerable time in looking after them. One way that he has attempted to do this is by distributing seeds. I have the honor of opposing this way of looking after farmers, believing that the farmers of my constituency are perfectly able to buy seeds for themselves. Originally the idea of this appropriation was all right, as it was based upon the idea to send out rare seeds which would benefit agriculture in the various parts of the states, but in later years this idea has been distorted."

From this point the Congressman reviewed the various kinds of work that the Federal Government has undertaken for the benefit of the agricultural interests of the country, speaking of the foundation of the land grant colleges, the annual appropriation to experiment stations and agricultural colleges and the extensive work of the Department of Agriculture.

He also spoke of the improvements in rural conditions by the introduction of the rural free delivery and rural telephone.

REMARKS OF SENATOR RAINES.

The last speaker on the morning program was Hon. John Raines, State Senator from the district which includes Geneva. In introduring Senator Raines, Dr. Jordan spoke of the Senator's resolution, expressed by letter, not to speak at the exercises; but said he felt compelled to pay tribute to him as a most loyal friend of the Station, who from his position had been able to do much to promote its interests. Senator Raines responded briefly, and after some jocular remarks relative to his relationship with the Governor, expressed his satisfaction at having been able to serve the Station and his pleasure at the cordial relations existing between this institution and its sister Station and College at Cornell University.

AFTERNOON PROGRAM.

The address of Speaker of the House, Hon. Sherman Moreland, was necessarily omitted, owing to his absence, but the other speakers were as given on the program. The remarks of Messrs. Godfrey and Woodward were quite informal, and though valuable and entertaining, especially the reminiscences by Mr. Woodward, are not capable of reproduction in print in a way to do them justice.

The papers by Mr. Flanders, Dr. Thompson and Dr. Bailey follow in full:

NEW YORK STATE'S POSITION IN AGRICULTURE.

G. L. FLANDERS.

I anticipate that a very important question for the consideration of those interested in agricultural matters in this State to-day is the question of the relation of the agricultural productions of the State of New York to the agricultural productions of the United States, and this same relation may be carried a step further as one of interest by making a statement as to the relativity of the agricultural productions of the United States to the agricultural productions of the rest of the world.

The Hon. O. P. Austin not long since in an address said: "But the real cause for anxiety in determining the rivalry of these countries is as to the growth of their producing power." To determine whether or not these countries are increasing their production with such rapidity as to indicate that they may take the markets of the world from the United States, he compared the wheat crop of 1901 with that of 1892, showing that during the ten year period Australia had increased her production of wheat 20,000,000 bushels, Argentina 36,000,000, Canada 43,000,000, India 39,000,000, Russia 53,000,000, United States 232,000,000; that of the United States being more than the increased production in Australia, Argentina, Canada, India and Russia combined. In this, he thought the response was easily found in the fact that the United States produces three-fourths of the world's corn, three-fourths of its cotton, 40 per ct. of the provisions entering into international commerce and more than 40 per ct. of the exported wheat.

The agricultural strides in the United States in the last forty years have been something remarkable. The last census shows that, by the use of machinery, the time for producing a bushel of wheat has declined from 4 hours and 34 minutes to 41 minutes, and the cost of human labor to produce this bushel from 35¾ cents to 10½ cents; that the human labor now required to produce a bushel of wheat is 10 minutes, while in 1830 it was 3 hours and 3 minutes, and that the cost of production has declined in that length of time from 17¾ cents to 3⅓ cents.

In the earlier period it required 35½ hours to prepare a ton of hay for market, and it has now been reduced to 11 hours 30 minutes; while the cost of production has been reduced in that length of time from $3.06 to $1.29, and in the two operations, the mowing and curing of the grass, the time of human labor per ton has been reduced from 11 hours to 1 hour 39 minutes, and the cost from 83⅓ cents to 16¼ cents.

To summarize briefly this great saving, due to improved methods and machinery, it was found for the seven crops of the single year of 1899 that the following amounts were saved in the production of the following named crops:

Corn	$523,276,642
Wheat	79,194,867
Oats	52,866,200
Rye	1,408,950
Barley	7,323,480
White potatoes	7,366,820
Hay	10,034,868

In other words, the total potential saving in the cost of human labor in these seven crops in the year of 1899, owing to the improved implements, machines and methods at the present time in the place of the old time manner of production, was $681,471,827 for this one year.

The standing of the United States in the agricultural markets of the world has been greatly affected by this production as an exporting nation. She has advanced from the fourth place in the list of exporting nations to the head of the list. In 1870 England, Germany and France exceeded the United States in their exports. To-day our exportation of domestic products exceeds that of any other nation in the world, and is advancing at a rate which gives assurance that we shall maintain this proud position as the world's greatest producer and exporter. In 1870 the domestic exports of the four great commercial nations of the world were:

The United Kingdom	$971,000,000
Germany	552,000,000
France	541,000,000
United States	376,000,000

In 1901 the domestic exports stood:

United States	$1,460,000,000
United Kingdom	1,365,000,000
Germany	1,113,000,000
France	804,000,000

Thus during that period France increased her exports of domestic products $263,000,000.

United Kingdom	$394,000,000
Germany	561,000,000
United States	1,084,000,000

The United States produces 1/5 of the wheat of the world, 1/2 of the meats, 4/5 of the corn, 3/4 of the cotton.

Having thus slightly touched the question showing the relative importance of the United States as an agricultural producer, to the other nations, permit me for a few moments to call your attention to the relation of the State of New York to the United States as such a producer, viz:

Number of bushels of wheat in

	United States.	New York.	Per ct.
1850	100,485,944	13,121,498	13.05
1860	173,104,924	8,681,105	5.01
1870	287,745,626	12,178,462	4.23
1880	459,483,137	11,587,766	2.52
1890	468,373,968	8,304,539	1.75
1900	658,534,252	10,412,675	1.58

Number of bushels of corn in

	United States.	New York.	Per ct.
1850	592,071,104	17,858,400	3.01
1860	838,792,742	20,061,049	2.34
1870	760,944,549	16,462,825	2.16
1880	1,754,591,676	25,690,156	1.46
1890	2,122,327,547	15,109,969	.71
1900	2,666,440,279	20,024,865	.754

Number of bushels of oats in

	United States.	New York.	Per ct.
1850	146,584,179	26,552,814	18.1
1860	172,643,185	35,175,134	20.03
1870	282,107,157	35,293,625	12.51
1880	407,858,999	37,575,506	9.21
1890	809,250,666	38,898,479	4.85
1900	943,389,375	40,785,900	4.32

Number of bushels of rye in

	United States.	New York.	Per ct.
1850	14,188,813	4,148,182	29.2
1860	21,101,380	4,786,905	22.7
1870	16,918,795	2,478,125	14.65
1880	19,831,595	2,634,690	13.28
1890	28,421,398	3,065,623	10.78
1900	25,568,625	2,431,670	9.5

Number of bushels of barley in

	United States.	New York.	Per ct.
1850	5,167,015	3,585,059	69.4
1860	15,825,898	4,186,668	26.5
1870	22,761,305	7,434,621	24.9
1880	43,997,495	7,792,062	17.7
1890	78,332,976	8,220,242	10.49
1900	119,634,877	2,943,250	2.46

Number of bushels of buckwheat in

	United States.	New York.	Per ct.
1850	8,956,912	3,183,955	35.5
1860	17,571,818	5,126,307	29.2
1870	9,821,721	3,904,080	39.7
1880	11,817,327	4,461,200	37.8
1890	12,110,349	4,675,735	38.6
1900	11,233,515	3,815,350	33.9

Number of sheep in

	United States.	New York.	Per ct.
1850	21,723,220	3,453,241	15.90
1860	22,471,275	2,617,855	11.65
1870	28,477,951	2,181,578	7.66
1880	35,192,074	1,715,180	4.87
1890	35,935,364	1,528,979	4.25
1900	61,605,811	1,745,746	2.83

Number of oxen in

	United States.	New York.	Per ct.
1850....................	1,700,744	178,909	10.50
1860....................	2,254,911	121,703	5.39
1870....................	1,319,271	64,141	4.86
1880....................	993,841	39,633	3.99

Number of milch cows in

	United States.	New York.	Per ct.
1850....................	6,385,094	931,324	14.58
1860....................	8,581,735	1,123,634	13.93
1870....................	8,935,322	1,350,661	15.11
1880....................	12,443,120	1,437,855	11.55
1890....................	16,511,950	1,440,230	8.72
1900....................	17,139,674	1,501,608	8.76

Number of swine in

	United States.	New York.	Per ct.
1850....................	30,354,213	1,018,252	33.54
1860....................	33,512,867	910,178	27.16
1870....................	25,134,569	518,251	20.6
1880....................	47,081,700	751,907	15.9
1890....................	57,409,583	843,342	14.6
1900....................	62,876,108	676,639	10.76

Number of cattle in

	United States.	New York.	Per ct.
1850....................	9,693,069	767,406	7.9
1860....................	14,779,373	727,837	4.9
1870....................	13,566,005	630,522	4.6
1880....................	22,448,550	862,233	3.84
1890....................	33,734,128	653,869	1.93
1900....................	67,822,336	2,596,389	3.83

It will be noticed from the above tables that the relation of the cattle of the State of New York to those of the United States has changed in 50 years from 7.9% to 3.83%

Milch cows..........................	14.58%	to	8.76%
Oxen	10.50%	"	3.99%
Sheep	15.91%	"	2.83%
Swine	33.54%	"	10.76%
Wheat	13.05%	"	1.58%

Corn	3.01%	"	.754%
Barley	69.4%	"	2.46%
Rye	29.2%	"	9.5%
Oats...............................	18.1%	"	4.32%
Buckwheat	35.5%	"	33.9%

Yet as to the amount of the products, New York produces practically as much in 1900 as she did in 1850. This is true of oats and buckwheat, while in the case of corn and cattle the product of the State of New York in 1900 exceeded that of 1850, nevertheless the difference in the relation of the agricultural productions of the State of New York and the United States in the period mentioned is due almost entirely to the increased production in the United States. Thus it will be seen that New York has grown to be less and less of a factor in the cereal and meat markets owing to the great progress made by the country as a whole; that she has had to turn her attention in other directions in order to maintain the position which she should occupy among the states of the union, having practically 1/10 of the population. To-day New York stands first among the dairy states of the Union, as will be seen by the following table:

1900	Dairy farms	Dairy cows	Gallons of milk	Value
N. Y.......	64,457	1,501,608	772,799,352	$55,474,155
Pa.	32,600	943,773	487,033,818	35,860,100
Wis.	25,246	998,397	472,274,264	26,779,721
Me.	17,740	....	....	....
Vt.	16,700	....	....	....
Ill.	15,605	1,007,664	457,106,995	29,638,619
Mass.	14,900	....	....	....
Mich.	14,116	....	309,617,046	16,903,087
Ohio	12,768	818,239	425,870,394	25,383,627
Iowa	......	1,423,648	535,872,240	27,516,870
Texas	......	861,023	251,342,698	15,510,978
Mo.	......	765,386	258,207,755	15,042,360
Minn.	......	753,632	304,017,106	16,623,460
Kansas	......	676,456	....	....

From every point of view New York ranks the leading dairy State.

It stands second as a fruit producing State, California alone being ahead of her, as will be seen by the following table:

California	$28,280,104
New York	15,844,346
Pennsylvania	9,884,809
Ohio	8,901,220
Michigan	5,859,362

These five states produce 52.3% of all the fruit in the United States.

As a dairy State, New York has produced, as shown by figures collected biennially by the Department of Agriculture since 1892, butter in factories as follows:

1892	19,497,357
1894	23,218,626
1896	21,429,694
1898	30,586,088
1900	39,183,311
1902	49,919,794
1904	64,923,779
1906	51,299,681

During the same period of time she has produced cheese in factories as follows:

1892	130,991,310
1894	115,760,325
1896	87,765,143
1898	105,405,266
1900	126,658,672
1902	123,987,516
1904	124,594,538
1906	135,863,770

The future of agriculture in New York State is to be determined or modified by the action that the State, itself, may take relative to it; but to keep abreast of the times, education, such as is given by the agricultural colleges, and information, such as is acquired and disseminated by the agricultural experiment stations, must continue to be given to the people so that this State may be in the front rank of all the movements involving the application of new knowledge in the agricultural world, and the State must protect the markets against the unfair substitution of imitations of food products for the pure food product, and the question of market values must be studied and influenced from an agricultural standpoint to such an extent that the agricultural producer shall not be a prey to the greed of the distributor.

The mistake, however, must not be made of thinking that the aid thus rendered by the State is for the benefit of the agriculturist, that aid is primarily and purely in the interest of agriculture and whatever is in the interest of agriculture, is in the interest of the great consuming public, and the public being interested, it is justly and essentially a cause of the people and for the people and should not be neglected by the people.

FEDERAL AND STATE AID TO INVESTIGATION.

W. O. THOMPSON.

The modern practice of government shows a considerable departure from the early theories current among those who laid the foundation upon which we have built. For a long time after the Constitution of the Federal government was adopted there were those who in accordance with a theory of strict construction of the fundamental law resisted any attempt to engage the government in enterprises based upon a liberal construction of the "general welfare" clause of the Constitution. Nor is there to-day any large class of thoughtful men who would recklessly commit either Federal or State government to lavish expenditures for causes not sanctioned by the people or approved by a sound theory of the functions of the State. The departure from early theory has not been without reason and ample debate. The Louisiana Purchase was a great strain upon the theories of men who had clear and well defined views upon the place of the United States among the nations, and upon the duties incumbent upon the young republic. A wise judgment upon the issues involved coupled with practical reasons of a substantial nature, set aside the theory to which men were devoted and opened the way for a national growth otherwise impossible. The evils avoided by this purchase were doubtless of as great importance as the positive advantages secured in the enlargement of territory. The universal approval now accorded to this departure from political theory demonstrates that our fears are often begotten of our fancies. The teaching of the publicist is not, however, to be lightly regarded, nor is it to be blindly followed. Theories should always be brought to the test of experience, and a wise people will always see the importance of harmonizing a conservative theory with a progressive practice.

Following upon this new accession of territory were certain others of less importance. It was an easy transition to the issue of internal improvements which assumed large proportions as expressed in national political platforms. The development of the new and unsettled country then encouraging most liberal emigration from Europe called for the improvement of public highways, means of transportation, and other forms of Federal or State aid under the theory of general welfare. Subsidies for railroads were justified under this plea.

The most important of all these movements was the Morrill Act which provided that the Federal government should initiate the movement for a form of education for the industrial classes which prior to that time had not received adequate consideration or attention. This act sought to bring to these classes, and indeed to all interested, education in the sciences related to agriculture and the mechanic arts. It is true that these sciences had not been overlooked in the existing system of education, and equally true that their application or study in the interest of these two great classes of industry had not received any serious attention. The government sought to develop this interest through the application of science to industry. In the debates concerning this measure much political and irrelevant discussion occurred, but it reflects great credit upon Mr. Morrill that he was able to fasten the attention of Congress and the country upon the essential and vital issues in the bill. Among these I make mention of the following: First, that the unappropriated public domain was the property of all the people and should be used for the benefit of all the people, a national domain for national purposes. It was in no sense a local question, but always to be regarded as the interest of the nation. Certain recent movements to preserve portions of the national domain for forestry reservations lay a clear and unmistakable emphasis upon this doctrine. The proceeds of this public domain when sold did not change in character because the title had passed from all the people to particular individuals. This theory of the public lands while under consideration brought to the public mind a new emphasis upon the responsibility for the use of public funds, suggested that the use of public money could not be justified for private purposes and compelled the statesman to give new consideration to the general welfare of all the people.

The second general consideration in the Morrill Act was that education being fundamental in the development and maintenance of national strength and prosperity should be universalized so as to include all classes of people. Prior to this time public lands had been dedicated to the support of common schools, but this act was the beginning of a revival in education applied to the industries of the country. No one familiar with the progress of modern education can fail to see that this act was the beginning of the most important feature of the new education.

The act could never have been passed and certainly could not have been justified if it had not brought to the attention of Congress its economic importance in maintaining and developing the resources of the country. It was clearly seen that the fundamental industry of agriculture upon which the nation was so dependent had already begun to lose ground and that a further continuance of the policy of indifference would surely result in an impoverished soil with all the attendant evils to both the people and the government. In the debates of Congress the education here provided was considered with reference to its relation to the wealth and wealth producing power of the country. The logic of the situation was that a fertile country permanently assured meant a happy and contented people and a strong, stable government. The formal statement of the economic importance of industrial education was not so complete as it has been made since we have had a generation of experience with it, but the essential truth was clearly apprehended by the leaders associated with Mr. Morrill. These men never lost sight of the main issue. The importance to the revenues of the nation of education in the mechanic arts was not so clearly defined or stated. Men could see its importance as related to the arts of war then so prominent in the minds of the people, but did not realize its infinitely greater importance in the arts of peace. That is now more clearly apprehended. The argument for one form is essentially the same as for the other. Industrial education, as a guarantee of the perpetuity of the resources of the people and therefore of the government, has a permanent place in the judgment and policy of the nation.

A third consideration should be mentioned, namely, the unifying effect this movement for industrial education has had upon the people north and south. The common school has been a great force in producing a common sentiment. It has been a bond of union, but in many ways it has failed to unite the people for the reason that there was lack of intelligence in the work, and the local spirit often prevailed, to such a degree, that its influence was much less than we should desire. The colleges of Agriculture and Mechanic Arts at once put emphasis upon their common work. The passing of teachers from north to south and from south to north was much easier and more frequent than in the experience of other forms of education. The first revival in the south after the war was the revival of the industries with which these colleges were associated. The fact that they were engaged in solving the same problems and in developing after full conference a new type of education led to a close fellowship from the start. No other educational body at this date is so heartily united in its work as the Association of American Agricultural Colleges and Experiment Stations. This unity has been a potent factor in developing a genuinely national spirit. It is to be observed also that the great increase in the number of students in our colleges since the war has been most marked in the direction of technical, industrial and professional education, especially that looking toward the professional training of teachers. These Colleges of Agriculture and the Mechanic Arts were sometimes separate institutions and often associated with the State universities of the west. They represent to this day the greatest and most important body of technical instruction in America. They are a part of the State and of the Nation, and are really national colleges located within the states for national development. The first effect of these colleges was to bind together certain educational forces representing the entire country. The commercial development of the country and the increasing importance of agricultural pursuits have made their students in great demand. As a patriotic measure these colleges have been most effective in bringing about a common interest among our industrial classes in the development and prosperity of the entire country.

When these colleges were put into operation it was under considerable embarrassment. There was no body of teachers prepared to do the work before these new enterprises. It became necessary to prepare men and women who were in full sympathy with the purposes in view. This fact, together with the commercial demand for the graduates, soon revealed a large field of usefulness. The several states were awake to the importance of the new form of education and supplemented the grants of the Federal government with local appropriations most generously. This joint participation by the Federal and State governments has resulted in deepening the interest in the work of the colleges and in spreading the interest among the secondary schools also. Recently, in a number of states, the question of extending industrial education to the rural schools has been taken up with vigor and intelligence. The colleges are in position now to advance this work by furnishing properly equipped teachers for such schools. The Federal government increased its grant to these colleges in 1890, by making a direct and equal appropriation to each State of $25,000 annually, and the last Congress before adjournment, made provision by which this amount should be annually increased in the amount of $5,000 until the appropriation shall reach the annual sum of $50,000, with the proviso that a portion of this increase might be used in the preparation of teachers in the subjects of instruction in these colleges. This provision, together with the aid given by the states, will make these colleges representing industrial education the greatest national force binding together in common aims and ideals the multitudes of our people.

Before these colleges were some important and difficult problems. They sprang into a popularity that made the demand upon teachers more than they could meet. The management believed that they were set to teach the sciences related to agriculture and the mechanic arts. Above all things else they were to be teaching institutions. They realized that if the sciences, especially those related to agriculture, were to be taught successfully there must be a body of truth constituting that science. The case was not so desperate in the mechanic arts. Unless the Colleges of Agriculture were to contiuue to teach men to plant their potatoes in the moon and to follow the signs of the zodiac in the several other agricultural operations, there must be something else than a body of agricultural tradition as the court of appeal in the class room. The laboratory of investigation and research was a fundamental necessity. This could not be the result of the sporadic effort of an enthusiastic and tireless worker here and there. It was soon discovered that a systematic and comprehensive plan of investigation into all the problems of agriculture was vital and fundamental both for the teacher of agriculture and for the practical farmer.

The transition to the Experiment Station was natural and easy. The Hatch Act, by which the Federal government made provision for experiment, investigation and research, was the logical result of steps already taken and of needs now manifest. Here, as in the case of the teaching institutions, the several states joined the Federal government in the maintenance and equipment of institutions whose function should be that of experiment and research. So satisfactory and yet so incomplete has been this work, that recently the Federal government has provided for doubling the appropriation of the Hatch Act, in order that the work of investigation and research should not be hampered, but given abundant opportunity for development. The co-operation and support of the several states in this matter has been on the whole very commendable. The states with largest resources and greatest interests have naturally been most generous. Even those states whose tax duplicates are small, land somewhat impoverished or undeveloped and population more or less limited, have not failed to make a commendable record in the maintenance of this fundamental work.

The third great movement in this general field has been the organization and development of the Department of Agriculture. The importance of this department to the country is well understood by intelligent men who are familiar with its work. Here as in many other places occasional statistical statements of brilliant achievements receive attention in the public press, but they do not in any great degree represent or convey to the public mind the solid, substantial work that is carried on by nearly two thousand men devoted to the scientific and administrative problems that underlie the successful administration of the great interests of agriculture. It is not the purpose to-day, to offer any discussion of this department futher than to suggest, that in the comprehensive view of Federal and State aid to investigation, a large place must be given to the Department of Agriculture, and that these three movements as represented in the Colleges, Experiment Stations and Department of Agriculture, are bound up in a harmonious attempt to preserve and develop the agricultural resources of the country. One of these lines is chiefly experimental, another is chiefly teaching, and yet another is chiefly, although not exclusively, administrative. As the country comes to recognize these three agencies and the importance of the work undertaken a new enthusiasm will be developed and a new interest taken in a study of what is purely a developmental function of the government.

Let us turn now for some consideration of the theory underlying these great movements. Let us ask ourselves what justification there is for so great an enterprise on the part of the people through their Federal and State governments. Here, I remark first, that it is a fundamental consideration in the administration of the State, that its patrimony shall not be diminished. Individuals are temporary, but states are perpetual. States exist because people may permanently occupy and inhabit a given territory. It is manifest upon first thought that the perpetuity of the State is dependent upon the ability of the people occupying a given territory to maintain themselves. There are just two ways of doing this — first by living at the expense of people in other territories as a reward for success in battle; the other is so to use and develop the resources of the native country as to make a continuous and commercial prosperity inevitable. It is further manifest that, if any State permits its natural resources to decline, it thereby threatens its own dignity, prosperity, and eventually its existence. Experiments abundantly prove that uneducated men left to themselves will neither preserve nor develop the original resources of a country. An impoverished soil precedes an improverished people, and a recklsss use of natural resources precedes a decline of national vigor. There is a certain high type of patriotism therefore in preserving and rightly using the resources at the command of any people. Now agriculture is the great industry which provides for the maintenance of the people. Food, shelter and protection are the most fundamental of human wants. With these agriculture has immediate relation. An aroused intelligence soon perceives two things: First, that a great population is necessary for the greatest national and individual development. Second, that unless the natural resources are preserved this increase of population is the prophecy of its own disaster. Agricultural education has already discovered that much of our country is less productive now than three generations ago. It has also discovered that much of this may be reclaimed by judicious treatment and brought to a high state of production. Even in a generation these experiment stations and colleges have demonstrated beyond question the open road to larger production, greater agricultural prosperity, and therefore a financially stronger government. On the theory, therefore, of self preservation, the State can clearly justify the expenditure of money for research that shall determine what use may most wisely be made of our patrimony. This body of knowledge is the condition preceding intelligent action. It must not be tradition or old wives' fables, but scientific truth on which may be based intelligent industry. If we assume that the day is not yet at hand when it becomes necessary for the people to make investigation of the means of subsistence we also assume that mere existence satisfies the demand of the State. From time immemorial, the individual through long and often bitter experience has discovered that intelligent application of knowledge of industry was profitable. He often discovered, however, that there were elements arising out of climatic conditons to which his intelliigence was not equal. The real issue in the progress of the country is whether individual men here and there through a long and painful experience should learn to profit by that experience, or whether the whole people through the State should join in a scientific investigation of the conditions of production that would bring to every producer the intelligence necessary to guide him and make him successful. Happily the State and Federal governments have decided that it is to the interest of both parties to preserve the resources of the country and have joined in the effort of scientific investigation in order to determine that issue.

A second important feature is that national perpetuity and greatness demand that resources shall be developed. This is another way of stating that civilization means progress from primitive nature to the highest possible fruitfulness. Burbank's work in California has been much in the public eye and demonstrates what can be done in the development of the productive power in agriculture. It is a happy circumstance that certain funds have been placed at his disposal, making it possible for him to carry on experiments on a scale quite impossible to the individual. It were folly, however, to suppose that one man here or there could meet the needs of a great nation. The wisdom of the present movement in Experiment Stations lies in the fact that in every State are found men familiar with local conditions and local problems. Coöperating with them is a national organization that may consider and give attention to the distinctly national phases of these problems of production. Up to date it may be conceded that the magnitude of this enterprise has not always been understood and appreciated, and it is but natural to expect that in the initial experiences of all these efforts there would be some misdirected energy. It could not be otherwise if it were human. But out of all these experiences men are learning and men are deepening their convictions that they are set to do a fundamental work in the development of the resources of this great nation. The interest in this work is not merely agricultural, it is of national character and dimension and affects the prosperity and happiness of millions who are not directly included in our rural or agricultural population. The development of agricultural possibilities opens up the way for other commerce and enterprises and readily contributes to the employment and happiness of millions of our commercial people. It ought not to need more than a mere statement to convince intelligent people that this commercial development can not be based on anything else than scientifically directed effort. Business cannot long be a series of blunders; and it must be the result of commercial intelligence and industry.

A third consideration may now be mentioned, namely, that there is a moral phase of this economic question of production and preservation that the State may not overlook. I suggest that no generation has a moral right to live as if there were to be no future generations. Reckless or useless waste of natural resources is a crime against our children. This world is God's endowment for the race, but no generation has, in my judgment, the right to create conditions that make the world less habitable than now. This may be a question of moral philosophy, but fundamentally it is a question of economics. To adjust this question Experiment Stations and Colleges of Agriculture must give attention. Somebody must speak with authority not only upon the moral issue involved but upon the economic issue also, upon the preservation of forests, the preservation of soils, the preservation of minerals, the production of new forests, the further development of existing fertility, and the wise and economic production for the world's need. Unless the intelligence of a generation shall rise a little higher on these problems than its predecessor there is some doubt whether our energies have been altogether wisely applied. This high ethical responsibility for the use and development of this great storehouse of divine goodness for men is an ethical problem that even a secular State may not ignore.

In the application of the above principles briefly stated there are problems that are chiefly local and there are problems that are national. There are some problems that may easily be undertaken and solved by the local State. There are other problems much too general in their nature for local consideration. Upon these the Federal Government will rightly expend its time and energy. For these reasons it is manifest that both the Federal and State governments engage in the work of investigation and research with equal propriety. The application of public money either from the Federal or State treasury to such work may be amply justified. The chief problem will always be that of co-operation and correlation of work. Adequate intelligence and willingness of mind will always solve that issue.

In conclusion let me indicate that the contest of the future will be between the two great forces represented by the police officer and the teacher. The former represents the repressive and protective functions of government, while the latter represents the developmental functions. As intelligence increases and education produces its ripened fruit the office of the former will grow less while education will make a constantly increasing field for itself. The police functions will become less the representative of force and more that of direction and guidance. The ascendancy of the future will be given to intelligence. Government will concern itself more with the problems of construction, of investigation, of teaching, and with such other activities as will develop both men and resources. Government by the people will be increasingly for the people. World building enterprises will occupy us not so much for the worlds we shall build as for the men we shall develop. In these interests there should be and will be no antagonism between the Federal and State governments. The happy co-operation of a brief generation is ample proof that one's successors in duty and office inspired by a high patriotism and a love of country will carry on the work so that the earth will yield her increase and that America will remain for her increasing millions the land of abundant opportunity.

LESSONS OF TO-DAY.

L. H. BAILEY.

The New York State College of Agriculture is glad of this opportunity to extend its congratulations to its sister and neighbor institution on the completion of its quarter centennary. This has been a quarter century of pioneering and of experiment in experimenting; but for the New York Agricultural Experiment Station it has also been an epoch of substantial leadership and of great and lasting accomplishment. It is only necessary to recall the names of those who have successively composed its staff, to collect the bulletins and reports it has published, and to remember the public services that have been rendered by its men, to estimate the immense contribution it has made to the knowledge and welfare of the State. In more than one great enterprise New York has set high standards and has attained unto them; and one of the most prominent and successful of these enterprises is its State Experiment Station. The State College of Agriculture is proud to join you all in these felicitations, and to be glad in the prospect of many more successful years.

If this institution has developed leadership, it must have touched and influenced many movements that relate to rural questions. The fundamental purpose of any experiment station is to increase the productiveness of the land; and yet, at the very time of this celebration, we are told that the agricultural affairs of New York State are in a deplorable condition of decline. We are reminded of the census figures showing that in the years between 1880 and 1900 there was an annual decrease in the value of farm property of seven and one-third millions of dollars and in the value of land and its improvements of eight and one-half millions of dollars. We are reminded also of statistics indicating that there has been a decrease of twenty per ct. in the rural population. It has been said that there are twelve thousand abandoned farms in the State. What have this Experiment Station and its sister institutions been doing all these years that such conditions should prevail? Are we spending hundreds of thousands of dollars with the result that our agriculture is decreasing in its efficiency, even to the point when new and Herculean efforts must be made to rescue it? Or is something fundamentally wrong with the agriculture of New York State, which such institutions as this cannot reach? Or, again, is it barely possible that in some way we have misjudged the nature of the so-called agricultural decline? If we find an agricultural question, what is to be our attitude toward it? Your program announces that I am to speak on "Lessons of To-day:" in these questions I think that I discover my subject.

THE GENERAL SITUATION.

It may be a question whether the census figures of the different years are in all respects comparable. Conditions of money and of values are not the same in any two twenty-year periods. In 1880 we may not yet have passed altogether the inflated values of the war period. These census figures are now old and great changes may have taken place in the seven or eight years since the more recent ones were made. A current discussion of "changes in farm values" published by the United States Department of Agriculture and covering the years 1900 to 1905, makes a very different showing from those that we have been in the habit of quoting. These figures of the Department of Agriculture are estimates and computations, and I do not know whether they or the census figures more áccurately represent the exact status of agricultural conditions. Even for the census year 1900, the differences in values as reported by the census and as computed by the Department of Agriculture amounted for New York State to nearly $99,000,000 for the value of land and improvements, including buildings. The computations of the Department as between the years 1900 and 1905 show a gain in similar values for the State of New York of more than $180,000,000. In more specific categories, the following figures from the same source show that there is a decided increase in farm values and therefore presumably in farm efficiency. The values of "medium farms" per acre for the years 1900 and 1905 in New York in the different classes of farming are as follows:

	1900	1905
Hay and grain farms	$40.29	$44.38
Livestock	33.83	37.94
Dairying	46.81	58.86
Fruit	70.87	84.46
Vegetables	69.98	81.91
General farming	38.98	44.00

The percentage increase of real estate value of such farms in the State for the years 1900 to 1905 are represented by the following figures, being much the highest percentage increase of any State in the group comprising New England, New York, New Jersey and Pennsylvania:

	1900–1905 Per ct.
All medium farms	18.3
Hay and grain	10.2
Livestock	12.1
Dairy farms	25.7
Fruit	19.2
Vegetables	17.0
General farming	12.9

A common measure of the supposed decline of farming is the fact that many farms can now be purchased for less than the buildings cost. This statement of itself does not appeal to me as having any special significance. A property is likely to sell for what it is worth, and this worth depends on its effectiveness as an economic unit or enterprise. Most of the buildings on farms were erected as much as a generation ago when the ideas of farming were radically different from those of the present day. It is doubtful whether most of these buildings were ever really effective even for the old kind of agriculture. At all events, few of them are adapted to the business that we must now conduct on the land. Many a farm would be worth more with the buildings off than with them on, for they would not then stand in the way of real betterment. Buildings are not permanent attachments to land and should not be so regarded. A countryman is always impressed, when he goes to the great cities, with the fact that buildings still in a good state of preservation are torn down to make place for new ones. These demolished buildings may not even be very old, but they are ineffective for present day business and it is unprofitable to keep them. The coming business of farming will demand a wholly new type of building in order to make the property effective, and we must overcome our habit of harking back to the time when the present buildings were erected. Every good farm ought to pay for itself all over again, land, buildings and all, every generation. Barns and other business buildings that were erected forty or fifty years ago should owe the farm nothing by this time. My hearer must realize the fact that we are beginning a new agriculture, not continuing an old one.

We must be careful, also, not to be misled merely by the appearance of farm property. It is often said, for example, that Tompkins County, from which I come, is a region of abandoned farms and declining agriculture, and the great number of deserted farm buildings is cited in proof. Now, the abandonment of farm buildings may or may not be a cause of apprehension and regret. Buildings may be abandoned because two or more properties have been combined into one and not so many buildings are now needed; or because the farmer has moved from an old building into a new and better one. In many parts of the State the buildings are no doubt too many and the farm properties too small for the greatest effectiveness. These properties were laid out or divided at a time when there was no great West and when these eastern lands grew the grain and other tilled crops for the large markets. Some of them were probably laid out in their present form in war time, when conditions were wholly abnormal. Many of the buildings were erected when lumber and other materials were cheap and when the comforts and facilities now placed in barns and residences were unknown. Moreover, deserted farm buildings are likely to stand until they fall down. In cities, land and location are valuable, and old buildings are torn down to make room for the new structures. Therefore, the country contrasts strongly with the city in respect to its buildings. The staring and windowless farm houses appeal to the imagination of the town visitor, and he accepts them at once as evidences of failure and decline.

In order to determine the significance of deserted farmhouses, we have made an inquiry in Caroline township, Tompkins County, cited as one of the abandoned farm regions. Every deserted farmhouse in that township has been seen by our representatives. Conditions in Caroline are as bad as anywhere in the county. Many of the farms are on the volutia silt loam, often undrained, high in elevation, and far from markets. Yet by actual count, there are only forty-five vacant farmhouses in the township, the area of which is more than forty-five square miles. One might draw the conclusion at once that there are forty-five abandoned farms in the township. It is doubtful, however, whether there is a single really abandoned farm in this area. It is true that there are many fields on the higher farms, especially in the south half of the township, that are not used except for hay and pasture and some that are not even used for these purposes. Practically all these so-called abandoned farms are either owned or rented by nearby farmers and have really become a part of the adjacent farm. The house is unoccupied for the simple reason that the farmer needs but one house. In at least one case a new house was built and the old one left because the farmer had not found time to tear it down. A few vacant houses have been deserted by families who have lost their homes on mortgage, but apparently not primarily from fault of the land. Many others have been sold because of discontent on the part of the owners, who wished to try their fortunes elsewhere. In some cases the owner has died and the house been left unoccupied because the estate has not yet been settled. A few more are vacant because tenants cannot be secured, and the farm is rented to whomever is willing to take it on shares.

Similar remarks may be made with respect to many of the apparently abandoned fields. Because of inability to secure labor, the fence-rows and fences are often not as clean as formerly, and the roadsides have a shabby appearance. Fields are often grown to weeds; yet these fields may be only resting until the owner finds time to put them into crop, or they may be used for light pasture, or they may be in the process of returning to forest. Of course, they are relatively ineffective pieces of property, but the conclusion must not be reached, because they are unkempt, and not in use at the time, that they are abandoned or that the owner considers that he is obliged to desert them.

THE SIGNIFICANCE OF THE GENERAL SITUATION.

It is unquestionably true that there is lessening utility of some of our farming lands. In the face of this fact, however, three other facts stand out prominently: (1) Markets are as good as ever, for there is no decline in the purchasing power of the people (rather there is a reverse tendency); (2) the land is still productive, notwithstanding a popular impression to the contrary; (3) good farmers are better off to-day than they ever were before.

We have heard much about the abandonment of farms and we are likely to think that it measures a lessening efficiency of agriculture. We must not be misled, however, by surface indications. We are now in the midst of a process of the survival of the fit. Two opposite movements are very apparent in the agriculture of the time: certain farmers are increasing in prosperity, and certain other farmers are decreasing in prosperity. The former class is gradually occupying the land and extending its power and influence. The other class is leaving the land. Abandoned farms are not necessarily to be deplored; rather they are to be looked on as an expression of a social and economic change.

The older farming was practically a completely self-regulating business, comprising not only the raising of food and of material for clothing, but also the preparation and manufacture of these products. The farmer depended on himself, having little necessity for neighbors or for association with other crafts. In the breaking up of the old stratification under the development of manufacture and transportation and the consequent recrystallizing of society, the old line fence still remained; persons clung to the farm as if it were a divinely ordained and indivisible unit.

We are now approaching a time when the traditional boundaries must often be disregarded. The old farms are largely social or traditional rather than economic units. Because a certain eighty acres is enclosed with one kind of fence and assessed to one man does not signify that it has the proper combination of conditions to make a good farm.

We must consider that the agriculture of the eastern states is now changing rapidly. It has passed through several epochs. The possibilities of agriculture in New York and the East lie largely in a new adaptation to conditions, and in its diversification. This diversification is already a feature of the East. It is significant to note that while New York ranks fourth in value of farm property, it ranks as low as seventeenth in farm acreage, showing that the yield per acre is far greater than in many of the competing states. In the total value of farm products New York is exceeded by Iowa, Illinois and Ohio. In the value of farm crops in 1899 it held fifth place, being exceeded by Illinois, Iowa, Texas and Ohio. Considered with reference to the value of farm products per acre it leads the states in this list, the figures being New York $15.73 per acre, Ohio $13.36, Illinois $12.48, Texas $12.25, Iowa $12.22; and New York is exceeded by New Jersey and some of the New England states. Considering the fact that New York State is one of the largest states east of the Mississippi, this condition also indicates that New York is internally less developed than some of its competing states. Illinois ranks first in value of farm property and first in available farm acreage; Iowa ranks second in the value of farm property and second in available acreage; Ohio ranks third in value of farm property and third in available acreage; New York ranks fourth in value of farm property and seventeenth in available acreage. The above statements indicate the reverse of decadence in our agriculture whatever may be the statistics that express changing values or whatever may be the popular fancy to the contrary.

A further evidence of the great diversification of agricultural enterprises in New York, as a representative of Eastern conditions, is shown by the fact that in a list now before me of twenty-two leading products of this latitude, New York stands first in the production of eleven of them, whereas no other State ranks first in more than two or three of them. While the agriculture of the State in general shows a decline as measured by the census figures, the main lines of special development are in a condition of increased vigor and effectiveness; and this remark may be extended to other Eastern States. The wonder is, not that certain lands are returning to forest, but that, in all this shift, we have been able to hold the position that we still occupy.

This rapidly moving readjustment and diversification will produce fundamental changes in the mode of farming and in the economic, social and political outlook of the people. In the mode of farming, it will force new business organization; and when new acres cannot be had, the old acres will be doubled by using them to greater depths. In very many ways, the shift is now demanding a new kind of study of agricultural questions. This reorganization of agriculture is bound to come in every State; it is naturally coming first in the East, and, in the interest of the whole country, we should meet it hopefully.

Nor would I have my hearer feel that this readjustment is all in the future. It is proceeding at the present time, and with greater momentum and effectiveness that many of us, I suspect, are aware. After many years of touch with the problem and with the men who are capable of judging it, I am impressed that the persons who are most alarmed are those confined largely to offices and who are given to the study of statistics.

THE SITUATION OF INDIVIDUAL FARMS.

A discussion of statistical generalities does not exhibit the status of the individual farmer nor give us specific reasons for the decline of profitableness in farming. Every farm is a problem by itself and what may have been responsible for the defeat of one farmer may not have been the cause of the embarrassment of his neighbor. Some of the decline no doubt lies directly with the man, quite independently of the land; it is psychological and perhaps even hereditary, and in its community aspects it is social; but these phases I am not now prepared to discuss.

The larger number of the farms of apparently declining efficiency are in the hill regions. Many of them are on soils of the volusia series, particularly on the volusia silt loam. This soil is of low humus content, usually with a high and compact subsoil, and limited root area. Many of these farms are unsuccessful in part because of their climate. They are elevated. It is often impossible to grow with profit the common varieties of corn and even of other grain. Sometimes the difficulty lies in their remoteness and the cost of transportation, together with the poor schools and social disadvantages that are a part of such isolation. Usually these hill lands are expensive to work and they do not lend themselves well to open tillage. Very frequently they suffer for lack of underdrainage. If the elevation is too high to grow good wheat it may also be too high for good clover, since clover is usually seeded with the wheat. These high and rough lands are not so frequently plowed as lower and flat lands and, therefore, they are not cleaned, do not receive the benefit of rotation and they are likely gradually to deteriorate in physical condition. There has also been great change in market demands. Beef raising has gone out of the East. It was a simple thing to grow the beef and to raise the milk in the old time, but it requires a high type of skill to grow and market a modern steer and to tend a modern dairy herd. With relatively few cattle, there is insufficient enrichment of the land. The farmer on these hills is likely to practice direct sales; that is, he sells his timothy hay and other products direct, removing thereby a large amount of fertilizing value and saving nothing of the crop except the roots and stubble to return to the land. This primitive mode of general farming allows a man to make a profit only on a single sale. The manufacturer tries to turn his property over more than once, each time expecting to realize a profit. When the farmer is able to market his forage largely in the shape of animal produce, he will not only save fertility, but should make a profit on both the crop and the animal. The selling of baled hay rather than pork and beef and milk and eggs, cannot be expected to yield much profit or satisfaction to the average farmer or to keep his land in living condition. Taking it by and large, no agriculture is successful without an animal husbandry.

The popular mind pictures these so-called abandoned lands as exhausted in their plant-food, but this is probably not often the case. Very many of them are potentially as productive as ever, but they are not able to satisfy a man who lives in the twentieth century. Human wants have increased. What would have made a good and comfortable living twenty-five or one hundred years ago, would not support him in the way in which he ought to live to-day, nor would it attract his boys to remain on the land.

All these and other causes of the decline of individual farms can be expressed as a lack of adaptation to the natural surrounding conditions. It is a biological fact that animals and plants cannot thrive unless they are well adapted to the conditions in which they live; and if they are wholly unadapted, they perish. Now, farming is not yet adapted to the natural conditions of soil and climate and market and other environmental factors. In fact, we really do not yet know what the soil factors are, if, indeed, we know to any degree of accuracy what any local factors are. If some of our Eastern farms have changed from corn and wheat to hay and if they have not prospered under this change, then it follows that they have not yet found their proper adaptation. It is not at all strange that this adaptation is lacking, since there has been no means of putting the farmer into touch with his own problem. Not one of the older farmers before me was adapted to his environment by the church or the school or by any other educational or social agency. If he is now adapted to the conditions in which he lives, it is because of some accident of heredity or circumstance. We can never adapt the business of the farm to its conditions until we understand thoroughly all the problems involved, and there has been no serious effort to understand these particular problems until within very recent time.

Much has been said about the disadvantage of the Eastern farms in competing with the Western farms. I am convinced that they often suffer quite as much by competing with each other or with regions close at hand. I recently took a thirty-mile drive, in the course of which I traveled a flat country where oats were a good crop and harvested by machinery and drawn from the fields in high-piled racks; on the same day I climbed a country of high and steep hills in which oats were a poor crop and not harvested by machinery and were hauled from the declivities in small loads. It was evident that the latter region could not compete in the raising of oats with the former, although they were less than twenty miles apart. The one region seemed to be well adapted to oats and the other, at least on the hillsides, was not a profitable oat country. In other words, the farmers on the hills had not adapted their farming to the hills. I suspect that a bushel of oats cost them at least 50 per ct. more than it cost the man at the other end of the county. Yet, I think that there is a way of profitably farming those hills; many men have proved it.

THE REMEDIES.

While I am convinced that the general condition of New York agriculture is prosperous and hopeful, we all know that there are very great problems before us and that some regions are much more disadvantaged than others. If we are to discuss remedies we must first of all establish a point of view.

We must first disabuse our minds of all prejudgments and consider the conditions as they actually exist and in their relations to the general progress of the race. Our outlook must be forward rather than backward. We must overcome the influences of many phrases and trite statements that have long been public property. It is said that the farms are the bulwark of the nation. Like all trite sayings, this is both true and false. We need a conservative element of the farm, that has its feet planted directly on the verities of the earth. But we must remember that poor lands usually raise poor people. I do not conceive it to be necessary that all the lands in any commonwealth should support farm families in the sense in which we have understood it in the past. It is much better for the commonwealth, both from the economic and social points of view, that many of the lands should be devoted to forests or even allowed to run wild rather than to produce people that are only half alive. I should want to keep the conservatism of the agricultural peoples, but I should want this conservatism to be constructive and progressive.

I am not ready to admit that the traditional "independent" farm family on 80 or 100 acres of land is necessarily essential, as we have been taught, to the maintenance of democratic institutions or to the best development of agriculture. The size of holdings and the relation of the family to the land, are likely to change radically in many regions, and we must be prepared to accept the fact.

In the discussion of abandoned farms, I fear that we have been misled or even scared by a phrase. We have accepted the term "abandoned farms" as itself a statement of fact and have seemed to reason from it as if it presented a single condition of affairs. Our imagination has often outrun our reason. It is not so much a question of abandonment as of shifting occupancy and radically changed conditions. If these conditions had been expressed with equal emphasis by some other phrase, the discussion of the question might have taken a wholly different direction. Suppose, for example, that a part of the problem had been expressed in the term "farms becoming forested;" the least imaginative of my hearers will at once see that a wholly unlike line of thought might have evolved from the discussion and wholly different conclusions might have been reached. There is really no problem of abandoned farms as such. The so-called abandonment of farms does not represent one condition, but many conditions; not one series of facts, but many series of facts; not one forthcoming result, but many results. The condition of agriculture, even though we admit it to be bad in many particulars, is not a cause for alarm, but is rather a reason for new and careful study. Nor is this subject peculiar to agriculture; it is rather a great question of public policy that fundamentally concerns the organization of society, and it cannot in any way be separated from the discussion of the great public questions of the day.

Mere public propaganda cannot solve these questions of land occupancy. Associations and conventions cannot solve them. Importation of labor cannot solve them, much as it may help the individual farmer here and there. It is a debatable question whether we should try to restock many of the present farms merely by putting a foreign family on them. Perhaps the very reason why these farms are in the process of decline is that they are necessarily ineffective economic units and are not capable of being directed into a farm management that is adaptable to present conditions. Merely to put families back on many of these farms would be to continue the old order; and it is this old order that we need to modify or to outgrow.

Viewed as an economic question, the shifting of farm occupation should not disturb us more than other shifting of population. In the present day, some of the lands that are now "abandoned" would not have been settled. They would remain in timber; and now, by the inexorable power of economic forces, they are returning into forest. The first flush of the settlement of the West has passed. Manufacturing industries have attained stable conditions. Persons are looking again to the country. The better farms again are being farmed. Farmers are buying up adjacent lands and extending their business. Near the railroads, city people are building cottages and retreats on the sites of old farms, to find respite and peace. Other lands hang in the balance between the old and the new. Change of ownership is perhaps the first step in the solution of the problem. The difficulty is that farm management may not change with the ownership, but a new set of ideas is likely to follow sooner or later.

No mere treatment of symptoms can have much permanent effect on agricultural conditions. The agitation about these so-called "abandoned farms" is largely misdirected. It is well enough to make great effort to sell the abandoned farms, but it is better to combine this effort with a movement to reorganize farming. No hasty or clamorous propaganda is likely to be of much service; no introduction of mere extraneous agencies or forces can count much toward the solution of any problem. Many agricultural localities are making great effort to secure summer boarders. This may aid a certain class of persons; but as the summer boarder advances into the open country, agriculture is likely to recede.

Let us bear in mind that the questions of ineffective farming are not new. Just now the emphasis seems to be placed on the so-called abandonment of farms and on certain kinds of propaganda that promise to solve these difficulties. We have passed through many epochs or eras of agricultural propaganda, in each one of which some one factor was supposed to afford the means of relieving agricultural distress. I can recall many of these eras. I remember that at one time the emphasis in agricultural discussion was placed very largely on the farm mortgage, but we have now learned that a mortgage on a farm is not inherently different from a mortgage on any other property. I recall very well when the era of compounded fertilizers was at its height: all one had to do was to have the soil and plant analyzed, to determine the deficiencies, and then to prepare a medicine to cure the disorder. I remember the advent of farm machinery, which was supposed to be able to solve the farmer's difficulties. I saw the beginning of spraying for insects and plant diseases, and it was figured up for us what losses we suffer from bugs that prey on our crops: it has cost us more to fight bugs than to fight Indians, counting the value of crops that they destroy; spraying would provide a remedy, and yet bugs are still with us. At one time the emphasis was placed on under-drainage, and we need a recrudescence of this teaching. In parts of the great West the emphasis is naturally placed on irrigation. We have looked to the rural free deliveries of mail as one of the great means of alleviating agricultural isolation and failure. The good-roads people have been sure that the lack of traversable highways is the cause of the so-called agricultural decline. Lately, various kinds of extension work have been strongly in the public mind. We are just now in the era of soil surveys and other soil studies. We are beginning to talk in a new way about the old and yet unknown subject of farm management. We are talking freely of social questions, without knowing just what they are.

Every one of these epochs has placed us on a higher plane, and yet we have never heard more about agricultural decline than within the past ten and twenty years, notwithstanding that this is the very time when the agricultural colleges and experiment stations and governmental departments have been expanding knowledge and extending their influence. The fact is that all these agencies relieve first the good farmers. They aid those who reach out for new knowledge and for better things. The man who is strongly disadvantaged by natural location or other circumstances is the last to avail himself of all these privileges. We have learned that it is not sufficient merely to start good movements, but that we must have some active means of reaching the last man on the last farm. This is by no means a missionary work; it is rather a duty that the State owes to its citizens, to provide those persons in difficult positions with the best possible means of making their property thoroughly serviceable. It becomes in the end, therefore, a personal question as to how information and education can be taken to the farms in such a way that the farming shall profitably adapt itself to its environment. Whatever may be the relative position of New York State as an agricultural region, or whatever may be the increasing effectiveness of our farming as a whole, it is nevertheless true that there are a great many farmers who are not making headway, and this may be less a fault of their own than a disadvantage of the conditions in which they find themselves.

It is fairly incumbent on the State to provide effective means of increasing the satisfaction and profit of farming in the less fortunate areas as well as in the favorable ones, both as an agency of developing citizenship and as a means of increasing the wealth of the State. The State cannot delegate this work, nor can it escape the responsibility of it. It is primarily an internal question. The questions must be attacked just where they exist, and with the sole purpose of solving them for the good of the people who meet them. The location of the work and the character of it must not be influenced by any consideration of personal politics. The time has come when government by influence should cease.

There are three classes of remedies for the ills that overtake the tillers of the soil:

1. Remove all handicaps and disadvantages that are not a natural part of the business, as the inequalities of transportation facilities, the effect of combinations in the interest of the few, discriminations in legislation, the oppression of systems of marketing.

2. Give the farmer information to aid him in making a living and in enjoying it.

3. Set some activity at work to arouse, energize and inspire, to set out the possibilities of living on the land.

These are primarily functions of the State. New York has the land, the location, the people and the wealth that should enable it to work out these ends. It also has three institutions of fundamental importance, already well established and actively engaged in the work:

1. The Agricultural Experiment Station, which is discovering the facts, which is unexcelled by any other, and which is devoting itself without reserve to the public weal.

2. The State Department of Agriculture, which, in breadth of organization, in extent of operations, and in the results it has accomplished, is not equaled, so far as I know, by any other similar department.

3. The College of Agriculture, which, I hope, will in time also be equal to any other.

These three organizations, liberally supported with money and good will, officered by capable and far-seeing men who are not disturbed by public alarm, hold the keys of the future for the farms of New York State.

A SPECIFIC EXPERIMENT.

If the problems that we are discussing are personal, then we must begin with the individual man on his own farm. The College of Agriculture at Cornell University has long tried to extend itself to the man and to see the problems as he sees it. Many "surveys" of special industries have been made in former years and the results have been published in readable expository bulletins. Recently this idea has been extended to the making of a complete census of all the farms in Tompkins County, in order that the actual agricultural status may be known and judged. This county is chosen because it is near at hand, allowing us to work out the method at the minimum of expense; and also because the region is representative of a great area of the hill country of the State. It is hoped that the inquiry may be extended to other counties. Already several counties have been surveyed in their fruit-growing relations. I speak of this work not so much to show what has been accomplished, as to illustrate the nature of the questions now under discussion and to let it be known that a beginning has really been made.

The "Tompkins County Agricultural Survey" was begun in the summer of 1906 when the townships in the western part of the county were surveyed. This included Ulysses, Enfield and the eastern two-thirds of Newfield. During the summer records of 486 farms were made in these three townships, practically every farm being visited and a record secured if possible. In the summer of 1907 Groton and Caroline townships were surveyed. In these two towns all the farms were visited and records of 474 farms secured. This makes a total of 960 farms studied in the two years. The work will be continued until every farm in the county is visited. We were fortunate to have the advantage of the soil survey of the county, made by the United States Department of Agriculture.

An attempt has been made to secure accurate tabulated information in the following lines:

Name and age of owner of farm.
Number of tenant farms.
Amount of rent paid by tenants.
Average acreage of farm.
Value per acre of land.
Amount of waste land.
Amount of timber.
Condition and extent of drainage.
The most profitable farm products.
Average yields of all farm crops.
Amount and character of all live stock.
The estimated value of farm cattle.
Total expenditures of each farmer.
Increase or decrease in soil fertility.
Increase or decrease in farm values.
Systems of rotation followed.
Condition of farm buildings and fences.
Condition of public and private roads.
And many other phases of the social and business side of farming.

It is hoped that by a careful study of the records valuable information of the following kinds, and others, may be secured:

Effect of system of farming on profits.
Effect of soil type and climate on system of farming.
To what extent are farms declining or abandoned.
Effect of topography and transportation facilities on prosperity.

To apply this knowledge in the actual management of a farm in the surveyed region, and by co-operative experiments with the farmers there.

A consideration of the methods followed by the most careful farmers in various sections of the country, to aid us in making suggestions of value to other farmers of the county and State, who have like problems.

In view of the frequent statements that this region is one of abandoned farms, the following figures of average value of land and buildings for five townships of Tompkins County may be helpful. According to the census report for 1900 the average value of land and buildings for New York State is $39.20 per acre. The table shows the value per acre of five townships in Tompkins County. Two of these are in the southern half of the county and are made up largely of hill farms of the volusia silt loam type of soil. Many of the farms are what are popularly known as "abandoned" farms. If the average for the whole county was known, the value per acre would not unlikely exceed that for the State.

Ulysses	$59.12 per acre
Groton	45.62 " "
Enfield	36.85 " "
Newfield	28.57 " "
Caroline	21.65 " "
Average	*38.26* " "

The question is often raised as to whether farm values are decreasing in this part of New York State. In order to secure accurate information, the question was included in the blanks for the townships that were surveyed in 1907. The figures give the percentage of farmers reporting in the different categories for the last five years; and they would appear to indicate that there is a steady rise in farm values at the present time:

	Increase.	Decrease.	Stationary.
Groton	64%	11%	25%
Caroline	46%	26%	28%

It will now be worth while to compare the yields of staple crops in these townships with yields for the State; these figures show that the lands are capable of good agriculture:

	1905				1906		
	Ulysses	Enfield	Newfield	N. Y. State	Groton	Caroline	N. Y State
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Corn	34.0	34.5	30.0	31.0	35.5	33.7	34.9
Wheat	21.8	19.6	17.7	21.0	20.3	18.7	20.0
Oats	43.9	38.3	33.2	34.2	33.5	28.1	32.3
Barley	35.6	27.6	24.5	25.7	22.7	20.5	26.3
Rye	18.1	15.7	14.5	17.5	17.5	15.0	17.6
Buckwheat	23.1	21.9	19.3	19.0	23.6	19.2	19.0
Potatoes	....	....	....	....	107.2	97.6	105.0
	T.	T.	T.	T.	T.	T.	T.
Hay	1.59	1.57	1.31	1.30	1.60	1.08	1.28

We also raised the question of increase or decrease in soil fertility. Each farmer was asked how long he had lived on his farm, and whether the soil had increased or decreased in crop-producing power in the years that he had personally known the farm. Only those cases are recorded in which the farmer had known the conditions for five or more years. Many farmers had resided on the home farm for fifty years or more, but the results given in the following figures represent a knowledge of conditions for an average of about twenty-five years. The records of only two townships are given here, Ulysses and Enfield. Enfield township is often spoken of by those not familiar with actual conditions as being in a badly run-down condition. If the statements of farmers who are actually running the farms are to be credited the results seem to indicate that conditions are really improving:

	Percentage reporting increase fertility.	Percentage reporting decrease.	Percentage reporting stationary.
Ulysses	53%	21%	26%
Enfield	60%	16%	24%

One finds good farms right in the so-called poor farming region. One man from two hundred acres sold last year over $5,700 worth of produce, raised under general farming operations.

The number of acres per farm animal for these five townships of Tompkins County was also taken. It is often stated that the number of farm animals in this county is insufficient to keep up the fertility of the land. This may be partly true, yet in comparison with other sections of the State, Tompkins County is very likely up to the average. From very accurate information at hand it would seem that in this section general farming may be very profitable if at least one farm animal is kept for each six acres of land. By one farm animal is meant a full-grown horse or cow, this being the unit. Five calves, swine, or sheep are considered a unit, or two colts or heifers. The following figures show the number of acres per animal in the five townships surveyed:

Groton	6.08	acres	per	animal
Ulysses	7.8	"	"	"
Newfield	9.0	"	"	"
Enfield	9.05	"	"	"
Caroline	9.4	"	"	"

THE OUTLOOK FOR THE HILLS AND REMOTE LANDS.

Wherever farming is not now profitable, a special effort should be made to readjust it to the conditions of climate, soil topography, markets and the like. New York is admirably adapted to trees and grass. Anyone who has traveled much even in the Northern States will have noticed the superior quality of the tree growth and the grass cover in our region. Of course, our unprogressive areas, whether on hills or plains, present very many conditions and they are adapted to many kinds of agriculture; but in the particular type of hill land and remote land which is now most in the public mind I look for the development of three strong forms of farming:

1. Fruit growing for export. We have developed great skill in the methods of caring for orchards on the relatively level lands of the special fruit sections, but we have given very little attention to the growing of first quality apples in the higher hill regions. In such regions we cannot practice the type of clean tillage that we advise for other lands. Some relatively simple and inexpensive type of farm management must be applied to them. There is every reason to think that vast areas in New York State that are now practically unknown to fruit may grow a grade of apples that would be in great demand in the foreign trade.

2. A revival of the animal industries and the extension of dairying. The dairy interest is now the leading special agricultural industry in New York. With the continued development of great city markets the dairy industry must grow. Many of our hill and outlying lands are no doubt admirably adapted to pasturage and

forage crops for cattle and sheep and swine, but the livestock interest aside from dairying is altogether too small in New York, and in the East in general.

3. The growing of forests. It is to the forest crop that vast areas of the roughest, highest and most inaccessible lands of the State are best adapted. As near as I can determine, about one-third of New York is woodland. In some counties, even outside the Adirondack region, two-fifths of the land is reported to be in wood lots. This is a greater area than is devoted to any other crop, and it probably yields less profit per acre; yet in the census year New York led all the States of the Union in the value of farm forest products. We must re-orient ourselves to the subject of forests. The forest is or ought to be considered as a crop. Natural forests are not necessarily the best forests so far as the production of timber is concerned. Nearly all natural forests abound in unproductive acres, and in trees of very slight commercial value, which are as much weeds in the forest as Canada thistles are weeds in the corn field. Man can produce a better commercial forest than nature usually does.

RECOMMENDATIONS AS TO STATE EFFORTS.

I am convinced that the State in its own interest should greatly extend its efforts for the betterment of its farming industries. Several new policies or enterprises are needed, four of which seem to me so urgent that I propose to state them:

1. A thorough-going survey of the exact agricultural status of the State should now be made. Such an inquiry made carefully and without haste by men who are thoroughly well prepared, and continuing over a series of years, would give us the data for all future work with local problems. We must have the geographical facts. We are now lacking them. We talk largely at random. We must discover the factors that determine the production of crops and animals in the localities, and the conditions that underlie and control the farm life. One part of this inquiry should consider the soil conditions. A study of these conditions involves a knowledge of the kinds, classification and distribution of the soils of the State and the relation of place and altitude to production of crops and livestock; determination of the best drainage practices on various soil types; a study of the cultural experiences and manurial needs as adapted to the types; and other questions in furtherance of surveys and investigations now under way. Such a survey of the State should be broad and general enough to consider the status of

all the agricultural industries in the State, and it should also take cognizance of educational and social conditions.

2. The State should establish experimental apple orchards of large area on some of the higher and cheaper lands in several parts of the State, at direct State expense, and under the guidance of experts, for the purpose of determining how far such lands can be used for the growing of export fruit, and what new methods must be developed for handling such plantations.

3. The State should make a thorough-going special inquiry into the status and prospects of the animal industries, collecting data on which safe and fundamental recommendations can be made for the improvement and extension of these industries.

4. There should be also a strong system of instruction and discussion of the farm forest wealth of the State, a movement which of itself would direct the utilizing of all lands otherwise unproductive, and which would be the greatest single contribution that the State could make to the solution of the questions that we are now discussing. Such a movement would be working in the line of least resistance and with nature rather than against it; for it would direct, hasten and concrete the natural and inevitable evolution of our higher and remoter lands. The State is giving good instruction in many kinds of crops that are of far less importance, both to the farming community and to the public weal than the forest crop.

AN APPEAL TO YOUTH.

Young men and women, I have something to say to you. I hope that I am speaking to some young person who has the love of the open country in his heart and who looks out to usefulness in the world. The opportunities out in that farming country are more numerous than the men or the farms that you will find there. Every question that is asked by a farmer suggests a subject for inquiry, and we all wait for the solution. Take hold of something because you feel that it will help your fellow man or woman. Do not be afraid to see visions. The man who never had a vision is dead. No person should enter into service for the purpose of developing leadership; he should serve for the sake of the service. Leadership is a result of good service and will come as a natural consequence. Whatever the problem and no matter how small it may seem to you, if you solve it, greater things will come to you. The opportunities will be measured only by your ability to see them and to handle them. Most of us are so blind that we never see the opportunity that lies directly before us. I bid you then, go back into the rural country, fully inspired with the idea that great opportunity for service awaits you. Here is a new thing in the world, and a new opportunity for usefulness.

I am convinced that the opportunity for personal development is now as great in the open country as in any other direction. Every man or woman on the land who makes a real success at farming and at living is a marked person. He is not buried in the mere multitude. The good new things that need doing are so many that I do not see how a man can escape them.

Above all, old and young, we must never lose faith in the soil. It is the source and condition of our existence. It never grows stale and it never wears out. The earth is always young.

The fields were parched with summer's heat,
  The life and green from swamps had fled,
The dry grass crunched beneath the feet,
  And August leaves dropped stiff and dead.

Then light south winds 'cross wood and shore
  Brought cooling clouds and slow sweet rain,
And hills and crops were new once more
  And grasses greened on marsh and plain.

So swift the magic sent its spell
  Thro' burning corn and pastures dumb,
'Twas clear the world had rested well
  Against the time when rain should come.

So virile is this earth we own
  So quick with life its soil is stung,
A million years have come and flown
  And still it rises green and young.

Plate IV.— Biological and Dairy Building.

REVIEW OF STATION WORK FOR TWENTY-FIVE YEARS.

THE STATION: ITS HISTORY AND WORK.

W. H. JORDAN.

The experiment station movement, which is now worldwide, had its origin in Germany about the middle of the last century. In 1851 a station was established at Möckern, Saxony, under the direction of Dr. Emil Wolff, and within a decade several others were organized on German soil.

Outside of the United States there now exist about 800 stations or similar agencies. Since 1875 sixty such institutions have been organized in the United States, the larger number coming into existence directly following the passage of the Hatch Act in 1887. Since 1888, when their aggregate income was $710,000, and their total working force 369 persons, the stations of the United States have reached an income of over $2,000,000, with 950 administrative officers and scientific workers. In 1906 they issued 3,000,000 copies of printed matter.

These stations are a direct outcome of the rise of scientific knowledge and are an organized means for increasing this knowledge and of bringing it into helpful relations to the art of agriculture. At the present time their assistance is invoked in almost every known agricultural problem, and evidently they have become a permanent and essential factor in the guidance of farm practice.

The New York Agricultural Experiment Station was the sixth one to be organized in the United States, probably the fourth to be established through legislative action and direct State aid. It would be difficult to trace out all the individuals and organizations that were active in securing the establishment of this Station and to assign to them the part each played in accomplishing the result. Such an attempt would almost certainly fail of mentioning many persons who actively assisted in this progressive move. Of organizations it may be said that the ones most prominently active in promoting the Station movement in New York were the State Agricultural Society, the State Grange, the Central New York Farmers' Club, the Elmira Farmers' Club and the Western New York Horticultural Society, to which was added the strong influence of Cornell University.

The first act of the Legislature establishing the Station became a law June 26, 1880 (Chap. 592). This law placed the management of the Station with a Board of Control of ten members to be made up of the Governor of the State, *ex officio,* the executive officers of the State Grange and the several agricultural societies and two members to be elected by the Board after its organization. This Board began its deliberations at once, holding its first meetings at Albany. It was inevitable that a variety of plans should be considered for organizing experiment station work, some of the more prominent of which were the creation of an independent institution with a farm attached, the location at Cornell University as a department of that institution, and the establishment of an office at Albany, the experimental work to be distributed among farmers in various parts of the State. Wisdom prevailed and the latter plan was rejected. Its adoption would have defeated the real objects of an experiment station. The final decision was in favor of an independent institution located on a farm. With this end in view the Board of Control made a public statement of its purpose and asked for proposals from different localities as to available farms and the conditions under which one could be acquired by the State. It is the remembrance of a member of this first Board that over one hundred proposals were received. A committee, consisting of Messrs. Barry, McCann and Woodward, finally narrowed the choice of a location down to three places, viz.: Geneva, Palmyra and Spencerport, and so reported to the full Board. Geneva was selected as the site of the new institution. Plans had so far been agreed upon by February, 1881. In the meantime the Comptroller had rendered a decision declaring defective the law establishing the Station on the ground that the Board created by the law was self-constituted and self-perpetuating, and as the State had no control over it public money could not be constitutionally used to pay its expenses. While the Attorney-General submitted a contrary opinion further legislation was thus rendered advisable. A bill was prepared creating a Board of Trustees, consisting of the Governor, *ex-officio,* and nine members appointed by him. This became a law

August 15, 1881. (Chap. 702). The title to the farm at Geneva passed to the State early in 1882.

Dr. E. Lewis Sturtevant of South Framingham, Mass., was elected director of the Station. He took possession of the Station property and entered upon his duties on March 1, 1882.

DEVELOPMENT OF THE STATION.

The Station property, when the State came into possession of it, consisted of a farm of 130 acres on which was located a brick mansion house and the usual set of farm buildings.

For quite a period of time the second and third stories of the mansion house served as the home of the Director, the first story and basement being converted into offices and laboratories. The farm buildings after more or less reconstruction were utilized in part for such experiments with animals as were carried on. The institution has developed gradually in building equipment, the more important additions having been made at the dates given below.

1888 Large cattle barn.
1891–2 Chemical laboratory.
1893 Forcing houses.
1895 Cold storage house for fruit.
1895–6 Triple house erected on north side of North street.
1897 New forcing house and new poultry house.
1897–8 Dairy and biological building.
1900–1 Director's house.
1901–2 Original mansion house converted into administration building.
1902 On May 7th fire destroyed five buildings,— three barns and two poultry houses.
1902–3 New cattle barn.
1903–4 New horse barn.
1903–4 Fire protection system.
1904–5 Storage building.
1907 Appropriations are now available for the erection of five dwelling houses.

These buildings provide fairly satisfactory facilities for the work of the Station, including well-equipped chemical, botanical, bacteriological, entomological and horticultural laboratories, experimental dairy rooms, library, and convenient administrative and department offices. The cattle barn, forcing houses and poultry houses are also well adapted to experimental work.

Outside of the increase of buildings, the main growth of material equipment has been the development of the fruit plantations, from a small apple orchard to a collection at times of over 5,000 varieties of large and small fruits, including apples, apricots, nectarines, peaches, pears, plums, and all the varieties of small fruits of importance in the Northern States.

The Station staff has increased in number from five in 1888 to between thirty and forty at the present time. Until 1897 there were no clearly recognized departments in the Station outside the chemical and horticultural. In that year a policy of enlargement was inaugurated and a closer subdivision of the staff was made, so that now there exist departments of animal husbandry, bacteriology, botany, chemistry, entomology and horticulture. The prominent features of the animal husbandry division are the dairy and poultry work.

Such an enlargement of the Station has been made possible only through greatly increased financial support. The initial sum provided by the State annually for the maintennance of the institution was $20,000 and is now $86,500. Besides this sum the institution receives one-tenth of the Federal appropriations under the Hatch and Adams acts, amounting this year to $2,200.

POLICY AND WORK OF THE STATION.

When experiment stations were first established in the United States various widely divergent views prevailed as to the work these institutions should do and the relations they should sustain to agricultural practice. In the discussions preceding legislation many things were said that created false impressions in the public mind as to the kind of service these new institutions would render. Comparatively few persons conceived of an experiment station as a means of acquiring scientific knowledge fundamental to farm practice. It was more generally thought that they were to be model farms where farmers would see the best known, and the most profitable, management. Recently a member of the first Board of Control of the New York Station was asked "What was it expected that the Station would do?" and he replied, "I think the general expectation was that we were to run a farm at a profit to show how to make it a paying institution." Gradually, however, the public has forsaken the idea of a model farm and has come to understand that the function of an experiment station is to solve the individual problems of the farm and not to dictate business management.

The initial policy of the Station at Geneva was largely determined, of course, by the point of view of its first director. It was fortunate that Dr. Sturtevant saw clearly the need of well-established fundamental facts and principles as a basis of farm practice. He was keenly alive also to the possible errors of prevailing methods of experimental work of the so-called practical character and gave much attention to determining their source and extent and the means of minimizing them. He held that much preliminary work was needed in order to learn how to experiment and how to interpret results and the first six annual reports of the Station contain many data on the errors of certain classes of experiments, especially those of the field and stable. As to the broad function of the Station, Dr. Sturtevant asserted that its object "is to discover, verify and disseminate." By this he meant that the Station should establish new principles and facts of importance to agriculture; discover and verify the uses of both old and new knowledge in agricultural practice and by some means acquaint the agricultural people with the new information. He believed the great want of agriculture to be the establishment of principles that shall serve as a guide to reasoning. This is a sound and well-balanced policy. Rightly interpreted it leaves no room for an all-absorbing effort of popular instruction into which so many station men have unfortunately been thrown.

Dr. Sturtevant held positive views in other directions. He believed that the organization of the Station was faulty in that it did not place the sole management and responsibility upon the director. He held that the function of the Board should be limited to the control of the financial interests and the appointment or displacement of the Director, giving the Director power to appoint his own employees and carry out his own ideas untrammeled. He declared that unity and continuity of direction could not be secured in any other way. If in any case the management is not successful, the remedy is to displace the Director and appoint another. It is quite safe to say that this view now prevails quite generally in practice, if not in theory, in the management of experiment stations.

Dr. Sturtevant also advised that the work of the Station should not be confined to the Station grounds. He practically advocated placing the Station on a Smithsonian footing with a central band of workers engaged in independent research and locating distinct practical problems with individuals selected according to their location and fitness. These views probably did not meet with popular approval, but had their essential spirit more fully prevailed in the organization and management of experiment stations, there would have been a greater advance in knowledge than has been attained.

During the years immediately following the administration of Dr. Sturtevant the Station entered upon a period of material development. Within the space of seven years, under the lead of Dr. Collier, a large cattle barn, the chemical laboratory and the forcing houses were erected and provisison was made for three staff houses.

Early in his administration Dr. Collier called attention to the importance of the stock interests of the State, especially the dairy industry, and advised that the Station should do more in this direction. As one result of this recommendation, breed tests were instituted, in the pursuance of which important data were collected concerning several breeds of dairy cattle. He also advised establishing a department of fertilizer control at the Station and through this movement a law was passed placing the inspection of fertilizers in the control of the Station and at the same time, and largely because of the law, funds were provided for the erection of a chemical laboratory.

Other recommendations of Dr. Collier were the organization of at least ten branch stations in the State, to be under the immediate supervision of local boards of control, the central control to be at Geneva, and the establishment at the Station of a department of agricultural implements. Neither of these propositions materialized and it is fortunate that the first one did not, for a much more efficient and economical method is now in vogue, viz.: The studying of problems in any place where opportunity offers. The only justification for establishing branch stations is that they offer a better opportunity for studying a variety of conditions than does a single station. But when it is remembered that each one of the sixty counties of the State has within itself a great variety of agricultural production under equally variable conditions, the futility of attempting to multiply branch stations to meet all local needs is made evident. The contention of the first Director of the Station that a central research effort should be maintained, combined with a study of practical application of knowledge in various parts of the State as opportunity offers, is the prevailing policy in some States, especially the older ones, and is one that experience appears to justify.

It was during the administration of Dr. Collier that the existence of the Station was jeopardized. In his annual message for 1893, Governor Flower suggested the discontinuance of the Station by concentrating all such efforts at Cornell University. Later he visited the institution and evidently changed his point of view, for in his message of the following year he advised that the Station be well sustained.

The directorship of the Station changed hands again about the middle of 1895, Dr. L. L. Van Slyke acting as director until July 1, 1896, at which time the writer assumed the office, which position he still holds. During the past twelve years the Station has continued to grow steadily in its equipment and scope of work practically along the lines which previously occupied its attention. The more notable results during this period have been a closer specialization of the work through additions to the staff and its more definite division into departments, the growth in laboratory facilities for special work, particularly in bacteriology, botany, entomology, and dairying, and a material increase of experimental work in various parts of the State in studying the use of fertilizers, the testing of spraying and other methods for the control of fungus diseases and injurious insects, the comparison of methods of orchard management, observations on alfalfa culture and other lines of work. We have rented land, leased orchards and made other business arrangements with farmers in order to carry on these outside observations satisfactorily. During the past three or four years from thirty to forty experiments have been in operation each year in co-operation with nearly as many farmers in different parts of the State. In addition to this, sixty or more farmers have received soil for inoculating new alfalfa, and volunteer observations on potato spraying have been reported to us by a large number of potato growers. This general plan has much to commend it and continued experience strengthens the conclusion that it is the most efficient way possible for testing Station conclusions and at the same time impressing the results upon the attention of farmers.

METHODS OF EXPERIMENTATION.

The first director of the Station held, and with much reason, that the first work of our experiment stations should be to establish safe methods of experimentation. At the time the New York Station was established, a great deal of field experimentation was in operation by the plat system and many feeding experiments were being carried on with different classes of animals. From the results so obtained conclusions were being drawn as to methods of practice. Dr. Sturtevant rendered useful service in showing by actual field trials the possibilities of very large errors from the assumption that plats of equal size would produce equal quantities of grain or other products. He conducted tests with sorghum, corn and potatoes where the plats were given as nearly uniform treatment as it was possible to give. During several years' work he found differences between duplicate plats of corn ranging from 14.3 bushels per acre to 39.2 bushels. With potatoes the differences ranged from 12 bushels per acre to 107 bushels. Dr. Sturtevant reached the sane conclusion that field experiments conducted on such a basis were utterly unreliable as a means of testing either methods of treatment and cultivation or the relative efficiency of fertilizers. The decrease in the number of field experiments conducted in the manner tested is an indication that the unreliability of the methods previously followed is generally recognized. To secure safe conclusions from plat experiments is a much more difficult matter than was at first supposed. Such preliminary work was needed and it served as a corrective of unsafe conclusions.

THE WORK ACCOMPLISHED BY THE STATION.

In the development of its work it cannot be said that the Station has given proportionate attention to each one of the agricultural industries, large or small. General farm crops, vegetable gardening, floriculture and bee keeping have either held a minor place in the efforts of the Station staff or have received very little or practically no attention in the way of investigation. The phases of agriculture which have received most prominent attention are dairying and fruit culture. There are at least two reasons for this limitation of Station work: One is that dairying and fruit raising are our leading agricultural industries, and the ones that offer the most attractive and the most available opportunities for helpful service. The second reason is that as it is not possible to carry on very many lines of inquiry at the same time, it has seemed advisable to select those problems of the largest importance. Those who have not engaged in scientific investigation do not appreciate how time-consuming and energy-consuming a single piece of research is. For these reasons many problems have remained untouched, some of them important, and doubtless it has often been felt that the limits of the Station work have been too narrow.

Plate V.— Forcing Houses and Barns.

In the pages which follow an attempt is made to summarize in a somewhat popular way the principal results that have been reached at the Station. In this immediate connection I shall only present a numerical and topical outline of the problems that have been studied. The subjects that have been considered in the way of inquiry are approximately 300, to say nothing of many minor questions to which more or less attention has been given. The studies of these various problems have occupied from a few weeks to several years.

A careful examination of the data secured indicates that something has been added to the existing knowledge of about 200 subjects. In about 100 cases the Station conclusions are believed to have been applicable to the betterment of farm practice. In many instances, of course, the data gained have been inconclusive. Some studies were begun ten or more years ago and are not yet completed.

The following is a partial list of the investigations made:

The promotion of the growth of alfalfa in the State of New York by illustrative work at the Experiement Station and by aiding proper inoculation of soil throughout the State; tests of relative value on same and different soils of varieties of field crops, new or little known species of grasses and new forage crops; demonstration of value of proper selection, curing (including kiln-drying), storage and testing of seed corn; proof that tip kernels of the ear make good seed; demonstration of value of deep preparation of soil for corn and of harmfulness of root pruning and weed growth in caring for crop; proof that large seed oats are most profitable, that productive hills of potatoes give best seed, that large-sized seed pieces are better than small, that large applications of fertilizers are not usually profitable on potatoes or onions, and that barnyard manure is not harmful to sugar production in sugar beets; a study of the canning of peas, resulting in a safe and efficient method; determination of the cause of fire-blight in apples, pears and quinces; test of bordeaux mixture and other fungicides for controlling apple scab; study of the bordeaux injury to fruit and foliage of apples and pears; effect of spraying apple trees while in bloom; cause and control of apple canker; control of bean anthracnose; demonstration of the black-rot germ on cabbage seed; spraying experiments for control of diseases of nursery stock; experiments on the control of cucumber downy mildew; experiments for controlling gooseberry mildew; tests of chemicals for treatment of oats to prevent smut; test of sulphur-lime treatment to prevent onion smut; determinations of sprayings necessary to control pear scab and best time for making them; the profits of spraying potatoes (five years' work already done); control of raspberry anthracnose; cause and control of raspberry cane blight; the exclusion of dodder seed from alfalfa seed; study of at least twelve garden insects and introduction of effective insecticides in place of proprietary remedies often unreliable and injurious; first Station to publish results on use of paris green for codling moth; extensive work on the control of San José scale; demonstrations in control of pistol casebearer, the tent caterpillars, the New York plum lecanium, the grape flea-beetle, the spring canker worm, and a great variety of other insects; twenty-five years' work on varieties of apples and other fruits; the preparation and publication of "The Apples of New York," the nearly complete preparation of "The Grapes of New York;" extensive tests of the profits from thinning apples; conclusive work on self-fertile and self-sterile grapes, and demonstration of harmonious varieties; the use of cover crops for orchards; the vitality of seed as affected by various factors, such as age, size, drying, the portion of the plant on which seed is borne, maturity, and specific gravity; winter vetch proved to be valuable as fall-sown cover-crop; demonstration of excessive and wasteful use of fertilizers on potatoes; extended aid to sugar beet growing in the State by studies of the crop in various portions of the State; availability of different phosphates for two different species of plants; influence of the amount of plant food on the composition and growth of plants; effect of the fineness of fertilizing material on availability; relation of the composition of the soil to plant growth; effect of plant growth upon the soluble materials of the soil; relation of the amount of fertilizer to the soluble matter of the soil; digestion experiments with new materials; tests of new cattle foods; increase in growth of maize up to maturity; relative effect of rations with wide and narrow nutritive ratios; effect of the ration upon the composition of the animal's carcass; the food source of milk fat; the metabolism of phosphorus compounds and their physiolgical influence; extensive observations on the growing of alfalfa as a forage crop and on the use of corn for silage purposes; numerous experiments with poultry, including such problems as general food requirements of hens of different type; the necessary nutritive ratio for laying hens; the supply of egg shell material; the particular value and effect of Indian corn and other feeding stuffs; influence of food on molt; the use of skimmed milk; the influence of salt; the production of capons; causes of feather eating; breeding experiments continued for many years; the relative profits of the larger and smaller breeds; the relative efficiency of ground and whole grain for laying hens and chicks; the importance and economy of using animal food; the importance of mineral matter and the value of grit; and the adaptability of certain concentrated by-products for poultry feeding; testing the value of several forage plants as a food for growing pigs; relative value of wet and dry grain for pigs; relative efficiency of corn meal and corn on the cob for pigs; relative cost of growing pigs of different breeds; feeding experiments with pigs of different crosses; investigations of syrup and sugarmaking, including adaptability of sorghums and sugar beets; chemical studies on milk and it products; composition of normal milk used at cheese factories; composition of milk in relation to yield of cheese; composition of milk in relation to the composition of cheese; composition of milk in relation to the quality of cheese; composition of whey and cheese; methods of paying for milk for cheese-making; conditions affecting weight lost by cheese in curing; commercial experiments in curing cheese at different temperatures; conditions affecting chemical changes in cheese-ripening; action of acids and bases on casein and paraceasein; first chemical changes in cheese; enzyms in relation to cheese-making and cheese-ripening; comparative study of different breeds of dairy cows; comparative profits derived from selling milk, butter, cream and cheese; proteids of butter in relation to mottled butter; composition of commercial soaps in relation to spraying; chemistry of home-made cider vinegar; and methods of analysis.

INSPECTION WORK.

In 1891 fertilizer inspection was inaugurated in New York, the work being placed wholly in the hands of the Experiment Station. In 1899 a similar inspection was established for commercial feeding stuffs. The inspection of these two commodities, including the collection of samples and analysis of samples, and action in the case of violations of the law, remained wholly with the Experiment Station until 1904, when new legislation was enacted transferring the general administration of the law to the State Department of Agriculture, reserving to the Experiment Station the duty of making the analyses of such samples of fertilizers and feeding stuffs as were transmitted to the Director of the Station by the Commissioner of Agriculture. Since the inspection of these two classes of commercial articles was established in New York, the Station has analyzed 11,826 samples of commercial fertilizers and 2,369 samples of concentrated commercial feeding stuffs. Twenty-five bulletins have been published giving the results of the inspection of fertilizers and nine bulletins reporting the inspection of feeding stuffs. This work is provided for by special funds and is not allowed to interfere with the fundamental purpose of the Station, because it is assigned to a special force of men who are not in any way related to investigational functions. The value of this inspection is unquestioned.

Manufacturers have been obliged to make definite statements concerning the composition of each brand of goods that has been placed upon the market. Consumers may now know pretty definitely what they are purchasing under a given brand name. Moreover, through the reports of the inspection the public has become well acquainted with the character of the goods that are offered in the markets. At the same time much has been learned, especially with feeding stuffs, concerning the nature of the materials from which many of the brands have been compounded, and farmers have been made acquainted with the inferior materials that are used for purposes of adulteration. Probably no experiment station effort has been of more direct financial benefit than has the inspection of these two classes of commodities.

STATION OFFICERS.

On pages III to VI there is given a complete list of the persons who have been, or are now, connected with the Station either in an administrative or a scientific capacity, with the terms of service. The following table gives a classified statement of the number of persons occupying various positions of administration or scientific service:

Trustees	50
Treasurers	2
Secretary and Treasurer	1
Directors	3
Directors, acting	1
Agriculturists	1
Animal Industry, assistant	3
Bacteriologists	1
Bacteriologists, assistant	4
Botanists	2
Botanists, assistant	4

Chemists	3
Chemists, associate	2
Chemists, assistant	32
Dairy Expert	1
Editor and Librarian	1
Entomologists	3
Entomologists, assistant	4
Horticulturists	3
Horticulturists, acting	1
Horticulturists, assistant	10
Student assistants	5
Stenographers	5
Clerks	2
	138

It appears that in all 138 positions have been filled. In some cases more than one position has been held by the same person. The number of individuals so far connected with the Station work is found to be only 126. Of these 59 have served the institution in an administrative capacity and 67 have been associated with its scientific work.

In looking over the record of former members of the scientific staff it is gratifying to note that approximately 25 are worthily filling positions of greater or less prominence in other institutions. Many of the young men who received their initial training in experiment station work at this Station have attained prominence in the scientific world and have accomplished results of great usefulness.

INVESTIGATIONS IN ANIMAL NUTRITION.

SUMMARIZED BY

W. H. JORDAN.

During the first ten or fifteen years that the Station was in operation a number of experiments with animals were conducted, having as their objects the testing of new feeding stuffs, a comparison of rations, and other problems involved in the growth of animals and the production of milk. It must be said that many of these experiments were carried on in a manner that rendered safe conclusions out of the question. The chief faults were the brief periods during which the rations or foods to be compared were fed, and the failure to plan the experiments so as to eliminate all but a single factor in the periods compared. There was not a sufficient recognition of the facts that the influence of a ration is not a temporary matter and that productiveness, either of flesh or milk, is modified by the cumulative influence of long-continued feeding. However, certain observations were made that were valuable and useful.

INFLUENCE OF STAGE OF GROWTH OF CORN UPON ITS YIELD OF DRY MATTER.

In 1888, a study[1] was made of the yield and composition of silage corn as affected by the stage of growth at the time of harvesting. Two acres of corn were cut in two lots, one September 11 and the other September 29, the amount of the crop at each cutting being weighed and samples taken for analysis. The main facts that were brought out by this work were that there was a material increase in the amount of dry matter during the eighteen days following a watery stage of the kernels and that this increase consisted largely of carbohydrate material. Later work at other stations confirms the fact that the increase of carbohydrates is mostly

[1] Rpt. 7:264, 265 (1888).

an increase of starch. This knowledge has had an important influence on the economy of corn production for silage purposes.

THE DIGESTIBILITY OF CATTLE FOODS.

Considerable work[2] was done in the earlier years of the Experiment Station in determining the digestibility of various cattle foods, including alfalfa, orchard grass hay and corn meal. The digestion coefficients derived from these experiments are now incorporated in the general tables of digestibility of cattle foods. Such determinations were useful and important in the earlier days when very little was known of the digestibility of characteristic American products. An attempt[3] was made to discover the influence of roots upon the digestibility of grain rations. It was concluded that the addition of roots to a hay ration decreased the percentage of digestibility of the albuminoids and increased the digestibility of the carbohydrates. As this work was carried on with only one animal and as the digestibility of the roots was assumed, the conclusions are of doubtful accuracy. Digestion experiments[4] conducted in 1884 with fodder corn, silage, soja bean fodder, and hay, are also open to the objection that the digestibility of the grain fed with these materials was assumed to be the same as those shown in German tables.

THE RELATION OF THE NUTRITIVE RATIO TO THE PRODUCTION OF MEAT.

At the time the New York Station began its work, discussion was rife concerning the compounding of rations and the influence in the ration of the relative amounts of digestible protein and digestible carbohydrates. Naturally in planning feeding experiments, this was one of the points first considered. Two experiments comparing rations for fattening were conducted, one with heifers and the other with both steers and heifers, the animals in all cases being approximately two years old. The conclusions failed to ratify the ratio for meat production suggested at that time in the German feeding standards. In the case of the first experiment[5] with two heifers, one made a better gain on the more nitrogenous ration and the other a larger gain on the less nitrogenous ration, the difference

[2] Rpts. **3**:26 (1884); **4**:341-349 (1885); **5**:337 (1886); **6**:408, 428 (1887); **7**:273-279, 304-307 (1888); **8**:130-150 (1889).

[3] Rpt. **8**:145 (1889).

[4] Rpt. **3**:26 (1884).

[5] Rpt. **7**:292-297 (1888).

in the rations being marked. In the latter experiment,[6] involving four animals, two steers and two heifers, neither kind of ration appeared to have any especial advantage in the way of producing gain of flesh. The conclusion was that the substitution of nitrogenous foods like cotton seed meal for corn meal and a small quantity of bran, was not followed by any advantage as a fattening ration so far as the increase in live weight indicates such advantage. The animals receiving the more nitrogenous ration had a sleeker appearance. No difference in the proportions of fat and lean were observed in the carcasses. A table test of the meat from the two lots of animals appeared to show that the meat from the steer receiving the wide ration was tenderer and "sweeter" than that from the other steer, a difference which may have been due to individuality. The conclusions from this early work, while based upon scant data, are abundantly corroborated by later experiments of a much more extensive kind. It is clear that the German feeding standards call for a larger proportion of protein in a ration for fattening animals than is necessary for good results.

INFLUENCE OF PROTEIN FEEDS IN THE PRODUCTION OF MILK.

It is unfortunate that the experiments[7] conducted by the Station with a view to testing the influence of the by-product protein feeds upon milk production were so faulty in plan that the data secured should hardly be considered as conclusive. It has been pointed out that the feeding periods in these experiments were altogether too short, being in one case, at least, only ten-day periods. One fact, however, was very evident in all the experiments, that while the figures given should not be considered as entirely satisfactory, the protein feeds unquestionably stimulated milk flow, especially where they were introduced into a ration consisting very largely of corn meal. It is fair to say, however, that the sudden changes from a ration of one standard to that of another may be properly regarded as a disturbing factor and the experiments therefore do not constitute a fair test of what the relative value of the rations would be when fed continuously through long periods. However, such results as these had much to do with the estimate in which protein feeds are held by milk producers and are in part responsible prob-

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[6] Rpt. **8**:117–130 (1889).
[7] Bul. 210; also Rpt. **20**:61–119 (1901).

ably for the position so often taken that the value of a feed should be measured almost entirely by its protein content. Unquestionably the experiments pointed to an important fact which has reacted favorably upon feeding practice as well as upon the financial interests of the manufacturers.

In carrying on these experiments, certain associated facts were clearly shown that were contrary to common beliefs and the knowledge of which has been of great value. One of these facts which has been developed in many experiments by other institutions, is that the quality of the milk is influenced very little in any immediate way by the character of the food, but is determined by the individuality of the animal. In other words, these experiments, along with others, show that the kind of milk is almost entirely determined by the breeding, development and fixed constitutional habit of the cow. Many attempts have been made to discredit this conclusion but all exact experiments go to sustain it.

Another disclosure of importance was the practical independence of the milk flow of the amount of water drank. Contrary to a notion held by many, it is not possible to water a cow's milk through her drink or through the ingesting of watery food.

In the course of these experiments with milch cows it was shown, sometimes as the direct purpose of the experiment, that the various by-products from the manufacture of glucose and other commodities were available feeds and a valuable addition to the supply of commercial feeding stuffs.

THE INFLUENCE OF ACID AND PUTRID FOOD UPON THE QUANTITY AND QUALITY OF MILK.

At the request of the Dairy Commissioner of New York, the Station undertook in 1884 a test[8] of the influence of wet brewers' grains, both in a sweet and a fermented condition, upon the quantity and quality of milk. The conclusions reached were much criticised because they were strongly opposed to common opinion, but they appear to have been based upon accurately observed data. The results of the test were the following: The wet brewers' grains had a favorable effect upon the milk flow and proved to be a valuable feeding material when used in proper proportions with the rest of the ration. A conclusion that was surprising to the general public was that the brewers' grains, even in a putrid condition, when

[8] Rpt. 3:49-62 (1884).

not fed to excess, were not detrimental to the production of milk nor to its quality for human consumption. It is true that in the early stage of the experiments the grains were fed injudiciously and exerted an ill effect upon the appetite of the cows. After the improper method of feeding was corrected, no difference could be observed in the milk as between the cows that were eating even putrid grains and those that were fed on the soundest kind of food. This should not be taken as an argument for feeding putrid material, because when the appetite of the animal and her general health are taken into consideration, there is always danger from such a food. It does mean, however, that many of the notions held by the public were not based upon accurately observed facts. A later test of wet starch waste, or slump, confirmed the conclusions of the first test, at least so far as acidity of food is concerned. This wet feed was fed after it had acquired 0.2 per ct. of free acid and during the same experiment hay and dry feed to which acetic acid had been added were given as one ration. The presence of this acid, either that from fermentation or that which was added, had no injurious effect whatever upon the health of the animals or upon the character of the milk. Indeed, the presence of a small amount of acid seemed favorable toward stimulating the appetite of the animals.

THE FOOD SOURCES OF MILK FAT.

One of the most elaborate and conclusive studies in animal nutrition that the Station has conducted was an investigation[9] into the food sources of milk fat.. The popular notion had for a long time prevailed that fat in the food was the source of the fat of milk. On the other hand it was held by certain scientific investigators that milk fat arises from the fatty degeneration of the proteid tissues of the udder. Previous investigations of this problem, including one made at the Station, had been inconclusive, because the rations fed were such that the fats present in the ration and the fat equivalent of the digestible protein of the ration were generally enough to account for all fat in the milk. The plan of the Station experiment involved the extraction of practically all of the fat in the materials of the ration so that only the fat equivalent of the digestible protein was to be considered outside of the carbohydrates. Experiments with two cows demonstrated beyond any shadow of a doubt that the carbohydrates in the food must have served as raw material for the

[9] Buls. 132 and 197; also in Rpts. **16**:49-522 (1897) and **20**:29-60 (1901).

production of a large proportion of the fat in the milk. This conclusion is not irrational in view of the fact that Lawes and Gilbert and other investigators have demonstrated the formation of fat in swine and other animals from starch and sugar.

THE INFLUENCE OF THE RATION UPON THE COMPOSITION OF THE CARCASS.

At one time the influence of the ration upon the composition of the animal's body was much discussed and one experiment[10] was instituted at the Station for the purpose of comparing rations heavily nitrogenous with one of a much wider nutritive ratio. One ration consisted of hay, bran and cottonseed-meal, and the other of hay and corn meal. These were fed to lambs. At the end of the experiment one lamb of each lot was killed and a mechanical analysis was made of the carcass. It was found that the carcass of the corn-fed lamb contained a much larger proportion of fat than the carcass of the lamb that was fed cottonseed-meal. This result is in entire accord with the outcome of Station investigations at other experiment stations.

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[10] Rpt. 7:300-303 (1888).

EXPERIMENTS WITH POULTRY.

SUMMARIZED BY

W. P. WHEELER.

This Station was one of the first to conduct any experiments with poultry. Some preliminary work was done in 1888 and since that time experiments in a limited way have been regularly continued. The first experiments were undertaken to get some of the more general facts in relation to the food requirements of fowls. Although reports were then available from considerable work done with larger animals in this country, and from much more in Europe, very little was on record concerning poultry, and there was an especial lack of reliable data in regard to nutrition.

COMPARISON OF RATIONS WITH LARGE AND SMALL HENS.

Feeding trials in 1888 to secure data upon which to base subsequent investigation,[1] were with rations largely of grain as usual, and contrasted chiefly as to protein content. Each ration was fed to two lots of hens, one representative of the smaller and the other of the larger breeds. A preliminary trial showed that the smaller hens ate about half as much as the larger when not laying, and about three-fourths as much when laying. Of the two rations then compared the average consumption was about alike, and the smaller hens took about seven-tenths as much food as the larger, calculated on the basis of dry matter. More eggs were produced under the ration containing corn meal with a nutritive ratio slightly wider than that of 1:7 than under the other ration with a ratio slightly narrower than that of 1:4, though the only fowls suffering in health were those fed freely on the wider ration. Account was kept of manure collected.

Analyses were made of a number of eggs and only slight differences found in food value as related to the breed from which they came or in regard to the ration fed.

[1] Rpt. 7:59-66 (1888).

LOSS OF WATER AND CHANGE IN SPECIFIC GRAVITY OF THE EGG.

Observations[2] were made as to the gradual loss of water by eggs exposed to the air for a month. The rate of loss increased slightly with rise in temperature, but was influenced more by character of shell, being slower with eggs of heavy shell and faster with lighter-shelled eggs.

About 500 determinations of specific gravity of eggs were made. Although there was a regular diminution in specific gravity with age, the rate varied with the character of the egg. It was concluded that certain methods advocated for determining the freshness of eggs by immersing them in solutions of definite specific gravity would be far from infallible. There was little difference in specific gravity of eggs noticed from hens fed differently, and there was a slight though constant difference between white-shelled and brown-shelled eggs which was accounted for by the average lighter shell of the latter.

The relative proportion of white and yolk was observed for a number of eggs. Some variations were found, but as a rule the proportion was close to the average which showed the white to constitute a little over 64 per ct. and the yolk a little less than 36 per ct. of the edible portion of the fresh egg.

SUGGESTION AS TO SUPPLY OF EGG SHELL MATERIAL.

It was estimated[3] that the amount of lime in the shells of eggs from one pen very greatly exceeded the amount in the ordinary food, indicating that this excess is derived from some other source than the ordinary grain and vegetable food.

Later, determinations were made of the phosphorus in yolks, white and shells of eggs from hens fed bone with ordinary food, and from others fed crushed oyster shell, to note any suggestion of possible differences in character of the mineral matter. No particular differences were observed, but the shells of eggs from bone-fed hens contained a slightly larger amount of phosphorus.

THE NUTRITIVE RATIO OF THE LAYING HEN'S RATION.

Feeding experiments[4] with hens were made the following year to study the relative effects of rations containing larger and smaller

[2] Rpt. **7**:66–70 (1888).
[3] Rpt. **8**:64, 65 (1889).
[4] Rpt. **8**:56–62 (1889).

proportions of protein. Neither ration fed was extreme, the average nutritive ratio for most of the time being about 1:4.3 for one ration and about 1:5.8 for the other. On the average for all hens fed the effect on egg production was not greatly different for the two rations, but when the type of hen was considered the difference was more apparent, hens of smaller and more active breeds laying better thoughout under the wider ration and those of heavier breeds better under the narrower ration. During the more productive months about 26 per ct. more eggs were obtained from the smaller hens under the wider ration, and from the larger hens about 21 per ct. more were obtained under the narrower ration.

Analyses made of the eggs showed, as in 1888, little difference in the general composition as influenced by the breed or by the two rations fed.

FEEDING TABLE FOWLS.[5]

During the winter months another feeding trial was made with cockerels and capons, for the earlier two months of which little difference was found in the rate of growth or in the amount of food required for it. Later in the season, after February, increase in weight was not obtained at a profit (the cockerels making somewhat the poorer showing) though it was considered that feeding at this stage might often be justified as carrying the fowls to a time of better market price.

POULTRY MANURE.

Account [6] was kept of the manure collected from pens of laying hens under different rations and from pens of fattening fowls. Analyses were made of a number of samples and also of some collected the preceding year.

Manure from fattening fowls had a higher fertilizing value than from laying hens with similar food. Manure from hens fed a nitrogenous ration was of greater value than from hens fed a more carbonaceous ration. It was found that over 40 per ct. of the nitrogen originally in the dung was lost in drying, though it was rapidly dried. Suggestion was made in the report that freshly collected poultry manure be at once mixed with some dry absorbent.

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[5] Rpts. **8**:63, 64 (1889); **9**:136 (1890).

[6] Rpt. **8**:62, 64 (1889).

THE EFFECT OF A RATION WITH MUCH CORN AS MODIFIED BY TYPE OF HEN.

Continuing the study of effects of rations varying in composition a feeding experiment[7] was made in 1890 with four lots of hens. The rations were contrasted as to protein content, influenced chiefly by the free use of corn in one ration. Neither ration was considered an extreme, the average nutritive ratio of one being about 1:3.9 and of the other about 1:5.2. To a certain extent the cumulative effect of the rations was involved, for these hens had been during the year preceding under rations similarly contrasted.

With hens of the larger breeds the two rations seemed about equally efficient, for while there was for the whole season a slightly larger production of eggs under the wider ration, there was during the six months of heaviest production a margin in favor of the hens having the narrower ration. With the hens of smaller breeds the wider ration containing the corn meal proved more efficient, for those under it laid about 50 per ct. more eggs than similar hens under the more nitrogenous ration. The consumption of food was about alike under both rations. Better average health was maintained under the more nitrogenous ration. The smaller hens, though using less food per fowl, required much more per pound of live weight.

Handling and weighing during the feeding trial indicated that the fowls under the more carbonaceous corn meal ration continued fatter, but when fed freely for several weeks after the laying and molting seasons were over, the hens having the narrower ration became somewhat fatter and carried less lean meat, as dissection of nineteen typical individuals showed. It was found also that the bones were slightly heavier in the hens that had been fed the wider ration. While this did not signify much in a positive way it showed that the continuous feeding for two years, commencing before maturity, on a ration about 60 per ct. of which was corn and corn meal did not result in more excessive development of fat or lack of bone than the use of considerably narrower rations.

Perhaps the chief interest in this result lies in the fact that at that time prominent writers, probably influenced by unfavorable results from the excessive or unvaried feeding of corn to certain animals, especially the young, were advising against any use of this grain, urging with little qualification that Indian corn was less efficient

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[7] Bul. 29; also in Rpt. 9:123-135 (1890).

than other grains, and used in any quantity would produce excessive fat, while a narrower ration would make lean meat.

In an experiment of feeding pens of hens and of young cockerels largely or altogether on corn and corn meal the vice of feather eating, and in one instance cannibalism, soon developed, while similar pens under more varied rations remained in good condition. In two instances the vice disappeared with change of food.

AN EXPERIMENT IN FEEDING FAT.

In connection with the unfavorable opinion concerning the use of corn it was held that corn contained too much fat, and that any ration containing much fat was injurious and inferior to any similar ration with less fat.

To observe what ill effects might follow the use of a ration carrying an unusual amount of fat a feeding trial[8] with sixteen hens was made. Two rations were fed, the one including all the tallow that was readily eaten with ordinary food, and the other a similar one except that linseed meal was substituted for the tallow. The proportion of fat to total dry matter was that of 1:8.1 in one ration and 1:29.5 in the other. The nutritive ratio of the ration with tallow was about 1:6.8 and of the more nitrogenous ration about 1:4.8.

For most of the time and on the average, egg production was slightly in favor of the more nitrogenous ration both in number and size of eggs. But for about six weeks of the hottest weather (July and August) more eggs were obtained from the tallow-fed hens. For about four and one-half months covering the better part of the laying season the amount of dry matter in the food for every pound of eggs produced was 4.3 pounds for the fat ration and 3.4 pounds for the more nitrogenous ration.

There was but little difference as to fluctuations in live weight, though the hens having the fat ration held to somewhat heavier average weight during all except the earliest periods.

INFLUENCE OF FOOD ON THE MOLT.

Except in the matter of plumage[9] the tallow-fed hens seemed throughout in better general condition than the others. The chief difference noted was that the hens having the more nitrogenous linseed meal ration molted earlier in the season, more rapidly and

[8] Bul. 39; also in Rpt. 10:194–199 (1891).
[9] Rpt. 10:195 (1891).

nearly all at the same time. By the first week in October only a few of the fat-fed hens had begun to molt while several in the other lot were in new plumage.

In reporting the experiment it was suggested that a highly nitrogenous ration be fed at the approach of molting time.

THE SOURCE OF MATERIAL FOR THE EGG SHELL.

It had generally been thought unnecessary to consider the mineral constituents of foods when feeding most animals, but it became an important matter when feeding numbers of laying hens in confinement, for considerably more than one-third of the total dry matter of an egg is mineral, chiefly lime.

For some time there had been active discussion among poultrymen over the question whether oyster shell could be of any use to the hen as a source of material for the egg shell. It was becoming more generally known that ordinary foods, principally grain, supply an insufficient amount of lime. Some experienced men whose opinions deservedly carried much weight, strongly maintained that the carbonate was too insoluble to be an available source of lime, and sought to supply the known deficiency by feeding large amounts of clover and similar foods comparatively rich in this constituent, although a ration carrying enough lime in such bulky foods would be otherwise inefficient.

Several limited feeding trials made in connection with the study of this subject gave suggestive but inconclusive results. In 1891 another experiment[10] was made after some preliminary work such as partial analyses of the soluble contents of a number of crops, gizzards and intestines and of large oviducts, inactive, and taken at time of active shell formation from hens that had been fed oyster shell and from others that had not. These examinations gave no conclusive information; but considerable free acid was always found in portions of the digestive tract, enough to dissolve carbonate of lime. After a pen of hens had been confined for ten days in a clean pen where nothing edible could be obtained except the intended food more detailed account was kept, for a period of ten days following, of the amount and composition of both food and product. Again after the close confinement for twenty-three days detailed account was continued for a period of twelve days following. Similar work with ducks was discontinued as they did not lay well enough to supply conclusive results.

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[10] Bul. 38; also in Rpt. 10:182-189 (1891).

During the first period eggs were produced by the hens at the rate of one pound for every 3.9 pounds of dry matter in the food, and during the second period one pound for every 2.6 pounds. The change in live weight during either period was slight, no more than might occur at any time within a few minutes.

The eggs laid during the first period contained calcium equivalent to 48.43 grams of carbonate of lime, mostly in the shell. The ordinary foods and drinking water given them contained calcium in different combinations enough to make 7.62 grams of carbonate of lime. Of the lime in the eggs over 84 per ct. was unaccounted for by any food except the oyster shell taken by the hens, which contained 93.8 grams carbonate of lime.

In the eggs laid during the second period there was found calcium, mostly in the shell, equivalent to nearly 88 grams carbonate of lime, while the food and drinking water contained calcium in different combinations equivalent to only about 10 grams of carbonate of lime. Over 88 per ct. of the lime in the eggs was unaccounted for except by that in the oyster shell eaten, which contained 181 grams of carbonate.

The margin was so great that no other conclusion seemed possible except that the egg shells were constructed from material derived in large part from the oyster shell.

In connection with this experiment another feeding trial was carried on with a pen of hens under similar conditions except that clear glass in small fragments was fed instead of oyster shell. Fewer eggs were laid by these hens, and with thinner shells. During one period the eggs and shells contained about 1.6 grams and in another 1.2 grams more calcium than was found in the food and water. The glass eaten contained, in one case twelve and in the other thirty times this amount, but it was not considered that any of this was available, being combined in the form of various silicates unaffected by ordinary solvents. It was thought more probable that the small amount was obtained from pebbles of limestone swallowed long before, for a few small rounded fragments of such were found in the dung, and these had been subjected to conditions that in the one case made oyster shell available.

The hens having access to oyster shell took this to the proportion of from about 5 to 7 per ct. of the total water-free food while those without shell ate glass to the proportion of 30 per ct. of the water-free food and would ravenously take very much more if permitted, apparently all that could be swallowed. Other hens given glass mixed with bone and shell were always satisfied with a moderate amount. It therefore seemed not improbable that in this one case they were instinctively searching for what the glass alone failed to supply.

SKIM MILK PROFITABLY USED.

To learn whether skim milk could be freely utilized for poultry feeding without ill effect, many chicks had been grown to maturity with this only for drink. None were sickly and the few losses were accidental. Unusually early and full feathering, especially among Asiatics, was attributed to the free use of the skim milk in the ration.

To get information as to the possibility of feeding it to chicks as profitably as to calves and pigs, two lots of the chicks[11] were fed in confinement where all the food could be accounted for. Except for the close confinement they were reared by ordinary farm methods and were brooded by hens so long as necessary.

The sweet skim milk constituted on the average about three-fifths of the total food. For the whole time that the feeding trial covered, one pound increase in live weight was made for every 3.4 pounds of dry matter in the food, very slightly less by one lot and very slightly more by the other. Allowing for the gain in weight made by the hens while they were kept with the chicks the figure would be reduced to about 3.2 pounds for each lot. The result compared favorably with the showing made by other farm animals of lower market values per pound than poultry.

Chicks averaging 2.4 pounds in weight at from ten and one-half to eleven and one-half weeks of age were grown at a cost for food of 5.3 cents per pound in one instance and of 5.4 cents per pound in the other, a cost very considerably below the market value of the poultry. While the foods and products have fluctuated considerably in price since then there has been no occasion to modify the conclusion then made that some of the skim milk of the farm could be profitably used for growing chicks.

THE USE OF SALT IN THE RATION FOR FOWLS.

Salt in some quantity is a necessity to the living animal. Some foods contain all that is probably needed, but the amount in others is small. In order to guard against any possible deficiency it is well

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[11] Bul. 39; also in Rpt. 10:189–193 (1891).

to feed some salt, especially if it increases the palatability of the ration.

Moderate quantities of salt had been fed to poultry with apparent advantage, but the limitations of its use were not known. A feeding trial[12] was therefore made with twelve hens to get some suggestion as to the approximate limit of its safe feeding to mature fowls. For one lot of hens salt was mixed in the food, increasing in amount by periods of feeding. Until it was fed at the rate of .063 oz. per day per fowl (nearly one-half pint per day for 100 hens) no bad effects were noticed. With this amount, however, diarrhea attacked a few of the hens, but the trouble disappeared when the amount of salt in the food was reduced about one-third. When the hens were allowed free access to boxes of coarse barrel salt, not enough was eaten to show ill effect, either by hens that had been fed salt freely for two months or by those that had been without any for the same time.

Little significance was attached to the egg yield from these old hens fed at an unproductive time of year, but twice as many eggs were obtained from the salt-fed hens as from the others, so there was no indication of unfavorable effect in this direction. When reporting the experiment it was suggested that salt at the rate of one ounce per day for 100 mature fowls could be fed without risk. In later feeding it was found that five ounces of salt in every 100 pounds of food was a safe proportion. The Station has not advised the feeding of any salt to young chicks or until they are two or three months old.

PRESERVING EGGS.

At different times tests[13] were made at the Station of a number of methods recommended for preserving eggs, and also of some modifications of these methods that seemed likely to be equally or more successful. No tests were made of cold storage, but only of those methods that could be used with little expense on a small scale. No method of dry packing was found to give satisfactory results whether the eggs were turned regularly or not, and most methods were worthless. The best results were secured by keeping the eggs immersed in solutions either of lime, lime and salt, water glass (from 10 to 20 per ct. solution) or a proprietary solution consisting largely of water glass. On the whole, preference was given

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[12] Bul. 39; also in Rpt. 10:200, 201 (1890).

[13] Report 10:201, 202 (1891).

to a solution of lime and salt (to which a little boracic acid was added) of a specific gravity somewhat lower than that of eggs, because the common materials could be cheaply obtained in pure condition and the preserved eggs were easier to clean than those from more costly solutions which gave no better results. Though of course no preserved egg could grade with a fresh one, little difference in quality of eggs, as tested by many individuals, could be detected between those preserved in the few efficient solutions.

THE FEEDING OF CAPONS.

Some years ago after general agricultural development brought a condition where the margin of profit in winter feeding of beef cattle and swine in this State had been so small that the chief advantage was the possibility of thereby using coarse fodders and by-products on the farm, the demand for other animal products attracted more attention. The unusually high prices quoted for capons led to considerable discussion in the agricultural and poultry press relative to the profit in producing them. This discussion was not free from exaggerated statements of interested individuals, and little satisfactory information was available. To get some data concerning the growth and food cost in fitting capons for market several feeding experiments[14] were made during the two seasons.

Six lots of capons and one lot of cockerels were fed for several months and several lots of capons for shorter periods of several weeks. Birds of several breeds and crosses were used, chiefly Asiatics, but none of the smaller breeds. No special comparison of breeds was attempted, although for the most part each lot was of one breed.

To all of these fowls sweet skim milk was fed nearly all of the time in place of water, and much of the time constituted about 60 per ct. of the total food, supplying generally from 12 to 15 per ct. of the total dry matter in the ration.

Detailed reports were published giving records of the food, its composition, the rate of growth and food cost of growth by short periods, and also charts showing graphically the increasing cost of added weight as the birds approached maturity, the food cost per pound weight at different stages, and the relation existing throughout growth between the cost of production and the market value.

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[14] Bul. 53; also in Rpt. 11:236–270 (1892).

On the average for the eight lots of capons for which records were kept the longest time, from hatching to maturity, the lowest cost per pound live weight was at the average weight of four pounds. Largely because the market prices were always lower for the smaller fowls the cost of food to grow the birds to four and one-half pounds in weight represented the highest proportion (a little over 50 per ct.) of their market value found at any time from earliest marketable size as broilers to the heaviest capons. From the time the capons weighed five pounds until they weighed ten and one-half pounds the total cost of food consumed did not at any time reach half of their market value. Although the cost of every pound added to the weight was greater as the birds approached maturity than it had been for any earlier increase, the prices for the largest fowls were so much higher than for the smaller that the margin over cost of production was always greater with the nearly full-grown capons. On this account the later feeding was justified, so long as there was a regular increase in weight, until the spring months, at which time the greatest demand for capons and highest prices usually prevailed.

COCKERELS AND CAPONS COMPARED.

One lot of capons[15] was fed for comparison with a lot of cockerels taken from the same flock of chicks. For the whole period that record was kept for the cockerels — nearly six months — they increased in weight about 30 per ct. faster than the capons, but the rate of growth was much more irregular. At the average weight of six pounds the capons had cost for food 12 per ct. more than the cockerels; but more food was required on the average by the cockerels, so that at nine pounds' weight they had cost over 8 per ct. more than the capons. As the cockerels grew faster and larger than the capons they averaged about ten and one-quarter pounds in weight before the capons had reached the weight of nine and one-half pounds, and at the heaviest weights had cost no more for food.

At the average prices then existing in New York State markets the cockerels could have been sold at the greatest profit at about six pounds' weight, and the capons not until they had reached the weight of nine pounds, at which weight the difference between the cost of food and the market value was two and one-half times as great as for the cockerels. In some markets and more generally in

[15] Bul. 53; also in Rpt. 11:259, 260 (1892).

recent years better relative prices have prevailed for such poultry as well-fed cockerels, so this difference found at the time in favor of capons would often be much smaller.

CONTRASTED RATIONS FOR CAPONS WITH MORE AND LESS NITROGENOUS GRAIN FOOD.

Two similar mixed lots of capons,[16] including birds of several breeds and crosses, were fed rations contrasted chiefly as to proportions of more and less nitrogenous grain products. Wheat, ground oats, wheat bran, wheat middlings, linseed meal, skim milk, crushed bone and, part of the time, alfalfa were used in both rations. With one corn meal was fed to the extent of about 35 per ct. of the total grain food, and in the other the amount of wheat bran was increased till it constituted on the average about 47 per ct. of the grain food. The skim milk supplied about 54 per ct. of the total food and over 12 per ct. of the total dry matter in the corn meal ration, and about 65 per ct. of the total food and over 18 per ct. of the dry matter in the wheat bran ration. The average nutritive ratio of the one ration was a little narrower than 1:5 and of the other a little narrower than 1:4.

The capons having the narrower ration made on the whole a little faster gain in weight and grew somewhat larger, but the rather slower increase under the wider ration was made at less cost, notwithstanding a higher price for corn meal than for wheat bran, for less food was required for the same gain. On the whole the results under the two rations were but little different, though during most of the time the capons fed the corn meal ration could have been sold at a little better profit.

KEEPING MALES WITH LAYING HENS.

It was commonly known among experienced poultrymen that hens kept away from male birds would lay well, but occasionally men who had kept fowls for years expressed surprise when such a result came to their notice. Some poultrymen were of the opinion that where there was no male, laying was deferred and not so many eggs obtained, though few or no comparable data seemed available to support any conclusion. It was also the common thing to find where a few hens were kept in very limited quarters solely for the eggs, the noisy presence of a cock was endured, while un-

[16] Bul. 53; also in Rpt. 11:264, 265 (1892).

favorably commented upon, under the supposition that without him there would be no eggs.

To get some information as to this question of relative egg production, an experiment[17] with four pens of pullets was made. Two similar lots of cross-bred pullets were used and two similar mixed lots of pure bred pullets. With two lots, one of each type, cockerels were kept and the other two were kept without any male bird. All the pullets used had been separated from males for some months before laying maturity was reached. A cockerel was put with each of the two lots of pullets two months before any began laying. Some pullets in each of the two pens in which no male was kept began laying about a month before any in the corresponding pens with cockerels began to lay.

Most of the birds were of Asiatic blood and rather persistent sitters. The broody hens were not given any special discouragement, and there were about the same number on the average in the contrasted pens. Of the cross-bred pullets the lot without a male laid better for the whole time that record was kept (about nine months) and also during the best part of the season. Of the other lots (Minorcas and Brahmas in each) the one without a male laid best during the first few months, but fell behind the other lot later on; so that the total production per laying hen was somewhat less, though the product per fowl was about alike for the contrasted lots. It was thought that this falling off might be partly due to the development of the feather-eating vice in the one closely confined lot and the treatment necessary to suppress it.

On the average for the whole time nearly 11 per ct. more eggs were obtained from the two lots without males than from the other two lots. During the best part of the laying season, for a period of 112 days, from the pens in which cockerels were kept eggs were obtained at the rate of one pound for every 4.2 pounds of dry matter in the food, and from the contrasted pens at the rate of one pound of eggs for every 3.9 pounds of dry matter in the food.

Records as to food and product for the greater part of a year showed the best average result from the hens kept without males, indicating, so far as the one trial could, that there was no advantage in egg production derived from keeping a male bird. Besides the expense of feeding the useless cockerels, fewer eggs per hen were obtained.

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[17] Bul. 57; also in Rpt. 11:270–282 (1892).

THE FOOD COST OF THE GROWN PULLET.

To get some data as to the approximate food cost represented by grown pullets produced under ordinary farm methods, records[18] were kept, from the egg, of food for the sitting hens, of food for the chicks of both sexes up to marketable size, and for the pullets to nearly laying maturity.

One hundred and more eggs from each of two breeds, Cochin and Leghorn, the latter of small-sized strain, representative of different types, were incubated under hens. As would usually, and preferably, be the case the Cochin chicks were hatched earlier in the season than the Leghorn, the Leghorn eggs having the advantage of season and a higher percentage of fertility. Sixty-five per ct. of the Cochin eggs and over 83 per ct. of the Leghorn eggs passed the last testing. Of the tested eggs about 78 per ct. hatched for the Cochins and about 92 per ct. for the Leghorns. Counting all losses and accidents in hatching, a fraction over 46 per ct. of all Cochin eggs set were represented by strong chicks and a fraction over 75 per ct. of all Leghorn eggs set. Considering the cost of food for sitting hens and allowing grocery value for eggs used, each Leghorn chick cost 40 per ct. less than a Cochin chick.

Sexes were separated when the Cochin chicks were about 15½ weeks old and averaged a little over 4 pounds in weight, and when the Leghorns were about 12 weeks old and averaged a little over 1.8 pounds in weight. At the time of separation the Cochin cockerels averaged about 4½ pounds in weight and the pullets about 3.6 pounds. The Leghorn cockerels averaged about 2.1 pounds and the pullets less than 1.7 pounds.

The food cost of the increase in weight made by the Cochin chicks was over 12 per ct. less per pound than for that made by the Leghorns. The cost of food for the Leghorn pullets during the next 3½ months after the sexes were separated was 35 per ct. less per fowl than for the Cochin pullets. Deducting from the cost of growing all the chicks the market value of the cockerels at the time they were removed, would give a net cost for each Leghorn pullet in November 20 per ct. greater than that of a Cochin pullet. With the Cochin chicks the sexes were in about equal numbers, but there were 37 per ct. more Leghorn pullets than cockerels — an unusual excess. Had the numbers been equal, at the same poultry value and proportionate cost of growing, the net cost of

[18] Rpt. 12:214–218 (1893).

each Leghorn pullet would figure the same as that of each Cochin — the average weight of the former being a little over 2.8 pounds and of the latter a little over 5.5 pounds. With the prices then prevailing this cost was a little less than 14 cents.

THE QUESTION OF MECHANICAL CONDITION OF THE FOOD.

In some form grain must usually constitute the larger part of the food for poultry, and among the questions constantly brought to attention was that concerning the relative efficiency of ground and whole grain. There were many reasons that would favor the use of whole grain, among them the saving of time in feeding and the expense of grinding with the possibility of inducing exercise by scattering the food. If ground foods were fed there was the possibility of often using cheaper by-products and in mixtures of ground grain more nitrogenous materials than any of the ordinarily available whole grains. The general practice of successful poultrymen was to feed both whole and ground grain.

To get some data suggesting the relative efficiency of whole grain and of ground, feeding experiments[19] were made, using one ration containing only whole and dry grain and another in which for the first season three-eighths and for the second one-half of the grain food was ground and moistened. There were fed for two successive years on the contrasted rations four lots of hens, two pens of Leghorns representing one type, and two pens of Cochins representing another.

With the exception of using wheat bran and wheat middlings instead of ground wheat, the same grains were fed ground that were fed whole in the contrasted ration. Corn, however, was cracked to the size of the smaller grains fed, which were wheat, oats, buckwheat, barley and flaxseed. Fresh bone was regularly fed to each pen and some succulent vegetable food and part of the time skim milk.

During the first season the consumption of food was greater under the whole grain ration for both breeds, and during the second season was still somewhat greater for the Leghorns, but about alike under both rations for the Cochins. During both years egg production by the Leghorns was greater under the ration with ground grain, the difference being slight the first year and more pronounced the second year. The excess was only a little over 3 per ct. the first season and over 17 per ct. for the second. With the less active

[19] Buls. 90 and 106; also in Rpts. **14**:494–516 (1895) and **15**:666–687 (1896).

Cochins, egg production was better both seasons under the whole grain ration, the excess being about 36 per ct. the first year and about 33 per ct. the second.

For the same egg production there was taken by the Leghorns under the whole grain ration about 19 per ct. more food during the first season and about 23 per ct. more during the second season. By the Cochins there was used for the same egg production during the first season over 20 per ct. more food under the ration with ground grain and nearly 30 per ct. more during the second season.

During 154 days of the first year covering the chief part of the laying season, there were produced by the Leghorns under the ration with ground grain about 8 per ct. more eggs at the rate of one pound of eggs for every 3.3 pounds of dry matter in the food as against one pound of eggs for every 4.2 pounds of dry matter in food under the whole grain ration. During a period of 140 days covering the chief part of the second laying season about 13 per ct. more eggs were produced under the ration with ground grain, at the rate of one pound for every 3.2 pounds of dry matter in the food as against one pound for every 3.7 pounds of dry matter in the food under the whole grain ration.

During a period of 182 days, including the chief part of the first laying season, about 35 per ct. more eggs were produced by the Cochins under the whole grain ration. For the same egg production 20 per ct. more food was used under the ration with ground grain. For the second year during a period of 259 days, covering most of the laying season, 15 per ct. more eggs were produced under the whole grain ration; and for the same production 17 per ct. more food was used under the ration with ground grain.

In this experiment as in others the results varied with the type of fowl as with the character of the ration.

It was thought that one reason for better results from the whole grain ration with the naturally inactive Cochins was the much greater amount of exercise induced by feeding the grain scattered in straw.

FURTHER EXPERIMENTS WITH THE WHOLE AND GROUND GRAINS IN COMMON USE.

Feeding experiments[20] with chicks and also with capons were made in connection with this study of relative efficiency of the ordi-

[20] Bul. 126; also in Rpt. **16**:561–578 (1897).

nary whole and ground grains. In these feeding trials it was chiefly sought to compare rations of foods ordinarily available and commonly used, contrasting the whole and ground grain foods. While there were minor differences in chemical composition the rations were made to correspond as closely as possible without feeding unusual products and not omitting the grains and by-products in general use. The differences were much less than would exist between the two types of rations commonly fed. There were fed wheat, cracked corn, barley, oats, granulated oatmeal, fresh bone, skim milk, dried blood, wheat bran, wheat middlings, ground oats and corn meal.

Two lots of chicks (of several Asiatic breeds) were fed from hatching to the age of three months, and afterward four lots of capons for about six months. The grain food of one ration consisted entirely of whole or cracked grain and of the contrasted ration entirely of ground grain. Skim milk was fed freely to both lots, some fresh bone and part of the time blood meal, and also for the chicks some green forage.

Considerably more food was eaten by the chicks under the ground grain ration and the growth was faster. Although more food was taken for the same increase in weight under the ground grain ration the cost of growth was less owing to the lower prices for the ordinary ground grain products than for whole grains.

The chicks fed ground grain from the start averaged one pound in weight at six weeks of age, and those having whole grain averaged one pound at seven weeks of age. At ten weeks old the lot fed ground grain averaged two pounds in weight, and the lot having whole grain 1.8 pounds. When the lot having whole grain averaged three pounds in weight at thirteen weeks of age the lot having the ground grain averaged 3.3 pounds. The chicks of both lots, and later the capons from these same lots, remained in equally good health throughout the trials.

The cockerels were caponized and continued under the contrasted rations for several months longer. For a little more than two months after caponizing the lot having the ground grain continued to make somewhat the faster growth; after that the other lot increased in weight faster and attained at maturity practically the same average. The greater consumption of food found with the chicks under the ground grain ration continued with the capons and more food was taken for the same rate of gain, so the cost of added weight was somewhat greater under the ground grain ration.

As the birds approached maturity a less expensive gain was made by birds of equal age under whole grain, but birds of equal size had made cheaper gains under the ground grain ration. The average weight of ten pounds was attained by the capons fed ground grain when 6.5 months old, at which age the contrasted lot averaged but 9.5 pounds in weight, although the total cost per fowl for food from hatching was slightly less. At nine months of age the ground grain lot averaged 11.5 pounds in weight, which average was not reached by the whole grain lot until ten months of age. At equal weights the total food cost from hatching was in favor of the lot having ground grain.

In the other feeding trial two lots of capons, similar in every way, were used. These were not fed the contrasted rations until caponized, and had been grown together on a common ration.

For the whole time that these capons were fed as well as during the earlier periods of most rapid growth more food was consumed under the ground grain ration. The growth was also enough faster to make the ratio of gain in weight to the dry matter in the food slightly in favor of the ground grain, as well as the cost of added weight.

The results from these feeding trials were on the whole somewhat in favor of the rations of ground foods; for faster growth was made, and at the prices then prevailing, at less cost. In the matter of healthfulness no difference appeared.

ANIMAL FOOD FOR POULTRY — THE IMPORTANCE AND ECONOMY OF ITS USE.

The necessity of having enough nitrogenous matter in the food to supply material for the growing body was known and the fact was becoming more generally recognized that this must be derived from a limited bulk of food. To make up for the small proportion of protein existing in the foods that must be utilized, products of various kinds rich in nitrogenous constituents were used to improve the ration. Different results with rations of similar "composition," so far as proportions of ordinary groups of constituents went, seemed often due to varying palatability of the foods used, but not always.

To get some suggestion as to the relative efficiency of the constituents grouped as total protein in the grains and animal products, a number of feeding experiments[21] were made. In the first series

[21] Buls. 149 and 171; also in Rpts. **17**:45–63 (1898) and **18**:75–124 (1899).

four lots of chicks, two lots of pullets, two lots of cockerels and two lots of ducklings were fed on contrasted rations in one of which all of the protein, except a small proportion derived from skim milk or skim milk curd, was supplied by vegetable food, mostly grain, and in the other much of the protein came from animal products, principally animal meal, with a little fresh bone, skim milk and blood meal.

Feeding was begun with two lots of chicks when four days old and with two other lots when three weeks old. After the cockerels were separated, in one case at twelve weeks and in the other at twenty weeks of age, the pullets were continued on the contrasted rations, and two lots of cockerels were fed for twelve weeks. The nutritive ratio of the ration containing animal food was on the average somewhat the wider, but the total amount of protein supplied per fowl was about the same under both rations.

For the whole period in each case, and especially during the earlier stages of growth, more food was eaten under the ration in which about two-fifths of the protein was supplied by animal food, and growth was much faster. As the birds approached maturity the difference in rate of growth became less or for a time was reversed, but never enough to permit the birds under the vegetable food ration to overcome the advantage that had so long been with the contrasted lot. The most noticeable result was the much more rapid and more profitable rate of growth under the animal food ration. Several pullets in the lot fed animal food commenced to lay nearly a month before any in the contrasted lot.

The contrasted feeding with the ducklings was begun so soon as they had learned to eat and was continued by weekly periods for ten weeks, and after modification of the ration, for five weeks longer; one lot being also fed another month on a reversed ration. The grain mixtures used in the "vegetable food" ration being less palatable to the ducklings than to chicks, it was modified by addition of corn meal, etc. The ration in which about one-half the protein was derived from animal food had, on the average a somewhat wider nutritive ratio, but owing to greater consumption supplied more protein per fowl. Except at the start, however, more protein per pound live weight was supplied by the ration containing, aside from the skim milk, only vegetable food.

With the ducklings the ration containing the large proportion of animal food gave much better results from the start, permitting rapid growth with vigorous health, while under the contrasted ration growth was slow and uneven and a lack of vigor apparent.

Although growth was seriously checked under the inefficient ration, the possibility of a fairly rapid growth under a better ration later was not altogether prevented. When the ducklings that had been fed the poorer ration for nearly sixteen weeks were changed to the animal food ration for a month there was at once a much more rapid increase in weight, but the birds never attained the full size reached by the other lot.

The average weight of one pound was attained by the ducklings having the animal food three weeks sooner than by the contrasted lot, and at seven weeks of age the average weight of three pounds as against one pound. The average weight of about 4.5 pounds was reached at nine weeks when the average for those fed the vegetable food was about 1.5 pounds.

The rations in which from 40 to 50 per ct. of the protein came from animal food gave in every trial more economical results than the rations in which most of the protein came from vegetable food—as usual chiefly different grains.

In this first series of experiments the effects of the rations compared were plain enough, but it was not certain how much the results were influenced by the difference in palatability of the two rations. This difference was not very apparent with the chicks and cockerels, but was quite evident in the case of the ducklings. With the foods then available this inferior palatability of the one ration could not be entirely remedied except by addition of too large a proportion of materials that could not class as vegetable. During the next season a second series of feeding experiments was continued in which a similar contrast of rations was provided, but by using an exceptional variety of grain foods rations were made which did not seem to differ as to palatability. There was little difference in the protein content between the two rations, but in the one vegetable food only was used, while in the other about 37 per ct. of the protein was derived from animal food.

Ten lots of chicks were fed these rations, also six lots of immature pullets, two lots of ducklings, two lots of young hens and two lots of old hens.

The results of feeding were like those of the first series of feeding trials. With every two lots of chicks contrasted, those having the animal food ration consumed more food, the excess varying from 12 to 34 per ct., and made a faster growth by from 22 to 100 per ct. The amount of dry matter in the food required for each pound gain in weight varied from 3.6 to 4.4 pounds under the animal food ration and from 4.3 to 6.8 pounds under the vegetable food ration. By chicks having animal food the average weight of one pound was reached by different lots from one to three weeks sooner, and the average weight of two pounds from three to four weeks sooner than by contrasted lots.

With each two lots of young pullets fed those having the animal food made faster growth than those having only vegetable food. In only one period was more food consumed by any lot under the ration of vegetable food, the excess in this instance being about 5 per ct., while in other instances there was a difference in consumption of from 14 to 37 per ct. in favor of the animal food, and in but one period was less food required under the vegetable food ration for the same increase in weight.

The two lots of ducklings were fed the contrasted rations for a month, commencing when they were one week old. By the end of four weeks' feeding those having only the vegetable food suffered so in health (one-half having died, and the survivors not gaining in weight), that a modification of the ration was made during three weekly periods by addition of some animal meal. After a few days on the changed ration there were no further losses, and the rate of growth rapidly increased. A fairly vigorous condition being restored, the birds were put back on the ration of vegetable food for two weeks, during which time the rate of gain in weight rapidly diminished. These retarded ducklings at ten weeks of age were then fed the standard animal food ration and at once began to make a steady and fairly rapid growth, increasing in weight during the five weeks about 140 per ct., though they never attained to quite the average weight reached by the contrasted lot at an earlier age.

The ducklings having the animal food continued from the start in vigorous health, making a steady and rapid growth, which during the first month was at the rate of one pound gain in weight for every 2.6 pounds of dry matter in the food as against six pounds required by the other lot. Up to ten weeks of age they made one pound gain in weight for every 3.3 pounds of dry matter in the food. With the help of three weeks on the modified ration the lot started on vegetable food only averaged during the nine weeks five pounds of dry matter in the food for each pound gain in weight. The average weight of five pounds was attained about a month sooner by the one lot, when the other lot averaged but little over two pounds in weight.

The two lots of young hens, or pullets in their first laying season, that were fed these rations had been grown on rations similarly contrasted which had been fed to them since they were hatched. The vegetable food ration, however, which the one lot had while growing included some skim milk and curd. The records under the final rations cover about seven and one-half months including the greater part of the laying season, although some of the pullets in both lots had been laying for several weeks under the first ration, those having the animal food starting a few weeks the sooner. Under the final rations over 30 per ct. more eggs were laid and about 13 per ct. more food was consumed by the hens having animal food, at an average rate of 3.7 pounds of dry matter in food for each pound of eggs. The contrasted lot produced one pound of eggs for every 4.3 pounds of dry matter in the food.

The two lots of older hens in their second laying season had been treated alike under average rations until this feeding trial began. During six and one-half months covering the greater part of the laying season the hens having the ration with animal food laid over 36 per ct. more eggs and ate nearly 15 per ct. more food than those of the contrasted lot, one pound of eggs being produced for every 4.3 pounds of dry matter in the food as against a ratio of one pound for every 5.5 pounds for the hens under the vegetable food ration.

With the two lots of younger hens already under contrasted rations the difference in egg production was apparent from the start. With these older hens no great difference in laying was shown on the average for the first twelve weeks, although for the first eight weeks production was considerably greater under the vegetable food ration; but after this more than twice as many eggs were laid by the hens having the animal food, no decrease in production occurring with them during the last twelve weeks of the trial.

During several months cockerels were kept most of the time in the several pens. They were fed separately and alternated frequently to obviate any general differences attributable to individual males. Eggs were tested several times as to fertility and hatching power. With the younger hens there were more fertile eggs, fewer weak germs, and a larger proportion of chicks hatched from the tested eggs from the lot fed animal food. With the older hens the percentage of fertile eggs was larger from those fed animal food, but there was little difference in the vitality of the germs.

From two other lots of older hens fed for a few months these same contrasted rations the eggs showed no difference in percentage of fertility; but there were fewer weak germs in the eggs and more chicks hatched from tested eggs from the hens fed animal food. No general differences appeared in the size attained by the chicks hatched from the contrasted lots nor in vigor of the growing chicks.

Little or no difference in nutritive value of the eggs was indicated by chemical analysis. Preferences as to table quality of different lots of eggs as tested by ten families did not coincide, though general opinion seemed influenced favorably by the usually darker colored yolks and firmer appearance of eggs from hens having animal food, while any preference as to flavor was as a rule in favor of eggs produced under the vegetable food ration, which consisted of course almost entirely of grains and grain by-products.

In the second series of experiments the results were again plainly in favor of the ration in which about 37 per ct. of the protein was derived from animal food. The contrasted ration in which all of the protein was of vegetable origin did not seem to any extent inferior in palatability. The most noticeable difference as to consumption was with the ducklings, but while the amount eaten per fowl was less, the amount eaten per pound live weight was much greater under the ration of vegetable food. While the rations differed little as to protein content there was, as in the first series, considerable difference in the amounts of ash or mineral matter, due chiefly to the large percentage of bone carried by the meat meal used. It was not evident to what extent the results were determined or influenced by this factor.

In the third series of experiments the contrasted rations differed little as to amounts of the several groups of constituents ordinarily considered. By the addition of bone ash to the one ration, all the organic matter of which was derived from vegetable food, the proportion of total mineral matter was made to equal or slightly exceed that in the contrasted ration in which about 36 per ct. of the protein came from animal food.

These rations were fed to six lots of chicks, two lots of ducklings and two lots of laying hens, using in all about 580 birds. Recorded feeding was begun with the chicks and ducklings when about one week old and continued to the age of twelve weeks. The three lots of chicks having the ration with animal food ate more than the contrasted lots by from 9 to 16 per ct. The rate of growth varied a little, but on the whole was nearly alike under the two rations. In every instance somewhat less food was required for the same increase in weight under the ration or vegetable food supplemented by bone ash than under the ration containing animal food, the average amount of dry matter in the food taken for each pound gain in weight being not far from 4.3 pounds under the one ration and 4.8 pounds under the other.

The ducklings having the animal food ate on the average about 26 per ct. more food than those with the contrasted ration, though during three different periods they ate less. The consumption of food per pound live weight was greater under the ration of vegetable food. Up to ten weeks of age the gain in weight was 65 per ct. greater under the ration with animal food, one pound increase in weight being made for every 3.3 pounds of dry matter in the food as against one pound for every 4.3 pounds under the contrasting ration. At ten weeks of age the average weight was 5.7 pounds for the one lot and 3.7 pounds for the other, and at twelve weeks 6.4 pounds and 4.7 pounds, respectively, the advantage being with the ducklings fed animal food; these birds reaching the average weight of five pounds about a month sooner than the others.

There was no loss in either lot, and the ducklings seemed in equally good health under both rations. With the ration wholly of vegetable origin, supplemented by bone ash, the ducklings made a moderate, regular and apparently healthful growth, though much slower than with a ration containing animal food. The chief disadvantage of the less efficient ration was the much slower growth, for the birds ultimately attained the size of those more quickly grown.

The two lots of hens were fed the contrasted rations for seven months, covering the principal part of the laying season. They had been laying well for two or three months before the recorded feeding began. The average food consumption under the two rations was almost exactly the same. For nearly six months there was very little difference as to laying, the average amount of dry matter in the food for each pound of eggs produced being 2.8 pounds for the hens fed animal food and 2.9 pounds for the contrasted lot. After this time the falling off was more rapid for the hens having the vegetable food ration. No general difference was noticed in regard to molting.

A cockerel was kept with each lot for over three months, these males being alternated between the pens by frequent changes and fed in part separately. Five hundred eggs, in all, from each lot were examined and incubated. Of the eggs from hens fed the ration with animal food, 86 per ct. were fertile, 19 per ct. of the fertile eggs had weak germs, and 77 per ct. of the tested eggs hatched strong chicks. Of the eggs from hens fed vegetable food, 78 per ct. were fertile, 34 per ct. of the fertile eggs had weak germs, and 64 per ct. of the tested eggs hatched strong chicks. No difference in the vigor of the chicks from the two lots while growing was apparent.

Summary of the three series of experiments. These experiments with animal food may be summarized about as follows:

Of rations which contained practically the same proportions of the groups of constituents ordinarily considered, those wholly and those very largely of vegetable origin proved much inferior for growing chicks to other rations, higher in ash content, containing animal food. When the deficiency of mineral matter was made good by the addition of bone ash, vegetable food rations for chicks equaled or somewhat surpassed in efficiency corresponding rations in which three-eighths of the protein was derived from animal food.

For laying hens rations containing animal food proved superior to others in which all or most of the organic matter was derived from vegetable sources. The vegetable food ration supplemented by bone ash proved equally efficient for several months, but egg production held up longer under the animal food ration, and the eggs were better for hatching.

Rations containing animal food proved very much superior for ducklings to rations wholly or largely of vegetable origin which, according to the ordinary methods of estimation, had practically the same nutritive value. A ration of vegetable food supplemented by bone ash proved inferior to another ration of similar "composition" in which three-eighths of the protein came from animal food. The ash-supplemented ration seemed palatable and equally healthful, but failed to induce a rapid growth, though permitting ultimate attainment of full size.

THE PROPORTION OF ANIMAL FOOD IN THE RATION FOR DUCKLINGS.

Under ordinary conditions grain or grain products of some sort must constitute the larger part of all rations for poultry, but the grains usually available contain but a small percentage of mineral matter. In the experiments recorded it was found that rations containing animal food gave better results than those consisting

largely or altogether of grain food. With abundance of green forage and grit the result was the same.

With chicks this advantage did not appear when care was taken to supply abundant mineral matter to the vegetable food ration, made more than usually palatable by using a large number of foods not always available. But with ducklings[22] a ration entirely of vegetable origin always proved inferior; and it seems necessary with all except costly or very unusual feeding materials to use considerable animal food for the most satisfactory results. In most of the feeding experiments from 35 to 40 per ct. of the protein in the efficient rations was derived from this source. To learn how much animal food in the prepared commercial forms could be used safely, and to get suggestions as to the proportion ordinarily desirable, supplementary feeding trials were made.

No injury to the health of ducklings appeared at any time when different animal foods were moderately or quite freely used.

Two lots, one two weeks old and the other seven weeks old, were fed for four weeks a ration in which 94 per ct. of the dry matter and 98 per ct. of the protein came from animal foods. Growth was about like the normal rate under efficient rations. Later the ration derived over 90 per ct. of its dry matter and nearly 97 per ct. of its protein from the animal foods. These animal products consisted of "meat meal," "animal meal," dried blood, bone meal and milk "albumen." Nothing else, besides sand and water, was fed except some green alfalfa. The nutritive ratio of the ration was excessively narrow, not wider than 1:1. No injury to the health of the birds was apparent, though some of them were from inferior and somewhat weaker stock than usual.

An experiment with four exactly similar lots of ducklings was made in which the rations differed according to the amount of animal food. The proportion of the total protein of the ration derived from this source was approximately 20 per ct. for the first lot, 40 per ct. for the second, 60 per ct. for the third and 80 per ct. for the fourth. So far as general experience went this grouping seemed to overlap the limits of most efficient feeding. To avoid any differences in amount of ash, and to prevent any possible deficiency of total mineral matter in any ration, bone ash was added to the three rations in varying proportion to compensate for the large percentage of bone carried by the animal meal fed. The re-

[22] Bul. 259; also in Rpt. 23:31–44 (1904).

corded feeding was begun when the ducklings were one week old and was continued for ten weeks.

During the first three weeks less food was required for the same increase in weight and the rate of growth was fastest for the lot having the "60 per ct. ration." Up to eight weeks of age the greatest increase in weight was made by this lot, and the average amount of food per pound gain was no greater than for any other lot. On the average for the entire time the amount of dry matter in the food for each pound gain in weight was greatest for the lot having the most animal meal, or the "80 per ct. ration," the amount required by the other lots being about alike. During the later periods (and also for a time by the same lot under a more fattening ration) growth was made at a somewhat more economical expenditure of food under the ration in which 20 per ct. of the protein came from animal food, but was slower. Under the rations containing larger proportions of animal food marketable size was reached about two weeks sooner. At twelve weeks of age the largest birds in the lot fed the "80 per ct. ration" exceeded the largest in the lot fed the "20 per ct. ration" by about 18 per ct. The largest in the other two lots were intermediate in size.

Results on the whole favored the use for the first four weeks of a ration in which 60 per ct. of the protein came from animal food, and later, rations containing larger and increasing proportions of grain foods.

THE IMPORTANCE OF MINERAL MATTER AND THE VALUE OF GRIT FOR CHICKS.

With rations composed of the grains and foods in ordinary use the benefit derived from addition of the animal by-products lies in several directions. Almost always they make good a lack of protein and generally they improve the palatability; but sometimes when the ration is palatable enough and supplies enough protein the benefit is chiefly due to the mineral matter they contain. The addition of bone ash alone to rations, otherwise entirely of vegetable origin, was found to bring them equal in efficiency for growing chicks to similar rations with animal food. It was not certain to what extent such inorganic material was of direct nutritive value and how much of purely mechanical assistance. Much of the bone ash was in particles like sand, and when sand was added to the food of chicks better results followed.

In collecting information on this point and to get further suggestion as to the availability of inorganic lime and phosphorus, a number of feeding trials[23] were made, and the results of several with chicks were reported. Nineteen lots of chicks were used. Rations without animal food and others with animal food were fed, some in each class having an ash content lower than usual, some a medium content and others higher than usual. To these rations were added in varying proportions clean glass sand, Florida rock phosphate ground to flour, ground oyster shell, bone ash, sand and ground rock, sand and ground shell, or bone ash and ground shell.

A brief summary of the results in general from these feeding trials is about as follows:

The mixing of sand in the food, both in a ration containing animal food and one without, resulted in better health for the chicks and more efficient use of the food.

The addition of raw, ground Florida rock phosphate and sand to rations both with and without animal food resulted in better growth and more efficient use of the food than when sand alone was added.

The addition of the ground rock to rations without animal food resulted in more rapid growth and more efficient use of food than the addition of sand alone.

The addition of ground rock phosphate to rations both with and without animal food was followed by better growth, and on the whole from less food, than the addition of finely ground oyster shell.

Food mixed with finely ground oyster shell proved less healthful and less efficient than the same food mixed with fine sand.

Mixing bone ash and ground oyster shell in the food resulted in more rapid growth than the mixing of sand alone. But injury to health attributed to the ground shell made the feeding less profitable.

In commenting on the results of these experiments when reporting them, it was suggested that while advantage often followed the feeding of inorganic phosphate from such unusual materials the results were not quoted as recommending the general use of Florida rock and bone ash. Their chief value was in helping better to plan and interpret other experiments. Fine raw or cooked bone is better material for supplying the lack of phosphorus and lime and more profitable to use, especially when so generally associated with other palatable animal matter of high nutritive value; and the advice

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[23] Bul. 242; also in Rpt. 22:37–59 (1903).

was given to feed such when necessary and not bone ash or Florida rock. The insertion of these comments in a conspicuous place at the end of the report of the work was justified, for at once and at intervals after its publication inquiries were received as to how much bone ash and ground rock to feed and where it could be obtained.

THE ADAPTABILITY OF CONCENTRATED BY-PRODUCTS FOR POULTRY FEEDING.

Because the ordinary grains and coarse foods which must usually constitute the bulk of the ration for poultry do not supply the proportion of protein and mineral matter needed at times, concentrated by-products of various kinds are fed. Foods which differ little in protein content as ordinarily determined, or in cost, do not correspond closely in efficiency. Sometimes palatability seems the chief cause for difference, and sometimes the condition of the food as affecting digestibility. Often the reasons for different effects are not very obvious.

The adaptability of many of these materials cannot be satisfactorily determined except by observing the effects of their use under various conditions. As contributing toward knowledge in this line the results from a few feeding trials in which several concentrated by-products were freely used were reported. As young birds show the effects of questionable foods plainer than older ones, young chicks and ducklings were used in these trials.[24] The general results may be summarized as follows:

Of three highly nitrogenous rations fed to ducklings, one containing dried blood and bone meal was associated with much slower rate of growth than one containing animal meal and another containing "milk albumen" and bone meal, though the same amount of food under each ration gave equal increase in weight. The superiority of the two rations seemed due almost entirely to their greater palatability.

Of four rations carrying much concentrated food one containing a large proportion of gluten meals proved inferior, when fed to chicks, to another having in addition bone meal, and much inferior to others in which most of the gluten meal was replaced by animal meal or by a by-product called "milk albumen." Unpalatability seemed to a large extent responsible for the inferiority of the

[24] Bul. 271; also in Rpt. **24**:37–42 (1905).

rations containing much of the gluten meals. The poorest ration was also deficient in mineral matter, the gluten meals carrying very little.

The rations containing "milk albumen," which was of higher grade than usual, were more palatable and seemed more healthful than the others, but owing to the higher price for this food at the time it was not profitably used in the desired quantity. The rations containing animal meal were more profitably fed.

The results and observations in general, like those from other trials, show a greater disadvantage in the free use of foods of uncertain palatability and healthfulness during earlier stages of growth than at any other time.

EXPERIMENTS WITH SWINE.

SUMMARIZED BY
W. H. WHEELER.

CORN SILAGE FOR PIGS.[1]

Some of the first feeding experiments with pigs related to the use of different coarse fodders that had been sometimes fed and often recommended for feeding pigs by writers and speakers.

In the trial of corn silage six pens of pigs (Durocs and Cheshires) were fed during several months in alternating periods of about five weeks, and in a second season two pens were fed during three separated periods and two pens for two periods.

Under a ration including silage more food was always consumed per pound gain in weight than when grain only was fed, and in general the rate of gain in weight was slower the larger the proportion of silage fed. When not more than about 40 per ct. of the total food was silage the rate of growth was sometimes not much behind that under a grain ration. Silage was fed to the extent, in some periods, of from 90 to 95 per ct. of the total food, supplying from 75 to 80 per ct. of the dry matter in the ration.

The results in general were that when corn silage constituted an average of about 70 per ct. of the total food the cost of pork production was considerably more than its market value and nearly 25 per ct. higher than when corn was substituted for the silage.

When not much more than 40 per ct. of the total food was silage the cost of pork production was about the same as when no silage was fed. The valuations of foods and the market value of pork were considerably lower that at the present time. In the later trials when silage constituted in different periods from 30 to 40 per ct. of the total food, growth was at a profitable rate and the ratio of food consumption to gain in weight compared not unfavorably with that under ordinary grain rations.

In four out of six periods when silage was fed the ratio of gain to food consumption was considerably improved when salt was added to the ration at the rate of from ⅛ to ¼ ounce per day for every 100 pounds live weight fed. In the two periods the rations without salt gave but slightly better results. It was noted that

[1] Bul. 22 (1890); Rpts. **9**: 141–151 (1890); **10**: 203, 204, 207 (1891).

though the moisture in the silage ration was six times as much as in the contrasted grain ration 16 per ct. more water was required under it than under the ration of grain.

An account was kept of the manure from several pens and the analyses made showed the manure from the silage fed pens but little inferior in value to that from the other pens. From the average records it was estimated, at the valuations then given to the essential fertilizing constituents in manures, that the manure was worth from $1.80 to $1.90 per year for every 100 pounds live weight fed.

PRICKLY COMFREY.[1]

Two pens of young pigs when fed a ration in which prickly comfrey (green) constituted about 90 per ct. of the total food and supplied about 58 per ct. of the dry matter lost steadily in weight for three weeks. Two lots of older pigs fed comfrey to the extent of over 50 per ct. of the total food, 15 per ct. of the total dry matter being supplied by it, gained in weight, but not at a profitable rate. Two other lots of larger pigs fed a ration in which comfrey consituted about 35 per ct. of the total food and supplied 12 per ct. of the dry matter, maintained a profitable rate of growth though inferior to that usually made under ordinary feeding of grain and skim milk.

With the four lots by which gains were made, those having salt at the rate of about ⅛ oz. per day per 100 pounds live weight required less food for the same increase in weight than those without salt, 13 per ct. less in one instance and about 34 per ct. less in the other.

CLOVER FOR PIGS.[2]

When fresh red clover was fed for several weeks to a pen of young pigs to the extent of about 90 per ct. of the total food the increase in weight was so slow that there was a loss from the grain fed with it even with no value given to the clover. Four other lots of pigs were fed clover to the extent of from 86 to 88 per ct. of the fresh food and with two of the lots there was the same slow and unprofitable rate of growth. The two other lots, having the same ration, with salt added to the amount of ¼ ounce per day for every 100 pounds live weight, made much faster growth but the

[1] Bul. 28 (1891); Rpts. 9: 151–161 (1890); 10: 203 (1891).
[2] Rpt. 9: 152–156 (1800); Bul. 28 (1891).

increase in weight was not at a profitable rate even with the clover rated at less than $1 per ton.

When the clover was fed with corn meal and constituted not more than about 40 per ct. of the total food there was a much more rapid rate of growth and the increase in weight was a profitable one even with the fresh clover rated at over $4 per ton. The ration with the small amount of salt added again gave slightly the better results.

SORGHUM FORAGE.[1]

When pigs that had been fed clover were changed to sorghum there was at once an increased consumption of food. The sorghum was fed as cut in the field, the entire stalk and seed. This was fed to the extent of nearly 90 per ct. of the total food. The increase in weight was much faster than when clover was fed, but under one ration was not at a profitable rate. Under the contrasted ration to which a small amount of salt was added the gain in weight was made at a profit with the fresh sorghum rated at $2 per ton.

Feeding trials during another season showed a profitable rate of growth under rations in which sorghum constituted during some periods over 65 per ct. of the total food. But the increase in weight was much faster and at a lower cost for food when the sorghum constituted from 10 to 12 per ct. of the total food than under the contrasted rations in which it constituted from 56 to 67 per ct. With the sorghum forage placed at a lower valuation the difference in cost was less.

MANGELS FOR PIGS.[2]

Of several coarse foods tried none was eaten entire or without considerable waste except mangels (or beets).

In a preliminary trial for several weeks a pen of pigs fed mangels to the extent of about 90 per ct. of the total food, half the dry matter in the ration coming from them, made a profitable increase in weight. Less dry matter in the food was required per pound gain in weight than is usual under rations not including a large proportion of milk. Another lot fed the same ration with addition of a little salt gained only about half as much in weight and at little profit except with a low price for mangels.

In further experiments with six lots of pigs, in several separated

[1] Rpt. 9: 156–158 (1890); Bul. 28 (1891); Rpt. 11: 283–285 (1892).
[2] Bul. 28 (1891); Rpts. 9: 158–161 (1890); 10: 205, 206 (1891); 11: 284, 285 (1892).

periods of feeding, when mangels were fed with grain, usually linseed meal, it was found that mangels were sometimes profitably fed even in large proportion. Four lots of pigs fed mangels to the extent of from 95 to 98 per ct. of the total food made steady and fair rates of gain. With two lots of Duroc pigs the increase in weight was at a profitable rate and with two lots of Cheshire pigs the increase was less and hardly made with profit. In these periods of feeding there was little difference on the average whether salt was fed or not. In two other periods, with mangels constituting from 95 to 96 per ct. of the food, there was a profitable rate of growth by one lot of each breed, but with salt added to the ration for the other lots (⅛ ounce per day per 100 pounds live weight fed), the growth was slower and unprofitable.

Two similar lots, each containing Poland China, Berkshire, Duroc and Chester White pigs and some of Cheshire cross, were fed mangels freely with linseed meal and some skim milk, with alternating periods when corn meal replaced a larger portion of the mangels. It was found that the increase in weight was made at considerably less cost for food when mangles constituted about 50 per ct. of the total food (about 38 per ct. of the dry matter) than when corn meal replaced them in part so that they supplied only from 9 to 13 per ct. of the total food.

Increase in weight was considerably faster under the rations largely of grain but was secured at a greater cost per pound. The mangels being rated at $3 per ton, the linseed meal at $28, and corn meal at $24 per ton.

OAT-AND-PEA AND BARLEY-AND-PEA FORAGE.[1]

Some limited feeding trials with these fodders, while not conclusive, indicated that only moderate quantities could be profitably used without great waste, and that mixed fodders might vary enough in character to give quite different results. Mixed fodders, especially those including cereals and grasses, are usually in condition for feeding pigs for only short periods.

SALT IN THE PIGS' RATION.[2]

The question of adding salt in small quantity to the ration for pigs that were not fed skim milk or similar products was considered

[1] Bul. 28 (1891); Rpts. **9:** 152, 153, 154, 161 (1890); **10:** 204 (1891).

[2] Bul. 22 (1890); 28 (1891); Rpts. **9:** 148–150, 154–161 (1890); **10: 203 207** (1891).

in a number of experiments. It was generally added in quantities varying from about ⅛ ounce to ¼ ounce per day for every 100 pounds live weight fed. The general results from eighteen different periods of feeding with several lots of pigs were:

With rations of ordinary grain the addition of salt was an advantage, but it was not always when some waste cereal products were fed.

When fresh forage, such as clover, sorghum, comfrey, silage and mixed fodders constituted the larger part of the ration much better results almost always accompanied the use of salt. When grain was fed more freely with the coarse fodders considerably better results on the average were obtained when salt was fed, but sometimes there was little difference.

When mangels were fed in large quantity the addition of salt to the ration was a marked disadvantage in all but one period, which latter did not give results strongly opposed. It was thought that this result was due to the fact that, as mangels contained naturally a much larger proportion of salt that most foods, any added made an injurious excess.

WET AND DRY GRAIN FOOD FOR PIGS.[1]

To get some data on the recurring question as to the relative efficiency of wet and dry grain food two feeding experiments were made, one during summer and one during winter. Four lots of pigs were used, seven and eight in each lot and of five breeds. Only water and several ground grain foods were fed.

In one ration the grain was fed dry and in the other after standing twenty-four hours mixed with water. On the average for several months during the first experiment the same growth was made and on practically the same amount of food, and there was little difference for the several periods of the experiment.

During the second experiment there was on the average, and during both periods, slightly greater increase in weight and at slightly lower expenditure of food under the wet grain ration. Results on the whole did not show much difference in favor of the wet food.

It had been assumed from observation in other feeding that when grain was fed dry it was more evenly distributed among the individual animals in the pen, and the fluctuations in rate of growth during these feeding trials were in accord with this assumption. In

[1] Rpt. 12: 219–223 (1893).

both experiments increase in weight was less regular and there were much wider fluctuations in the individual weekly gains under the wet food ration.

CORN OR CORN MEAL.[1]

A limited experiment was made comparing corn on the cob with an equivalent amount of corn meal for pig feeding. There was not much difference in the amount of food consumed under the two rations, although it was slightly less under the ration with corn meal, but during both of the periods of feeding increase in weight was much faster under the corn meal ration.

Over 30 per ct. less dry matter in the food per pound gain in weight was required during both periods by the pigs fed corn meal and the cost per pound gain was from 16 to 18 per ct. less than when corn on the cob was fed.

FEEDING EXPERIMENTS WITH YOUNG PIGS.[2]

Feeding experiments were made to get data as to the relative rate and cost of growth made by pigs fed with and partly by the sow, and when fed separately, and of those kept with the mother for longer and shorter periods. Detailed data were published from 30 feeding trials in this connection in which pigs of six pure breeds and pigs of seven first crosses were fed. The pigs were fed with the dam until from four to nine weeks old, usually until the age of six weeks, weekly records being kept.

Practically without exception much less food (on the basis of dry matter) was required per pound total live weight fed when young pigs were fed alone than while fed with the sow. With very few exceptions, and these during severe weather, the increase in weight made by the pigs after removal from the sow cost much less per pound than during the period just before separation or even during the first few weeks with the mother. By considering the cost of restoring the weight lost by the sow while giving milk the difference was much greater. In several feeding trials made to determine the cost of bringing back the weight lost by the sow (and this weight was very rapidly restored), it was found that the cost per pound was much greater than the cost of increase with pigs, not far from twice as great as the average with young pigs about two months old.

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[1] Rpt. 12: 235, 237 (1893).

[2] Rpts. 11: 286–290 (1892); 12: 224–234 (1893); 14: 476–493 (1895); 15: 659–665 (1896).

On the average of twenty-six feeding trials, including all of the most normal as to food and season the food cost per pound gain in weight made by pigs during the first period after separation from the sow was about half as much (51 per ct.) as that during the period immediately preceding removal. The difference from the average cost for all the time with the sow was not much less. It was considered that where sweet skim milk was to be used pigs should have the opportunity to feed in part separately from the mother as young as possible. The best time for separating altogether would depend upon the character of the food to be used, the time of year, and the special purpose for which the animals, young and old, were intended.

COMPARISONS OF PIGS OF DIFFERENT BREEDS AND CROSSES.[1]

During four years a number of feeding trials were made with different lots of pigs of five pure breeds and of seven first crosses. In all thirty different lots were fed, some of them for only about three months when young, but most of them for from seven to nine months. Weekly records were kept and most of them published in reports of the station averaged by periods of from three to five weeks.

There was not very great difference on the average in the size reached at any medium stage of maturity, except that pigs of the Small Yorkshire breed were always smaller at the same age than those of the other breeds tried. Pigs of the Yorkshire–Tamworth cross, however, were some of the largest grown, resembling the dam in type, as did also the reverse cross of these breeds, the Tamworth–Yorkshire, which gave smaller pigs. All pigs of both these crosses were white. The pigs of Yorkshire–Tamworth also were in some respects the most satisfactory of any fed. Some of the largest grown were of the Tamworth–Poland China cross. In average size of pigs when farrowed there were in order: Berkshire, Poland China–Duroc cross, Poland China, Tamworth–P. China cross, Yorkshire–Tamworth cross, Tamworth–Yorkshire cross, Duroc, O. I. Chester–P. China cross, Tamworth, Tamworth–Duroc cross, Berkshire–Cheshire cross and the Yorkshire, the average weight for the latter breed being 2 pounds and for the Berkshire 3.4 pounds.

Of three lots fed at one time the Poland China pigs made considerably the more profitable growth, the Duroc next and the Berk-

[1] Rpts. 11: 286–290 (1892); 12: 224–234 (1893); 14: 475–493 (1895); 15: 658–665 (1896).

shire the least profitable. With three other lots of Berkshire, P. China and P. China–Duroc cross no difference resulted from a long feeding trial in cost of pork production, rate of growth or size attained and very slight difference in relation of dressed carcass to live weight. In both these trials, however, the P. China pigs dressed to slightly the better advantage.

In a shorter feeding trial pigs of P. China–Duroc cross made a more profitable showing than others fed, the Duroc, Poland China and Berkshire pigs following in order of profitable growth. In another trial Small Yorkshire pigs made increase in weight at considerably the lowest cost though less pork was produced in the same time by an equal number of these smaller pigs. Pigs of the other lots listed in order of profitable growth were Tamworth–P. China cross, Tamworth, Tamworth–Duroc cross and Poland China.

Another long feeding trial showed slightly the more profitable rate of growth by Tamworth pigs, the Berkshire and Tamworth–P. China pigs giving results about alike and nearly as good as the Tamworth, and the Poland China pigs being not far behind. Pigs of Tamworth–Duroc cross made a considerably poorer showing than any of the others.

In another extended feeding trial Yorkshire pigs again made increase in weight at somewhat the lowest cost per pound, though attaining smaller size than other pigs, averaging at the close of feeding about 30 per ct. lighter than the Tamworths which were considerably the largest of any. The Poland China pigs and those of Tamworth–Duroc cross were not far behind the Yorkshire in cost of production. The Tamworth pigs, though the largest at the end of feeding, had attained their weight at a cost somewhat in excess of that for the other three lots.

With five lots of cross-bred pigs in another long feeding trial the most profitable rate of growth was made by those of Yorkshire–Tamworth cross, those of Tamworth–P. China cross following closely. There was a still further increase in cost of growth for the O. I. Chester–P. China cross. The Tamworth–Yorkshire and Tamworth–Duroc pigs gave nearly the same result in cost of growth which was somewhat less profitable than that made by the other three lots.

BACTERIOLOGICAL INVESTIGATIONS.

SUMMARIZED BY

H. A. HARDING.

While the Bacteriological Department was not created until 1899, problems involving the activity of bacteria have been studied from the very foundation of the institution. In discussing plant pathology reference is made to the work with pear blight,[1] bacteriosis of beans[2] and sweet corn[3] and soft rot of cabbage[4] and cauliflower.

PASTEURIZATION FOR BUTTER MAKING.

Great interest in the struggle against tuberculosis followed the introduction of the tuberculin test about 1890; and about the same time difficulties were met with in manufacturing a satisfactory grade of butter in the attempts at winter dairying which then began to be common. Pasteurization was an agency employed in solving both problems; so that much interest in this subject was felt by owners of cattle, veterinarians, milk handlers and consumers of dairy products. The mingling of the two dissimilar ideas produced a confusion which for a time prevented progress in pasteurization for butter making and caused severe criticism of pasteurization for the city milk trade.

The butter work demanded a cheap and rapid means of destroying the major portion of the germs present, so that those added in the form of a starter might have the desired effect. The continuously-flowing Danish machines had been developed to meet this need.

The city milk trade required the destruction of the disease germs with certainty, but at the same time the consumer expected a well-marked cream line and objected to any cooked flavor. To avoid changes in the physical condition and flavor of the milk it is neces-

[1] See page 142.
[2] See page 125.
[3] See page 132.
[4] See page 126.

sary to pasteurize it at a comparatively low temperature, while to have the desired killing effect the milk must be held at the pasteurizing temperature for a correspondingly longer interval. Accordingly a different type of machine was required for this work.

Since the cheapness and rapidity of action of the continuous flow machines are increased by running them at a lower temperature, the public easily confused the two types of machines. The attempt was generally made to use the continuous machines for pasteurizing milk for all purposes, running them at the low temperatures adapted to the other type. The results were bad from every point of view.

Believing that the low temperature used would account for the poor results, a careful study was conducted of the germicidal action of a continuous pasteurizer when run at different temperatures.[5] This work showed that the temperature was really the keynote to the trouble. When the milk was pasteurized at 158° F. the killing action was quite variable and rarely well marked. When the temperature was raised to 178° F. the destruction was so nearly complete as to leave little opposition to the germs to be later added in the starter. It was further shown that while pasteurizing at 185° F. did not produce a noticeably greater reduction in the germ content it was not attended with any bad effects upon the butter. Since this latter temperature is sufficiently high to destroy the tubercle bacillus it was recommended for use where there was any danger of this organism being present in the milk. The general utility of pasteurization was shown so markedly while these experiments were being conducted that it has been used in our dairy continuously since that time. Its value in combating the spread of tuberculosis was well illustrated in our experience (see p. 112) with tuberculosis in our herd. When the presence of the disease was first detected all of our young stock was found to be infected, and the most probable explanation was a spread of the germs through the use of infected milk. After this date all of the milk which was fed to our calves was passed through the machine at 185° F. Although twenty-five calves were thus raised upon the milk from tuberculous cows not one of them contracted the disease.

TUBERCULOSIS IN CATTLE.

Among the problems which have confronted the dairyman during the past quarter of a century none has presented greater difficulty

[5] Bul. 172; same in Rpt. **18**:127–149 (1899).

and few have been more important than that of tuberculosis. The attempt to stamp out this disease a decade ago failed, largely because of the magnitude of the task and the revolt of the public at the destruction of so much valuable property. Then followed a period of conflicting advice which could not fail to bewilder the dairymen. Just at this stage it was discovered that about one-half of the animals in the Station herd were affected with this disease. Taking advantage of this misfortune, it was decided to follow a plan devised by Dr. Bang[6] of Denmark for ridding the herd of the disease. This plan consisted in dividing the herd on the basis of the tuberculin test and raising the calves from both divisions upon pasteurized milk. The diseased animals were retained for their product and for breeding purposes until they showed signs of physical breaking down, when they were killed. It was shown that when care was exercised the herds could be kept within a few feet of each other and the same men could care for both herds without spreading the contagion.[7] In our case the fifteen diseased animals were replaced by an equal number of sound calves within four years. There seems to be no good reason why the results obtained with the Station herd may not be duplicated by any dairyman who has an otherwise valuable herd which has become affected with this disease.

MILK AND CHEESE STUDIES.

In addition to the study of the ripening of cheese, which is discussed under its own heading,[8] considerable work has been done which is closely related to this subject. Among the abnormalities in flavor or texture which sometimes confront the dairyman there are few which are not commonly referred to the food of the cows. Except in rare instances there is really little foundation for this charge except the fact that it creates less bad feeling to assign as the cause the depraved taste of the animal rather than some negligence of its owner.

Fishy flavor.— We investigated a case[9] where the output of a dairy was rendered unsalable because of a penetrating, disagree-

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[6] Bang, B. The struggle with tuberculosis in Denmark. *The Veterinarian*, **68**:688 (1895).

Bang, B. Tuberculosis in cattle. Appendix, Bulletin 75 of the Department of Agriculture of the State of Pennsylvania (1901).

[7] Bul. 277; same in Rpt. **25**:27–55 (1906).

[8] See page 185.

[9] Bul. 183:179–181; same in Rpt. **19**:36–38 (1900).

able, herring flavor. This flavor was found to be due to the milk of a single cow, the flavor being very pronounced in the freshly drawn milk. The rejection of the product of this cow rendered the remaining output entirely satisfactory. Careful observation failed to show anything in the food which produced this condition, nor could germs be found in the milk which would reproduce the fishy flavor when inoculated into the udder of another cow. A case of a similar flavor in another dairy was recently brought to our attention and the trouble located again in the product of a single cow. In this case the cow had been giving milk for a long period and had nearly dried up. The rejection of her milk was followed at once by a disappearance of the trouble. In both these cases the trouble seemed to be due to some physiological disturbance of the cow, its exact nature not having been more closely determined.

Bitter flavor.[10]— One of the frequent troubles of milk in winter is the formation of a marked bitter flavor. A case of this in the manufacture of neufchatel cheese was found to be due to the milk from a single dairy and probably due to germ action. More recent work with the product of another dairy was rewarded by the isolation of an organism, which was present in large numbers and readily reproduced the bitter flavor when introduced into good milk.

Sweet flavor.[11]— There are various objectionable flavors in cheddar cheese which are referred to indiscriminately as sweet or fruity flavors. While they appear at irregular intervals in the product of any factory, in the aggregate they cause a heavy loss to the dairy industry each year. The study of a large number of cheeses having these flavors indicated that the trouble is probably due to the presence of yeasts. In some cases we were able to reproduce these flavors when making experimental cheese by adding starters of certain yeasts at the beginning of the process of manufacture. Important as this discovery promised to be we were unable to make further progress because of the fact that the methods of recognizing and studying yeasts were not sufficiently developed to permit us to follow the matter and determine the avenue through which these yeasts gained entrance to the milk.

Rusty spot[12] is the name given to small yellowish-red points or patches which sometimes appear scattered quite evenly through the

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[10] Bul. 183-181-183; same in Rpt. 19:38-40 (1900).
[11] Bul. 183:184-187; same in Rpt. 19:40-44 (1900).
[12] Bul. 183:187-193; same in Rpt. 19:44-57 (1900).

mass of cheddar cheese. While this trouble has been confined to a comparatively small number of factories its effect upon their financial returns when it does appear is marked. In a number of cases the factories have been compelled to quit making cheese. These rusty spots mark the point of growth of *Bacillus rudensis* Connell,[13] a species of bacterium which is peculiar in that it produces a marked color. While the affected cheese is entirely wholesome it is unusual, and, remembering the tales which they have heard of poisoned cheese, the intending purchasers view it with distrust.

It was found that an occasional careful steaming[14] of all of the factory utensils which came in contact with the milk or curd resulted in a decrease of this trouble to a point where it rarely caused financial loss.

The question of the original source of the trouble is not settled. If it appeared first in a dairy it would be carried thence to the factory. When it gained a foothold in a factory it would be spread to all the dairies in turn through the whey. It was shown that in a number of cases where the factories had been put in good condition by the steaming process they were frequently reinfected by the milk from the dairies. In such factories it was only when a heavy infection was furnished simultaneously by a number of dairies that any financial loss on the cheese was experienced. As favorable opportunities offer the study of the source from which the farmer's milk becomes infected in such cases is being continued. The results of these studies will be embodied in a later bulletin.

CANNERY TROUBLES.

Few agricultural industries have developed more rapidly in this State than the canning of fruit and vegetables. In 1900 there were reported 511 establishments in the State of New York engaged in such canning. This was a gain of 352 since 1890. These factories used in a year $5,592,463 worth of materials and turned out products valued at $8,975,321.

From the beginning of the canning industry there have been losses because a portion of the goods failed to keep. There is always a small loss, due to leaky cans, but frequently losses occur too large to be accounted for on this basis. These failures are

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[13] Connell, W. T. Discoloration of cheese. Circular of Dept. of Agr., 1897.

[14] Bul. 225; same in Rpt. 21:27–53 (1902).

commonly spoken of by the canners as "swells" and "sours." Cans are said to be swelled when the normally depressed ends bulge outward. When such cans explode or are opened the material contained is usually decomposed, vile smelling and worthless as food. There are at least two classes of exceptions to this description of the contents: Certain fruits often bulge slightly when held over winter in storage, but on opening they are found unchanged and fit for food; and cans which have undergone souring will often swell if kept for a time in a warm place.

The fact that fermentations in general are so commonly caused by the lower forms of plant life has led to the widespread belief that all the difficulties in keeping canned goods could be attributed to the same cause. While it is probably true that a large proportion of the swelling and souring is due to the growth of bacteria within the cans, undoubtedly exceptions will be found. The bacteria which are capable of destroying canned goods are not only of different species, but what is of more importance to the canners, the spores of different species are capable of withstanding different amounts of heating. As a result of this, canners who have been processing successfully at a low temperature for a number of seasons suddenly find themselves in trouble when a more resistant species gets into the cans.

Swelling of peas.[15]— In peas, acid is lacking, the amount of sugar and nitrogen is such as to favor fermentation, and heat alone must be relied upon to prevent decomposition. In 1902 our attention was called to a serious outbreak of swelling in the product of a large factory. In connection with this work we attempted to determine three points: (1) The cause of the trouble, (2) the amount of heating necessary to obviate the trouble, (3) the amount of heating which was allowable without injury to the commercial quality of the peas.

It was found that the trouble was due to the presence of a single species of bacteria in the cans, and it was shown that this germ was able to withstand more heat than had been employed in the factory in canning the peas.

Work at the laboratory showed that heating infected cans at 240° F. for thirty minutes was sufficient to destroy this bacterium. The reliability of these results was demonstrated first by canning a ton of peas at the factory as an experiment with all the conditions

[15] Bul. 249; same in Rpt. 23:47–61 (1904).

under careful control, and later by the use of the recommended temperatures in connection with the entire output of a factory for a season. This temperature, continued for this time, was found to be close to the limit of heating which could be done without injury to the quality of the commercial output.

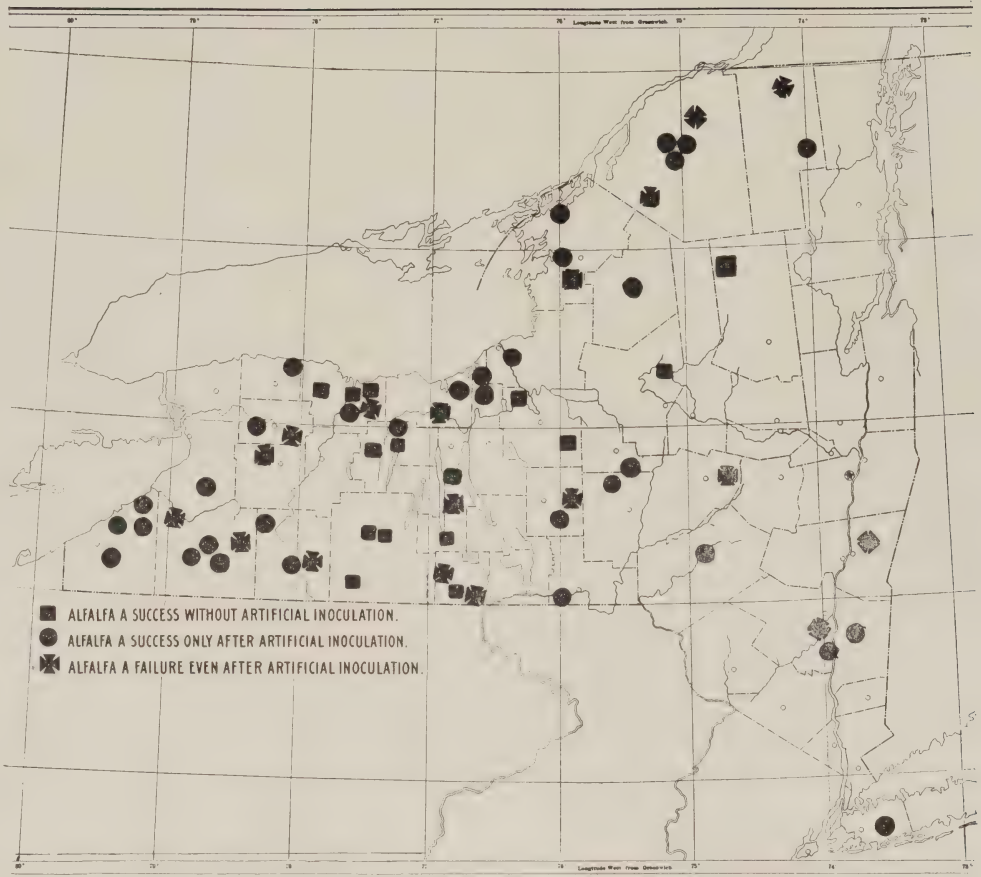
TEST OF COMMERCIAL CULTURES FOR LEGUMES.

The fact that the leguminous plants alone are able to profit by the presence of large quantities of nitrogen in the atmosphere, and that this ability is, in turn, the result of the assistance of certain bacteria living within the roots of the legumes has been known for about twenty years. About ten years ago an attempt was made in Europe to utilize this knowledge in the distribution of the needful bacteria in commercial form, but the effort was not successful. The year 1905 is memorable for the awakening in agricultural circles in the United States of a widespread interest in this subject. As a result of this suddenly awakened interest large quantities of inoculating material were sold to the agricultural public by commercial companies at fancy prices before its real value could be determined by the agricultural experiment stations.

During the winter and spring of this year inquiries were constantly coming to the Station from farmers regarding commercial cultures for inoculating legumes. Many of these inquiries asked specifically concerning the purity and quality of these so-called nitro-cultures. As it was the first season that they had been upon the market, there were no data from which to answer these questions, and accordingly an investigation was planned.

A preliminary examination of these cultures failed to show that there were any living bacteria of the desired kind upon them. In order to add greater certainty to the results a co-operative experiment was planned in which duplicate tests of these cultures were arranged with three other experiment stations and a large commercial firm. As a conclusion from these tests[16] all united in pronouncing these commercial cultures as worthless for practical purposes. Sixteen[17] experiment stations have not joined in denouncing this propaganda of legume cultures dried upon cotton.

[16] Bul. 270; same in Rpt. **24**:45–85 (1905).
[17] Bul. 282; same in Rpt. **25**:109–116 (1906).



MAP II.—LOCATION OF ALFALFA-INOCULATION EXPERIMENTS.

INOCULATION AND LIME IN GROWING ALFALFA.

As has been noted elsewhere (p. 268), this Station has exerted itself for years to extend the growing of alfalfa among the dairymen of the State. Previous to 1905 some work had been done with marked results in supplying inoculation for alfalfa by soil from our alfalfa field, but in 1905 the matter of determining the real need of inoculation for alfalfa growing was taken up. Observations on nearly 200 fields distributed over practically every agricultural county of the State show that only about one-third[18] of the fields are sufficiently inoculated to meet the needs of the plant in this respect.

We have tested the inoculation of the seed with the appropriate germs just previous to sowing and also the application of soil from our alfalfa field as a means of supplying this need.

The application of the cultures to the seed was made in our laboratory and the seed sent by express to the farmers for immediate sowing. The results were entirely negative. The germs failed to induce the formation of nodules on the growing plants in any noticeable way. On the contrary the application of soil from our alfalfa field at the rate of 100 pounds to 200 pounds per acre gave, almost without exception, uniformly good results in the formation of nodules on the plants. In about one-third of the cases this application made the difference between success and failure in the growing of the alfalfa.

In connection with these experiments the effect of lime or ashes applied at the rate of 1,500 pounds of stone lime or its equivalent to the acre was tested in a number of cases. In practically all of these instances the influence of the lime was beneficial, and in some cases it made the difference between success and failure in the resulting crop.

MILKING MACHINES.

Notwithstanding the vast changes which have been made by the introduction of machinery into practically all branches of agriculture, milking cows has until recently retained its primitive place in the division of hand labor. The increasing difficulty of getting sufficient labor on the farms of the State, and the increasing disinclination of farm help to milk cows, has produced a situation which practically demands a milking machine.

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[18] Syllabus of lecture at Normal Institute, Ithaca, November 25–27, 1907.

Machines which gave promise of accomplishing the desired end began to be put upon the market in 1905, and one called the Globe was purchased in December of that year. It was installed the following May and used until it finally broke down in September of the same year. During this time it was used upon eighteen cows with varying success. While it sometimes milked certain cows in an acceptable manner, it often failed to do so, and in some cases was a complete failure from a mechanical point of view.[19] The quality of the milk obtained through its use was also poor. A bacteriological examination of the milk as it came from the machine on thirty-nine trials showed an average of 801,000 germs per cubic centimeter, while thirty-six trials of hand-drawn milk under the same barn conditions gave an average of 16,800 germs per cubic centimeter.

While the results with this machine were not such as to entitle it to be considered as a successful milker, they were distinctly promising in that they were so near a success that they gave strong hopes for the future.

In March, 1907, a Burrell-Lawrence-Kennedy cow milker was installed and is at present in use upon twenty-two cows. The machine obtains apparently all of the milk that the cows are prepared to give, since after-milking by hand does not produce more milk than would be normally obtained by the same process applied after the usual hand milking.[20] The influence of the continued use of the machine upon the productivity of the cows can only be computed after a considerable interval.

The germ content of the milk obtained with this machine is markedly lower than with the machine formerly tested. A large part of this reduction is due to the practice of keeping the milking tubes in a brine solution during the intervals between milkings. A further reduction was brought about by the use of cotton filters to remove the foreign particles from the barn air which entered the machine while in use. When all the details are carefully attended to it is possible to obtain milk with a germ content considerably lower than would be obtained by hand milking under similar barn conditions.

[19] Syllabus of lectures at Normal Institute, Geneva, Nov. 26–Dec. 1, 1906.

[20] Syllabus of lectures at Normal Institute, Ithaca, Nov. 25–27, 1907.

BOTANICAL INVESTIGATIONS.

SUMMARIZED BY
F. C. STEWART.

During nine of the first thirteen years of its existence the Station had no Botanist, so-called. Nevertheless, considerable botanical work of one kind or another has been in progress throughout the entire history of the Station. Much botanical work has been done by the Horticultural Department. The Botanical Department, proper, has devoted most of its effort to the investigation of plant diseases and their treatment, largely because of the great demand for information along this line. Hence, the present article deals chiefly with plant diseases while other lines of botanical activity are discussed in the section on horticultural investigations.

PLANT DISEASES.

Owing largely to the discovery of bordeaux mixture in France in 1885, the simultaneous founding of agricultural experiment stations throughout the United States and the organization of a Section of Vegetable Pathology in the United States Department of Agriculture, the past quarter century has been a period of great activity in the study of plant diseases, particularly in their control, in which field more real advance has been made, probably, than in all previous time. In this work the New York Agricultural Experiment Station has had its full share. For convenience, the Station investigations on plant diseases will be treated by host plants arranged alphabetically by their common names.

APPLE.

Since the apple stands first in importance among cultivated fruits in New York it is proper that the Station should give considerable attention to the investigation of apple diseases. The first such disease studied was fire blight,[1] which causes the new growth of apple

[1] *Bacillus amylovorus* (Burr.) De Toni.

twigs to die suddenly in midsummer. Although fire blight is quite common and sometimes a destructive disease of apples in New York, pear trees suffer most from it. Consequently, in the investigation of fire blight attention was centered on the pear, and the apple given only secondary consideration. Practically all that was done with the apple was the making of cross-inoculation experiments[2] to determine whether the organism causing fire blight of apple was the same as that causing fire blight of pear. Twigs and fruit of apple were artificially inoculated with pure cultures of bacteria obtained from blighted pear twigs. Likewise, twigs and fruit of pear were inoculated with bacteria from blighted apple twigs. In both cases fire blight was successfully reproduced, showing that the disease is the same on the two hosts. The fire blight investigations will be discussed more fully under pear diseases on page 142.

Scab,[3] the most important apple disease, has been given attention commensurate with its importance. Almost all of the work done by the Station on this disease has been in the nature of experiments in its control. Twenty-five years ago almost nothing was known concerning the control of apple scab. In 1883 Prof. Burrill,[4] a noted authority on plant diseases, still living, recommended spraying the trees with *kerosene emulsion!* Chiefly through experiments made by various experiment stations, led by the Ohio Station,[5] we have to-day a treatment for scab which, although not entirely satisfactory, is yet thoroughly practicable and profitable; namely, spraying with bordeaux mixture. The earliest experiments of this Station were with hyposulphite of soda as a spray.[6] This reduced the amount of scab somewhat without injury to the foliage. Another fungicide,[7] a mixture of copper sulphate, ammonia and water, ruined the foliage. Then potassium sulphide and calcium sulphide were tested.[8] The former proved of some value, but calcium sulphide was a complete failure. The first experiments with bordeaux mixture on apples at the Station were made in 1894. In the report of these experiments[9] it was recommended that three sprayings be made as

[2] Rpt. 3:359 (1884).
[3] *Venturia inæqualis* (Cke.) Aderh.
[4] Burrill, T. J. Trans. Mississippi Valley Hort. Soc. 1:206 (1883).
[5] Green, W. J. Ohio Sta. Bul. Vol. IV, No. 9, pp. 193–212 (1891).
[6] Rpts. 4:260 (1895); 5:173 (1896); 6:99 (1897).
[7] Rpt. 6:101 (1887).
[8] Rpt. 7:154–157 (1888).
[9] Bul. 84:19, 29–33 (1895); same in Rpt. 13:663, 673–678.

follows: (1) After the buds break, but before the blossoms open; (2) immediately after blossoming; (3) from ten to fourteen days after the second treatment. This is still the standard treatment. Another result of the experiments in 1894 was a considerable addition to our knowledge of the injury to apples (russeting of the fruit) which sometimes results from the use of bordeaux mixture. Taking advantage of the opportunity offered by the large number of varieties in the Station orchard, the different varieties of apples were classified according to their susceptibility to spray injury. Further investigation of spray injury was made in 1902[10] when the yellowing and dropping of apple leaves were so common in western New York as to cause widespread alarm among apple growers. Although it was proven that much of the trouble was caused by spraying, orchardists were advised, nevertheless, not to discontinue spraying because, notwithstanding the injury, spraying usually did more good than harm.

However, in 1905, when spray injury was more common than ever, many fruit growers began to think seriously of giving up the spraying of apples. This idea became so prevalent that it seemed necessary for the Station to go yet more deeply into the matter in order to discover if possible the exact cause of spray injury and a way to prevent it. This investigation was conducted in 1906 by the Horticultural Department.[11] Some of the principal facts definitely determined were the following:

(1) Bordeaux mixture, no matter how carefully prepared, may cause injury to foliage and fruit.

(2) It is the copper sulphate, and not the lime, which is the injurious ingredient and the greater the amount of copper sulphate the greater the injury.

(3) Wet weather favors the production of the injury.

(4) An excess of lime in the bordeaux does not prevent spray injury nor even lessen it materially.

In the light of these and other established facts the following practical suggestions for spraying were made: "Use less copper sulphate; give the 3-3-50 formula for bordeaux mixture a thorough trial. Spray in moderation; spray to cover the foliage and fruit with a thin film and yet not have the trees drip heavily. So far as possible the bordeaux mixture should be used only in dry weather. Use equal amounts of lime and copper sulphate. Some varieties of

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[10] Bul. 220 (1902); same in Rpt. **21**:67–75.

[11] Bul. 287 (1907).

apples may be sprayed without much fear of injury. Others must be sprayed with great care. Distinguish between varieties in spraying operations. Many varieties of apples are nearly immune to attacks of the scab fungus. These need comparatively light applications of bordeaux mixture in the average season. Bordeaux mixture is the best fungicide known to the apple grower. Its use cannot be given up in fighting the apple scab even though it cause some injury; apple scab causes a far greater loss than bordeaux injury."

In order to test the correctness of an opinion prevalent among New York orchardists in the nineties, namely, that apple trees can be fed so as to enable them to resist scab, one of the Station orchards was for five years devoted to an investigation of the question whether fertilizing the soil liberally with wood ashes may make the apples more resistant to scab.[12] The results show "that with the conditions under which this investigation was made, immunity from apple scab is not at all increased by liberal applications of hard-wood ashes to the soil."

The practice of spraying fruit trees while in bloom having become so common in New York as to threaten (supposedly) the interests of apiarists by the wholesale poisoning of bees, a law was enacted in 1898 prohibiting the practice. Many fruit growers felt this to be a hardship, since they believed that superior results were to be obtained from spraying in bloom. Accordingly, it was arranged that the merits of such spraying should be thoroughly tested in experiments made by the Station in co-operation with the Cornell University Experiment Station. These tests were made in 1900.[13] Briefly stated, the results showed that the claims made for the practice of spraying in bloom were unfounded. Spraying apple trees while in bloom resulted in injury to the blossoms and a decrease in the yield of the fruit. "Even with trees which had a great abundance of blossoms spraying in bloom decreased the yield on the average from one-third bushel to one and a half bushels per tree. Spraying trees at several different times while they were in bloom so as to hit both the early and late blossoms with the spray ruined the crop of fruit."

Investigations on the New York apple-tree canker were carried on during three seasons (1898–1900) and two bulletins on the subject were published.[14] This disease attacks the limbs and trunks of ap-

[12] Bul. 140 (1897); same in Rpt. **16**:316–341.
[13] Bul. 196 (1900); same in Rpt. **19**:351–412.
[14] Bul. 163 (1899); same in Rpt. **18**:331–360; Bul. 185 (1900); same in Rpt. **19**:342–350.

ple trees often causing severe injury. Orchardists had been familiar with the disease for years, but the cause and remedy were wholly unknown. In the course of the investigation it was discovered that the primary cause of canker is a parastic fungus, *Sphæropsis malorum,* well known as the cause of the common black rot of apple fruit. Typical cankers were produced by artificial inoculation of apple wood with pure cultures of the fungus obtained from rotten apples. The fungus was also successfully inoculated onto pear, quince and hawthorn wood. The treatment suggested for canker consists in the removal of diseased limbs, thorough spraying with bordeaux mixture, scraping and washing the trunks and larger branches with bordeaux mixture or with a mixture of whale oil soap, slaked lime, wood ashes and water, and the planting of resistant varieties.

In the autumn of 1902 the apple crop was damaged to an enormous extent by an unusual form of decay called pink rot. Many thousands of barrels of apples were completely ruined soon after they were harvested. An investigation made by the Station showed the cause of the trouble to be a white or pinkish mildew[15] which took possession of the spots caused by the common scab fungus and transformed them into brown, sunken, bitter, rotten spots. It was proven that this pink mildew was unable to force its way through the unbroken skin of the apple and that its principal avenue of entrance is through breaks in the skin caused by scab fungus. This fact being determined the remedy was plain, namely, thorough spraying with bordeaux mixture to prevent scab.[16]

Other apple diseases investigated are the following:

(1) Two decays of stored apples[17] — one a rot similar to pink rot but caused by a different fungus,[18] and the other a core decay the cause of which was not definitely determined.

(2) The fruit spot, which is characterized by brown, sunken spots on the surface of the fruit with pockets of brown, corky tissue underneath. It was shown that neither fungi nor bacteria are concerned in this trouble.[19]

(3) Blisters on the under surface of apple leaves caused by late spring frost, hence called "frost blisters."[20]

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[15] *Cephalothecium roseum* Corda.

[16] Bul. 227 (1902); same in Rpt. **21**:141–162.

[17] Bul. 235 (1903); same in Rpt. **22**:108–116.

[18] *Hypochnus* sp.

[19] Bul. 164:215–219 (1899); same in Rpt. **18**:176–181.

[20] Bul. 220 (1902); same in Rpt. **21**:57–67.

(4) Rust,[21] a disease caused by a fungus which in one of its stages attacks the leaves, fruit and twigs of the apple and in another stage inhabits the red cedar producing the so-called cedar apples. This work was in co-operation with the Iowa Experiment Station and its object was to determine why the cultivated apple in Iowa is exempt from rust so common in New England and on Long Island. Definite conclusions were not reached, but it appears probable that the exemption of Iowa apples from rust is due, in part, to the fact that the varieties planted in Iowa are chiefly those which are rust-resistant.[22]

(5) Belting and russeting of apples due to frost.[23]

(6) A leaf spot caused by the fungus *Phyllosticta limitata*.[24]

(7) Powdery mildew, a fungus disease which is sometimes quite injurious to seedlings in the nursery.[25]

ASPARAGUS.

In New York there is but one really important asparagus disease, namely, rust,[26] which has been destructive every season since its first appearance on Long Island in 1896.[27] During 1899 and 1900 a special investigation was made of rust and its control.[28] At the outset it was suspected that a spray of bordeaux mixture would be effective, but it was found that ordinary bordeaux does not adhere well to the foliage. This difficulty was overcome by the addition of resin to the bordeaux. Another difficulty was the lack of suitable machinery for applying the spray, which made it necessary for the Station to devise an asparagus sprayer. Although the results of the experiments showed plainly that rust may be largely prevented and the yield and quality of asparagus much increased by spraying, Long Island asparagus growers have not adopted the treatment. Many have attempted to avoid rust by planting such varieties as Palmetto and Argenteuil, supposed to be rust resistant, but the results have been unsatisfactory. The California sulphur treatment[29] has not been tested on Long Island.

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[21] *Gymnosporangium macropus* Lk.
[22] Rpt. **14**:535–544 (1895).
[23] Rpt. **14**:544.
[24] Rpt. **14**:545; **15**:454.
[25] Rpt. **11**:663 (1892).
[26] *Puccinia asparagi* DC.
[27] Rpt. **15**:458 (1896).
[28] Bul. 188 (1900); same in Rpt. **19**:122–166.
[29] Cal. Sta. Buls. 165 and 172.

BEAN.

According to the United States Census Report for 1900 New York has 129,298 acres devoted to the culture of beans and produces 26.8 per ct. of the dry beans grown in the United States. Three bean diseases — anthracnose,[30] bacteriosis and rust[31] were studied in 1892.[32] Anthracnose (frequently, but incorrectly, called rust) is a common and very destructive disease, often causing losses of 25 per ct. and sometimes ruining the crop. It being known that anthracnose is transmitted by the seed an effort was made to find some seed treatment by means of which diseased seed could be made safe to plant. Experiments were made in which diseased beans were soaked in hot water and various fungicides, but in no case was there any benefit. In another experiment in which sorted and unsorted seed beans were compared, a much greater amount of anthracnose was found in the crop from the unsorted seed. Spraying experiments, also, were made. Of the three fungicides tested, bordeaux gave the best results. Four applications very nearly doubled the yield of healthy pods. As a result of the experiments the following treatment was recommended:

" 1. Selection of healthy seed.

" 2. Immediate removal of affected seedlings from the field.

" 3. Keeping the foliage covered with bordeaux mixture."

During the investigation of anthracnose it was discovered that there is another common disease of beans, considerably resembling anthracnose, which in some cases may be even more destructive than anthracnose. No doubt it is frequently confused with anthracnose. The leaves become spotted and yellow and the pods show soft, watery spots either with or without a red border. It was in this investigation that the bacterial nature of this disease was established for the first time. The germ was isolated and pods of Lima beans inoculated with pure cultures of it. " These inoculations produced decay at the spots where the virus was introduced, while punctures made at the same time, but not inoculated, showed no signs of decay." Subsequently, the organism was described and named by Dr. Erwin Smith.[33]

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[30] *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav.

[31] *Uromyces appendiculatus* (Pers.) Lk.

[32] Bul. 48 (1892); same in Rpt. 11:531–556.

[33] Originally described under the name *Bacillus phaseoli* (Proc. Amer. Asso. Adv. Sci. 46:288. 1898) which was later changed to *Pseudomonas phaseoli* and finally to *Bacterium phaseoli* (Erw. Sm.) (Bacteria in Relation to Plant Diseases 1:171. 1905).

The true rust of beans was found to be an unimportant disease in New York.

Since 1892 nothing has been done with bean diseases except to note the occurrence of a stem rot probably caused by Rhizoctonia.[34]

BEET.

In 1899 the Station made an investigation of a sugar beet disease complained of by farmers in Yates and Ontario counties.[35] The trouble was characterized by the death of the leaves and a browning of the flesh of the root in its outer layers. It was decided that drought was responsible for the trouble.

One other sugar beet disease, a root rot caused by Rhizoctonia, was given brief study in 1900.[36]

CABBAGE.

Black rot[37] is a destructive bacterial disease in which the leaves show brown or yellowish areas, then wither and fall. Its most characteristic symptom is the blackening of the fine veins in the leaf and the appearance of black streaks in the leaf-stalk and stem. The cause of black rot and the biology of the causal organism were quite thoroughly worked out by Smith[38] in the United States Department of Agriculture and Russell and Harding[39] at the Wisconsin Experiment Station.

These investigators had suggested the removal of affected leaves as a promising line of treatment. Their theory was that by promptly removing from the field the diseased leaves as fast as they appear the disease might be checked.

Owing to an epidemic of black rot in New York in 1898 there was an urgent demand from farmers for information concerning it, and it became imperative that the Station should undertake some experiments on the control of the disease. It was decided to test thoroughly the leaf-pulling treatment.[40] During four consecutive

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[34] Bul. 186:11 (1901); same in Rpt. 19:104.

[35] Bul. 162:165–171 (1899); same in Rpt. 18:153–159.

[36] Bul. 186:12 (1901); same in Rpt. 19:105.

[37] *Bacterium campestre* (Pammel) Smith.

[38] Smith, Erwin F. *Centbl. Bakt.* [etc.] 2 Abt. 3:284, 408, 478 (1899); ibid. U. S. Dept. Agr. Farmer's Bul. 68 (1898).

[39] Russell, H. L., and Harding, H. A. Wis. Sta. Bul. 65 (1898).

[40] In this, as well as all other investigations on bacterial plant diseases undertaken since the organization of the Department of Bacteriology in 1899, the Departments of Botany and Bacteriology have worked in co-operation.

years (1899–1902) an acre of cabbage was devoted to the experiment, one-half the acre being treated and the other half left untreated for a check. During the first three years of the experiment so little black rot appeared in the experiment field that no conclusions could be drawn; but in 1902 the disease was abundant and the conditions excellent for the test. The results were disappointing. "The treatment was even more than a complete failure. It not only failed to prevent the disease, but actually reduced the yield by 5.25 tons per acre."[41] The worthlessness of the treatment was so thoroughly demonstrated that further experimentation with it was abandoned. However, investigations on the disease were continued, one of the chief objects being to determine by what agencies the disease is spread. It was discovered that seed-bearing plants are subject to black rot and that the germ causing the disease is present on the seed of such plants. Moreover, it was proven that the black rot germs may remain alive on the seed for at least eleven months. These were important discoveries, since they show that the disease may be transmitted by the seed. As a cheap, safe and effective method of destroying the germs on the seed the Station recommends soaking the seed, just before planting, for fifteen minutes in a 1:1000 corrosive sublimate solution or a 0.4 per ct. formalin solution. It is not expected that this treatment will give complete protection against black rot, but it will certainly remove all danger of infection from disease germs on the seed.[42]

Since about 1900 the Station, coöperating with the Vermont Station, has had under investigation a bacterial soft rot[43] of cabbage and cauliflower which is especially destructive to seed cabbage on Long Island, where this crop is an important one. Only a preliminary report of this work has been published.[44]

CARNATION.

The Legislature of 1894 made a special appropriation for Station investigations in the Second Judicial Department, which includes Long Island and five counties north of New York city. Floricultural interests being large in this part of the State, it was decided to use a part of the appropriation for the investigation of greenhouse pests. The replies to a circular letter of inquiry sent out

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[41] Bul. 232 (1903); same in Rpt. 22:85–107.
[42] Bul. 251 (1904); same in Rpt. 23:62–78.
[43] *Bacillus carotovorus* Jones.
[44] *Science,* n. s., 16:314 (1902).

to the florists indicated a general desire for an investigation of carnation rust.[45] Although this disease had but recently made its appearance in the United States it was already widespread, and florists were much alarmed over it.

The Station investigations[46] included tests of spore germination in fungicides, soaking the cuttings in fungicides, and spraying experiments. The spore germination tests brought out the fact that, as a preventive of germination, potassium sulphide is much more efficient than copper sulphate. Potassium sulphide solution, strength 1:3000, completely prevented germination; whereas, copper sulphate solution ten times as strong did not wholly prevent germination.

The object of the experiments on the soaking of cuttings was to find a method of killing the fungus mycelium within the tissues without injury to the cuttings. The results indicated that potassium sulphide is better adapted to this purpose than copper sulphate or common salt, but definite conclusions were not reached.

In the spraying experiments weekly applications of copper sulphate solution (2 lbs. to 45 gals.) brought 58 per ct. of the plants through to "lifting time" free from rust, while untreated plants under parallel conditions were all rusty. Potassium sulphide solution (1 oz. to 1 gal.) gave nearly as good results as copper sulphate, but bordeaux mixture (1 to 7½ formula) and salt solution (8 lbs. to 45 gals.) proved complete failures. None of the solutions injured the plants.

In the light of subsequent events it must be admitted that this work on carnation rust was not productive of any important results so far as the practical control of the disease is concerned. Although copper sulphate and potassium sulphide sprays are fairly efficient, as shown by the experiments, few florists now use either to any great extent. At the present time, carnation rust is combated chiefly by giving careful attention to the temperature and moisture in the greenhouse and by the use of rust-resistant varities.

In 1897 it was shown by experiment that common salt solution applied to the foliage of carnations or to the soil in which they are grown will neither prevent rust nor give the plants a more vigorous growth. The popular opinion that common salt has value in the culture of carnations is probably not founded on fact.[47]

In 1899 a brief study was made of an unusual leaf spot disease

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[45] *Uromyces caryophyllinus* (Schrank) Schroet.

[46] Bul. 100 (1896); same in Rpt. 15:461–495.

[47] Bul. 138:635–636 (1897); same in Rpt. 16:423–425.

of carnations caused by a fungus belonging to the genus Fusarium.[48]

In 1900 the discovery was made that the carnation rust fungus is, itself, frequently attacked by a parasitic fungus, *Darluca filum*. This is a well-known parasite of various rust fungi, but up to this time it was not known that it attacks carnation rust. Probably the parasite is not a very important factor in the control of rust.[49]

Studies made by the Station on carnation stem-rot have revealed the fact that there are two distinct diseases passing under this name. One is a dry rot caused by a species of Fusarium and the other a soft rot caused by a species of Rhizoctonia. Both kinds of stem rot are common and destructive. It is believed that the discovery of the true cause of stem rot will lead, ultimately, to successful methods of controlling it. As yet, only brief accounts of the investigations have been published.[50] A more complete report will appear later.

CAULIFLOWER.

Cauliflower, being closely related to cabbage, is subject to most of the diseases affecting cabbage. In the work with black rot and soft rot of cabbage described on page 126, considerable attention was given to these diseases on cauliflower. During four consecutive years the leaf-pulling treatment for black rot was tested in cauliflower fields on Long Island, but the experiments were barren of results because of a lack of the disease.[51] When the treatment was found to be a complete failure on cabbage the experiments on cauliflower were abandoned. Other experiments, on the control of black rot in cauliflower by spraying the plants with resin-bordeaux mixture, were conducted during four years, also. Owing to the absence of the disease nothing was learned as to the value of this treatment.

The experiments on cabbage and cauliflower bring out strikingly a difficulty often met in experiments on the treatment of plant diseases. Frequently it is necessary to carry the experiments through several seasons before the disease appears in sufficient abundance to test the value of the treatment.

In the latter part of August, 1899, the newly-formed leaves of cauliflower plants throughout eastern Long Island showed black-

[48] Bul. 164:219 (1899); same in Rpt. 18:181.
[49] Bul. 175 (1900); same in Rpt. 19:55–60.
[50] *Bot. Gaz.* 27:129 (1899); Bul. 186:26 (1901); same in Rpt. 19:116.
[51] Bul. 232:62 (1903); same in Rpt. 21:104.

ened, shriveled margins. Apparently, the trouble was brought about by bright sunlight following a period of foggy weather. Some farmers, fearing it might be a new disease, were much alarmed, but it proved to be unimportant. A brief account of it was published in one of the Station bulletins.[52]

CELERY.

The only extended investigation of celery diseases conducted by the Station was made in 1892 and the results published in Bulletin 51.[53] The purpose of this bulletin was "to give a brief description of some of these [celery] diseases, to state some of the results of investigations made under the direction of the Station in the summer of 1892, and to collate such other information on the subject of celery diseases as may be deemed reliable and important to celery growers." The subjects treated were center blight, stalk blight, Septoria leaf spot, Cercospora leaf spot, experiments on spraying and the danger from eating sprayed celery.

It was discovered that the Septoria leaf spot attacks all parts of the plant above ground, including the seeds. Hence the disease may be transmitted with the seed and, consequently, spraying to be most effective should be commenced while the plants are in the seed bed. It was shown that celery seedlings may be safely sprayed with bordeaux. In the spraying experiment on celery in the field there was not sufficient disease to warrant definite conclusions as to the value of the treatment. "One of the most important results of the season's work on celery diseases and their treatment is the establishment of the fact that the copper mixtures prepared and applied as recommended in this bulletin may be used in treating celery diseases with no fear of poisonous results." Samples of sprayed celery, stripped and prepared as for market, were submitted to the chemist for analysis. The results showed that in order to secure a dangerous dose of copper by eating celery sprayed with bordeaux mixture, for example, one would need to eat 66,400 heads!

CHERRY.

Of the diseases affecting cherries, leaf spot and fruit rot have received most attention, although other less important diseases have not been entirely neglected.

During 1891 and 1892 the United States Department of Agri-

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[52] Bul. 162:176 (1899); same in Rpt. **18**:164.

[53] Essentially the same in Rpt. **11**:571–585 (1892).

culture coöperated with the Station in some experiments on the treatment of the diseases of nursery stock. Most of this work consisted of spraying experiments.

On cherry stocks tests were made with bordeaux mixture and the ammoniacal solution.[54] The latter injured the foliage some, but the bordeaux did no harm and the trees sprayed with it held their leaves better and made a better growth than untreated trees, which were prematurely defoliated by leaf spot[55] and powdery mildew.[56] In 1893 the experiments were continued by the Station, but no additional information was gained owing to the scarcity of leaf diseases that year.[57]

In 1895 and 1896 experiments were made on the prevention of leaf spot and fruit rot[58] in bearing cherry orchards by spraying the trees with bordeaux and eau celeste.[59] Unfortunately, very little leaf spot appeared in the orchards under experiment, and there was only a moderate attack of fruit rot. The conclusion reached was that the spraying of bearing trees is of doubtful utility. In 1895 spraying with bordeaux injured the foliage; besides, during a considerable portion of the time when the treatment should be given, the use of bordeaux is objectionable, since it remains upon the fruit and injures its market value.

In the spring of 1885 it was discovered that the fruit rot fungus is sometimes responsible for the destruction of large numbers of cherry flowers. A brief study of the fungus was made at this time and the report of this work constitutes one of the early publications on the subject.[60]

In 1901 the interesting observation was made[61] that the leaf spot fungus may attack cherry fruit-stems as well as the leaves. It appears that this had not been previously known.

Other cherry diseases studied more or less are black knot,[62] witches' brooms[63] and leaf scorch.[64]

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[54] Rpt. 11:654–659 (1892).
[55] *Cylindrosporium padi* Karst.
[56] *Podosphæra oxyacanthæ* (D.C.) De By.
[57] Bul. 72 (1894); same in Rpt. 12:688–693.
[58] *Sclerotinia fructigena* (Pers.) Schrt.
[59] Bul. 98:15–17 (1896); Bul. 117:140 (1897); see also Rpt. 15:402–407.
[60] Rpt. 4:280–285 (1885).
[61] Bul. 200:85–87 (1901); same in Rpt. 20:146–148.
[62] *Plowrightia morbosa* (Schw.) Sacc. Bul. 40 (1892).
[63] *Exoascus cerasi* (Fckl.) Sad. Rpt. 14:532 (1895); Rpt. 15:459 (1896); Bul. 191:309 (1900).
[64] Bul. 162:171–176 (1899); same in Rpt. 18:159–164.

CHRYSANTHEMUM.

The common Septoria leaf spot of chrysanthemums being prevalent among plants in the Station greenhouse in the fall of 1891, an experiment on its control by spraying was undertaken.[65] Three fungicides were tested — potassium sulphide, ammoniacal solution of copper carbonate and bordeaux mixture. Bordeaux gave results sufficiently good to warrant the recommendation of its use combined with the careful removal of diseased leaves.

CLEMATIS.

Stem rot, or the decay of clematis plants at the surface of the soil, has long been known as a destructive disease and a puzzle to plant pathologists. In 1884 the Station botanist made an attempt to learn the cause of this disease.[66] A fungus belonging to the genus Phoma was found growing in the decayed roots of diseased plants, and it was suspected of being the cause of the trouble; but positive proof of this was lacking. Up to the present time the cause of the clematis disease has not been definitely determined.

CORN.

While New York is not one of the so-called corn States, corn is, nevertheless, a very important crop here. Fortunately, it is subject to but few diseases, smut being the most important. In some seasons truck farmers on Long Island suffer considerable loss from a wilt disease of sweet corn. Affected plants wilt and dry up without apparent cause. This may occur at any stage of growth, but most commonly about the time of tasseling. The disease is most destructive to early dwarf varieties. The most characteristic symptom of the disease is the appearance of conspicuous yellow streaks within the lower portion of the stem.

An investigation of this disease was made by the Station in 1896 and 1897.[67] Strange to say, it was found to be an undescribed disease and the organism causing it unknown to science. It soon became evident that the cause of the trouble is a yellow bacterium which multiplies to enormous numbers in the water-conducting vessels of the stem, clogging them and thereby hindering the ascent of water from the roots to the leaves. The bacteria-laden vessels appear as yellow streaks in the white pith of the corn stalk.

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[65] Rpt. 11:557–560 (1892).
[66] Rpt. 3:383–385 (1884).
[67] Bul. 130 (1897); same in Rpt. 16:401–416.

Plate VIII.— Sprayed and Unsprayed Cucumber Plats.
Profit from spraying, $163.50 per acre.

Studies were made on the symptoms of the disease and on the biology of the causal organism. Attempts were made to reproduce the disease by artificial inoculation with pure cultures, but the results were unsatisfactory. In experiments on treatment lime and sulphur applied to the soil failed to prevent the disease. It was observed that some varieties of sweet corn are much more susceptible to the disease than are others. Subsequently, this corn wilt was studied by Dr. Erwin Smith of the United States Department of Agriculture, who described and named the causal organism[68] and added much to our knowledge of it.

The only other corn disease studied by the Station is a fungus leaf blight[69] of sweet corn on which brief notes were made in 1896.

CUCUMBER.

Scab[70] is a disease which produces sunken spots on the fruit and stems of cucumbers. It is sometimes quite destructive. The earliest studies on cucumber scab were made at this Station[71] by the botanist, Dr. Arthur, in 1887, shortly before his removal to the Indiana Station, where the work was completed.[72]

The most important work of the Station on cucumber diseases was done during the years 1896–1898, when the value of bordeaux mixture as a preventive of downy mildew was demonstrated. On Long Island the cucumber pickle industry is of considerable magnitude. In the early nineties the yield of cucumbers began to drop off until by 1896 the average yield was scarcely one-fourth of a full crop. The main cause of the reduced yield was the ravages of a fungus disease which causes the leaves to turn yellow and die. This disease, downy mildew,[73] made its first appearance in the United States in 1889 and soon after became widespread. From the apparent success of an experiment in New Jersey[74] and the fact that bordeaux mixture had proven so effective against similar diseases of other plants, such as the grape downy mildew, it was confidently expected that it would control the new cucumber disease,

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[68] Originally described under the name *Pseudomonas stewarti* (Proc. Amer. Asso. Adv. Sci. **47**:422–426. 1898), and later changed by same author to *Bacterium stewarti* (Bacteria in Relation to Plant Diseases, 1:171. 1905.).

[69] *Helminthosporium turcicum* Pass. Rpt. **15**:452 (1896).

[70] *Cladosporium cucumerinum* Ell. & Arth.

[71] Rpt. 6:316 (1887).

[72] Ind. Sta. Bul. 19:8–10 (1889).

[73] *Peronplasmopara cubensis* (B. & C.) Clint.

[74] N. J. Sta. Rpt. for **1895**:304.

and the Station made arrangements to put it to the test. The first experiment[75] was made at Woodbury, Long Island, in 1896. On a field of one and one-half acres seven sprayings increased the value of the crop at the rate of $173 per acre. The expense of the treatment being $9.50 per acre, there was *a net profit of $163.50 per acre.* The following year two more experiments were made,[76] and in 1898 coöperative experiments with farmers were made in three localities.[77] In the later experiments no checks were left. The object was to determine what could be accomplished when entire fields are sprayed under ordinary farm conditions. The disease was kept well under control at a total cost of from $2.43 to $3.39 per acre. Judging from the condition of unsprayed fields in the same localities the spraying was highly profitable. Farmers seeing the excellent results of the experiments soon began spraying. At the present time the spraying of cucumbers is practically universal on Long Island. It is generally conceded that the Station experiments saved the Long Island pickle industry.

Other cucumber diseases mentioned in the Station publications[78] are: (1) Powdery mildew on field-grown cucumbers; (2) dodder on cucumbers under glass.

CURRANT.

The Station has under way a rather comprehensive work on currant diseases, but as yet only three diseases have been treated at length in the Station publications, viz., anthracnose,[79] cane blight[80] and rust.[81]

Attention was directed to anthracnose at the time of an epidemic of this disease in the Hudson Valley in 1901. It causes the leaves to become specked with brown spots of pin-head size, then turn yellow and fall prematurely. The only really new fact discovered was that the anthracnose fungus attacks the wood of the new canes as well as the leaves. However, it was thought best to publish a compilation of what is known about the disease and its treatment for the information of fruit growers who were deeply interested in it.

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[75] Bul. 119 (1897); same in Rpt. 16:345–375.
[76] Bul. 138:636–644 (1897); same in Rpt. 16:425–433.
[77] Bul. 156 (1898); same in Rpt. 17:67–89.
[78] Bul. 164:213–215 (1899); same in Rpt. 18:174–176.
[79] *Pseudopeziza ribis* (Lib. Kleb. Bul. 199 (1901); same in Rpt. 20:123–141.
[80] Fungus undetermined Bul. 167:292–294 (1899); same in Rpt. 18:200–202.
[81] *Cronartium ribicola* Fisch. de Waldh. Tech. Bul. 2 (1906).

During a fruit disease survey of the Hudson Valley made by the Station in 1899, it was learned that currants in that section suffer severely from a disease in which canes here and there suddenly wilt and die. Fruit growers call it cane blight. This disease was originally described by Fairchild,[82] who discovered it in the Hudson Valley in 1891 and ascribed it to the action of a sterile fungus working in the wood. Ever since 1899 the Station has had cane blight under observation without learning any very important new facts about it; but, recently, a thorough investigation of the disease has been undertaken and it is expected that more complete knowledge of it will soon be obtained. Experiments on its treatment, also, are in progress.

In the fall of 1906 the Station currant plantation was found to be abundantly infested with a rust fungus hitherto unknown to America. It appeared as a conspicuous orange-colored powder on the under surface of the leaves. With the exception of a single affected leaf it was not found outside the Station grounds. This rust has been known in Europe for fifty years and is there widely distributed. As a currant disease it is unimportant. The chief danger from it lies in its effect on white pines, which are also attacked by it. Doubtless it is a recent importation from Europe, but just how it came onto the Station grounds is not known. In order to stamp out the disease, if possible, all Ribes plants on the Station grounds were destroyed.

GOOSEBERRY.

The European varieties of gooseberries and their American grown seedlings suffer from powdery mildew[82a] to such an extent that their cultivation is largely prevented in America, notwithstanding their superiority in the size and quality of their firuit. Mildew first appears as a whitish, frost-like growth, covering leaves, young shoots and berries. Later, it becomes brown and felt-like. The efficiency of potassium sulphide spray as a preventive of this disease was thoroughly established by experiments made at this Station.[83] Commencing in 1887 tests were made each year during five consecutive years. The results were highly satisfactory. When the remarkable fungicidal properties of bordeaux mixture became

[82] *Bot. Gaz.* 16:262 (1891).

[82a] *Sphærotheca mors-uvæ* (Schw.) B. & C.

[83] Rpts. 6:349; 7:153; 8:334; 9:307; 10:474; 14:354; 15:342–344; Bul. 133 (same in Rpt. 16:307–315); Bul. 161 (same in Rpt. 18:321–330).

known it was thought by some that this fungicide might be even more effective than potassium sulphide. Lysol and formalin also came into prominence as fungicides about this time. Accordingly, it was deemed advisable to make a series of experiments to determine the relative merits of these four fungicides for the control of gooseberry mildew. The experiments were continued through three years, 1897–1899. Each year potassium sulphide gave the best results. Lysol and formalin also made a fair showing, but bordeaux proved almost valueless. In only one series of tests did the bushes sprayed with bordeaux show less mildew than untreated bushes.

Upon the results of these experiments the Station bases the following recommendations for the treatment of gooseberry mildew:[84] "Spraying should begin early in spring after the buds break and before the first leaves unfold, using one ounce of potassium sulphide for two gallons of water. This treatment is repeated at intervals of from seven to ten days, depending on the amount of rain that comes to wash off the applications."

In Bulletin 167[85] there is given an account of a fungus root-rot of gooseberry bushes observed at Marlboro in 1899.

GRAPE.

Although the grape is one of the important fruit crops of the State, the Station has done very little with grape diseases. One reason for this is that the Cornell Experiment Station made investigations[86] on the subject in 1894. Another reason is that experiments made by the United States Department of Agriculture had shown that the principal grape diseases, black rot and downy mildew, may be controlled by spraying with bordeaux mixture. Yet a third reason is that the Station finds it impossible to do *all* that needs doing.

The experience of the Station on the spraying of grapes with bordeaux mixture for black rot and mildew has been entirely satisfactory. Most grape growers, too, have had fairly good results from spraying. However, in 1905 and 1906, when black rot was exceedingly destructive in certain localities, some growers found it impossible to control the disease. Accordingly, interest in black

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[84] Bul. 170:408 (1899); same in Rpt. 18:427.
[85] Bul. 167:295 (1899); same in Rpt. 18:203.
[86] Cornell Sta. Bul. 76 (1894).

rot investigations has revived and the Cornell Experiment Station has again taken up the work.

In September, 1891, the New York city board of health seized and destroyed large quantities of grapes, on the ground that they had been sprayed with copper compounds and were poisonous. This drastic action aroused grape growers and the Station was requested to investigate the supposed dangerous character of sprayed grapes. Pains were taken to secure the worst sprayed bunches of grapes obtainable from those vineyards from which the condemned grapes came. These samples were analyzed by the Station chemist.[87] It was found that in order "to get an amount of copper that would be regarded as serious, if taken at one dose, one would need to eat not less than 3,000 pounds of grapes, skins included, or not less than 500 pounds, including berries and stems." These results are in harmony with those obtained in similar analyses made in Germany and France. The conclusion is "that it is simply an absolute impossibility for a person to get enough copper from eating grapes to exercise upon the health any injurious effect whatever."

HOLLYHOCK.

In May, 1889, hollyhock plants in one of the Geneva nurseries and also some on the Station grounds were found to be suffering from a disease new to this locality.[88] Specimens of it were sent to three mycologists, all of whom pronounced it the true hollyhock rust, *Puccinia malvacearum*. It appears that this fungus had not been found previously in New York. In fact it had made its first appearance in the United States only three years earlier. Dr. Farlow[89] records its occurrence in Massachusetts in 1886. At present it is a widespread and destructive disease throughout the United States.

At the Station, unsuccessful attempts were made to control the disease by spraying the plants with potassium sulphide and with a solution of common salt.

LETTUCE.

No extended study has been made of lettuce diseases. Only three diseases of this plant have been discussed in the Station publications; viz., a Septoria leaf spot[90] which was very prevalent on

[87] Rpt. **10**:401–403 (1891).
[88] Rpt. **8**:335 (1889).
[89] *Bot. Gaz.* **11**:309 (1886).
[90] Rpt. **4**:277–279 (1885).

the Station grounds in 1884 and 1885; lettuce mildew;[91] and a damping off and leaf rot caused by the fungus Rhizoctonia.[92]

LILY.

Two destructive lily diseases were studied in 1895.[93] One of these was an Easter-lily disease which was causing florists much trouble and loss at that time. It is characterized by the spotting and distortion of the leaves and flowers which gives the plants a sickly, yellowish, rusty appearance, making them unsaleable. The cause of the disease being unknown, an unsuccessful attempt was made to discover it. Finding the problem a very complicated one, involving the treatment of the bulbs in Bermuda, where they are grown, the investigation was abandoned. Subsequently, the subject was taken up by Dr. Woods, of the United States Department of Agriculture, and worked out.[94] It was found that the disease is due to a combination of causes, one of which is the weakening of the plants through the use of immature, unrested bulbs for planting and propagation. This renders them susceptible to the attacks of aphides, mites, fungi and bacteria.

The other lily disease studied is a fungus disease[95] in which elliptical, orange-brown spots appear on the leaves, buds and stem. Attempts were made to control the disease by spraying the plants with bordeaux. While sprayed plants held their leaves somewhat better than unsprayed ones, the difference was not great. Probably the treatment was not commenced early enough.

MAPLE.

Maple diseases which have been studied and discussed in the Station publications are: (1) An anthracnose[96] which attacks Norway maples in the nursery. The leaves and young shoots blacken and die, the result being the formation of a bushy top which must be pruned away in order to re-establish the "leader." (2) Scorching of maple foliage by dry winds. This was conspicuous on Norway maples on Long Island in 1895,[97] and on both sugar and Norway maples the State over in 1899.[98]

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[91] *Bremia lactucæ* Regel. Rpt. **4**:279.
[92] Bul. 186:16 (1901); same in Rpt. **19**:108.
[93] Rpt. **14**:520–524 (1895).
[94] U. S. Dept. Agr. Div. Veg. Phys. and Path. Bul. 14 (1897).
[95] *Botrytis* sp. See *Ann. Bot.* **2**:319 (1888).
[96] *Glœosporium apocryptum* E. & E. Rpt. **14**:531 (1895).
[97] Rpt. **15**:453 (1896).
[98] Bul. 162:177 (1899); same in Rpt. **18**:165.

OATS.

In 1884 the average loss from oat smut on the Station farm was 9.5 per ct., as shown by careful counts made at several different points.[99] In 1886 the loss was 8.48 per ct. No doubt the loss on many farms over the State was equally large. In 1886 two experiments on oat smut were carried out.[100] One experiment was designed to determine whether oat smut is carried with the seed. The other was a test of different chemicals for treating the seed to prevent smut. In the first experiment a quantity of badly smutted oats was divided into four lots and sown in four widely separated parts of the Station farm. On all four plats the resulting crop was badly smutted — in one case there was 30.86 per ct. of smut. So high a percentage of smut in the crop was strong evidence (but not rigid proof) that the disease had been transmitted with the seed. We now know that such is actually the case.

In the second experiment an attempt was made to kill the smut spores on the seed oats by soaking the oats in chemicals. Tests were made with copper sulphate, iron sulphate, caustic potash, common salt, saltpeter, cattle urine and a mixture of cattle urine and lime. The results were encouraging. In all the plats from treated seed there was considerably less smut than in the check plat from untreated seed. In one of the copper sulphate plats and in the caustic potash plat there was no smut at all, while the check plat showed 28.81 per ct. smut.

Further experiments along this line were discouraged for a time by the discovery in Denmark, in 1887, of the Jensen hot water treatment, which soon became popular because of its cheapness. Then came the formalin treatment, which has been tested by many of the experiment stations and is the one now most generally recommended and used.

At this Station, tests of formalin were made in 1897.[101] Different strengths of formalin, Ceres powder, lysol and potassium sulphide were compared with hot water. Ceres powder and potassium sulphide failed to wholly prevent smut. Moreover, they were expensive. Lysol, formalin and hot water all prevented smut completely, but when cheapness and simplicity of treatment were taken into consideration, formalin seemed to have the advantage. The

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[99] Rpt. 3:382 (1884).
[100] Rpt. 5:124–130 (1886).
[101] Bul. 131 (1897); same in Rpt. 16:294–306.

accepted method of using formalin on oats is to sprinkle the seed thoroughly with a solution containing one pint of formalin to 45 gallons of water.

ONION.

Smut[102] is a fungus disease which attacks onions grown from seed, killing many of the seedlings outright and stunting others. In Orange County, where the onion is an important crop (about 1,570 acres being grown annually), smut has been very troublesome. At a Farmers' Institute held at Goshen, N. Y., in March, 1896, there was a lengthy discussion of onion smut and its treatment. The Station mycologist, who was present, explained the transplanting method which the Connecticut Station[103] had shown to be a complete preventive of smut. The growers present were unanimous in the opinion that transplanting would not be practical for their conditions. They were positive that it would prove too expensive. Moreover, the market to which they cater requires small onions, so that the increased size due to transplanting would be objectionable. As a result of the discussion a resolution was passed requesting the Station to undertake some experiments on the treatment of onion smut.

It was decided to make a thorough test of the sulphur-lime treatment discovered at the Connecticut Station,[104] to determine whether it was applicable to farm practice. The Connecticut experiments had shown good results but were on a small scale.

The Orange County experiments were begun in 1896 and continued five years.[105] In the first season little progress was made, owing to an unfortunate selection of land for the experiment. In 1899 the conditions of the test were better but not entirely satisfactory. The first object sought was the proper quantity of sulphur and lime to use. To this end, sulphur and lime (equal parts by weight) were applied in the drills with the seed in quantities varying from 125 to 1,500 pounds per acre. The best results were obtained on plats receiving 125 and 250 pounds per acre, where the gain over untreated plats was at the rate of 15,000 pounds of onions per acre. The second object was to determine whether sulphur alone would give as good results as the mixture of sulphur

[102] *Urocystis cepulæ* Frost.
[103] Conn. Sta. Rpt. **19**:176–182 (1896).
[104] Conn. Sta. Rpts. **1889**:146–153; **1890**:103–104.
[105] Bul. **182** (1900); same in Rpt. **19**:69–96.

and lime. Definite conclusions could not be drawn, but it seemed that the efficiency of the sulphur was somewhat increased by the addition of lime.

During the last three years the experiments were so planned as to show three things: (1) The increase in yield due to the use of sulphur and lime applied in the drills; (2) whether injury to the crop may result from the accumulation of sulphur in the soil through repeated applications of the treatment; (3) whether lime and sulphur applied broadcast are as effective as when applied in the drills. The conclusions reached were as follows: "There seems to be no doubt that onion smut can be prevented to a considerable extent, but not wholly, by the application of sulphur and air-slaked lime in the drills at time of sowing the seed. What quantity of sulphur and lime it is best to use has not been definitely determined, but in our experiments excellent results have been obtained from the use of 100 pounds of sulphur to fifty pounds of lime (equal parts by measure) per acre. We recommend the use of this quantity until it has been shown by experiment that some other quantity gives better results.

"There is no danger of harmful results from the accumulation of sulphur in the soil, provided it is not used in excessively large quantities. Broadcast applications of the sulphur and lime have little if any effect on smut; the application *must* be made in the drills."

The results of these experiments show plainly that the sulphur-lime treatment is a practical and profitable remedy for onion smut. Yet Orange County onion growers have made no use of it. So far as they are concerned the expense of the experiment was absolutely wasted.

The only other onion disease studied by the Station is a bacterial rot common in Orange County in 1898. It appears to have been brought about by the excessively wet weather during July and August of that year. Thorough drainage and clean cultivation are recommended as preventive measures.[106]

PEACH.

Although several peach diseases have received more or less attention at the Station, an extended investigation has been made of none of them.

[106] Bul. 164:209-212 (1899); same in Rpt. 18:169-173.

The Third Annual Report[107] of the Station contains articles on peach yellows, leaf curl and gumming. In the discussion of leaf curl it was pointed out that the fungus is perennial within the tissues of the twigs, as suggested by the German plant pathologist, Frank.[108] The article on gumming is a résumé of the knowledge of the subject at that time with the addition of some original observations and experiments, none of which were of much importance. An instance is cited in which a violent attack of gumming resulted from hail injury.

In the Sixth Annual Report[109] the perennial habit of the leaf curl fungus is reaffirmed and record is made of an experiment in which the cutting out of all limbs showing signs of leaf curl produced no sensible decrease in the amount of the disease the following year.

Bulletin 191 [110] contains short notes on leaf curl, fruit rot, "little peach" disease, yellows, brown spot of the fruit and canker of the twigs, trouble with peach trees in the nursery cellar, double peaches, hail injury, Cytospora canker and splitting of peach trunks. The most important of these notes is the one on brown spot.[111]

In Bulletin 200, an account is given of an interesting case of imperfect fertilization in peaches.[112] It was observed "that imperfectly fertilized peaches may attain considerable size and remain hanging on the tree until September. In such cases this trouble may be mistaken for the "little peach" disease by persons unfamiliar with the latter. However, in the "little peach" disease the pit is of normal size and provided with a well-developed kernel; while in cases of imperfect fertilization the pit is abnormally small and has no kernel, or at least only a partially developed one."

PEAR.

Pear diseases have received their full share of attention. The investigations on pear blight published in the Third, Fourth and Fifth Annual Reports[113] of the Station are quite generally recognized by plant pathologists as important contributions to the knowl-

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[107] Rpt. 3:372–379 (1884).
[108] Frank, A. B. Krankheiten der Pflanzen, p. 526. Breslau. 1880.
[109] Rpt. 6:353 (1887).
[110] Bul. 191:312–319 (1900); same in Rpt. **19**:189–197.
[111] *Helminthosporium carpophilum* Lév.
[112] Bul. 200:89–93 (1901); same in Rpt. **20**:149–153.
[113] Rpts. **3**:357–367 (1884); **4**:268–275 (1885); **5**:259–273 (1886).

edge of this destructive disease. In estimating the value of this work it should be remembered that at the time it was done scarcely anything was known about bacterial diseases of plants. That bacteria might be the cause of pear blight was first suggested by Prof. T. J. Burrill[114] of the University of Illinois in 1878. Two years later he made inoculation experiments which showed that the disease may be communicated from one pear tree to another by introducing into healthy tissue a bit of the bacteria-laden exudate from diseased twigs; also, that the disease may be artificially produced in the apple and quince in the same manner. Little more than this was known about the pear disease when the investigations at the Station were begun in 1884; and the only other recognized bacterial plant disease was the hyacinth disease studied by Dr. Wakker, in Holland, in 1882.[115] Undoubtedly, the illuminating pioneer work of Burrill and Arthur on pear blight has been an important factor in the rapid advances which have been made in our knowledge of bacterial plant diseases during the past twenty years.

As regards the nature and results of the Station investigations on pear blight, they are best stated in Dr. Arthur's own words. He says:[116] " The report of 1884 goes over the ground of Professor Burrill's investigations, confirming his observations respecting the presence and activity of bacteria in connection with the disease, its infectious character as shown by inoculation, and the identity of pear blight and twig blight of the apple and quince. It was found that the disease could also be extended to various pomaceous fruits not tested by Professor Burrill, but could not be induced in plants of other orders. Inoculation in green fruit, taking up an original line of research, was found more certain of results than in the branches, and this with other things led to the belief that succulency has to do with the fullest development of the disease. Reasons are given for thinking that the bacteria accompanying the disease are the cause of it. The probable manner of the propagation of the disease from tree to tree is outlined, and suggestions made as to remedies and preventions. In 1885 a rigid proof is given that the bacteria (*Micrococcus amylovorus* Bur.), which are always found accompanying the disease, are the actual cause of it. The discovery was made that the entrance of the bacteria into the

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114 Trans. Ill. Hort. Soc. for **1878**:80 (1879).
115 *Bot. Centbl.* **14**:315 (1883).
116 Rpt. **6**:363 (1887).

tissues of the trees is effected through the center of the flowers and through the delicate growing tips of branches. An attempt was made to learn why some varieties suffer more from the disease than others, but with indifferent success. The mode by which the disease is normally propagated and spread is more fully stated. Some facts are given about the development of the germs in artificial cultures, and the chemical and other changes which they bring about. In 1886 the proof of the bacterial nature of the disease is reviewed and further strengthened, the forms and transformations of the germs are described and illustrated, and the chemical changes they bring about further treated of, including the proof that they do not form a poison in the branches of the trees. Statistics and experiments are produced to further show the relation of blight to succulency and to explain why the disease varies in different varieties of the same kind of fruit. It is further shown that the bacteria may live and propagate in common garden soil."

The work of the Station on pear scab[117] has had to do almost entirely with experiments on its control. Small experiments with hyposulphite of soda were made in 1886[118] and with potassium sulphide in 1887.[119] In 1893 and 1894 extensive spraying experiments with bordeaux mixture were made in a 42-acre pear orchard near Geneva. In the experiments of 1893 information was sought on two points:[120] (1) The value of dilute bordeaux mixture (1 to 11 formula) for the prevention of scab; (2) the best number of treatments to make prior to blooming. The results of the experiments furnished satisfactory answers to both questions. By the use of dilute bordeaux, scab was kept so well under control that the net profit from spraying ranged between $4.77 and $6.10 per tree. Three sprayings before blooming gave no better results than two sprayings.

The experiments in 1894 were designed to answer three questions:[121] (1) What is the least number of treatments with bordeaux mixture (1 to 11 formula) which will practically prevent injury from the scab fungus in pear orchards, and at what time in the season ought the treatments to be made?

(2) To what extent is late spraying liable to cause russeting or roughness of the fruit?

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[117] *Venturia pirina* (Lib.) Aderh.

[118] Rpt. 5:174 (1886).

[119] Rpt. 6:350 (1887).

[120] Bul. 67 (1894); same in Rpt. 12:694–717.

[121] Bul. 84 (1895); same in Rpt. 13:649–683.

(3) To what extent will the benefits of spraying one season influence the crop of the next season?

Again, satisfactory answers were obtained. It was decided that the least number of sprayings which may be relied upon to control scab on susceptible varieties is three. The first of these should be made after the buds break, but before blossoming; the second, immediately after blossoming; and the third, from ten to fourteen days after the second.

Although there had been no trouble in 1893, much russeting of the fruit resulted from spraying in 1894 and a considerable study of it was made.

As regards the third question, it was found that pear trees which had been sprayed in 1893, and thereby protected from scab, gave no larger yield in 1894 than trees which had not been sprayed in 1893. However, this does not prove that spraying was not beneficial to the trees, because the sprayed trees entered the experiment at a disadvantage, having borne, in 1893, three times as much fruit as the unsprayed trees.

These experiments established the treatment for pear scab in New York. Essentially the same treatment is in general use at the present time.

The experiments in preventing leaf diseases of nursery stock in western New York conducted by the United States Department of Agriculture in coöperation with this Station included some experiments on the control of pear leaf blight[122] in nurseries. These experiments were made in 1891 and 1892 and the results published in the Eleventh Annual Report. In the experiments on pear stocks[123] bordeaux mixture proved superior to the ammoniacal solution of copper carbonate and was entirely efficacious. On pear seedlings[124] a comparative test was made of twenty-five spray mixtures — compounds of copper, iron and zinc. Bordeaux mixture was not included. Most of them were untried as fungicides. Six applications were made with each of them, and there was sufficient leaf blight to give them a thorough test; but only a few gave results which would warrant further trial. None prevented leaf blight entirely.

Some other pear troubles studied at the Station are the follow-

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[122] *Entomosporium maculatum* Lév.

[123] Rpt. 11:643–652 (1893); same in *Jour. Mycol.* 7:241–247.

[124] Rpt. 11:673–677; a more complete account in *Jour. Mycol.* 7:338–351.

ing: (1) A case of premature coloration and dropping of pear leaves which was ascribed to defective nutrition.[125]

(2) Trouble with pear trees stored in a nursery cellar.[126] The upper portions of the trees turned black. Upon investigation it was found that the trouble had been brought about by sudden thawing of the trees. The sand covering the roots of the trees had become frozen, and in order to thaw it quickly a fire had been built in the cellar.

(3) Body blight.[127] Studies on this were made in connection with the investigation of apple canker. A full understanding of body blight was not obtained, but it was proven that the apple canker fungus[128] may attack pear wood and produce lesions similar to those found on pear trunks affected with body blight.

PLUM.

Of the various plum diseases, leaf spot has received most attention. During three years, 1885 to 1887, a considerable study was made of the life history of the leaf spot fungus.[129] While not fully demonstrated, it was shown to be highly probable that the fungus has three different spore forms, one of which is an ascigerous form. Strange to say, this matter stands to-day where it was left by the Station twenty years ago. The occurrence of an ascigerous form in the life cycle of the fungus has been neither proven nor disproven.

Experiments on the treatment of leaf spot were begun in 1887, when promising results were obtained with potassium sulphide used as a spray.[130] In 1891 and 1892 bordeaux mixture and the ammoniacal solution of copper carbonate were tried on nursery stock.[131] The latter injured the foliage, but the former gave results sufficiently good to warrant further trial. The experiments were continued in 1893 with bordeaux only.[132] This year the beneficial effect of spraying was marked. The sprayed trees held their foliage longer and made a larger growth of tops and roots.

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[125] Rpt. 3:369 (1885).

[126] Bul. 200:83–85 (1901); same in Rpt. 20:143–146.

[127] Bul. 163 (1899); same in Rpt. 18:331–360; Bul. 185 (1900); same in Rpt. 19:342–350.

[128] *Sphæropsis malorum* Pk.

[129] *Cylindrosporium padi* Karst. Rpts. 5:276–281 (1886); 6:347 (1887).

[130] Rpt. 6:350 (1887).

[131] Rpt. 11:659–664 (1892).

[132] Bul. 72 (1894); same in Rpt. 12:690–693.

In 1895 and 1896 experiments were made in bearing orchards. In the first season's work[133] eau celeste soap, which had given promising results in the hands of certain fruit growers, was compared with bordeaux mixture and shown to be inferior to it. Hence, in the second season's work[134] only bordeaux was used. At the time these experiments were undertaken the efficiency of bordeaux mixture for plum leaf spot had already been thoroughly demonstrated by experiments at various experiment stations and by the experience of many practical fruit growers. But the least number of treatments necessary and the best time for making them had not been determined. The Station experiments were planned to throw light on these points. Without going into the details of the experiments the conclusions reached may be stated as follows:[135] "In some seasons two treatments are most economical, but under conditions favorable to the disease at least three should be given. If but two treatments be made give the first ten days after the blossoms fall, but not later than June 1; make the second treatment about three weeks later. The disease may be better controlled by three treatments and usually three treatments will be most profitable. Make the third from three to four weeks after the second."

In the summer of 1893 the Station Horticulturist made some interesting and important observations on plum black knot.[136] Plain evidence was found that the summer conidia of the black knot fungus are capable of reproducing the disease through infection of young shoots; also, that the first knots and conidia resulting from such infection appear in June of the following year.[137]

Station Bulletin No. 40, Black Knot of Plum and Cherry, which was published in the spring of 1892, is little more than a compilation of existing knowledge of the subject.

POTATO.

Most of the Station's work on potato diseases has been along the line of spraying to prevent blight and rot. The need of a remedy for these diseases must be evident to all who are familiar with New York potato culture. For example, on the Station farm,

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[133] Bul. 98 (1896).

[134] Bul. 117 (1897); same in Rpt. **16**:207–213.

[135] Bul. 170:432 (1899); same in Rpt. **18**:454.

[136] *Plowrightia morbosa* (Schw.) Sacc.

[137] Rpt. **12**:686–688 (1893).

in 1885, the average loss from rot on thirty-four plats of one-twentieth acre each was 65 per ct.[138] The variety was White Star. Several other varieties rotted even worse, the loss being as high as 100 per ct. in some cases. (In this connection it should be stated that some varieties were found to be more susceptible to rot than others and that a vigorous growth of vines encourages rot.[139])

The Station makes no claim to having had any important part in establishing the value of bordeaux mixture as a preventive of potato blight. Its chief service has been in showing what spraying will do for the potato crop in New York. Notwithstanding that losses from blight and rot are great and that experiments in Vermont[140] and other states have shown that the disease may be controlled by spraying, New York farmers have been slow to adopt the practice of spraying potatoes. Moreover, the successful results of experiments made on the Station farm in 1891[141] and 1892[142] and on Long Island farms in 1895[143] and 1896[144] failed to make much impression. As late as 1902 but few farmers in New York made a practice of spraying potatoes for blight. The argument advanced was that late blight is not destructive every season and, consequently, the spraying is done at a loss in some seasons, because it must be commenced before it is known whether or not blight will appear. For this reason it was quite generally doubted that the spraying of potatoes is profitable one year with another. Of course the weak point in this argument is the fact that spraying is of value not only for late blight but also for the control of other pests such as early blight, flea beetles and bugs, one or more of which is almost always present.

Finally, it became evident to the Station authorities that New York potato growers would never adopt spraying until it could be shown by a long series of reliable experiments that it is profitable one year with another on the average. Accordingly, in 1902, a ten-year series of experiments was begun on the Station grounds.

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[138] Rpt. **4**:65 (1885).

[139] Rpt. **4**:239–244 (1885).

[140] At the Vermont Experiment Station the average gain from spraying potatoes during 16 consecutive years has been 114 bu. per acre. ((Vt. Sta. Rpt. **19**:267. 1907).

[141] Bul. 41:44–46 (1892); same in Rept. **10**:485–487.

[142] Bul. 49:13–16 (1893); same in Rpt. **11**:696–699.

[143] Bul. 101:73–78 (1896); same in Rpt. **15**:498–504.

[144] Bul. 123 (1897); same in Rpt. **16**:376–400.

Yields, 476¾ lbs., 302½ lbs., 380¼ lbs.

PLATE IX.—THREE ROWS IN TEN-YEAR POTATO-SPRAYING EXPERIMENT, 1904.

Spraying Potatoes.

Results of Spraying.
Yield increased 130 bu. per acre.
Plate X.

MAP III.— LOCATION OF POTATO-SPRAYING EXPERIMENTS IN 1905.

These experiments were designed to show the increase in yield due to spraying and also how the benefit from three sprayings compares with that obtained from five; but no account was to be taken of the expense. A duplicate of this series was to be conducted at Riverhead on Long Island. The following year (1903), a series of farmers' business experiments was begun with the intention of continuing them until 1912. Each year several of these business experiments are conducted in coöperation with farmers in different parts of the State who spray several acres doing all the work in their own way and keeping a full account of all expense of it. In each experiment a few rows are left unsprayed for comparison. At digging time a representative of the Station assists with the digging and weighing of sprayed and unsprayed rows for the purpose of determining the increase in yield due to spraying. In this manner the Station attempts to determine the profit from spraying potatoes as it is done by farmers under actual farm conditions. Additional data bearing on the subject are obtained from numerous farmers who have made spraying experiments on their own account. Each year the Station secures reports of as many as possible of such experiments, which are called volunteer experiments.

At the end of the first five years the results stand as follows: In the Station ten-year experiments the average increase in yield from spraying has been: At Geneva, 132 bu. per acre for five sprayings and 103.3 bu. for three sprayings; at Riverhead, 66.3 bu. per acre for five sprayings and 35.3 bu. for three sprayings. In the farmers' business experiments (48 experiments in 4 years) the average gain from spraying has been 52 bu. per acre. The average total expense of spraying, $4.85 per acre and *the average net profit* $20.51 *per acre.* In the volunteer experiments (153 experiments in three years), the average gain from spraying has been 58 bu. per acre.[145]

What will be the final results of the experiments can not be foretold, but up to the present time spraying has certainly made a good showing. Since about 400,000 acres of potatoes are grown in New York a net profit of $20 per acre on the average means a saving which amounts in the aggregate to $8,000,000 annually.

It is gratifying to note that potato growers are showing much

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[145] Bul. 221 (1902); same in Rpt. **21**:77–104.
Bul. 241 (1903); same in Rpt. **22**:117–162.
Bul. 264 (1905); same in Rpt. **24**:89–194.
Bul. 279 (1906); same in Rpt. **25**:119–187.
Bul. 290 (1907).

interest in the experiments and the number who practice spraying is rapidly increasing. No doubt the recent improvements in potato spraying machinery have had much to do with the advance of potato spraying. There are now upon the market several thoroughly practical horse power sprayers for potatoes.

In addition to the spraying experiments above described studies and experiments have been made on closely related subjects. For example, in 1904 and 1905 a mixture of sal soda, copper sulphate and water, called soda bordeaux, was compared with the regular bordeaux mixture as a preventive of potato blight. The regular bordeaux gave slightly better results in both seasons.[146]

Another of these experiments was a comparison of warm and cold water for making bordeaux mixture to spray potatoes.[147] Some persons held the opinion that bordeaux mixture prepared with cold water, such as comes from deep wells, is injurious to potato foliage. The results of the experiment showed this opinion to be without foundation in fact.

A third line of investigation was on the effect of certain arsenites upon potato foliage.[148] It had been claimed by some that arsenical compounds are injurious to the potato plant even when applied with properly made bordeaux mixture. Inasmuch as paris green and arsenite of soda, the leading insecticides used on potatoes, are both compounds of arsenic it was deemed advisable to look into the matter. The chief conclusions reached were:

(1) That paris green is not injurious to potato foliage if applied in moderate quantity with lime water or bordeaux mixture evenly distributed;

(2) That paris green possesses considerable value as a preventive of potato late blight;

(3) That arsenite of soda is much less liable to injure the foliage when used with bordeaux than when used with lime water even if the same quantity of lime is used in both cases.

Analyses of sprayed and unsprayed potatoes showed the former to contain a larger percentage of starch;[149] and a test of their cooking qualities showed the sprayed potatoes to be much the more mealy.[150]

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[146] Bul. 264:187–194; same in Rpt. 24:177–183.
Bul. 279:215; same in Rpt. 25:174–176.

[147] Bul. 279:222; same in Rpt. 25:180, 181.

[148] Bul. 267 (1905); same in Rpt. 24:195–214; see also Bul. 279–217.

[149] Buls. 221:253; 241:265; 264:114.

[150] Bul. 264:115.

In 1904 the Station ten-year experiment at Geneva gave the enormous gain of 233 bu. per acre due to spraying. In order to determine whether the sprayed potatoes were better than the unsprayed ones for seed purposes, tubers from sprayed and unsprayed rows were planted in alternate rows the following season. There was a difference in yield of 12 bu. per acre in favor of the sprayed seed.[151]

The Station has done some work on potato scab,[152] without, however, making an important addition to the knowledge of that troublesome disease. Experiments made in 1887[153] and 1888[154] were designed to throw light on the following points: (1) Influence of the soil; (2) effect of an excess of moisture in the soil; (3) scabby vs. smooth tubers for seed; (4) effect of stable manure; (5) disinfection of seed tubers; (6) effect of special fertilizers; (7) relation of millipedes to scab; and (8) relation between color of skin and susceptibility to scab. The results seem to warrant the conclusion that scab is more virulent in wet soils than in dry ones, and in manured soils more than in unmanured ones; also that millipedes are not active agents in producing scab. On other points the experiments were inconclusive. This was before the cause of scab was known.

After the discovery of the true cause of potato scab by Dr. Thaxter at the Connecticut Station[155] in 1890 further experiments on the treatment of scab were undertaken in 1892.[156] Several different fungicides were tested in two ways: (1) By soaking the seed tubers in them; and (2) by spraying the seed pieces and the surrounding soil with fungicides. While there were some indications of benefit from both methods of treatment no conclusions could be drawn.

In 1897 an experiment was made on green manuring with rye as a preventive of potato scab.[157] This has sometimes been recommended as a means of securing a smooth crop of potatoes on land infested with scab. The method is to sow the rye in the fall and plow it under the following spring shortly before planting time. In the Station test the use of rye in this way did not lessen the amount of scab in the least.

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[151] Unpublished.

[152] *Oöspora scabies* Thax.

[153] Rpt. 6:307–315 (1887).

[154] Rpt. 7:224–227 (1888).

[155] Conn. Sta. Rpt. for 1890:81–95 (1891).

[156] Bul. 49:3–13 (1893); same in Rpt. 11:561–570.

[157] Bul. 138:629–631 (1897); same in Rpt. 16:418–420.

Other potato diseases studied more or less are the following:

(1) An internal browning of potato tubers[158] observed on Long Island in 1895. Tubers, outwardly perfect, show, within, numerous brown spots scattered irregularly through the flesh. The cause was not determined.

(2) A stem blight or wilt disease often destructive on Long Island.[159] The leaves at the tips of the shoots roll up, turn yellow or purplish, then the entire plant wilts and dies. The tubers appear sound, but when cut at the stem end blackened fibers are seen penetrating the flesh to a considerable distance. Affected tubers do not rot. The seat of the trouble is plainly in the stem just below the surface of the soil where it first becomes discolored then dry and shriveled. Apparently, the disease is not transmitted with the seed.[160] The cause was not determined. We can not agree with Dr. Erwin Smith[161] who has expressed the opinion that this disease is caused by the potato dry-rot fungus, *Fusarium oxysporum.*

(3) Pimply potatoes caused by the larvae of the flea beetle boring into the growing tubers.[162] Previous to this time the feeding habits of flea-beetle larvæ were unknown.

(4) A new, but unimportant, Fusarium disease of potato stems.[163]

(5) Rhizoctonia on potato tubers and stems.[163a]

QUINCE.

No extended investigation of any quince disease has been carried out at the Station. However, at various times, some observations and notes have been made.

In the investigation of the fire blight disease of the pear, reviewed on a previous page, it was shown by means of cross-inoculation experiments that the fire blight of quince and apple twigs is due to the same cause, namely, to bacteria. And in the investigation of apple canker (page 122) the quince was taken into consideration because of its close relationship to the apple. It was found that the apple canker fungus, *Sphæropsis malorum,* is capable of attacking also living quince branches. That Sphæropsis may

[158] Bul. 101:78–83 (1896); same in Rpt. **15**:504–509.
[159] Bul. 101:83–84.
[160] Bul. **138**:632–634 (1897); in Rpt. **16**:421–423.
[161] U. S. Dept. Agr. Bur. Plant Indus. Bul. 55:10 (1904).
[162] Bul. **101**:84–85; Bul. **113** (1896) (same in Rpt. 15:513–519).
[163] Bul. 101:85.
[163a] Bul. 186:17–22 (1901); same in Rpt. **19**:110–113.

cause the rotting of quince fruits had been previously demonstrated by experiments made at the Station some fifteen years earlier.[164]

In 1887 quince bushes sprayed with a solution of potassium sulphide became severely affected with fire blight, thereby showing the inefficiency of the treatment.[165]

In the third[166] and fourth[167] reports of the Station the quince spot disease,[168] which affects both the fruit and leaves, is described and illustrated and the interesting statement made that no remedy for it is known. A few years later it was shown by the experiments of Thaxter at the Connecticut Station[169] and by experiments on nursery stock at this Station[170] that quince spot is very readily controlled by three to five applications of bordeaux mixture.

A brief account of powdery mildew[171] of quince leaves is given in one of the early reports.[172]

RASPBERRY.

Anthracnose[173] is a common fungus disease of raspberries and blackberries. Its most characteristic symptom is the formation of discolored spots and blotches on the canes. It is often exceedingly destructive to black varieties of raspberries, but does not attack red varieties to any great extent.

Experiments on the control of anthracnose were carried on during three successive seasons (1894–1896).[174] The principal object of the experiments was to determine the value of spraying as a preventive of the disease. At first it was thought likely that a very early spraying with some strong fungicide would be helpful. Accordingly, applications of copper sulphate, iron sulphate and sulphuric acid were made before the foliage appeared and this followed by several applications of bordeaux mixture. Ultimately, it was learned that the early applications were unnecessary; moreover,

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[164] Rpt. 3:372 (1884).
[165] Rpt. 6:351 (1887).
[166] Rpt. 3:371.
[167] Rpt. 4:275 (1885).
[168] *Entomosporium maculatum* Lév.
[169] Conn. Sta. Rpts. 1890:99; 1891:150–152.
[170] Rpt. 11:652–654 (1892).
[171] *Podosphæra oxyacanthæ* (DC) De By.
[172] Rpt. 3:371 (1884).
[173] *Glæosporium venetum* Speg.
[174] Bul. 81:592–594 (1894); same in Rpt. 13:684–686.
Bul. 124 (1897); same in Rpt. 16:231–244.

sulphuric acid injured the plants. It was demonstrated that anthracnose may be prevented by three to five applications of bordeaux mixture, the first being made when the new canes are a few inches high and the others at intervals of ten to fourteen days; but it was not clear that such treatment is profitable. It may be more profitable to fight anthracnose by adopting a short rotation of crops, the use of strictly healthy plants when setting new plantations and the removal of the old canes immediately after the fruit is gathered.

In 1900 a study was made of a curious cane-knot trouble of Cuthbert raspberries.[175] The knots were rough, of spongy texture and often had a diameter twice that of the normal cane. The knots were found to be due to the anthracnose fungus.

Another raspberry disease to which the Station has given much attention is that known as cane blight.[176] This first came to the attention of the Station in 1899 during the prosecution of a plant disease survey of the Hudson Valley. Although abundant and destructive and evidently not new to fruit growers, the disease was, nevertheless, entirely unknown to science at that time. It seems strange that so conspicuous and widespread a disease should so long have escaped the attention of plant pathologists. In the season of 1900 observations were extended to central and western New York where the disease was again found in abundance, and further observations made in 1901 and 1902 indicate that it occurs more or less abundantly in a majority of the raspberry plantations throughout New York State. It also occurs in some other parts of the United States. The symptoms of cane blight are the sudden wilting and dying of the fruiting canes (either wholly or in part) here and there through the plantation. Both red and black varieties are attacked and the disease is most severe about the time the fruit is ripening.

A thorough study was made of cane blight and its treatment. It was proven that the cause of the disease is a parasitic fungus (*Coniothyrium* sp.) which attacks the cane at some point, killing and discoloring the bark and wood thereby causing the death of the parts above. The fungus is disseminated by means of infected nursery stock; by wind, rain and washing of the soil; and in picking, pruning and laying down the canes. No definite and effective

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[175] Bul. 191:328 (1900); same in Rpt. **19**:206.

[176] Bul. 167:305–307 (1899); same in Rpt. **18**:214–216.
Bul. 191:330 (1900); same in Rpt. **19**:208.
Bul. 226:331–362 (1902); same in Rpt. **21**:105–136.

line of treatment was established. Among several precautions to be observed the most important are: (1) To secure healthy plants with which to start the plantation; (2) to remove the old canes immediately after the fruit is gathered. Spraying the plants with bordeaux mixture proved wholly ineffective.

Studies have also been made on raspberry yellows, a disease which is believed to be chiefly responsible for the socalled running out of the Marlboro red raspberry in the Hudson Valley.[177] It is characterized by stunted growth, mottled yellowish-green foliage and dry, insipid fruit. Neither the cause nor a remedy was found. The inefficiency of bordeaux mixture for the disease is shown by the fact that plants sprayed thirteen times were quite as much affected as unsprayed plants. Various combinations of commercial fertilizers were applied to the soil in a badly affected plantation without any appreciable effect on the disease.

SNAPDRAGON.

The cultivated snapdragon (*Antirrhinum majus* L.) suffers severely from a fungus disease, called anthracnose, in which the stems and leaves are covered with elliptical or circular sunken spots. This disease and its treatment were made the subject of a special investigation.[178] The fungus was found to be new to science. It was fully described and figured and given the name *Colletotrichum antirrhini*. This fungus enjoys the distinction of being one of the two new species described in the Station publications during a period of twenty-five years.

For a time it was believed that *Colletotrichum antirrhini* attacks only the snapdragon, but later it was found to infest also yellow toad-flax, a common weed belonging to the same family.[179]

A complete remedy for the snapdragon anthracnose was discovered. "In an experiment made on Long Island, plants sprayed once a week with bordeaux mixture remained entirely free from the disease while unsprayed plants under parallel conditions were completely ruined by it."

In connection with the investigation of anthracnose some studies were made on another disease — a stem rot.[180] This attacks succu-

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[177] Bul. 226:362–364.
[178] Bul. 179:105–109 (1900); same in Rpt. 19:61–66.
[179] Bul. 200:87–89 (1901); same in Rpt. 20:148.
[180] Bul. 179:109–110.

lent shoots causing them to suddenly wilt and die. By means of inoculation experiments it was proven that a fungus belonging to the genus Phoma is responsible for the disease. Although no experiments have been made it is probable that stem rot may be prevented by spraying with bordeaux mixture as for anthracnose.

STRAWBERRY, SUNFLOWER, SYCAMORE AND TURNIP.

In the Fifth Annual Report (p. 275) is given an account of a powdery mildew[181] found on strawberries on the Station grounds in the summer of 1886. This is thought to be the first record of the occurrence of powdery mildew on strawberries although what appears to be the same fungus had long been known as a parasite of hops, dandelions and several other plants. The interesting observation was made that while the fungus adapts itself readily to plants of very diverse nature it attacks the different varieties of the same species of dandelion in widely different degrees.

In the Sixth Report (p. 351) there is an account of an experiment in which potassium sulphide, used as a spray, kept the strawberry leaf spot[182] well under control.

The Fifteenth Report contains short articles on two common diseases (rust and leaf spot) of the cultivated sunflower (p. 455), the anthracnose[183] of sycamore trees which is very common and injurious on Long Island (p. 457), and an unusual leaf spot disease[184] of flat turnips found on Long Island in 1896 (p. 451).

TOMATO.

The blossom end rot of the tomato has long been a puzzle to plant pathologists. Even at the present time it is very imperfectly understood. It has been ascribed to various causes, scarcely any two investigators being in complete agreement on the subject. The probable explanation of this is that the symptoms may be produced by any one of several causes.

While this disease has never been given extended study at the Station, observations and small experiments have been made upon it from time to time. Notes on it appear in every one of the first five

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[181] *Sphærothica humuli* (DC.) Burr.
[182] *Sphærella fragariæ* (Tul.) Sacc.
[183] *Glæosporium nervisequum* (Fckl.) Sacc.
[184] *Macrosporium herculeum* E. & M.

reports[185] of the Station and in two of the later ones.[186] Some of the points covered by these studies are: The symptoms and behavior of the disease; amount of damage done by it; the relative susceptibility of different varieties; the use of immature seed as a predisposing cause; attempts to reproduce the disease by artificial inoculation; and a search for fungi and bacteria in the diseased tissue.

The only other tomato disease to receive attention at the Station is a fungus leaf spot (*Cylindrosporium* sp.).[187] An experiment made on Long Island in 1895 showed that spraying the plants with bordeaux mixture at frequent intervals checks this disease considerably but that it can not be controlled satisfactorily if the spraying is discontinued when the fruit commences to ripen.

MISCELLANEOUS PLANT DISEASES.

The review of the work on plant diseases given in the preceding pages includes most, but not all, of the Station investigations on this subject. There are a few of the Station bulletins which contain notes and short articles on so large a number of diseases that it has seemed inadvisable to mention them all. To do so would lengthen this review considerably without adding much to its value. It is thought that a better method is to discuss these miscellaneous bulletins separately.

Bulletin 186,[188] The Sterile Fungus Rhizoctonia as a Cause of Plant Diseases in America, contains a report of some investigations made in coöperation with the Cornell Experiment Station. Each of the Stations having undertaken independent studies on certain plant diseases caused by Rhizoctonia it was thought that the work could be prosecuted to better advantage by coöperation. With the exception of beet root rot, very little was known at this time about Rhizoctonia diseases in America. It was found that Rhizoctonia attacks many different plants causing root rot, stem rot and damping off. Some of the plants affected are bean, beet, cabbage, carrot, carnation, cauliflower, celery, china aster, cotton, coreopsis, lettuce, ornamental asparagus, potato, radish, rhubarb, sweet william and violet.

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[185] Rpts. 1:138; 2:194; 3:227, 379; 4:210, 276; 5:170, 273.

[186] Rpts. 14:529; 16:271 (same in Bul. 125:305).

[187] Rpt. 14:529–531.

[188] Reprinted in Rpt. 19:97–121; also published as Cornell Sta. Bul. 186 (1901).

Bulletin 167,[189] A Fruit Disease Survey of the Hudson Valley in 1899, and Bulletin 191,[190] A Fruit Disease Survey of Western New York in 1900, contain notes on a large number of fruit diseases. While special attention is given to the distribution and amount of damage done by the various diseases other points of interest are noted in many cases. The purpose of the Station in making these surveys was to secure more accurate information concerning the diseases affecting fruits in the State. Some of the more important notes not previously mentioned are:

In Bulletin 167: Orange rust of blackberry and raspberry; black knot of plum and cherry; currant leaf spot; dying of dewberry canes; grape root-rot; grape black knot; and strawberry leaf spot.

In Bulletin 191: Crown gall and hairy root of apple; winter injury to apple; collar rot of apricot; yellow fall rust[191] of blackberry; leaf scorch and winter injury of pears; Cytospora canker of plum trees; hail injury to plum trees; gum pockets in plum fruit; and powdery mildew on raspberry.

Both 1899 and 1900 being dry seasons, many diseases were less prevalent than usual. One of the most important results of these surveys was the discovery of the destructive cane blight of raspberry and the rediscovery of Fairchild's cane blight of currant. Subsequently, the former disease was given thorough study and the latter is under investigation at the present time.

The voluminous correspondence of the Station brings many inquiries concerning the nature and treatment of the more important diseases and insect enemies of plants. In order to meet this demand for practical information the Station has prepared three special bulletins on the subject, viz.:

Bulletin 35,[192] Some of the Most Common Fungi and Insects, with Preventives, published in 1891.

Bulletin 86,[193] Treatment of Common Diseases and Insects Injurious to Fruits and Vegetables, published in 1895.

Bulletin 170,[194] Common Diseases and Insects Injurious to Fruits, published in 1899.

Each disease and insect trouble treated in these bulletins is first

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[189] Reprinted in Rpt. **18**:184–217.
[190] Reprinted in Rpt. **19**:167–209.
[191] *Uredo mülleri* Schrt.
[192] Reprinted in Rpt. **9**:334–345.
[193] Reprinted in Rpt. **14**:345–388.
[194] Reprinted in Rpt. **18**:398–465.

briefly described in such a way as to enable the fruit grower to identify it and then the best methods of control are outlined. With a few exceptions, these bulletins contain only matter which has been previously published in one form or another. Yet they are something more than mere compilations. In several instances the short articles found in them contain the condensed results of many years of observation and experiment at the Station. This is true, particularly, of the chapters on apple and pear troubles in Bulletin 170.

FUNGICIDES, INSECTICIDES AND SPRAYING MACHINERY.

With the widespread interest in the methods of treating fungus diseases and insect pests there has come, also, a constant demand for information concerning the preparation of fungicides and insecticides and spraying machinery for applying them. With the exception of making chemical analyses of spraying materials and of sprayed celery and grapes, the Station has done but little investigation in this field. However, three informational bulletins on the subject have been published, viz.:

Bulletin 74,[195] Observations on the Application of Fungicides and Insecticides, published in 1894.

Bulletin 121,[196] Spray Pumps and Spraying, published in 1897, with an appendix published in 1899.

Bulletin 243,[197] Spray Mixtures and Spray Machinery, published in 1903.

These bulletins, like Nos. 35, 86 and 170, contain little that is really new, but they reflect the long experience of the Station with these matters.

It has ever been the policy of the Station to avoid recommending the goods of any particular manufacturer of spraying machinery.

WEEDS.

The Station has given but little attention to weeds. Doubtless there are some weed problems which would make appropriate subjects for Station investigation, but this line of work is relatively unimportant. The progressive farmer has little to fear from weeds. He knows that they are mastered by thorough cultivation and eternal vigilance and that there are few short cuts and few special methods.

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[195] Reprinted in Rpt. 13:687–706.
[196] Reprinted in Rpt. 16:215–230.
[197] Reprinted in Rpt. 22:321–386.

The First Annual Report[198] of the Station contains an account of an investigation to determine the number of seeds which average individuals of the common kinds of weeds may be expected to produce. Fifteen kinds of weeds were studied. It was found that the dandelion produces upwards of 1,200 seeds per plant; the ox-eye-daisy, 800 to 96,000; the common plantain, 4,500; the pig weed, 825,000; and the purslane, 2,146,500. Certainly the prolificacy of some weeds is marvelous!

A few years later an attempt was made to determine the number of weeds of different kinds which may grow on an acre.[199] Plats containing one-twentieth acre each were plowed and harrowed in May and then left undisturbed for the remainder of the season. The weeds were pulled and counted on three different occasions. One plat produced 8,809 weeds, which is at the rate of 176,180 per acre; a second plat yielded at the rate of 81,900 per acre; a third plat, 241,360; and a fourth plat (old meadow), 767,640.

An answer to the query concerning the number of weeds which may grow upon a definite area of cultivated soil was sought in yet a different way.[200] On December 11 a square foot of surface soil taken to a depth of three inches from a field which had had clean culture was transferred to the greenhouse. The same was done with a square foot of soil from a plat which had been allowed to run to weeds unchecked the previous season. Once a month the germinations in both lots were counted, the plantlets removed and the soil thoroughly stirred for the succeeding month's growth. From the square foot of clean cultivated soil 92 weeds were obtained and from the foul soil 384. On April 14 the experiment was repeated with similar foot-square samples taken from the same plats, but only to one-half the depth, and treated in the same manner. This time the clean cultivated soil gave 138 and the foul soil 649 weeds. "It is interesting to note that the soil which was longest exposed to the winter cold gave the largest number of germinations although there was only half as much of it."

In the course of some investigations on the germination of weed seeds it was discovered that some kinds of weed seeds when gathered, preserved and tested in the same way as garden seeds give only from none to seven or eight per ct. of germination.[201]

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[198] Rpt. 1:85–87 (1882).
[199] Rpts. 4:289–291 (1885); 5:281–283 (1886); 6:356–360 (1887).
[200] Rpt. 6:360–361.
[201] Rpt. 6:362–363.

This is true of wild aster, beggar ticks, heal all, shepherd's purse and common plantain. Commenting on this discovery the writer says: "Weeds seem well able to take care of themselves, but some of them, at least, do not appear to be well fitted for the ways of cultivated plants. If, indeed, it proves to be true upon further inquiry that some weed seeds are made incapable of germination by being kept dry for three or four months or so, it will be a comforting fact to know, as the danger of fouling land with those particular kinds of weeds, by seeds conveyed in grain and garden seeds, will be shown to be much less than supposed."

The recent rapid extension of alfalfa culture in New York has brought to the front the chief weed pest of that crop, namely, dodder. The dodder plant consists chiefly of slender, yellow threads which twine closely about the alfalfa stems and kill them. It is, in reality, a parasite. In most cases dodder gets into the field through the use of impure alfalfa seed; and when once established it is impossible to eradicate it without at the same time destroying the alfalfa. Accordingly, it is of the utmost importance that only clean seed be sown. Because of the difficulty in recognizing dodder and the absence of any law regulating the sale of alfalfa seed, farmers found it very difficult to secure dodder-free seed.

In this situation the Station helped out by offering to make free tests of samples of alfalfa seed to determine whether they contain dodder. Also, a method of removing dodder from alfalfa seed was devised.[202] It was shown by experiment that almost any alfalfa seed may be made practically free from dodder and safe to sow by hand sifting it through a sieve made of 20x20 mesh (No. 34 wire) wire cloth. With the facilities now at hand the farmer who gets dodder in his alfalfa fields has only himself to blame.

MISCELLANEOUS.

Some odds and ends of botanical work which can not be classified under any of the preceding headings are the following:

(1) An account of a tile drain clogged by fungus.[203] The tile drain to a vinegar cellar at Milton, N. Y., became thoroughly clogged by a vigorous growth of the fungus *Leptomitus lacteus*. The fungus was readily removed by placing a quantity of copper sulphate crystals in the upper end of the drain.

[202] Circular No. 8 (1907).

[203] Bul. 200:93–98 (1901); same in Rpt. 20:154–157.

(2) A fungus growing in refrigerator waste pipes.[204] It is a common occurrence for the waste pipes to house refrigerators to become clogged with ropy masses of grayish slime. In the main, this slime consists of a fungus growth, but a part of it is dirt from the melting ice. To avoid this trouble the waste pipe should be washed out occasionally with hot water.

(3) An apparatus for testing the germination of seeds has been devised at the Station.[205] This apparatus, known as the Geneva Seed Tester, has been widely used by experiment stations and other institutions in which seed testing is carried on. It is not patented.

(4) Another apparatus, ingeniously devised by the botanist, was one in which a constant high temperature could be maintained in a space large enough to hold one or two germinating pans for testing seeds.[206]

(5) The Fourth, Fifth and Sixth Reports[207] contain notes on a fungus disease of the clover-leaf weevil, an insect destructive to the clover crop. It being thought that the fungus was new to science, it was fully described and illustrated and given the name *Entomophthora phytonomi*. It was predicted that the fungus would prove an effective check to the insect.

Subsequent studies by Dr. Thaxter[208] disclosed the fact that the fungus had been described some fifty years earlier under the name *Entomophthora sphærosperma* and that it attacks several other insects besides the clover-leaf weevil. Thaxter transferred the fungus to the genus Empusa, which makes its name *Empusa sphærosperma* (Fres.) Thaxt.

In spite of the fungus the clover-leaf weevil continues to be a destructive insect in New York clover fields.

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[204] Bul. 200:98–101.

[205] *Bot. Gaz.* 10:425 (1885).

[206] Rpt. 6:355 (1888).

[207] Rpts. 4:285–289; 5:274; 6:353.

[208] The Entomophthoreæ of the United States. Mem. Boston Soc. Nat. Hist. Vol. 4, No. 6. 1888.

SOME OF THE RESULTS OF WORK DONE BY THE CHEMICAL DEPARTMENT.

SUMMARIZED BY

L. L. VAN SLYKE.

INTRODUCTION.

The chemical work of the Station began July 1, 1882, when S. M. Babcock, Ph.D., entered upon his duties as the first chemist of the Station. Accepting a call to Wisconsin, Dr. Babcock left Geneva December 1, 1887, when E. F. Ladd, B.S., who had been his assistant about three years, was made chemist. Mr. Ladd was succeeded July 12, 1890, by L. L. Van Slyke, Ph.D., who has since continued as Station chemist. The personnel of assistants has inevitably undergone more or less constant change, about thirty-five different assistant chemists having been connected with the laboratory. Beginning with one assistant chemist in 1884, the number has gradually increased as the volume of work demanded, until there are at present seven.

The original laboratory consisted of one room about 30 by 15 feet, located on the east side, first floor, in what is now the administration building. In 1890, when official fertilizer analysis was made a duty of the Station, outside quarters were temporarily hired to accommodate this added work. In 1891, the present commodious laboratory building was completed, in which has since been carried on all the chemical work.

During the first year, after the chemical laboratory was fully organized, the work consisted mainly of miscellaneous analyses, such as pig weed, cow peas, string beans, tomatoes, soja beans, samples of milk, sugar in corn stalks, etc.

The first formal report[1] of the Station chemist includes chemical determinations in foods, milk, sugar in corn stalks and in sorghum juice, fertilizers, soils, water and plant ash. Detailed methods are given for fodder analysis, milk analysis, and estimation of sugar.

[1] Rpt. 2:149-174 (1883).

The lines of chemical work were gradually extended, as new forms of investigation were undertaken. The general work of the chemical department during its first quarter century can be more advantageously considered under specific lines and topics than by following a chronological order.

LINES OF CHEMICAL WORK.

The various lines of chemical activity which have been carried on at the New York Agricultural Experiment Station during the first twenty-five years of its existence may be grouped under the following heads:

1. Milk and its products.
2. Composition and digestibility of cattle foods.
3. Plant-food composition of vegetable and animal materials.
4. Soil fertility and crop production.
5. Methods of analysis.
6. Official analysis of commercial fertilizers.
7. Official analysis of paris green.
8. Manufacture of vinegar.
9. Analysis of spraying materials.

The special portions of work selected for consideration will be presented under the following divisions:

1. Investigations relating to cheese.
2. A comparative study of different breeds of dairy cows in relation to the production of milk, cream, butter and cheese.
3. The proteins of butter in relation to mottled butter.
4. The inspection of commercial fertilizers.
5. Analyses of paris green and other insecticides.
6. Analysis of copper compounds used in spraying plants.
7. The composition of commercial soaps in relation to spraying.
8. The composition and production of sorghum and sugar-beets.
9. The chemistry of home-made cider-vinegar.
10. Methods of analysis.

INVESTIGATIONS RELATING TO CHEESE.

The work of the chemical department has been particularly identified with the study of questions relating to cheese, both practical and scientific. The work began in 1891 and has been continued, with occasional interruptions, until the present. The object first in mind in undertaking the investigations was to extend our knowledge about the relations of milk to cheese, especially in relation to yield and quality. It was a matter of surprise how very little had been done in these lines previous to 1891. The first portion of the investigation[2] was confined to some eight experiments in cheese-making, in which milk was used varying in milk-fat content from 2.35 to 6.5 per ct., the special objects being to ascertain: (1) How much fat can be readily worked into cheese; (2) what influence varying amounts of fat in milk have upon the amount of fat and of casein that can be recovered in cheese; (3) a comparison of the cheddar and stirred-curd processes with reference to yield and losses; (4) comparison of homemade and commercial rennet-extracts; and (5) what general changes take place in the ripening of cheese.

In 1892, the work was much extended and included 106 experiments,[3] extending from May to October, about half of which were done at the Station and half at several different cheese factories. In the work about 200,000 pounds of milk were used, representing the product of not less than 1,500 cows. The points covered by the season's work are indicated as follows.

In each of the 106 experiments, we have made special study of the following points:

1. The loss of fat in the process of cheese-making and its relation to the amount of fat in the milk.

2. The loss of casein and albumin in the process of cheese-making.

3. The relation of casein to albumin in milk.

4. The relation of fat to casein and albumin in milk.

5. The relation of fat in milk to composition of cheese. Does milk containing a certain percentage of fat always make cheese containing a uniform percentage of fat?

6. The relation of casein and albumin in milk to composition of cheese.

7. The relation of fat in milk to yield of cheese. How much cheese should be made for each pound of fat in normal milk? Is there any definite relation?

8. The relation of casein and albumin in milk to yield of cheese.

9. The relation of fat to solids not fat in cheese.

10. The relation of fat to casein and albumin in cheese.

11. Is it possible to establish such definite relations between the composition of milk and the composition of the corresponding cheese, that, from knowing the composition of one, we can tell the composition of the other with a fair degree of accuracy?

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[2] Bul. 37; Rpt. 10:220–300 (1891).

[3] Buls. 43, 45, 46, 47 and 50; Rpt. 11:299–467 (1892).

In addition to the foregoing points of study, there were made special experiments for the purpose of securing information regarding other facts:

12. The influence of the removal of fat from normal milk upon the composition of milk and the composition, yield and quality of cheese was studied in seven experiments.

13. The influence of the addition of fat to normal milk upon the composition of milk and the composition, yield and quality of cheese was studied in three experiments.

14. In twenty experiments, a special comparative study was made of the cheddar and stirred-curd processes.

15. In two experiments, the use of a temperature of 106° F. was employed and its effects studied.

16. In ten experiments, the effects of using amounts of rennet more or less above the usual amount were observed.

17. In nineteen experiments, a study was made of the result of cutting curd in hard and soft condition.

18. In two experiments, a comparison was made between the effects of cutting curd in fine and coarse condition.

19. In fifteen experiments, the influence of using tainted milk upon cheese-making was studied.

20. In three experiments, the milk was shut up warm in cans and cooled down, being held over night before making into cheese. The effects of this treatment were carefully noted.

21. In three experiments, the milk was exposed over night to foul odors and then made into cheese.

22. In three experiments, both taint and acid were developed in the milk before it was made into cheese.

23. In three experiments, the milk was aerated by being passed through a De Laval Baby No. 2 Separator, the cream and skim-milk being mixed together again before making into cheese; and, in two other experiments, the milk was aerated by an ordinary aerator.

24. A comparative study has been made of the composition of the milk, whey and cheese for the different months, in order to note changes of composition taking place during the factory season, and the effect of such changes upon the quantity and quality of cheese.

25. A few of the October cheeses were made with special reference to studying the chemical changes that take place in the process of ripening. These cheeses will be kept as long as practicable and analyzed from time to time.

In February and March, 1893, forty experiments[4] were made with milk obtained from a herd of Jersey cows in order to study the questions of yields and losses with normal milk rich in fat. At about the same time, some twenty experiments were made in the manufacture of edam and gouda cheese.[4½]

In 1893, from April 12 to October 31, 100 experiments[5] were made. This work was done at fifty different cheese factories. There were used about 750,000 pounds of milk, representing the average of not less than 5,000,000 pounds of milk, the product of over 15,000 cows. The points under special investigation were:

1. The conditions of manufacture as found at cheese factories.
2. The composition of normal factory milk in New York State.
3. The composition of whey.
4. The composition of green cheese.
5. Loss of milk constituents in cheese-making.
6. Influence of composition of milk upon cheese.
7. Influence of composition of milk on yield of cheese.
8. Influence of advancing lactation and of season upon the composition of the milk, yield of cheese, etc., during the factory season.

In 1894, from May 9 to October 3, over twenty experiments[6] were carried on in one representative cheese factory for the purpose of making a special study of the variations in composition of milk as affected by the season and the influence of such variations on the yield and quality of cheese. The work done during the season represented average results secured in handling 1,500,000 pounds of milk.

In 1895, analysis of the milk of each of fifty herds of cows, whose milk was taken to a cheese factory, was made regularly once in two weeks for six months, May to October inclusive.[6½] The object of the work was to study the variations in composition which milk undergoes as the result of climatic conditions. It so happened that opportunity was offered to note the effects of drought on yield and composition of milk.

In 1898, there was begun an extended, systematic study[7] of the various conditions that affect loss of weight in cheese during the process of curing.

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[4] Bul. 54; Rpt. 12:285-319 (1893).
[4½] Bul. 56; Rpt. 12:244–269 (1893).
[5] Buls. 60, 61, 62, 65, 68; Rpt. 12:319–481 (1893).
[6] Bul. 82; Rpt. 13:452–523 (1894).
[6½] Buls. 105 and 110; Rpt. 15:37–65, 66–106 (1896).
[7] Bul. 207; Rpt. 20:194–223 (1901).

During the past six or seven years, the work has been directed along such lines of study as enzyms in cheese;[8] the relation to cheddar cheese of the action of acids upon casein and paracasein;[9] some of the compounds present in American cheddar cheese;[10] the relation of carbon dioxide to proteolysis in the ripening of cheddar cheese;[11] experiments in curing cheese at different temperatures;[12] conditions affecting chemical changes in cheese-ripening;[13] some of the first chemical changes in cheddar cheese;[14] chemical studies of camembert cheese.[15]

There have been published since October, 1891, up to June, 1907, thirty-three bulletins treating various phases of the subject of American cheddar cheese and aggregating over 1,400 pages.

The general subject will be treated under the following divisions:

1. The composition of cows' milk in relation to yield, composition and quality of cheddar cheese.
2. The composition of whey and of cheese.
3. The conditions of manufacture of cheese in relation to yield and quality of cheese.
4. Method of paying for milk for cheese-making.
5. Curing of cheddar cheese.
6. Action of acids on casein and paracasein.
7. Changes in cheese in early stages of manufacture.
8. Enzyms in cheese-making and cheese-ripening.

I. THE COMPOSITION OF COW'S MILK IN RELATION TO YIELD, COMPOSITION AND QUALITY OF CHEDDAR CHEESE.

Previous to the time when this Station undertook its extensive investigation of cheese, dairy literature furnished very little information in regard to such fundamental questions as the relation of fat and casein in milk to yield, composition and quality of cheese,—the character and extent of losses of milk constituents in cheese-making, their causes, remedies, etc. Attention had previously been given almost wholly to mere methods of cheese-making.

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[8] Buls. 203 and 233.
[9] Buls. 214, 237, 261 and Tech. Bul. 3.
[10] Bul. 219.
[11] Bul. 231.
[12] Bul. 234.
[13] Bul. 236.
[14] Tech. Bul. 4.
[15] Tech. Bul. 5.

I. COMPOSITION OF NORMAL FACTORY MILK.

In the tabulated statement below we give the extreme range of variations and average of the constituents of normal cheese-factory milk, consisting of the mixed milk of numerous herds of cows. These data represent several hundred analyses.

Table I.— Composition of Normal Cheese-Factory Milk.

	Least	Greatest	Average
	Per ct.	*Per ct.*	*Per ct.*
Milk solids	11.47	13.91	12.67
Water	86.09	88.53	87.33
Fat	3.04	4.60	3.75
Casein	1.93	3.00	2.46
Albumin	0.47	0.88	0.68
Sugar, ash, etc	5.32	6.37	5.78
Solids-not-fat	8.27	9.66	8.92
Cheese-producing solids (fat, casein and insoluble ash)	5.22	7.60	6.46
Whey solids (albumin, sugar, etc.)	5.86	6.87	6.21
Ratio of casein to albumin	2.60	5.58	3.66
Ratio of fat to casein	1.38	1.78	1.52
Ratio of fat to casein and albumin	1.07	1.33	1.19

Influence of advance of lactation on composition of milk.— The composition of milk from month to month during the cheese-factory season (May to October) represents normal changes taking place as the result of advancing lactation, modified more or less by seasonal influences.

Table II.— Change of Composition of Milk with Advance of Lactation.

	April.	May.	June.	July.	Aug.	Sept.	Oct.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Milk, solids	11.98	12.43	12.64	12.52	12.65	12.86	13.50
Water	88.02	87.54	87.36	87.48	87.35	87.26	86.50
Fat	3.43	3.58	3.64	3.62	3.84	3.98	4.23
Casein	2.29	2.34	2.47	2.43	2.39	2.55	2.81
Albumin	0.52	0.68	0.77	0.64	0.61	0.65	0.74
Sugar, ash, etc	5.74	5.83	5.76	5.83	5.79	5.68	5.73
Solids-not-fat	8.55	8.85	9.00	8.90	8.81	8.88	9.27
Cheese-producing solids (fat, casein and insoluble ash)	5.97	6.17	6.36	6.30	6.48	6.78	7.29
Whey solids (albumin, sugar, etc.)	6.01	6.26	6.28	6.22	6.15	6.08	6.22
Ratio of casein to albumin	4.40	3.44	3.21	3.80	3.92	3.92	3.80
Ratio of fat to casein	1.50	1.53	1.48	1.49	1.60	1.56	1.50
Ratio of fat to casein and albumin	1.22	1.18	1.12	1.18	1.28	1.24	1.19

The following facts are worthy of being noticed in connection with the preceding table:

(1) The cheese-producing solids (fat, casein and insoluble ash) tend to increase from month to month and with special rapidity after August.

(2) The decrease of casein in July and August can be traced to the influence of dry weather and its effect upon pastures.

(3) The fat and casein increase in about the same proportion from month to month, leaving out the abnormal month of August.

(4) The whey solids (albumin, sugar, etc.) tend to decrease as the period of lactation advances.

2. THE COMPOSITION OF MILK IN RELATION TO THE YIELD OF CHEESE.

The following facts have been firmly established by our investigations:

(1) *Yield of cheese variable with different milks.*— The amount of cheese made from 100 pounds of milk varies in the case of different milks. Such differences in yield are due to differences in the composition of milk.

(2) *Yield of cheese dependent upon certain constituents of milk.* — It has been shown by our results that the yield of cheese depends most largely upon two milk constituents, *fat* and *casein.*

The milk solids may be roughly divided into two general classes: (a) cheese-producing and (b) whey solids. The former includes fat, casein and insoluble ash; the latter, albumin, sugar and soluble ash constituents. A little fat and casein go into whey, while a small amount of albumin and sugar goes into cheese. Most of the water goes into whey. On an average, 49.1 per ct. of the milk solids goes into whey and 50.9 per ct. into cheese (Tables I and II).

(3) *Amounts of milk-fat and milk-casein in different milks.*— Milk-casein varies in amount in different milks, but not as much as fat does. The following table illustrates the relations of fat and casein in cheese-factory milk.[16]

TABLE III.— AMOUNTS OF FAT AND CASEIN IN FACTORY MILK.

Fat in milk.	Casein in milk.
Per ct.	*Per ct.*
3.00	2.10
3.25	2.20
3.50	2.30
3.75	2.40
4.00	2.50
4.25	2.60
4.50	2.70

[16] Bul. 110; Rpt. 15:66–106 (1896).

In general when the fat in milk increases one-fourth of one per ct. the casein increases one-tenth of one per ct. This applies to milk produced at about the same stage of lactation. For example, if we compare a sample of milk containing 3.5 per ct. of fat produced early in the period of lactation with another sample containing 4.5 per ct. of fat produced, at a period of lactation, say, three or four months later, the casein will be found, as a rule, to increase in proportion to the fat, as shown above in connection with Table II.

(4) *Increase of cheese yield with increase of fat in milk.*— Fat and casein in milk produce the solid portion of cheese for the most part. When fat increases in milk, casein increases also. Hence, milk richer in fat produces larger yields of cheese than milk poorer in fat. The yield of cheese from milk varies as the amount of fat and casein in milk varies. As normal milk grows richer in fat, the same amount of milk makes more cheese, as shown by the following table:

Table IV.— Yields of Cheese from Milks Varying in Fat.

Fat in milk.	Cheese made from 100 pounds of milk.	Cheese made from one pound of fat in milk.
Per ct.	*Lbs.*	*Lbs.*
3.00	8.30	2.77
3.25	8.88	2.73
3.50	9.45	2.74
3.75	10.03	2.67
4.00	10.60	2.65
4.25	11.20	2.63
4.50	11.75	2.61

(5) *Method of calculating cheese yield from percentage of fat in milk.*— In average factory milk we can find the yield of green cheese from 100 pounds of milk by multiplying the percentage of fat in milk by 2.7 as shown by us.[17] This rule applies only to normal milk containing 3.6 to 3.8 per ct. of fat. For milk containing fat above 3.8 per ct., the results are usually too high.

(6) *Method of calculating cheese yield from percentage of fat*

[17] Bul. 43.

and of casein in milk. A closer approximation to cheese yield from any given normal milk can be found when the amount of fat and of casein is known.[18] Multiply the percentage of fat in milk by 1.1 and the percentage of casein by 2.5; add the two products.

This rule can also be applied to normal milk, when only the percentage of fat in milk is known, by first using the following rule to ascertain the amount of casein in milk: *Subtract 3 from the percentage of fat in milk, multiply the result by 0.4, and add this result to 2.1.* This rule is based upon our work embodied in Bul. 110.

(7) *Losses of milk constituents in the manufacture of cheese.*—The yield of cheese from milk depends, of course, upon the amount of milk constituents lost in the process of cheese-making. Under normal conditions of manufacture, about 83 pounds of the water present in 100 pounds of milk go into whey and along with it most of the albumin and sugar and soluble ash. These losses are normal but the losses of fat and casein require special consideration.

(a) *Loss of fat.* In the several hundred experiments made by us in cheese-making, the amount of fat lost in whey varies from 0.20 to 0.50 pound and averages 0.33 pound for 100 pounds of milk. Of the fat in factory milk, from 86.5 to 94.3 per ct., with an average of 91.2 per ct., goes into cheese, while 5.7 to 13.5 per ct., with an average of 8.8 per ct., goes into whey. The amount of fat lost is practically independent of the amount of fat in milk, as shown by the results embodied in the following table:[19]

TABLE V.—LOSS OF FAT.

No. of Different experiments.	Fat in 100 pounds of milk.	Fat lost in whey for 100 pounds of milk.	Fat in milk lost in whey.
	Lbs.	*Lbs.*	*Per ct.*
22	3.0 to 3.5	0.32	9.55
112	3.5 to 4.0	0.33	8.33
78	4.0 to 4.5	0.32	7.70
16	4.5 to 5.0	0.28	5.90
7	5.0 to 5.25	0.31	6.00

The belief universally held by cheese-makers previous to fifteen years ago to the effect that all fat in milk over 3.5 per ct. is inevi-

[18] Bul. 60, p. 514.

[19] Bul. 68, p. 214.

tably lost in cheese-making is fully disproved. Upon this false belief was based largely the pernicious practice of partially skimming milk that was to be used for cheese-making. The loss of fat in cheese-making occurs mechanically. The fat-globules on the cut surfaces of the curd are disengaged from these free surfaces and go into the whey. The following are some of the conditions that increase loss of fat in cheese-making, as worked out by our experiments and those of others: (1) Any condition that interferes with complete coagulation by rennet, such as dilution with water, presence of preservatives like salt, formalin, etc., and certain other compounds. (2) Abnormal composition of milk, in which casein is abnormally low in comparison with fat. (3) Jarring or stirring milk after rennet coagulation has commenced and before it is completed. (4) Cutting curd when too soft. (5) Violent, careless and rapid motions of knife in cutting curd. (6) Heating curd too rapidly or to too high a temperature. (7) Piling curd too much. (8) Putting curd in press too warm. (9) Too rapid application of pressure in press. (10) Fermentations that produce floating curds or excessive acidity or that dissolve casein.

(b) *Loss of casein.* The casein lost in cheese-making is lost mostly in the form of fine particles of curd, which pass through the strainer when the whey is removed from the curd. This loss is not entirely avoidable but is made needlessly greater than normal by violence or carelessness in cutting curd and in subsequent handling, by agitation while drawing off whey, and by imperfect strainers. Any condition that interferes with the complete coagulation of the milk-casein by rennet causes loss of casein. The average loss of casein in cheese-making is 0.10 to 0.15 pound for 100 pounds of milk. Taking casein and albumin in milk together, we have found from 73.7 to 80 per ct. goes into cheese, with an average of 75.7 per ct.; while 20 to 26.3 per ct. goes into whey, the average being 24.3 per ct. Of course, most of this loss is due to milk-albumin.

(8) *The distribution of milk-constituents of 100 pounds of milk in whey and cheese.*— In connection with the preceding discussion, it is a matter of interest, by way of illustration, to show in a more comprehensive and concrete manner what becomes of the constituents of milk in cheese-making. The following table illustrates how much of each milk-constituent goes into cheese and how much into whey in a given case.

TABLE VI.— DISTRIBUTION OF MILK CONSTITUENTS IN CHEESE AND WHEY.

		Water.	Milk-solids.	Fat.	Casein.	Albumin.	Sugar, ash, acid. etc.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Milk	100	87.00	13.00	4.00	2.50	0.75	5.75
Whey	89.35	83.00	6.35	0.30	0.10	0.70	5.25
Cheese	10.65	4.00	6.65	3.70	2.40	0.05	0.50

(9) *The comparative cheese-producing efficiency of milk rich in fat and milk poor in fat.*— An examination of Tables I and II suggests that milk rich in fat contains cheese-producing solids in greater proportion than it does whey solids. In other words, the milk-solids in rich milk, pound for pound, are more efficient for cheese-production than in poor milk. This is demonstrated by the data contained in the following table:

TABLE VII.— CHEESE-PRODUCING EFFICIENCY OF MILK-SOLIDS IN RICH AND POOR MILKS.

TOTAL SOLIDS.	Fat in milk.	Cheese-making solids (fat and casein) in milk.	Whey solids (sugar, albumin, ash, etc.) in milk.	Total solids in form of cheese-making solids.	Total solids in form of whey solids.
Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
11.47	3.00	5.03	6.44	43.8	56.2
12.41	3.50	5.97	6.44	48.1	51.9
13.26	4.00	6.60	6.66	49.8	50.2
13.76	4.50	7.46	6.30	54.2	45.8
14.63	5.00	8.14	6.49	55.6	44.4
14.94	5.25	8.35	6.59	55.9	44.1

The data in Table VII show that in milk containing 3 per ct. of fat, only 43.8 per ct. of the solids are available for cheese-making, but in milk containing larger amounts of fat, larger proportions of milk-solids go into cheese until, with milk containing 5 per ct. of fat, about 56 per ct. of the milk-solids is available for cheese-making and only 44 per ct. constitutes whey solids. Taking the average of our several hundred experiments carried on under cheese-factory conditions, we find that, of the milk-solids, about 49.5 per ct. is lost in whey, while 50.5 per ct. is recovered in cheese.

3. THE COMPOSITION OF MILK IN RELATION TO THE COMPOSITION OF CHEESE.

Since the two principal solid constituents of cheese come from two constituents of milk (fat and casein) with comparatively little loss under normal conditions, it follows that fat and the casein-derived constituents of cheese are present in cheese in proportion somewhat similar to those present in milk. It also follows that the relation of fat and casein in milk largely determines the relation of these constituents in cheese. In other words, the composition of cheese depends on the composition of milk, provided the cheese-making is normal. The addition of cream to normal milk or the removal of cream from normal milk at once changes these relations in both milk and cheese. We have, therefore, to consider the relation of the composition of milk to the composition of cheese in case (1st) of normal milk, (2d) of milk from which fat has been removed (skimmed milk), and (3d) of milk containing added cream.

(1) *In case of normal milk.*— Milk rich in fat, as compared with milk poor in fat, produces cheese containing a larger percentage of fat and, of course, a correspondingly smaller proportion of water and nitrogen (casein) compounds, as is illustrated in the following table:

Table VIII.— Composition of Cheese Varying with Composition of Milk.

Fat in Milk.	Casein in milk.	Ratio of fat to casein.	Fat in cheese.	Casein compounds in cheese.	Ratio of fat to casein compounds in cheese.	Water in cheese.
Per ct.	*Per ct.*	1:	*Per ct.*	*Per ct.*	1:	*Per ct.*
3.00	2.10	1.43	32.2	23.4	1.38	39.4
3.25	2.20	1.48	32.9	23.1	1.42	39.0
3.50	2.30	1.52	33.9	23.0	1.47	38.1
3.75	2.40	1.56	34.7	22.8	1.52	37.5
4.00	2.50	1.60	35.2	22.5	1.56	37.3
4.25	2.60	1.63	35.7	22.3	1.60	37.0
4.50	2.70	1.67	36.3	22.2	1.64	36.5

(2) *In case of skimmed milk.*— The removal of fat from milk reduces the amount of fat in relation to casein, since only a little casein is removed with the fat. The effect of skimming milk upon the composition of milk is illustrated in the following table in the

case of milk containing normally 4 per ct. of fat. For the sake of simplicity we assume that the percentage of casein remains constant, but in reality it would increase slightly.

TABLE IX.— EFFECT OF REMOVING FAT FROM MILK UPON ITS COMPOSITION.

	Fat removed from 100 pounds of milk.	Fat left in 100 pounds of milk.	Casein in milk.	Ratio of fat to casein.
	Lbs.	*Lbs.*	*Lbs.*	1:
Normal milk	0.00	4.00	2.50	1.60
Skimmed milk	0.50	3.50	2.50	1.40
" "	1.00	3.00	2.50	1.20
" "	1.50	2.50	2.50	1.00
" "	2.00	2.00	2.50	0.80
" "	2.50	1.50	2.50	0.60
" "	3.00	1.00	2.50	0.40
" "	3.50	0.50	2.50	0.20
" "	4.00	0.00	2.50	0.00

The figures below give the essential composition of the green cheese made from normal and skimmed milks, as based upon the data contained in Table IX.

TABLE X.— EFFECT OF SKIMMING MILK ON COMPOSITION OF CHEESE.

	Fat removed from 100 pounds of milk.	Fat left in 100 pounds of milk.	Fat in cheese.	Casein compounds in cheese.	Water in cheese.	Ratio of fat to casein compounds in cheese.
	Lbs.	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	1:
Normal milk and cheese	0.00	4.00	37.3	22.5	35.2	1.56
Skim-milk and cheese	1.00	3.00	31.4	26.2	37.4	1.20
" "	2.50	1.50	19.0	31.6	44.4	0.60
" "	3.50	0.50	7.3	37.0	50.7	0.20

In the case of skim-milk cheese found in the market, the percentage of moisture was found to be 55; of casein, 36; and of fat, about 3.

(3) *In case of milk containing added cream.*— Addition of cream to normal milk produces upon the composition of cheese an effect opposite to that of skimming milk; that is, it increases the proportion of fat in cheese in relation to the other constituents.

4. THE COMPOSITION OF MILK IN RELATION TO THE QUALITY OF CHEESE.

Assuming that the best conditions of manufacture are uniformly observed, the following statements have been generally found in our experience to hold true:

(1) Cheese made from milk containing added cream is superior in flavor and texture to that made from ordinary normal milk.

(2) Cheese made from normal milk is superior in flavor, texture body, and keeping quality to cheese made from skimmed milk.

(3) Cheese from skim-milk is made to contain a larger than normal amount of moisture in order to imitate the characteristic body of cheese made from normal milk, due largely to the fat.

(4) Skim-milk cheese is made to contain so large an amount of moisture, in order to imitate the texture of normal cheese, that it dries out very rapidly after being cut.

(5) Skim-milk cheese, on account of its abnormally large moisture content, will acquire disagreeable flavors more easily and quickly than will normal cheese.

(6) Market prices of cheese made from normal milk recognize its superiority in comparison with cheese made from skim-milk, and the market also recognizes differences in the quality of cheese made from different grades of skim-milk.

II. THE COMPOSITION OF WHEY AND OF CHEESE.

The extensive experiments in cheese-making carried on by this Station have furnished a mass of data regarding the composition of whey and cheese. These subjects have been already touched upon incidentally in connection with the subjects previously discussed. It is desirable, in addition, that a comprehensive summary should be presented, embodying more fully the results of our work.

1. THE COMPOSITION OF WHEY.

The composition of whey varies according to (1st) the composition of the milk from which it comes, and (2d) the losses of milk-constituents due to conditions present in the operation of cheese-making. It is too obvious to need further elaboration that the larger the amount of sugar and albumin in milk, the larger will be their amount in whey. The question of losses of fat and casein in whey are treated elsewhere (pp. 172, 173) and does not need further discussion here.

The amount of acid in whey varies greatly, depending largely on the time the determination of acidity is made. When the whey is removed from the curd, the acidity (calculated as lactic acid) may vary from 0.10 to 0.15, and this amount will be increased up to the end of the cheese-making. Fresh whey shows less acidity than the milk from which it comes, because the whey does not contain the calcium casein of the milk, this compound by itself showing a considerable apparent acidity. The percentage of sugar in whey depends upon the time when the whey is tested, the sugar decreasing in amount as it is changed into lactic acid. In the following table we give a comprehensive statement of the results obtained in the analysis of whey:

TABLE XI.— COMPOSITION OF WHEY.

	Least.	Greatest.	Average.
	Per ct.	*Per ct.*	*Per ct.*
Water	92.48	93.57	93.04
Total solids	6.43	7.52	6.96
Fat	0.22	0.55	0.36
Casein	0.05	0.15	0.10
Albumin	0.65	0.90	0.74
Sugar, lactic acid and ash	5.39	6.43	5.76

2. THE COMPOSITION OF NORMAL FACTORY CHEESE.

In addition to the facts already discussed in connection with the relation of composition of cheese to composition of milk, we will present a comprehensive tabular summary of our experimental results and will also consider in more detail how a cheese made from whole milk can be distinguished by its composition from a cheese made from milk that has been skimmed, whether much or comparatively little fat has been removed. We will give also a statement of the average of composition of ripened cheese.

TABLE XII.— COMPOSITION OF CHEESE MADE FROM NORMAL FACTORY MILK.

	IN GREEN CHEESE.		
	Least.	Greatest.	Average.
	Per ct.	*Per ct.*	*Per ct.*
Water	32.69	43.89	36.84
Total solids	56.11	67.31	63.16
Fat	30.00	36.79	33.83
Solids-not-fat	27.50	32.29	29.33
Nitrogen (casein) compounds	20.80	26.11	23.72
Ash, acid, etc	3.12	7.02	5.61
Ratio of fat to nitrogen (casein) compounds	1.27	1.60	1.42
Percentage of total solids consisting of fat	50.39	56.83	53.56
Percentage of total solids consisting of solids-not-fat	43.17	49.61	46.44

3. METHOD FOR DISTINGUISHING WHOLE-MILK FROM SKIM-MILK CHEESE.

Cheese made from normal milk rarely contains when green less than 32 per ct. of fat, but such cheese may contain only 30 per ct. of fat if an unusually large amount of moisture has been held in the cheese. The percentage of fat varies, of course, with the percentage of moisture, and hence the percentage of fat in cheese may not always be a reliable guide as to whether the cheese is made from whole milk or skim-milk. The percentage of fat becomes a reliable guide if we eliminate the moisture, which is a quite variable constituent. In all of our work, it has been found that the cheese-solids (cheese minus water) contain over 50 per ct. of fat if the cheese is made from whole milk. The variation is from 50.39 to 56.83 per ct., with an average of 53.56 per ct. The remainder of the cheese solids or solids-not-fat consists of nitrogen compounds, ash, etc. Our work was made the basis of the United States Government standard for cheese, which requires that in whole-milk cheese 50 per ct. of the cheese-solids shall consist of fat. Cheese containing less fat is presumed to have been made from skimmed milk.

Another relation can be used for distinguishing whole-milk from skim-milk cheese and that is the ratio of fat to nitrogen compounds. We have found that in no case in cheese made from normal milk is the proportion of fat to nitrogen compounds less than 1.27. The ratio varies from 1.27 to 1.60 and averages 1.42. It is safe to say that in cheese made from normal milk this ratio should not be less than 1.25.

When, in the process of cheese-making, abnormally large amounts of fat are lost, the result may be the same as if the cheese were made from partially skimmed milk. Such cases are rare but it is easily possible that they may occur now and then.

III. THE CONDITIONS OF THE OPERATION OF CHEESE-MAKING IN RELATION TO YIELD AND QUALITY OF CHEESE.

Variation of conditions during the operation of cheese-making makes profound differences in the character of the resulting product. We have studied the effect of varying certain conditions of cheese-making upon the yield and quality of cheese and we will now briefly review the results of these experiments after giving a summary of the various conditions which were found to be employed at different cheese factories.

1. SUMMARY OF CONDITIONS OF MANUFACTURE AT CHEESE FACTORIES.

(1) *Ounces of rennet-extract used for* 1,000 *pounds of milk.*—The amount of rennet-extract used for 1,000 pounds of milk varied from two to five ounces and averaged three in the case of fifty different factories. The wide variation was due in part to the fact that different kinds of rennet-extract were used and these varied considerably in strength.

(2) *The temperature of the milk when rennet was added* varied from 80° to 88° F. and averaged 84.5° F. Some of the variation was undoubtedly due to the use of inaccurate thermometers.

(3) *The time required for the rennet to coagulate the milk completely* varied from 5 to 78 minutes and averaged 32 minutes.

(4) *The temperature to which the curd was heated after being cut* varied from 95° to 105° F. and averaged 99° F. Where a high temperature was used, extra losses of fat were noticed to occur.

(5) *The time from cutting curd to drawing whey* varied from 1 hour and 25 minutes to 5 hours and 30 minutes, averaging 3 hours and 18 minutes. The time decreased somewhat from month to month as the season advanced.

(6) *The length of string on a hot iron* when whey was drawn varied from a trace to 1¼ inches and averaged ¼ inch.

(7) *The time from drawing whey to putting curd in press* varied from 40 minutes to 6 hours and 15 minutes, averaging 1 hour and 53 minutes.

(8) *The length of string on hot iron when curd was put in press* varied from ½ inch to 4 inches and averaged 1½ inches.

(9) *The temperature of curd when put in press* varied from 70° to 90° F. and averaged 81° F.

(10) *The time consumed in the operation of cheese-making* after adding rennet varied from 2 hours and 12 minutes to 9 hours and 50 minutes, and averaged 6 hours.

2. COMPARISON OF THE CHEDDAR AND STIRRED-CURD PROCESSES OF CHEESEMAKING.

Results were obtained in twenty different experiments and they showed on an average very little difference in yield or quality. The cheddar process lost a little less fat and retained slightly more moisture and gave, therefore, a slightly higher yield.

3. COMPARISON OF ORDINARY AND HIGH TEMPERATURES IN HEATING CURD.

Experiments were made in which was tested the effect of heating curd to 106° F. There was an increase of the amount of constituents lost in whey, less moisture in cheese and decreased yield. In quality, the cheese showed imperfect flavor and lack of firmness in body.

4. EFFECT OF USING DIFFERENT AMOUNTS OF RENNET-EXTRACT.

In 20 sets of experiments, we made comparison of using 3 and 6 ounces of rennet-extract (Hansen's) for 1,000 pounds of milk. When the larger amount of rennet was used, the loss of milk constituents was slightly greater and the yield slightly less. The moisture content of the cheese was practically the same. The use of a large amount of rennet was not attended with any advantages as regards yield of cheese. The ripening was hastened by the increased amount of rennet.

5. EFFECTS OF CUTTING CURD IN HARD AND SOFT CONDITION.

In about 20 experiments, curd was cut in softer condition than usual and also in harder condition than usual. The results showed very little difference in any respect, except that the hardest curd showed a tendency to retain a little more water.

6. EFFECTS OF CUTTING CURD COARSE.

When the curd was cut less fine than usual, the proportion of loss in manufacture was less than when cut more fine. The yield was increased by coarse cutting, because of the retention of a larger amount of moisture than usual, owing to which the cheese made from coarse-cut curd was salvy in body.

7. THE EFFECTS OF TAINTED MILK IN CHEESE-MAKING.

The word "tainted" is used to describe the defective condition of milk which contains bacteria producing undesirable flavor in cheese made from it. Owing to excessive losses due to the condition of the milk and to the manner in which it had to be treated in cheese-making, the losses, especially of fat, were excessive as compared with normal milk. One hundred pounds of tainted milk made about one-half pound less of cheese than the same milk in normal condition.

8. EFFECT OF AERATING MILK BY PASSING THROUGH A SEPARATOR.

Tainted milk was passed through a separator and the cream and skim-milk mixed again before making into cheese. The yield was not increased but the quality was much improved. Milk of good quality that is thus treated by a separator makes cheese of higher quality but lower yield.

IV. METHODS OF PAYING FOR MILK FOR CHEESE-MAKING.

In the summer of 1890, the Babcock test first made possible the determination of fat in milk by a simple method. While its usefulness was apparent at once as a basis for paying for milk at creameries, it was not regarded as having any practical application in the case of cheese factories, because milk-casein as well as milk-fat must be considered. So little was then known of the quantitative relation of the constituents of milk to the constituents of cheese that no one was in position to deny or disprove the belief universally held. By the fall of 1892, we had accumulated sufficient data in our investigations of cheese-making to demonstrate for the first time that for all practical purposes the fat alone in milk is a fair basis on which to pay for milk at cheese factories, at least much fairer than the old method of paying for milk solely by weight. The application of the results of our investigation to this question was fully presented in Bulletin No. 68, " Fat in milk, as a practical basis for determining the value of milk for cheese-making," and Bulletin No. 110, " Milk-fat and cheese yield."

The main facts bearing on the question have already been presented in the pages preceding and it will be sufficient here merely to recapitulate some of the more important statements.

(1) Milk varies greatly in its composition. In paying for milk for cheese-making, absolute fairness can be realized in every individual case only by a careful determination of both fat and casein. But no practicable test for both fat and casein is yet known.

(2) Cheese made from milk rich in fat is greater in yield and its constituents, pound for pound of cheese, possess a higher value than cheese made from milk poorer in fat.

(3) When a pound of fat in poorer milk is equivalent to more cheese than is a pound of fat in richer milk, the difference can be wholly removed by adding skim-milk to, or removing fat from, the richer milk. The difference in composition between cheese made from poor and rich milk is a skim-milk difference and a skim-milk cheese difference.

(4) Of all practicable methods suggested, the use of milk-fat as a basis in paying for milk for cheese-making gives the nearest approach to real fairness.

(5) All proposed modifications of the milk-fat method have been in the interest of the producer of poor milk as against the interest of the producer of richer milk.

(6) One modification of the milk-fat method proposes to add 2 to the percentage of fat in milk, aiming to take into consideration casein as well as fat. The fairness of such a method is based upon two false assumptions. First, it assumes that cheese made from poor milk has the same composition and that the constituents yield the same value as cheese made from richer milk. Second, it assumes that all milk, rich and poor alike, contains just 2 per ct. of casein, no more and no less. It ignores the general rule that casein increases when the fat increases, even though the increase may not be proportional to the increase of fat. It provides payment for all the casein in poor milk but only for a part of the casein in richer milk. The proposal to introduce this modification has caused great confusion in the mind of the average dairyman, giving the general impression that the Babcock test itself is wrong. The result has been in many cases a check to progress and a reversion to the old method of paying for milk by weight alone.

We will conclude this brief discussion by giving the practical reasons for substituting the fat basis for the weight basis in paying for milk at cheese factories.

REASONS FOR DISCARDING THE METHOD BASED ON WEIGHT ALONE OF MILK.

1st. Because it is based upon the false assumption, that all kinds of milk have the same cheese-producing value. It fails to recognize the fundamental fact that milks differ in regard to the amount of cheese they can produce.

2d. Because the method, being founded upon a false basis, is unjust and is, therefore, not business-like. By this system, money which belongs solely to the producer of the better milk is taken from his pocket and transferred to that of his neighbor, who produces poorer milk.

3d. Because the old system discourages the production of better milk and is a positive barrier to improvement. When milk is paid for by weight alone, then more money can be gained by increasing the amount of milk produced, without regard to its composition.

It is a well-known fact that under this system the composition of milk has deteriorated in the last generation, and, so long as a premium was offered for increasing the amount of milk produced, there was no inducement to pay any attention to the composition of the milk, if only it met the legal requirements.

4th. Because the old system encourages the addition of water, removal of cream and all similar forms of dishonesty. When quantity and not quality is paid for, some will be found who will try dishonestly to take advantage of the system; and this can hardly be surprising, when the system itself is founded upon an untruth, and is itself dishonest.

REASONS FOR USING THE MILK-FAT BASIS IN PAYING FOR MILK AT CHEESE FACTORIES.

1st. Because the amount of fat in milk offers the most accurate, practicable and just basis we have for determining the cheese-producing value of milk.

2d. Because this method recognizes the fundamental truth that different milks possess different values for cheese-making.

3d. Because this method, being based upon the truth, is just to all and is, therefore, in the highest sense, business-like. It guarantees pay for what is in the milk that makes cheese.

4th. Because the adoption of this method will result in an improvement in the character of the milk production. Why? Because it offers an inducement to each dairyman to improve the composition of his milk. It puts more money into the pocket of the man who produces the better milk. This improvement will be realized as a result of more careful selection of dairy animals, more attention to breeding, more intelligent and economical feeding, more humane treatment of dairy animals and better care of milk.

5th. Because all temptation to adulterate milk by watering or skimming is removed, since a man receives pay for just what he furnishes that is of most value for cheese production.

6th. Because the adoption of this system lies at the very foundation of the future improvement of the dairy industry. Nothing will so quickly open the eyes of dairymen and show them the need of improvement in milk production as the application of this system to their herds and individual animals.

7th. Because improvement in the character of dairy animals and in the consequent yield and composition of milk means economy of production and increased profit. Our investigation with different breeds of dairy animals has emphasized the fact that a pound of fat in rich milk is produced at a lower cost than in poorer milk. It would not be difficult to show that it would be easily possible within a few years to increase the yield of our annual cheese-product by an amount equal in value to one million dollars, with fewer animals and at an actually less cost than at present.

V. STUDIES RELATING TO THE CURING OR RIPENING OF CHEDDAR CHEESE.

At the very beginning of our cheese investigation in 1891 some attention was given to a study of the process of cheese-ripening, the process by which green cheese, which is practically flavorless, rubber-like and insoluble, is changed into a palatable, well-flavored, digestible and soluble substance. The cheeses first made were examined at intervals of one, three and five weeks to determine (1) the total loss of weight in ripening, (2) influence of ripening on (a) fat, (b) casein and (c) acidity.[19a] In 1892 cheeses were made under varying conditions and changes were studied at the end of five months. Comparison was made (1) of cheese made from milk containing added cream and cheese made from partially skimmed milk; (2) of cheese in the manufacture of which we used three and nine ounces of rennet; (3) of cheese containing an excessive amount of moisture (42.9 per ct.) and cheese containing normal amounts. A more thorough study was made of the changes taking place in the nitrogen compounds.[20]

It was realized that temperature and atmospheric moisture play so important a part in the process of cheese-ripening that work was necessarily suspended until adequate provisions could be made for controlling temperature and moisture in specially constructed curing-rooms. These conditions were not available until 1898, when the study was renewed. Our equipment then consisted of six rooms in which the temperature could be controlled with a variation of only one or two degrees from a given point. Our studies were made with cheese kept at 55°, 60°, 65°, 70°, 75° and 80° F. The moisture was usually kept between 70 and 80 per ct. of moisture. In special experiments, cheese was cured in a saturated atmosphere, and in some cases were covered with paraffin. In Bulletin 207 (1901) the results are given of studies carried on for

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[19a] Bul. 37, pp. 705–711.

[20] Bul. 54, pp. 261–269.

three years concerning the conditions affecting weight lost by cheese in curing.

In 1902 experiments[21] in curing cheese at different temperatures were undertaken in coöperation with the United States Department of Agriculture. During all our work extensive studies were also made of conditions affecting chemical changes in cheese-ripening.[21a] We will present a summary of the results of our work under following divisions:

1. Conditions affecting weight lost by cheese in curing.

2. Commercial experiments in curing cheese at different temperatures.

3. Conditions affecting chemical changes in cheese-ripening.

4. Some practical applications of the results obtained in studies of cheese-ripening.

1. CONDITIONS AFFECTING WEIGHT LOST BY CHEESE IN CURING.

It is well known among cheesemakers that cheese begins to lose weight immediately from the time it is taken from press and placed upon the shelves of the curing-room; this loss continues indefinitely. While there has been some study in Europe relating to the conditions and extent of loss of weight in cheese-curing, the results thus obtained are not generally applicable to the conditions prevailing in this country. Some study of this question had been made in America, but it had been rather desultory in character, lacking in systematic plan and thoroughness, and under circumstances not permitting careful control of conditions.

The loss of weight in cheese during the process of curing under proper conditions may be regarded for practical purposes as being due entirely to the evaporation of water from the cheese. Of course, the mechanical loss of fat by exudation from cheese kept at high temperatures must be considered, but with proper control of temperature such loss will not take place. The small amount of loss due to the formation and escape of carbon dioxide and other gases from cheese can be neglected for practical purposes.

The rapidity and extent of loss of moisture in cheese during the process of curing vary with several conditions, chief of which are the following:

(1) The percentage of moisture originally present in the cheese.

(2) The texture of the cheese.

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[21] Bul. 234.

[21a] Bul. 236.

(3) The temperature of the curing-room.

(4) The size and shape of the cheese.

(5) The proportion of water-vapor present in the air of the curing-room.

(1) *Loss of moisture in cheese as influenced by the percentage of water present in green cheese.*— There is a general marked tendency for very moist cheese to lose water more rapidly than for cheese having less moisture, other conditions being uniform. This is true also even when the amount of moisture in the green cheese varies within comparatively narrow limits. The following tables illustrate the truth of these statements:

TABLE XIV.— LOSS OF MOISTURE IN CHEESES CONTAINING DIFFERENT PERCENTAGES OF WATER.

WATER IN 100 LBS. OF GREEN CHEESE.	WATER LOST BY 100 LBS. OF GREEN CHEESE.			
	In 1 week.	In 2 weeks.	In 3 weeks.	In 4 weeks.
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
55	9.0	11.2	12.3	16.8
50	5.5	9.2	11.0	12.9
45	4.5	6.3	8.0	9.5
35	3.3	4.2	4.9	5.7

The data in the following figures represent averages obtained with four different lots of cheese. The cheeses weighed about thirty pounds each.

Water in 100 lbs. green cheese, lbs.	41.7	38.7	37.6	35.4
Water lost by 100 lbs. cheese in 6 weeks, lbs.	5.3	4.6	4.5	4.2

(2) *Loss of moisture as influenced by texture of cheese.*— Cheese filled with holes will occupy more volume than the same weight of cheese free from holes. Hence, cheese with such faulty texture has a larger surface exposed for evaporation relative to its weight and will lose more moisture. Then, in addition, the presence of numerous holes in cheese greatly facilitates the escape of moisture from the interior of the cheese to the surface. This is a partial explanation of the fact that cheese high in moisture loses water more rapidly than cheese containing less moisture. It is well known that cheese containing high percentages of water usually develops

holes abundantly, especially when cured at or above ordinary temperatures.

(3) *Loss of moisture as influenced by temperature.*— In our study of the influence of temperature upon loss of moisture we used six different temperatures, viz.: 55°, 60°, 65°, 70°, 75°, 80° F. The degree of moisture was kept as nearly uniform as possible in the different curing-rooms.

In this connection we present the results secured with cheeses fifteen inches in diameter, and weighing, fresh from press, about sixty-five pounds, the usual standard size of the most common type of American cheddar cheese.

TABLE XV. — LOSS OF MOISTURE AT DIFFERENT TEMPERATURES.

TEMP. OF CURING-ROOM.	WATER LOST BY 100 LBS. OF GREEN CHEESE IN									
	1 week.	2 weeks.	3 weeks.	4 weeks.	8 weeks.	12 weeks.	16 weeks.	20 weeks.	24 weeks.	28 weeks.
Deg. F.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
55.............	1.6	2.6	3.2	3.7	5.2	6.1	6.8	7.5	8.1	8.6
60.............	1.7	2.8	3.4	3.9	5.5	6.5	7.5	8.5	9.3	9.9
65.............	1.9	3.0	3.6	4.1	5.8	7.0	8.2	9.2	10.1	10.5
70.............	2.0	3.1	3.7	4.3	6.0	7.8	9.0	10.1	11.1	12.0
75.............	2.2	3.3	4.0	4.7	7.2	9.7	11.4	....	....	.....
80.............	2.4	3.7	4.5	5.2	8.3	11.6	15.5	....	....	.....

AVERAGE WEEKLY LOSS AT DIFFERENT TEMPERATURES.

TEMP. OF CURING ROOM.	AVERAGE LOSS PER WEEK. WATER LOST BY 100 LBS. OF GREEN CHEESE.									Lbs. total loss for six months.
	1st week.	2d week.	3d week.	4th week.	2d month.	3d month.	4th month.	5th month.	6th month.	
Deg. F.	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Lbs.*
55.......	25.6	16.0	9.6	8.0	6.0	3.6	2.8	2.8	2.4	8.1
60.......	27.2	17.6	9.6	8.0	6.4	4.0	4.0	4.0	3.2	9.3
65.......	30.4	17.6	9.6	8.0	6.8	4.8	4.8	4.0	3.6	10.1
70.......	32.0	17.6	9.6	9.6	6.8	4.8	4.8	4.4	4.0	11.1
75.......	35.2	17.6	10.2	10.2	10.0	10.0	6.8	.....	.....	......
80.......	38.4	20.8	12.8	10.2	12.4	13.2	15.6	.....	.....	......

These data show that loss of moisture (a) increases with temperature, (b) is greater in the first week than during any succeeding week, and (c) decreases continuously as the cheese grows older, except at high temperatures (80° F.), when noticeable leakage of fat may occur after the fourth week, thus increasing total weekly loss.

(4) *Loss of moisture as influenced by size and shape of cheese.*— Cheeses may vary in size in one of two ways, (a) in height and (b) in diameter. The proportion of moisture lost in cheese having the same diameter is greatest when the height is least. The loss decreases with increase of height. This is illustrated in the following table:

TABLE XVI.— WEIGHT LOST BY CHEESE OF VARYING HEIGHT AND UNIFORM DIAMETER —(7 INCHES).

HEIGHT OF CHEESE.	Weight of green cheese.	WATER LOST BY 100 LBS. OF GREEN CHEESE IN								
		1 week.	2 weeks.	3 weeks.	4 weeks.	8 weeks.	12 weeks.	16 weeks.	20 weeks.	24 weeks.
Inches.	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
3	4.6	3.4	5.3	6.4	7.0	10.7	12.9	13.9	15.9	17.0
4	6.1	3.3	5.1	6.1	6.7	9.7	11.5	13.0	14.0	15.6
5	7.9	2.8	4.2	5.5	6.3	8.3	9.8	11.2	12.6	13.4
6	9.3	2.5	3.9	5.2	6.0	7.8	9.4	10.6	11.6	12.8
7	11.0	2.3	3.4	4.7	5.6	7.4	8.9	10.5	11.2	12.4

In the case of cheese uniform in height and varying in diameter, the loss of weight increases when the diameter of the cheese decreases. This is true at various temperatures. The following table illustrates this:

TABLE XVII.— WEIGHT LOSS BY CHEESES OF DIFFERENT DIAMETERS.

DIAMETER OF CHEESES.	Weight of green cheese.	Temperature of curing-room.	WATER LOST BY 100 LBS. OF CHEESE IN							
			2 weeks.	3 weeks.	5 weeks.	7 weeks.	8 weeks.	12 weeks.	16 weeks.	20 weeks.
Inches.	*Lbs.*	*Deg. F.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
13	36	55	2.9	3.6	4.5	4.9	5.4	6.4	7.2	8.1
7	10	55	3.9	4.9	6.3	6.9	7.2	8.7	9.9	11.5
13	29	60	2.8	3.7	4.7	5.7	6.0	7.3	8.2	9.3
7	9	60	3.8	4.8	6.7	7.9	8.2	9.7	11.2	12.5

(5) *Loss of moisture as influenced by proportion of water-vapor present in air of curing-room.*— The relative amount of moisture in air, or, more properly, the degree of saturation, exercises a marked influence upon loss of water in cheese-ripening. The greater

the humidity of the air, the less will be the loss of moisture from the cheese, as is shown by the following data:

TABLE XVIII.— LOSS OF MOISTURE IN CHEESE KEPT IN AIR COMPLETELY AND PARTIALLY SATURATED WITH MOISTURE.

AGE OF CHEESE.	IN AIR PARTIALLY SATURATED.		IN AIR COMPLETELY SATURATED WITH MOISTURE.	
	Moisture in cheese.	Water lost by 100 lbs. of cheese.	Moisture in cheese.	Water GAINED by 100 lbs. of cheese.
	Per ct.	*Lbs.*	*Per ct.*	*Lbs.*
2 weeks........	35.99	....	35.93	....
1 month.........	35.23	0.76	35.87	....
2 months........	34.86	1.13	36.01	0.08
6 "	31.87	4.12	37.04	0.11
12 "	26.30	9.69	37.63	1.70
15 "	24.85	11.14	37.85	1.92

2. COMMERCIAL EXPERIMENTS IN CURING CHEESE AT DIFFERENT TEMPERATURES.

Experiments were undertaken in coöperation with the United States Department of Agriculture to study, on a commercial scale, the effects of curing cheese at different temperatures and the effect of covering cheese with paraffin, upon (1) the commercial quality of the cheese, (2) the loss of weight, and (3) the chemical changes taking place. Cheese was secured, representing the product of the states of New York, Pennsylvania and Ohio, and placed in cold storage at the temperatures of 40° F., 50° F. and 60° F. These were examined commercially by a committee of experts when first placed in cold storage and later after being in cold storage 10, 20, 28 and 35 weeks. Cheeses of different size were used, weighing 70, 65, 45, 35 and 12.5 pounds. Also, in one case, cheeses were covered with coating of paraffin. Chemical analyses were made at intervals.

The general results are given in the following statements:

(1) *Loss of weight.*— The loss of weight increased with increase of temperature, being on an average in 20 weeks 3.8 pounds per 100 pounds of cheese at 40° F., 4.8 pounds at 50° F. and 7.8 pounds at 60° F. The large-sized cheeses lost less weight per 100 pounds than the smaller-sized ones, as shown by the following table:

TABLE XIX.— LOSS IN WEIGHT BY CHEESES OF DIFFERENT SIZES.

AVERAGE WEIGHT OF SINGLE CHEESES.	WEIGHT LOST PER 100 POUNDS OF CHEESE IN 20 WEEKS AT		
	Temp. 40° F.	Temp. 50° F.	Temp. 60° F
	Lbs.	*Lbs.*	*Lbs.*
70 lbs.	2.5	2.4	4.2
45 "	2.7	3.7	5.1
35 "	3.9	5.9	8.5
12½ "	4.6	8.1	12.0

(2) *Results of scoring cheese.*— Cheese cured at 40° F. was superior in quality to the same kind cured at higher temperatures. That cured at 50° F. was superior in quality to that cured at 60° F. The general averages of the scores at the end of 20 weeks were as follows: 95.7 at 40° F., 94.2 at 50° F. and 91.7 at 60° F. The difference in quality was confined in most cases to flavor and texture, the color and finish being little or not at all affected in cheese that was in good condition at the beginning.

(3) *Effects of covering cheese with paraffin.*— The method of covering cheese with paraffin greatly reduces the loss of moisture. The loss of moisture in cheese covered with paraffin was only 0.3 pound per 100 pounds of cheese in 20 weeks at 40° F., 0.5 pound at 50° F. and 1.4 pounds at 60° F. In the same kind of cheese not thus covered the loss of moisture was much greater at all temperatures. By covering cheese with paraffin, a saving in loss of moisture can be effected, amounting to 5 or 6 pounds per 100 pounds of cheese at 60° F. and at 50° or below the total loss of moisture can be reduced to less than 1 pound per 100 pounds of cheese. In addition, the use of paraffin prevents the growth of molds. In every case, cheeses covered with paraffin were entirely clean, while the others were more or less heavily coated with molds. The commercial qualities of the cheese were favorably influenced after six months in the case of those covered with paraffin, especially flavor.

(4) *Advantages of curing cheese at low temperatures.*—(1) The loss of moisture is less at low temperatures, and therefore there is more cheese to sell.

(2) The commercial quality of cheese cured at low temperatures is better and this results in giving the cheese a higher market value.

(3) Cheese can be held a long time at low temperatures without impairment of quality.

(4) By utilizing the combination of paraffining cheese and curing it at low temperatures, the greatest economy can be effected.

3. CONDITIONS AFFECTING CHEMICAL CHANGES IN CHEESE-RIPENING.

It is well known that, during the cheese-making process, chemical changes soon begin in the freshly coagulated curd or calcium paracasein, which is formed when milk-casein is acted upon by rennet. These chemical changes in paracasein are followed by others, and we have a series of such changes from the time the cheese-making process begins, continuing for many months. The same cheese examined at intervals is found to show quite marked variations in the character of its nitrogen compounds. Cheeses made from the same milk under the same conditions of manufacture and subjected to different conditions during the ripening process show a difference in chemical composition. Cheeses manufactured under different conditions and ripened under uniform conditions may vary in the character of their nitrogen compounds. It was desirable that a somewhat comprehensive study should be made of the changes actually found in the nitrogen compounds of cheese, using in the work only cheeses made and ripened under known, controlled conditions. The study extended to some of the more prominent factors, such as time, temperature, moisture, salt, rennet, acid, etc.

Starting with the casein of milk, we have in cheese-curd and in ripening cheese the following nitrogen compounds formed in something like the following order: paracasein, paranuclein, caseoses, peptones, amido compounds and ammonia compounds. Paracasein is soluble in 5 per ct. solution of salt, while the other compounds are soluble in water. Among the amido compounds there have been found (Bulletins 219, 231) the following: Lysatine, histidine, lysine, tetramethylenediamine (putrescine), tyrosine, oxyphenylethylamine, arginine, guanidine, etc. The amounts of these different compounds and classes of compounds and their relations to one another will be briefly considered.

(1) *The relation of time to the cheese-ripening process.*—The amount of water-soluble nitrogen increases as cheese ages. The rate of formation of these compounds is more rapid in the early stages of ripening, about 66 per ct. being formed during the first three months and over 90 per ct. in the first nine months of an eighteen-month period of study. The data upon which these statements are based are contained in the following table:

Table XX.— Showing Effect of Time on Cheese-Ripening.

Age of Cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—						
	Para-casein.	Water-soluble nitrogen compounds.	Para-nuclein.	Caseoses.	Peptones.	Amides.	Ammonia.
Months.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	20.18	21.44	2.06	3.15	3.84	9.88	1.56
3	27.26	30.98	4.45	4.56	4.65	14.36	2.45
6	27.55	36.15	3.57	4.92	4.22	19.96	3.52
9	24.14	43.45	4.02	4.59	3.56	26.53	4.74
12	19.04	44.75	3.52	4.16	3.95	28.38	5.41
18	12.65	47.25	3.40	3.88	2.57	30.46	6.62

(2) *The relation of temperature to the cheese-ripening process.*— Other conditions being uniform, it appears that (a) the water-soluble nitrogen compounds in cheese increase, on an average, very closely in proportion to increase of temperature; (b) from the average of our results, there is an increase of 0.5 per ct. of water-soluble nitrogen compounds for an increase of one degree of temperature between the limits of 32° F. and 70° F.; (c) the amido compounds and ammonia are formed in cheese more abundantly at higher temperatures and accumulate in the cheese, while the other water-soluble compounds of nitrogen and also paracasein do not appear to be regularly influenced by temperature in the early stages of ripening, but after some months they decrease in quantity with increase of temperature.

(3) *The relation of moisture in cheese to the ripening process.*— Other conditions being uniform, cheese containing more moisture generally contains larger amounts of water-soluble nitrogen compounds, especially after the early stages of ripening.

(4) *The relation of size of cheese to the ripening process.*— Cheeses of large size usually form soluble nitrogen compounds more rapidly than smaller cheeses under the same conditions, because large cheeses have a higher water content after the early period of ripening.

(5) *The relation of salt in cheese to cheese-ripening.*—Cheese containing more salt forms water-soluble nitrogen compounds more slowly than cheese containing less salt. This appears to be due, in part, to the direct action of salt in retarding the activity of one or more of the ripening agents and, in part, to the tendency of the salt to reduce the moisture content of the cheese.

(6) *The relation of varying amounts of rennet to cheese-ripening.*—The use of increased amounts of rennet-extract in cheese-making, other conditions being uniform, results in producing increased quantities of water-soluble nitrogen compounds in a given period of time, especially such compounds as paranuclein, caseoses and peptones.

(7) *The relation of acid to cheese-ripening.*—Acid is essential to different stages of manufacture of cheddar cheese. Its presence appears to be necessary in the changes preliminary to the formation of water-soluble nitrogen compounds.

(8) *Tranisent and cumulative products in cheese-ripening.*—Paracasein, caseoses and peptones usually vary within small limits and do not usually accumulate in cheese in increasing quantities but after a while decrease, while amides and ammonia are found to accumulate continuously during the normal ripening process. Low temperatures favor some accumulation of the transient products, while high temperatures favor the more rapid accumulation of amides and ammonia.

(9) *Influence of products of proteolysis on cheese-ripening.*—The accumulation of soluble nitrogen compounds in cheese appears to diminish the action of the agents causing the changes, so that cheese ripens less rapidly after the first period.

(10) *Why moisture affects the cheese-ripening process.*—An increased moisture content in cheese favors more active chemical change for two reasons: (1) Moisture in itself favors the activity of ripening ferments; (2) the presence of increased amounts of moisture serves to dilute the fermentation products that accumulate.

4. SOME PRACTICAL APPLICATIONS OF THE RESULTS OBTAINED IN THE STUDIES OF CHEESE-RIPENING.

Taking the facts presented in the foregoing pages what applications can we make of them to the interests of the cheese-factory owner, of his patrons, and of the consumers of cheese? These applications can be discussed under the following divisions:

The relations of (1) water; (2) temperature, and (3) chemical changes to the value of cheese.

(1) *Value of water in cheese to dairymen.*—To the cheese-maker and producer of milk, water in cheese is money when put there *in the right way and in proper proportions.* It is essential, in the process of manufacture, to incorporate water in cheese in quantities best suited to the requirement of the market for which the cheese is

intended, and then it is equally essential that the water be kept there with the least possible loss. From the dairyman's standpoint, it is desirable to sell as much water in cheese as will suit the consumer. In preventing excessive loss of moisture, there is more water to sell at cheese prices.

From inquiries made among cheese-makers, we find quite a variation in respect to the loss of moisture experienced by them in curing cheese. One of the most complete records, covering an entire season, furnished by a cheese-maker and factory owner who has better than average conditions for curing-rooms, makes the average loss of weight during thirty days amount to about five pounds per hundred pounds of cheese. Others report an average loss for the first thirty days as high as ten pounds per hundred pounds of cheese. The average loss lies somewhere between these two extremes and would probably not be far from seven pounds per hundred pounds of cheese.

By curing cheese at low temperatures or by covering new cheese with a thin coating of parffin and keeping at even moderate temperatures (about 60° F.), moisture in cheese can be properly conserved. This is well shown by the data in Bulletin 234, from which we quote the following statements:

"We have seen that the loss of moisture in curing cheese can be reduced by using a lower temperature or by covering cheese with a thin coating of paraffin or by a combination of these two conditions.

"*Increased amount of cheese resulting from using low temperatures.*— Taking the longest period of time for which we were able to compare the results at the different temperatures employed, 20 weeks, we found that the cheese cured at 40° F. had lost, on an average, 3.8 pounds for 100 pounds of cheese; the cheese at 50° F. had lost 4.8 pounds; and that at 60° F., 7.8 pounds. For 100 pounds of cheese originally placed in the curing-rooms at the different temperatures, we had for sale at the end of 20 weeks 96.2 pounds of cheese cured at 40° F., 95.2 pounds at 50° F., and 92.2 pounds at 60° F.

"Assuming that the cheese sells at a uniform price of 10 cents a pound, we should have receipts from our original 100 pounds of each of the different cheeses as follows:

Cheeses cured at 40° F.	$9 62
Cheeses cured at 50° F.	9 52
Cheeses cured at 60° F.	9 22

Under these conditions, the receipts from the cheese kept at 40° F. are 10 cents a hundred more than for that kept at 50° F. and 40 cents more than for that kept at 60° F. As we shall point out later, the differences are really greater than this.

"*Increased amount of cheese resulting from covering cheese with a coating of paraffin.*—At the end of 17 weeks, cheese covered with paraffin had lost only 0.3 pounds for 100 pounds of cheese originally placed in storage at 40° F., 0.5 pounds at 50° F. and 1.4 pounds at 60° F. The saving thus effected, based on the uniform price of cheese at 10 cents a pound, would average about 35 cents for 100 pounds of cheese cured at 40° F., 43 cents at 50° F., and 64 cents at 60° F.; or, comparing cheese kept at 40° F., covered with paraffin, with cheese kept at 60° F. not so covered, there would be a difference of about 75 cents a hundred in favor of the paraffined cheese. The cost of covering cheese with paraffin is slight."

In this connection, it is pertinent to inquire what percentage of moisture American cheddar cheese should have.

Much of the cheese made in New York State contains, in the fresh state, from 36 to 37.5 per ct. of water. The home-trade cheese, much of which is made in the fall, contains 38 to 40 per ct. of water. For the average consumer, it is safe to say, the amount of moisture in cheese should be not less than between 33 and 35 per ct. at the time of consumption. Taking everything into consideration, it is reasonable to expect better results in reference to quality by holding a moderate amount of moisture in the green cheese and so curing as to lose only a small amount of water, than by holding an excessive amount of moisture in the green cheese and so curing as to lose a larger amount of moisture. Some cheese-makers expect that they must lose ten pounds of weight per hundred pounds of cheese in curing, and they attempt to meet this loss by retaining 40 per ct. or more of moisture in the cheese. Such a practice can not lead to good results from any point of view.

A fact that should not be lost sight of in this connection is this: Cheese cured at such low temperatures as are favorable to diminishing the loss of moisture can carry larger amounts of moisture from the start without impairing the quality.

Water in cheese in proper proportions is of importance from the consumer's point of view. In the first place, cheese that has not lost too much of its moisture is more pleasing to the taste of the average consumer. In the next place, the more completely a cheese dries out, the harder and thicker is the rind and the greater the loss to the consumer. Most people have become accustomed to such a waste, but much of it is unnecessary. In a carefully cured cheese, the rind is comparatively moist and only a very thin portion need be lost, and even this can be used in cooking.

It has been pointed out that cheeses of small size lose more moisture per hundred pounds than do cheeses of larger size. In making small cheeses like "Young Americas" the proportion of loss is much greater, and hence the demand is still more imperative that these shall be cured under conditions where the loss of moisture shall be greatly reduced. This applies also to such sizes as "Flats" and "Twins." It is not surprising that the manufacture of small cheeses of the cheddar type has been discouraged. Even at the higher prices that they bring, the extra loss of moisture and additional cost of manufacture are not satisfactorily covered. In the manufacture of small fancy kinds of soft cheese, these statements do not apply, because an essential part of the equipment consists of curing-cellars of fairly low temperature and high moisture content.

(2) *Increased market value of cheese resulting from improvement of quality in curing cheese at low temperature.*—We have just called attention to increased receipts coming from cheese, as a result of preventing excessive loss of moisture. Such saving of moisture not only increases the amount of cheese to be sold but also increases the value of the cheese from the standpoint of commercial quality. The relations existing between moisture and flavor are known only in a very general way. But we know something of the general relation between moisture and texture. Excessive moisture produces undesirable softness, from a commercial standpoint, and at ordinary temperatures favors the formation of holes, a serious fault in the texture of cheddar cheese. On the other hand, deficient moisture favors the production of a crumbly, dry, mealy texture, which is an undesirable condition. High temperatures cause excessive loss of moisture and result in the production of crumbly texture. This condition injures the commercial quality of cheese and results in lower prices for such cheese. The following figures represent averages taken from data given on page 202, Bulletin 184, showing the general relation between texture and loss of moisture.

EFFECT OF TEMPERATURE OF CURING ON TEXTURE AND MOISTURE OF CHEESE.

TEMPERATURE OF CURING-ROOM.	Texture of cheese. (Perfect texture is 25.)	Moisture lost by 100 lbs. of cheese.
		Lbs.
55 degrees F.	24.6	8.5
60 "	24.4	9.0
65 "	23.6	9.2
70 "	22.0	10.2
75 "	21.4	10.7
80 "	20.6	13.1

From Bulletin 234 we quote as follows:

"At the end of 10 weeks, the cheese cured at 40° F. was worth 12½ cents more a hundred pounds than the cheese cured at 50° F., and 35 cents more than that cured at 60° F. The cheese cured at 50° F. was worth 22½ cents more than that cured at 60° F.

"At the end of 20 weeks, the cheese cured at 40° F. was worth 22½ cents more a hundred pounds than that cured at 50° F., and 60 cents more than that cured at 60° F., while that cured at 50° F. was worth 37½ cents more than that cured at 60° F.

"At the end of 28 weeks, the cheese cured at 40° F. was worth 20 cents more a hundred pounds than that cured at 50° F.

"We have seen that the curing of cheese at low temperatures has the effect of (1) preventing loss of moisture and (2) increasing the market value of the cheese. Therefore, we not only have more cheese to sell but can sell it at a higher price. Taking cheese 20 weeks old as a basis for comparison, we know how much weight is lost at different temperatures and also the difference in market price. From these figures, we can prepare the following tabulated statement:

TEMPERATURE OF CURING.	Cured cheese equivalent to 100 pounds of green cheese.	Market price of one pound of cheese.	Receipts from cheese.
	Lbs.	*Cents.*	
40° F.	96.2	13.275	$12 77
50° F.	95.2	13.050	12 42
60° F.	92.2	12.675	11 69

"These figures indicate that, from 100 pounds of cheese put into the curing-room, we were able to realize from that cured at 40° F. 35 cents more than from cheese cured at 50° F., and $1.08 more than from that cured at 60° F. From the cheese cured at

50° F., we received 73 cents more a hundred pounds than from that cured at 60° F.

"If we compare our results obtained with cheese covered with paraffin with those given by cheese not so covered, we have the following tabulated statement:

TEMPERATURE OF CURING-ROOM.	CURED CHEESE EQUIVALENT TO 100 POUNDS OF GREEN CHEESE.		MARKET PRICE OF ONE POUND OF CHEESE		RECEIPTS FROM CHEESE.	
	Paraffined.	Not paraffined.	Paraffined.	Not paraffined.	Paraffined.	Unparaffined.
	Lbs.	*Lbs.*	*Cents.*	*Cents.*		
40° F.	99.7	96.2	14.25	14.25	$14.21	$13.70
50° F.	99.5	95.2	14.25	14.25	14.19	13.56
60° F.	98.6	92.2	13.75	13.50	13.56	12.45

At 40° F. the difference in favor of the paraffined cheese is 51 cents for 100 pounds of cheese originally placed in the curing-room; at 50° F. the difference is 63 cents; and at 60° F. $1.11. Covering cheese with paraffin results in greater saving at higher than at lower temperatures.

"Comparing paraffined cheese cured at 40° F. with unparaffined cheese cured at 60° F., we find a difference of $1.76 for 100 pounds of cheese in favor of the paraffined cheese and the lower temperature."

(3) *The relations of chemical changes to the quality of cheese.*—(a) *Quick-ripening and slow-ripening cheese.*— We have observed that certain conditions affect the rate of chemical changes taking place in the nitrogen compounds of cheese, that is to say, the rate of ripening. Certain conditions promote, while certain other conditions delay, these ripening changes. The general relation of different conditions to the rapid or slow rate of cheese-ripening may be shown by the following form of statement:

Conditions that may promote ripening:	Conditions that may retard ripening:
(1) Increase of temperature.	(1) Decrease of temperature.
(2) Larger amount of rennet.	(2) Smaller amount of rennet.
(3) More moisture in cheese.	(3) Less moisture in cheese.
(4) Less salt.	(4) More salt.
(5) Large size of cheese.	(5) Small size of cheese.
(6) Moderate amount of acid.	(6) No acid or excess of acid.

The element of time is a factor that modifies all other conditions, since, as a rule, increase of ripening results from an increase of the ripening period, at least within the usual limits of the commercial life of cheese.

It will be observed that the factors of time and temperature and, to some extent, moisture are connected with the management of cheese after it is made, while the other conditions are associated with the process of manufacture. All of these conditions can be under control, so that the cheese-ripening process may be delayed or hastened. If a cheese is desired that ripens quickly, it should contain more than the usual amount of rennet, a moisture content of about 40 per ct. or more, and about 1 to 1½ pounds of salt for 1,000 pounds of milk. Then it should be kept at a temperature between 60° F. and 70° F., if it is to be placed in the hands of consumers in one month or six weeks, and the atmosphere of the curing-room should have a humidity of 75 to 85 per ct. of saturation. However, it should be stated that cheese made to ripen quickly gives better commercial results when ripened at a lower temperature than 60° F. and held a longer time.

For a slow-ripening cheese, not more than 2½ ounces of rennet-extract, such as Hansen's, should be used for 1,000 pounds of milk, and about 2 to 2½ pounds of salt. The other conditions that influence the moisture content of cheese, such as the temperature of heating the curd, the fineness of cutting curd, the amount of acid developed in the curd, cheddaring, etc., should be well under control, so as to produce a cheese containing, when fresh from the press, about 37 per ct. of water. For ripening, it should be kept at a temperature below 50° F. in a fairly moist atmosphere for a period of 3 to 6 months or more.

According to results given in Bulletins Nos. 184 and 234, cheese that ripens slowly is of higher commercial value than cheese ripened more quickly. The commercial life of cheese made to ripen quickly is much shorter than that of cheese made to ripen slowly; in other words, quick-ripening cheese must be consumed at an earlier age, since, after once reaching its best commercial condition, it deteriorates in quality more rapidly than slow-ripening cheese.

(b) *Relation of conditions of ripening to flavor in cheese.*— Increase of temperature favors a more rapid development of cheese-flavor, but the continuation of such a condition causes rapid deterioration of flavor. Sharpness of flavor is usually met with only in cheese cured above 60° F. High moisture content favors a more rapid development of cheese flavor and also more rapid development of objectionable flavors, especially when accompanied by higher temperature. Absence of salt in cheese is, in our experience, invariably accompanied by the presence of bitter flavor, the intensity increasing with increase of temperature. Increased amounts of salt, other conditions being uniform, tend to a slower formation of cheese flavor. Excess of acid in cheese delays the development of cheese flavor, while the sour taste caused by the excessive acidity is seriously objectionable, especially in the early stages of ripening.

(c) *Relation of conditions of ripening to texture in cheese.*— High temperatures in cheese-ripening favor the production of a crumbly, dry, mealy texture and also the formation of holes. Excessive moisture with moderately higher temperature results in a texture of undesirable pasty softness. Excessive use of rennet-extract produces pasty texture. Large amounts of salt produce a texture that is dry, harsh and hard. Excess of acid acts much the same way. It is possible to overcome to some extent the faults of texture produced by excessive use of salt and acid by keeping the cheese for a long time in a moist atmosphere between 40° F. and 50° F.

VI. THE ACTION OF ACIDS AND BASES ON CASEIN AND PARACASEIN.

For more than fifty years there has been dispute over the question as to whether casein combines with acids to form insoluble casein salts of acids. When milk undergoes the process of ordinary souring or is treated directly by addition of an acid, the milk casein curdles or precipitates as soon as a certain amount of acid is reached. The view first expressed in 1780 by Scheele, who first isolated and studied lactic acid, was to the effect that the solid, white substance thus formed is a compound produced by the union of the acid with milk-casein. This view was disputed in 1843 by Rochleder who held that no definite chemical compound is formed when milk-casein is precipitated by an acid. Thirty years later Hammarsten devoted much attention to the subject and reached the same conclusion as Rochleder. Different workers in later years have been divided between these two views, since no results have been so conclusive as to settle the question beyond all possible doubt.

(1) *Insoluble products formed by action of acids on casein and paracasein.*— In 1901 a study of this subject was undertaken at this

Station and has been continued since at intervals. The results have been published in the following Bulletins: No. 214 (A study of the salts formed by casein and paracasein with acids; their relations to American cheddar cheese); No. 245 (Chemical changes in the souring of milk); No. 261 (Some of the relations of casein and paracasein to bases and acids and their application to cheddar cheese); Technical Bul. No. 3 (The action of dilute acids upon casein when no soluble compounds are formed).

In connection with a study of the chemical changes that occur in cheese-ripening, it was observed that in the operation of cheese-making a substance is formed which is soluble in a warm (55° C.) 5 per ct. solution of sodium chloride and also in hot 50 per ct. alcohol. This substance appeared to be formed only when an acid was present in certain amount. When this salt-soluble substance was treated with more acid, it was changed into a substance insoluble in dilute salt solution. It was also found that, when milk is treated with a certain amount of acid, a coagulum is formed soluble in salt solution and that, when more acid is added, the salt-soluble substance is changed into one not soluble in dilute salt solution. This action was explained by saying that when milk-casein or paracasein is treated with an acid, it unites with the acid in a certain proportion, forming a casein salt of the acid which is soluble in warm dilute salt solution; and that this compound, when treated with more acid, unites with twice as much acid as the first compound, forming a substance which is not soluble in warm, dilute salt solution. The salt-soluble substance was called casein (or paracasein) monolactate and the second substance casein (or paracasein) dilactate. It was later found that the above explanation, owing to imperfect experimental work, was erroneous. It was then supposed, as the result of further work, that the salt-soluble substance (monolactate) was simply base-free casein (or paracasein), containing no acid at all in combination, in other words, milk-casein (calcium casein) from which the calcium had been removed by the acid, forming a calcium salt of the acid and calcium — free casein. It was then believed that the insoluble substance resulting from treatment with further acid (dilactate) was a simple, definite combination of casein (or paracasein), one gram of casein (or paracasein) combining with an amount of acid equivalent to about 0.5° cc. of $\frac{n}{10}$ hydrochloric acid. This conclusion was based on the fact that when casein is shaken with acid and filtered, some of the acid is taken up by the casein from the solution. In reviewing this work later, with more delicate means of measuring the amount of acid that might combine, it was found that some portions of the former experimental work were too imperfect to afford basis for definite, quantitative conclusions. As a result of our latest more complete and accurate work, it has been established that casein, while capable of removing acid from a surrounding solution, does not form any simple, definite combination with acids. The amount of acid taken up by casein is not fixed and definite but varies (1) with the concentration of the acid, (2) with the duration of contact until equilibrium is reached, (3) with the degree of agitation, (4) with the temperature, and (5) with the kind of acid. The simplest and most satisfactory explanation of the facts is that when acids act upon casein, no definite chemical combination occurs, but the acid is simply adsorbed by the casein; adsorption meaning the process whereby a solid substance A (like casein) in contact with a solution of a dissolved substance B (dilute acid) concentrates B upon its surface, withdrawing a portion of B from solution without forming with it a definite chemical compound. This conclusion may possibly be modified by more exhaustive work, but the data upon which it is based are far more complete and satisfactory than any others that have been contributed so far to the study of this question.

(2) *Soluble products formed by action of acids on casein and paracasein.*— Casein and paracasein are very easily soluble in acids, even in dilute acids. The ease with which dilute acids dissolve casein was not appreciated until our recent work was published (Technical Bul. No. 3). Acids of $\frac{n}{125}$ concentration dissolve considerable amounts of casein at ordinary temperatures and much more at 45° C. Acids as dilute as $\frac{n}{1000}$ and $\frac{n}{2000}$ dissolve appreciable amounts of casein at 45° C. It is probable that the dissolved product is the result of definite chemical combination between casein and acid.

(3) *Preparation of calcium-casein and paracasein compounds.*— Base-free casein can be prepared by treating diluted skim-milk with acids, removing the acid and inorganic matter by repeated washing and filtration. This uncombined protein, casein, when triturated with calcium carbonate suspended in water, or when dissolved in lime water and then treated with an acid until the solution is neutral to phenoephthalein, combines with about 2.40 per ct. of calcium oxide, forming a compound known as *basic calcium casein.* By treating base-free casein dissolved in lime water with acid until the reaction is almost neutral to litmus, there is found a compound of

casein and calcium oxide, containing about 1.50 per ct. of calcium oxide, known as *neutral calcium casein.* These facts were first made known by Söldner and were confirmed by our work, in which these products were isolated and studied more thoroughly. Similar preparations were made with paracasein.

(4) *Comparison of properties of casein and paracasein, and their calcium compounds.*— Basic calcium casein and paracasein appear soluble in water, forming slightly opalescent solutions. Neither is coagulated by rennet, but both are precipitated by soluble calcium salts on warming. Neutral calcium casein is coagulated by soluble calcium salts in warming to 35° to 40° C., but not at ordinary room temperature, while neutral calcium paracasein is completely and quickly coagulated at room temperatures by soluble calcium salts. Neutral calcium casein behaves like milk-casein in its behavior toward soluble lime salts on warming, and at ordinary temperatures after treatment with rennet, and casein is probably present in cows' milk as the neutral calcium casein.

Freshly prepared casein and paracasein, when apparently base-free and in the presence of soluble calcium salts, are readily soluble in warm 5 per ct. salt solution and in hot 50 per ct. alcohol. When freshly prepared and sufficiently warmed, they become very plastic and ductile, capable of being drawn out in fine, long, silky threads. Whether the presence of soluble calcium salts is, as claimed by Laxa, in any way responsible for these properties can not be stated at present, but in all the experiments made soluble calcium salts were present.

(5) *Suggestions regarding nomenclature of casein and paracasein and their compounds.*— In most of the literature on the subject, the word casein is used indiscriminately to mean milk-casein, free casein, or those casein salts formed by acid precipitation. In many cases it is used comprehensively to include all the proteids in cows' milk. A similar state of confusion exists in regard to the use of the word paracasein. It would therefore seem pertinent to make the following suggestions, tentatively at least, in regard to the nomenclature of these compounds.

(1) That the word *casein* be applied only to the *free proteid,* that is, the *base-free casein.*

(2) That the *compound existing in cows' milk* and commonly called casein be called *calcium casein.*

(3) That the casein *compound* containing about *2.40 per ct. of CaO* be called *basic calcium casein.*

(4) That the same nomenclature be applied to the corresponding paracasein bodies, simply substituting the word paracasein for casein, with the following addition: Calcium paracasein should be applied to the soluble or uncoagulated substance produced in milk by rennet enzyme, while the coagulum of this substance caused by soluble calcium salts should be called *insoluble or coagulated* calcium paracasein.

VIII. SOME OF THE FIRST CHEMICAL CHANGES IN CHEESE

We have previously discussed the chemical changes taking place in the proteids of cheese a day or more old. We will here discuss briefly the chemical changes occurring while the cheese is being made, in other words, while the materials are in the vat and in the press, covering approximately the first 24 hours after the addition of rennet to milk at the beginning of the operation of cheese-making.

One of the first operations in cheddar cheese-making is to "ripen" the milk previous to adding rennet. This is accomplished by allowing the milk to stand some time at a temperature of about 86° F. (30° C.), or the operation may be hastened by adding to the milk special cultures of lactic-acid-producing organisms. This process, commonly known as the "ripening of milk," has for some time been recognized as an acid-producing form of fermentation, that is, a fermentation brought about by the action of lactic-acid organisms on the milk-sugar, resulting in the formation of lactic acid. In ripening milk, the cheesemaker increases the quantity of lactic acid in the milk, not only before adding rennet, but continuously throughout the rest of the process of manufacture.

The amount of acid in cheese-curd may be roughly measured in a mechanical way by means of the so-called "hot-iron test." When a piece of curd is pressed against a hot iron and then drawn away carefully, fine, silky threads are formed, adhering to the iron. This phenomenon is closely associated with the formation of acid, and the length of the strings, shown by the hot-iron test, is utilized as a measure of the amount of acid present and as an indication when to perform certain operations. Thus, when the curd strings on the hot iron to the length of one-eighth of an inch, the whey is removed from the curd, after which the curd is "packed" in a pile and allowed to lie until it has passed through the so-called "matting" or "breaking-down" process, when it furnishes strings an inch or more in length by the hot-iron test. When this stage is reached, the remaining steps of the manufacturing process are at once completed, such as milling, salting, and putting in molds for pressing.

While it has been generally supposed that the presence of some acid, presumably lactic acid, in the cheese-making process is, in some way or other, responsible for the most important changes taking place, such as the shrinking of the curd, the acquired ability to form strings on hot iron and the change in appearance and plasticity of curd, no one has ever been able to show in what way these changes were brought about by acids. It has been commonly supposed that the observed changes were purely physical in character and were not the result of chemical changes in the curd. We have studied more fully than has been done previously the real function of acids in relation to the important changes taking place in cheese-curd during the cheddar process of cheese-making.

I. ACTION OF LACTIC ACID UPON INORGANIC CONSTITUENTS OF MILK AND CURD.

The first work of lactic acid appears to be its action upon some of the inorganic constituents of milk and curd, especially the calcium and phosphoric acid compounds. The phosphates at first present in cheese curd are insoluble. These are acted upon by lactic acid, forming soluble phosphates and calcium lactate. The main fact is that the calcium and phosphoric acid compounds of cheese-curd, which are insoluble at the start, gradually become soluble until about 80 per ct. of the calcium and all of the phosphates appear in water solution. This change is due to the formation of lactic acid and its action upon the phosphates of the cheese, changing insoluble into soluble phosphates and forming at the same time calcium lactate. The maximum amount of calcium is found in water solution at about the same time the phosphoric acid becomes entirely water-soluble. This appears to indicate that the water-soluble calcium present in cheese in its early history comes from inorganic combinations, namely insoluble phosphates, and not from the calcium combined with paracasein as calcium paracasein.

2. CHANGES IN PROPERTIES OF CHEESE-CURD.

After the curd is cut in the process of cheese-making and after heat is applied, the curd undergoes some marked changes. The pieces of curd gradually shrink in size, as the result of loss of whey, and become more firm in consistency. After the whey is removed from the curd in the process of cheese-making, the curd is "packed," or "matted," that is, piled in a heap, and kept in this condition, with occasional repacking, until it has gone through the regular "breaking-down" process, in the course of which the curd undergoes several marked, easily discernible changes in physical properties. From a tough, rubber-like consistency, with a high water-content, the curd changes to a mass having a smooth, velvety appearance and feeling, and a softer, somewhat plastic consistency. The texture also changes so that the curd acquires a peculiar kind of grain and tears off somewhat like the cooked meat of a chicken's breast. Moreover, the curd undergoes a marked change with reference to its solubility in a 5 per ct. solution of common salt. The curd is, at first, soluble only slightly, if at all, in such a solution. The solubility of the curd in dilute salt solution increases very rapidly between the time when the whey is removed from the curd and when it is put in press, and the solubility also continues to increase for several hours after. These marked changes in the physical properties of the curd can be most readily and satisfactorily explained by attributing them to the increasing quantity of the salt-soluble substance produced throughout the cheese mass, as the result of continuous formation of lactic acid by the fermentation of the milk-sugar present. These changes in the properties of curd appear to take place simultaneously with the formation of salt-soluble substance. It is also noticeable that the amount of salt-soluble substance increases at the same time with the conversion of insoluble phosphates into acid phosphates and with the formation of calcium lactate. (Technical Bulletins 4 and 5.)

3. WHAT IS THE SALT-SOLUBLE SUBSTANCE IN CURD AND CHEESE?

Views previously held regarding this salt-soluble substance are given on page 202. The matter has not yet been fully cleared up to our satisfaction, but a point of interest in this connection, furnished by our most recent work, is that we find calcium present in the salt-soluble portion of cheese. In the cases in which special determinations have been made we find that about 20 per ct. of all the calcium in the cheese is in the salt-soluble portion. This suggests that the salt-soluble proteid either holds calcium salts mechanically or that the protein molecule is still combined with calcium or some calcium compound and is not entirely calcium-free as we have previously believed. In the case of work done on camembert cheese, it was found that the salt-soluble product became completely insoluble, at which time the calcium was entirely water-soluble. Question arises as to whether the salt-soluble proteid is necessarily free paracasein or whether it may not be a calcium salt of paracasein or a mixture of free paracasein and calcium paracasein. Another question is as to the character of the change in the proteid in going from the salt-soluble to the insoluble form.

Associated with these questions is the characteristic behavior of the cheese curd which it manifests in its ductile and plastic properties. Has the presence of soluble calcium salts any peculiar influence upon the curd which accounts for these properties, apart from any change in the composition of the proteid itself?

4. SUMMARY OF CHANGES IN THE PROTEIDS OF CHEESE.

In the manufacture of cheddar cheese, the proteid of the insoluble curd (calcium paracasein) changes rapidly into a form that is soluble in 5 per ct. solution of sodium chloride at 50 to 55° C., until, in a few hours (9 or 10) after putting in press, the proteid, originally insoluble in warm dilute salt-solution, becomes completely soluble in this solution. After reaching this condition of solubility, the brine-soluble proteid undergoes another change into a form that is insoluble in warm dilute salt solution, the change going on rapidly at first and then gradually. Proteid in water-soluble form appears to increase only slightly, if any, until after all the proteid has become soluble in warm, dilute salt solution and has then changed to some extent into a form insoluble in salt solution.

Thus, there appears to be the following series of successive changes: (1) From insoluble proteid as represented in the fresh curd (calcium paracasein) into (2) proteid soluble in warm, dilute salt solution, this into (3) proteid insoluble in salt solution and this into (4) water-soluble proteid. Under these conditions, we should have:

(1st.) All insoluble proteid (calcium paracasein).

(2d.) Mixture of (a) insoluble proteid and (b) proteid soluble in salt solution, the latter increasing at the expense of the former.

(3d.) All salt-soluble proteid.

(4th.) Mixture containing (a) salt-soluble proteid and (b) proteid insoluble in salt solution, the former predominating at first and then diminishing while the latter increases.

(5th.) Mixture containing (a) proteid soluble in salt solution, (b) proteid insoluble in salt solution and (c) water-soluble proteids, the second form (insoluble in salt solution) decreasing and the water-soluble form increasing.

VIII. ENZYMS IN RELATION TO CHEESE-MAKING AND CHEESE-RIPENING.

Enzyms are substances without life, capable of causing deep-seated chemical changes in certain other substances, the enzyms themselves undergoing little or no change. They are produced by the activity of plant or animal cells. Certain enzyms are intimately connected with the manufacture of cheddar cheese. We have (1st) an enzym or, perhaps, a collection of enzyms, present in the milk itself as drawn from the cow, known as galactase; (2d) one or more enzyms contained in rennet-extract, and (3d) enzyms produced by bacteria which get into the milk after it is drawn. We have studied particularly the relation of the first two kinds of enzyms to cheese-making and cheese-ripening. (Bulletin No. 203, "A Study of Enzyms in Cheese" and Bulletin 233, "Rennet-Enzyms as a Factor in Cheese-Ripening.") Such studies are attended with unusual difficulties, because it is as yet practically impossible to obtain enzyms in an absolutely pure condition. Then, too, it is necessary to exclude in such experiments all possible chance for action of organisms and, in order to accomplish this, conditions must be introduced which are more or less abnormal.

1. CHANGES IN CHEESE CAUSED BY ENZYMS IN MILK AND RENNET.

In order to study the combined action of galactase and rennet-enzym, chloroform was successfully used to exclude bacterial action and the cheese was kept in an atmosphere of chloroform during ripening for periods varying from a few months to two years. Under such conditions no lactic acid was formed and in some of the experiments lactic acid to the amount of 0.2 per ct. was introduced into the milk to stimulate the normal cheese-making process.

The amounts of water-soluble nitrogen compounds formed in the cheese under the conditions of the experiments represent work done by the enzyms present as galactase and in rennet-extract. At the end of one year the normal cheese contained 37 per ct. of its nitrogen in water-soluble form, while the chloroformed cheese contained 23 per ct. The character of the water-soluble nitrogen was quite different under the two sets of conditions. In normal cheese the proportion of amido compounds is large in comparison with albumoses and peptones; in chloroformed cheese, the reverse is true. Again, in chloroformed cheese, little or no ammonia is formed, while in normal cheese ammonia appears early and increases steadily. These results show that there is some nitrogen-digesting agent at work in normal cheese which is not active in cheese made in the presence of chloroform.

In those cases in which lactic acid was added to chloroformed milk in the process of cheese-making, the amount of soluble nitrogen compounds was much increased. The presence of acid favored enzym action.

In 1897 Babcock and Russell discovered galactase in milk and, as the result of an extended investigation regarding its action in milk, they concluded that it was the chief agent of cheese-ripening. When our work demonstrated that galactase does not produce in cheese ammonia, which is a normal constituent of ripened cheese, they examined samples of our cheese and confirmed our results as to the absence of ammonia. They then acknowledged, as the result of our experiments, that galactase could not be the chief agent of cheese-ripening.

Moreover, in their study of the properties of galactase, Babcock and Russell found it so sensitive to the presence of acids that its activity was easily diminished by small amounts of acid. Our experiments demonstrated that the presence of acid increases the soluble products of cheese-ripening, an effect characteristic of rennet but not of galactase. These experiments showed the combined, but not the separate effects of rennet and galactase in cheese-ripening.

The action of galactase and rennet-enzym has been studied also from a quite different point. The amounts of carbon dioxide given off by a normal cheese and a chloroformed cheese were measured for a period of thirty-two weeks. (Bulletin No. 231.) In addition, certain compounds were determined in the cheese at the end of the investigation. The results are summarized as follows:

In Normal Cheese.	*In Cheese Containing Chloroform.*
(1) Production of carbon dioxide.	(1) Production of carbon dioxide.
(a) Total in 32 weeks, 15.099 grams.	(a) Total, 0.205 gram.
(b) Weekly variation from 0.735 gram in first, to 0.224 gram in last, week.	(b) Ceased entirely after three weeks.

In Normal Cheese.	*In Cheese Containing Chloroform.*
(2) Proteolytic end-products formed.	(2) Proteolytic end-products formed.
(a) Tyrosine in small amounts	(a) Tyrosine.
(b) Oxyphenylethylamine.	(b) No oxyphenylethylamine.
(c) Arginine in traces.	(c) Arginine in marked quantity.
(d) Histidine.	(d) Histidine.
(e) Lysine.	(e) Lysine.
(f) Guanidine.	(f) No guanidine.
(g) Traces of putrescine.	(g) No putrescine.
(3) Analysis of cheese.	(3) Analysis of cheese.
(a) Ammonia formed.	(a) No ammonia formed.
(b) Amido compounds more abundant.	(b) Amido compounds less abundant.

A consideration of the possible sources of carbon dioxide in the two cheeses indicates that, in the case of the chloroformed cheese, the carbon dioxide came from that present originally in the milk and that formed in the milk from the decomposition of milk-sugar before treatment with chloroform. In the case of the normal cheese, the carbon dioxide given off in its early age came largely from the decomposition of milk-sugar by lactic acid organisms, while a small amount was probably due to the carbon dioxide present in the milk and, perhaps, to the respiration of living organisms present in the cheese. The carbon dioxide produced after the first few weeks came apparently from reactions taking place in some of the amido compounds, among which we were able to identify the change of tyrosine and arginine into derived products with simultaneous formation of carbon dioxide.

In the chloroformed cheese, the only active proteolytic agents were lactic acid, galactase and rennet-pepsin. Under the conditions of our experiment, these agents were able to form neither ammonia nor secondary amido compounds with production of carbon dioxide. The presence of chloroform could not account for this lack of action. These results suggest that, in the normal cheese, there must have been some agent at work not present in the chloroformed cheese and that this extra factor was of a biological character.

2. CHANGES IN CHEESE CAUSED BY RENNET-ENZYM.

Rennet extract contains an enzym which is a peptic ferment, as shown by the following characteristics: (a) Neither rennet-enzym nor pepsin causes much, if any, proteolytic change except with the help of acid; (b) the quantitative results of proteolysis furnished by rennet-enzym agree closely when working on the same material under comparable conditions; (c) the classes of soluble nitrogen compounds formed by the two enzyms are the same both qualitatively and, under uniform conditions, quantitatively; (d) neither enzym forms any considerable amount of amido compounds and neither produces any ammonia; (e) the soluble nitrogen compounds formed by either enzym are chiefly confined to the groups of compounds called paranuclein, caseoses and peptones (Bul. No. 233).

In normal cheese, we find an accumulation of amides and ammonia, as the cheese grows older and a corresponding diminution of the compounds previously formed. The formation of all the ammonia and of a large proportion of the amides found in ripened cheese must be due to some agency other than rennet-enzym, and the only other agents present, besides milk-enzyms, that can do this work appear to be organisms or their enzyms. The first stage in normal cheese-ripening is essentially a peptic digestion of paracasein or some derivative compound. Gradually amides are formed and later ammonia. It is probable that the first chemical work done in normal cheese-ripening is the conversion of paracasein or some modification of it by rennet-enzym into paranuclein, caseoses and peptones. The question naturally arises as to whether these compounds must be formed before other agents can take part in the work and carry it along farther, producing amides and ammonia.

A COMPARATIVE STUDY OF DIFFERENT BREEDS OF DAIRY COWS.

In 1889 an extended investigation with different breeds of dairy cattle was undertaken which had for its object a comparison of seven different representative breeds with reference to economy of milk, butter and cheese production. The work was continued for about seven years. The breeds of cows used in the investigation were American Holderness, Ayrshire, Devon, Guernsey, Holstein-Friesian, Jersey and Shorthorn. The following detailed data are given in the Station reports for the years 1890 to 1896: (1) Tabulated statements, giving ages and dates of calving of different cows. (2) Prices of food used. (3) Amounts, composition and cost of food eaten. (4) Amount and cost of milk produced. (5) Composition of milk. (6) Yield of cream and butter. (7) Yield of cheese.

As a basis for comparison, a uniform lactation period was used consisting of the first ten months of lactation. The results represent work done with twenty-two different animals for one to four periods of lactation, aggregating between forty and fifty periods. The summary of the work is here presented under the following headings: (1) Production of milk,[23] (2) production of cream and butter,[24] and (3) production of cheese.[25] The data will be presented largely in tabular form.

MILK PRODUCTION.

Tabulated Summary Giving Comparison of Results Secured with Different Breeds of Dairy Cattle with Reference to the Production of Milk. Average per Cow for One Period (10 Months) of Lactation.

	American-Holderness.	Ayrshire.	Devon.	Guernsey.	Holstein-Friesian.	Jersey.	Short-Horn.
Number of cows	2	4	3	4	4	4	1
Total number of periods of lactation	4	12	5	6	4	11	2
Cost of food eaten	$42 90	$49 32	$37 52	$46 15	$50 73	$45 49	$46 22
Pounds of milk given	5,721	6,824	3,984	5,385	7,918	5,045	6,055
Cost of milk in cents per pound	0.76	0.74	0.94	0.86	0.65	0.90	0.78
Cost of milk in cents per quart	1.63	1.58	2.02	1.85	1.39	1.95	1.68
Pounds of milk-solids produced	724.1	869.4	577.4	804.0	936.5	775.4	866.2
Percentage of solids in milk	12.66	12.74	14.50	14.93	11.83	15.37	14.30
Cost of milk-solids in cents per pound	5.93	5.68	6.50	5.73	5.42	5.87	5.34
Money value of milk at 1.28 cents per pound	$73 22	$87 24	$51 00	$68 93	$101 35	$64 58	$72 50
Money value of milk based on milk-solids at 9⅓ cents per pound	67 58	81 14	53 89	75 04	87 41	72 37	80 85
Money value of milk based on milk-fat at 26⅔ cents per pound	56 12	64 47	48 27	75 18	70 07	74 30	72 03
Apparent profit (money value of milk less cost of food)	24 69	31 73	16 37	28 88	36 65	24 63	34 60
Calculated value of skim-milk	15 61	19 06	12 00	15 81	20 49	13 78	18 20
Market value of skim-milk	7 81	9 53	6 00	7 90	10 25	6 89	9 10
Actual profit (apparent profit less market value of skim-milk)	16 89	22 20	10 37	20 97	26 40	17 74	25 50

[23] Bul. No. 77.

[24] Bul. No. 78.

[25] Bul. No. 79.

An explanation of how the different money values of the milk given in the above table are reached is now given.

The final test of a cow's value for dairy purposes is the amount of profit to be derived from her. In calculating the money value of milk, we may be guided solely by the amount of milk produced, allowing a fixed price for a pound of milk, regardless of composition; or, we may consider the composition of the milk and fix a price which shall be dependent upon the composition. In calculating the money value of milk as based on its composition, we can use the total solids of the milk or the fat alone.

For the sake of comparison, therefore, we give three values for milk in the foregoing tables: First, the money value of milk calculated on the basis of 2¾ cents per quart, or 1.28 cents per pound; second, the money value of the milk calculated on the basis of the milk-solids at 9⅓ cents per pound; and, third, the money value of the milk calculated on the basis of milk-fat at 26⅓ cents per pound.

If we take the value of all the milk produced by all the cows as calculated at 1.28 cents per pound and divide this by the total number of pounds of milk-solids produced by all the cows, then we get, as the average selling-price of one pound of milk-solids, 9⅓ cents. In other words, with milk selling at 1.28 cents per pound, milk-solids have an equivalent value of 9⅓ cents per pound. In a similar way, milk-fat has an equivalent value of 26⅓ cents per pound.

The following explanation shows how the figures representing profits from milk are derived.

In considering the profit derived from selling milk, we must fix on a uniform system of valuation. We have presented calculations based on three different methods for fixing the money value of milk, when sold for consumption as milk. Which of these methods will serve our purpose most fairly for making a comparison of the approximate value of milk? While the milk-fat furnishes the only fair and practicable basis for determining the value of milk that is to be made into butter or cheese, and while this method could also be utilized in enabling us to make a valuation of milk that is to be sold for consumption as milk, we shall probably approximate more closely the actual market value of milk as now sold, by making the milk-solids our basis of valuation. Therefore, in making our comparison of profits derived from selling milk, we will make use of the value furnished by this method of calculation. If from the selling value of the milk, thus found, we subtract the cost of food eaten by the animals, we obtain the approximate amount of profit. However, when the milk is taken from the farm and no part retained in any form, a certain amount of food and fertilizing material is removed, which the dairyman must replace in some form. To illustrate, when we sell and carry away from the farm 1,000 pounds of average milk for $12.50, we take from the farm materials which have a food and fertilizing value of 25 cents for each 100 pounds of milk or $2.50 for the 1,000 pounds of milk. By retaining the skim-milk and buttermilk and selling only the fat in the form of butter, we could secure the same amount of money for 1,000 pounds of milk and still retain on the farm the materials which are worth $2.50 for food and fertilizer. Therefore, when we take the milk from the farm, we must, for each 1,000 pounds, pay out from the money received $2.50 to replace the food and fertilizing materials sent away in the milk, if we are to keep the farm and animals in the same condition we should were we to retain on the farm the skim-milk and buttermilk. In theory, then, at least, of the $12.50 received for the milk, we must pay out $2.50 to buy food and fertilizer to take the place of that removed in the milk sold, and the actual profit derived from selling 1,000 pounds of milk would be $2.50 less than the apparent profit.

In regard to the actual market value, skim-milk can be purchased at creameries for 12½ cents per 100 pounds or one-half of what we usually rate it for in theory. Since this is so, it will represent actual results more closely, if we deduct the latter amount in determining actual profits.

We have, therefore, presented tabulated results showing the apparent and actual profit derived from selling milk. In determining the amount of money to be deducted for feeding and fertilizing values, we use the solids-not-fat as a basis for calculation, because the skim-milk of different breeds varies in both feeding and fertilizing value. We deduct the amount of fat which would in butter-making go into butter, from the entire yield of milk solids. The remaining solids, mostly waste fat, would have a theoretical value of about three cents a pound, but a market value of only half this, since, as pointed out above, skim-milk can be purchased at about one-half of its real feeding and fertilizing value. By using the solids as a basis of determining the value of the skim-milk, we secure results that represent the truth more nearly than we should if we rated all the skim-milk at the same price per 100 pounds, regardless of composition.

CREAM AND BUTTER PRODUCTION.

For the sake of uniformity in comparison, we make all the cream contain 20 per ct. of fat and assign it a market value of 20 cents a quart. In calculating the profits derived from selling cream, we deduct the value of the serum or skim-milk, that is, the cream less the milk-fat, assigning a value of 12½ cents a hundred pounds.

The yield of butter is obtained by deducting 0.16 as lost in skimming and churning from the fat present in 100 pounds of milk and calculating the remainder into butter containing 85 per ct. of fat. The value of the butter is fixed at 25 cents a pound. The following table gives the results:

TABULATED SUMMARY GIVING COMPARISON OF RESULTS SECURED WITH DIFFERENT BREEDS OF DAIRY CATTLE WITH REFERENCE TO THE PRODUCTION OF BUTTER AND CREAM. AVERAGE PER COW FOR ONE PERIOD (10 MONTHS) OF LACTATION.

	American-Holderness.	Ayrshire.	Devon	Guernsey.	Holstein-Friesian.	Jersey.	Shorthorn.
Number of cows	2	4	3	4	4	4	1
Total number of periods of lactation	4	12	5	6	4	11	2
Percentage of fat in milk	3.73	3.60	4.60	5.30	3.36	5.60	4.44
Pounds of milk-fat produced	213.1	244.8	183.3	285.5	266.1	282.1	269.0
Pounds of butter produced	239.9	275.2	208.4	325.6	298.1	322.4	305.1
Pounds of butter made from 100 lbs. of milk	4.20	4.05	5.22	6.05	3.76	6.40	5.04
Pounds of milk to make one pound of butter	23.80	24.70	19.15	16.53	26.60	15.63	19.84
Pounds of butter made for one pound of milk-fat	1.126	1.125	1.135	1.14	1.12	1.143	1.135
Cost in cents of one pound of milk-fat	20.13	20.15	20.47	16.14	19.06	16.12	17.18
Cost in cents of one pound of butter	17.90	17.92	18.00	14.15	17.02	14.11	15.15
Money value of butter produced	$59 98	$68 80	$52 10	$81 40	$74 53	$80 60	$76 28
Profit derived from butter	$17 08	$19 48	$14 58	$35 25	$23 80	$35 11	$30 06
Pounds of cream produced	1,065.5	1,224	916.5	1,427.5	1,330.5	1,410.5	1,345
Pounds of milk for one pound of cream	5.37	5.58	4.35	3.80	5.95	3.60	4.50
Cost in cents of cream per pound	4.03	4.03	4.09	3.23	3.81	3.22	3.44
Cost in cents of cream per quart	8.50	8.50	8.63	6.82	8.04	6.79	7.26
Money value of cream produced	$101 00	$116 02	$86 86	$135 27	$126 10	$133 70	$127 48
Profit derived from cream	$57 03	$65 48	$48 44	$87 70	$74 04	$86 80	$79 92

CHEESE PRODUCTION.

A large amount of work has demonstrated that, knowing the percentage of fat and of casein in milk, one can with fair accuracy determine the yield of cheese (green) by multiplying the percentage of fat by 1.1 and adding to this result the percentage of casein multiplied by 2.5. This method favors milk poorer in fat, making the yield of cheese larger in relation to the cheese-solids in the milk than in richer milk.

In calculating the money value of cheese, an average price of 10 cents a pound is used, equivalent to green cheese at 9⅔ cents a pound.

In calculating the profit derived from selling milk in the form of cheese, an allowance of 12½ cents a hundred pounds of milk is made for the feeding and fertilizing materials taken from the farm. The summary of results is given as follows:

TABULATED SUMMARY GIVING COMPARISON OF RESULTS SECURED WITH DIFFERENT BREEDS OF DAIRY CATTLE WITH REFERENCE TO THE PRODUCTION OF CHEESE. AVERAGE PER COW FOR ONE PERIOD (10 MONTHS) OF LACTATION.

	American-Holderness.	Ayrshire.	Devon	Guernsey.	Holstein-Friesian.	Jersey.	Shorthorn.
Number of cows	2	4	3	4	4	4	1
Total number of periods of lactation	4	12	5	6	4	11	2
Pounds of fat in milk	213.1	244.8	183.3	285.5	266.1	282.1	269.0
Pounds of casein in milk	139.3	164.7	112.1	155.4	185.0	150.8	172.9
Pounds of green cheese produced	582.7	681.1	481.9	702.6	755.2	687.3	728.2
Pounds of cheese made from 100 lbs. of milk	10.18	9.98	12.10	13.05	9.54	13.62	12.03
Pounds of milk required to make one pound of cheese	9.82	10.02	8.27	7.66	10.48	7.34	8.31
Pounds of cheese made for one pound of fat in milk	2.73	2.77	2.63	2.46	2.84	2.43	2.71
Percentage of fat in cheese	36.57	35.95	38.04	40.63	35.24	41.05	36.94
Percentage of casein in cheese	23.90	24.20	23.26	22.12	24.50	21.94	23.74
Percentage of water, ash, etc. in cheese	39.53	39.85	38.70	37.25	40.26	37.06	39.32
Cost of one pound of cheese in cents	7.36	7.24	7.78	6.57	6.72	6.62	6.35
Money value of cheese produced	$56 33	$65 84	$46 58	$67.92	$73 00	$66 44	$70 39
Profit from cheese	$5 62	$7 00	$3 06	$13 87	$12 02	$13 42	$15 06

COMPARATIVE PROFITS DERIVED FROM SELLING MILK, BUTTER, CREAM AND CHEESE.[25]

A question of practical importance, now often asked by dairymen, relates to the form in which milk can be sold. From what form of product can the greatest profit be derived, from selling milk as milk or from selling it in the form of cream, butter or cheese? Several different factors enter into a complete answer of such a question. One of them may be cost of transportation to the best market. Another may be the greater relative market value

[25] Bul. 89; also Rpt. 14:11–26 (1895).

of milk in the form of one product than in another. Thus, in the form of cream milk generally sells for more than in any other form, and occasionally cheese sells for a higher price relatively than butter, while the opposite may also be frequently true. In discussing this question, we must consider conditions which are normal or average rather than those which are exceptional. The data which we need to know are (1st) the cost of production and (2d) the market value of the product. In regard to cost of production, the data given in the preceding articles can be utilized in considering the relative profits to be derived from selling milk in different forms. We have also fixed prices for milk and its different products, which represent average conditions and which are as nearly accurate, relative to one another, as we may easily approximate.

BASIS OF CALCULATIONS.

For convenience of ready reference, we will give a brief statement here in regard to the basis upon which our calculations are made in ascertaining the profits derived from selling milk, cream, butter and cheese.

(*a*) *Cost.*— The food-cost of products alone is considered.

(*b*) *Value of milk.*— The value of the milk is based on the amount of total solids in milk, allowing 9⅓ cents a pound for milk-solids, which is equivalent, on an average, to 2¾ cents a quart for milk or 1.28 cents a pound.

(*c*) *Value of butter.*— The value of the butter is placed at an average price of 25 cents a pound; the butter contains 85 per ct. of fat.

(*d*) *Value of cream.*— The value of the cream is placed at 20 cents a quart; the cream contains 20 per ct. of fat.

(*e*) *Value of cheese.*— The price for cheese is placed at 10 cents a pound for cheese about one month old.

(*f*) *Method of calculating profit.*—A deduction is made from the gross profit (the difference between the value of the product and its food-cost), amounting to 12½ cents for each 100 pounds of milk, representing the amount of feeding and fertilizing materials taken away from the farm in the case of selling milk and cheese. A smaller but proportionate reduction is made in the case of cream.

The foregoing prices placed on the different dairy products do not represent actual prices at this writing, but they represent fairly the average prices prevailing during a period of normal years. In any case they may be regarded as relatively accurate, whether absolutely so or not.

AVERAGE PROFITS DERIVED FROM SELLING MILK AND ITS PRODUCTS FOR ONE PERIOD OF LACTATION.

(*a*) From cheese, $9.79.
(*b*) From milk, $19.80.
(*c*) From butter, $25.64.
(*d*) From cream, $72.52.

THE AMOUNT OF PROFIT GAINED IN SELLING MILK AND ITS PRODUCTS IN ONE FORM OVER OTHER FORMS.

(*a*) Butter over milk, $5.84 profit.
(*b*) Milk over cheese, $10.00 profit.
(*c*) Butter over cheese, $15.85 profit.
(*d*) Cream over butter, $46.88 profit.
(*e*) Cream over milk, $52.72 profit.
(*f*) Cream over cheese, $62.73 profit.

COMPARATIVE STATEMENT OF PROFITS DERIVED FROM SELLING MILK AND ITS PRODUCTS.

(*a*) Ratio of profit of milk to butter, 1 : 1.30.
(*b*) Ratio of profit of cheese to milk, 1 : 2.02.
(*c*) Ratio of profit of cheese to butter, 1 : 2.62.
(*d*) Ratio of profit of butter to cream, 1 : 2.83.
(*e*) Ratio of profit of milk to cream, 1 : 3.66.
(*f*) Ratio of profit of cheese to cream, 1 : 7.40.

THE PROTEIDS OF BUTTER IN RELATION TO MOTTLED BUTTER.[26]

Little study has been made of the proteids of cream, buttermilk and butter, especially in relation to mottled butter. The form of casein in cream ripened by ordinary methods of creaming is free casein when the lactic acid is allowed to exceed 0.5 per ct. Free casein, the result of combination of lactic acid with the calcium of the calcium casein of normal sweet milk, holding more or less lactic acid is the substance most familiar as curdled sour milk.

When the amount of lactic acid in cream exceeds 0.5 per ct., the casein in the butter and buttermilk is present as free casein holding more or less lactic acid by adsorption. In butter and buttermilk made from so-called sweet cream, we usually find calcium casein and some free casein, but, on standing some weeks, these may be changed in the butter into free casein.

It has been quite universally believed that the light-colored spots or streaks in butter, known as mottles, are caused solely by the uneven distribution of salt without reference to the composition of

[26] Bul. 263.

the butter. It was thought that the more concentrated brine had the effect of deepening the yellow color of the fat, the lighter portions being the unsalted or lightly salted areas.

The following points were studied with reference to their possible relations to mottled butter: (1) Richness of cream, (2) degree of ripeness of cream, (3) temperature of churning, (4) size of butter-granules, (5) temperature of wash-water, (6) working of butter. When the churning was so managed as to make the butter-granules of the size of rice-grains or wheat-kernels and these were carefully washed twice with water below 45° F., removing most of the buttermilk adhering to the outer surface of the granules, no mottles were obtained, however much conditions were varied in other respects. Mottles were always found when the buttermilk was not sufficiently removed.

The amount of proteid (usually free casein) in mottled butter is greater in the light portions than in the darker portions and is the cause of the lighter color of the mottles. Salt-brine does not change in any way the color of butter-fat. Salt-brine, as it commonly occurs in butter, has the power of hardening and localizing the proteid particles, the action requiring several hours for completion. Butter which is free from buttermilk adhering to the outer surface of the granules does not produce mottles when salted, whether the salt is evenly or unevenly distributed. Mottles do not occur in unsalted butter. In mottled butter, the light portions usually contain less salt than the darker portions.

Mottles in butter are due, primarily, to the presence and uneven distribution of buttermilk adhering to the outer surface of the small granules; and, secondarily, to the hardening and localizing effect of salt-brine upon the protein of the buttermilk thus retained in butter. The light portions of mottled butter owe their lighter color to the presence of localized protein, usually free casein. The yellow or clear portions occur when the spaces between the butter-granules are filled with clear brine and are comparatively free from casein. Several hours are required to complete the action of brine upon the protein of butter. In the absence of buttermilk in butter-granules, we have no mottles. In the absence of salt we have no mottles. The combined conditions necessary to produce mottles are (1) the presence of sufficient buttermilk unevenly distributed, and (2) the presence of salt-brine. Mottles in butter can be prevented by avoiding those conditions that retain buttermilk in the butter and observing those conditions that favor the removal of buttermilk from butter-granules before salting. The butter-granules should be about the size of rice-grains or wheat-kernels and should be washed twice with water at a temperature of 35° to 45° C., using an amount of water for washing about equal to the buttermilk removed.

INSPECTION OF FERTILIZERS.

HISTORICAL REVIEW OF FERTILIZER LEGISLATION IN NEW YORK.

There are five dates, deserving special notice, connected with the attempts made by legislative enactment to afford protection against fraud to purchasers of commercial fertilizers. These dates are 1878, 1890, 1894, 1896 and 1899.

In 1878 the first law was passed, but as no provision was made for its execution, it was a dead letter. After intermittent agitation of the subject for ten years, a systematic effort was finally made to secure new legislation of a practical character. A new and strong interest in the matter was aroused by some work done at this Station which brought to light evidence of the existence of serious frauds in fertilizers. As an instance, a fertilizer, known as "Mason's High-grade Potash Fertilizer," made at Binghamton and sold at $30 a ton, was found to contain 0.2 per ct. of nitrogen, 0.18 per ct. of available phosphoric acid, and a small trace of potash. It was guaranteed to contain 5 per ct. of nitrogen, 3 per ct. of available phosphoric acid and 8.1 per ct. of potash. It was sold at $30 a ton, but the value of its fertilizing constituents was about one dollar.

Finally, in 1890, a law was passed, the execution of which was placed in charge of this Station. Efforts to enforce the provisions of this statute revealed exceeding looseness in its language, as well as other serious defects. The general principles embraced in the act were satisfactory to both consumers and manufacturers of fertilizers, and the law was efficient in making public each year the composition of the fertilizers sold in the State; but in prosecuting violations of the law it was found impossible to secure effective convictions against offending parties. The first prosecution begun under the enactment of 1890 was successful in the lower court, but, on appeal to the Supreme Court, the decision of the lower court was reversed on account of certain technical defects in the statute. An effort was made to remedy these defects by amendments, which became operative May 9, 1894. Again proceedings were instituted against violators of the law, but only to show that the statute was still practically useless so far as it enabled the State to secure the punishment of violations of the law by legal process in the courts.

In 1896 the statute was completely revised and greatly simplified, and in this new form was enacted into law. Under this and the preceding enactments, the cost of executing the law was borne by special State appropriations. Under these circumstances manufacturers increased the number of brands to an extent undreamed of, the different brands of fertilizers offered for sale jumping from 245 in 1890 to nearly 2,300 in 1899. This condition greatly increased the cost of executing the law and was, moreover, a practical hindrance rather than a help to farmers. To meet this condition, the law of 1896 was amended in 1899 by requiring a license fee of $20 a year for each brand offered for sale in this State and also extending the law to all goods selling for more than $5 a ton, the former law placing the limit at $10. This at once reduced the number of brands from nearly 2,300 to about 600, near which the number has since remained. In 1904 the law was further changed so as to place the collection of samples and the responsibility of making prosecutions in the hands of the State Commissioner of Agriculture. Also, specific provision was made for the publication of the results of analysis.

FERTILIZER LAW.

The main provisions of the law, as it now stands, are as follows:

To what goods the law applies.— The provisions of the statute apply to "any commercial fertilizer or any material to be used as a fertilizer, the selling price of which exceeds five dollars," when such goods are sold, offered or exposed for sale in this State. The law, in its past interpretation and in the intention of those who drew the first laws, applies to all mixtures containing nitrogen, phosphoric acid or potash, or any combination of these, and also to all unmixed fertilizing materials containing any of these elements of plant-food when sold for more than $5 a ton. Therefore, such materials as nitrate of soda, potash salts, dried blood, tankage, acid phosphate, etc., come under the provisions of the law.

What must be stated on each package of fertilizer.— The statute requires that four things shall be stated on each package of fertilizer:

(1) The net weight.

(2) The name, brand or trademark.

(3) The name and address of the manufacturer.

(4) The chemical composition expressed in the following terms:

(a) Percentage of nitrogen.

(b) Percentage of available phosphoric acid or, in case of undissolved bone, total phosphoric acid.

(c) Percentage of potash soluble in distilled water.

These forms *must* be stated; other expressions in addition may be used.

Filing statements and payment of license fees.— A statement covering the points already indicated must be filed each year with the Commissioner of Agriculture before goods are offered for sale. At the same time the license fee of $20 for each brand is required.

Requirements regarding inert nitrogenous materials.— "No person shall sell, offer or expose for sale in this State leather or its products or other inert nitrogenous material in any form, as a fertilizer or as an ingredient of any fertilizer, unless an explicit statement of the facts shall be conspicuously affixed to every package of such fertilizer and shall accompany every parcel or lot of same."

Publication of results of analysis.— Samples of fertilizers are collected each year for analysis and the results are published at least once in each year together with such other information as may seem desirable.

Justification for the fertilizer law.— The fact that the farmers of New York State expend for plant-food, in the form of commercial fertilizers, about $4,500,000 annually justifies the protection afforded by law, especially when it is kept in mind how much fraud has been known to exist when no such protection was given.

General outline of work done.— Since July, 1890, there have been collected for analysis about 13,000 samples, representing about 8,000 brands. During this time the Station has published over thirty fertilizer bulletins, containing about 1,600 pages. The number of each bulletin printed has varied from about 5,000 in 1890 to over 40,000 in recent years, and hence the aggregate number of pages distributed among farmers of the State on this one subject amounts to about 45,000,000 pages. In addition to the analyses of fertilizers, the publications have covered the discussion of such important, practical subjects as the description of materials used as fertilizers, the methods of purchasing and using fertilizers, the composition and value of various fertilizing materials, of farm crops, etc. Ten or twelve years ago there was a very great demand for information of this kind and untold good was accomplished by placing such literature in the hands of farmers, as has been frequently evidenced by the numerous expressions of appreciation received from the farmers.

Some direct results of fertilizer inspection.— In the form of a brief summary, we will call attention to some of the more prominent, direct results of the work done by this Station in the line under discussion.

1. It has driven dishonest fertilizer manufacturers out of existence in this State, and in the case of fraudulent goods manufactured outside of the State, it has had the effect of eliminating them from our State commerce. One of the most notable cases was the so-called "Natural Plant-Food," the sale of which was being pushed vigorously in 1896 with most pretentious claims. It sold at $25 to $28 a ton and was worth much less than $10 a ton, being chiefly an impure insoluble phosphate of lime.

2. There has been direct protection to farmers against fraud by placing in their hands specific and reliable information about the composition of commercial fertilizers in the market. The publicity afforded by the annual publication of the results of analysis has been the most efficient means of protecting farmers. Many farmers refuse to purchase a fertilizer unless the Station analysis shows that it has been up to its guarantee in previous years. Manufacturers fully understand this and are usually anxious to make their goods up to or well above their guarantee. The legal prosecution of those manufacturers whose goods fall below guarantee has had very little effect in restricting the manufacture of fraudulent fertilizers as compared with the publication of the results of analysis. Manufacturers whose goods are below guarantee would much prefer to pay fines and have the analysis suppressed than to have the results published and the fines remitted. This belief is based upon the results of eighteen years of experience in observing facts connected with fertilizer inspection.

3. The fund of information about the composition of special fertilizers and also about the general principles underlying the wise use of plant-foods has been greatly enlarged and brought within the personal knowledge of the farmers.

4. Such increased knowledge has led to a more judicious selection and economical use of plant-foods.

5. The general standard of composition of commercial fertilizers has been made more uniform and, in general, the number of brands falling below guarantee has decreased.

ANALYSIS OF PARIS GREEN AND OTHER INSECTICIDES.*

During recent years paris green has come to be used to such an extent by farmers and offered such an inviting field for adulteration, that in 1898 a law was passed to prevent fraud in the sale of paris green in New York State. This law was defective because it failed to define paris green properly and did not prevent the addition of white arsenic (arsenious oxide). The presence of white arsenic in paris green may render it unfit for spraying purposes, because white arsenic is sufficiently soluble in water to burn foliage, if present in amounts exceeding 3½ per ct. These defects were corrected in 1901. As amended, the law was essentially as follows:

1. It provided that every manufacturer should guarantee the percentage of arsenious oxide in paris green or any analogous product.

2. Paris green must contain *arsenic in combination with copper,* equivalent to not less than 50 per ct. arsenious oxide.

3. Paris green must not contain arsenic in water-soluble forms equivalent to more than 3½ per ct. arsenious oxide.

Paris green contains as its chief constituent a compound called *copper aceto-arsenite,* which, when chemically pure, contains

Arsenious oxide	58.64	per ct.
Copper oxide	31.30	" "
Acetic acid	10.06	" "

It may be regarded as approximately consisting of

Copper arsenite	82	per ct.
Copper acetate	18	" "

During the four years, 1899 to 1902, 130 samples of paris green were examined. The amount of arsenious oxide varied from 55.34 to [illegible].87 per ct., averaging 57.24 per ct.

The amount of copper oxide varied from 26.53 to 31.2 per ct. and averaged 29.82 per ct.

The amount of arsenious oxide in combination with copper varied from 49.70 to 58.45 per ct. and averaged 55.87 per ct.

The amount of water-soluble arsenic varied from 0.61 to 2.24 per ct. and averaged 1.30 per ct.

The results showed that the paris green in the market at the time the samples were taken were of good commercial quality. It

* Bulletins 165, 190, 204, 222.

was noticed that the amount of water-soluble arsenic grew less each year after the amendment of the law.

We append the analysis of several special materials sold as insecticides.

ARSENOID.

Total arsenic, equivalent to arsenious oxide	58.82 per ct.
Water-soluble arsenic, equivalent to arsenious oxide	2.94 per ct.
Copper, equivalent to copper oxide	30.76 per ct.
Moisture	1.91 per ct.

BLACK DEATH.

Arsenious oxide	0.79 per ct.
Copper oxide	0.41 per ct.
Sulphate of lime (gypsum)	45.34 per ct.
Magnesium oxide	3.98 per ct.
Iron and aluminum oxides	3.02 per ct.
Silica	5.42 per ct.
Loss on ignition	28.91 per ct.
Moisture	9.78 per ct.

BUG DEATH.

Zinc oxide	86.80 per ct.
Iron oxide	5.20 per ct.
Lead oxide	2.01 per ct.
Silica	2.96 per ct.
Loss on ignition	2.43 per ct.
Phosphoric acid	0.03 per ct.
Nitrogen	0.04 per ct.
Potash	0.00 per ct.

Some claims are made for this material as a fertilizer but the claims are not supported by the analysis.

ENGLISH BUG COMPOUND.

Arsenious oxide	1.46 per ct.
Copper oxide	0.60 per ct.

HAMMOND'S SLUG SHOT.

Sulphate of lime (gypsum)	74.72 per ct.
Arsenious oxide	1.04 per ct.
Copper oxide	0.59 per ct.
Iron, aluminum, silicon oxides, etc	6.92 per ct.
Moisture	10.88 per ct.

LAUREL GREEN.

Arsenious oxide	4.85 per ct.
Copper oxide	12.68 per ct.

This contains also large amounts of carbonate and hydrate of lime.

LONDON PURPLE.

Arsenious oxide	32.32 per ct.
Water-soluble arsenious oxide	12.27 per ct.

PARAGRENE.

Total arsenic equivalent to arsenious oxide	36.11 to	52.30 per ct.
Water-soluble arsenious oxide	0.88 to	1.47 per ct.
Copper equivalent to copper oxide	17.87 to	21.06 per ct.
Calcium equivalent to calcium oxide (lime)		14.20 per ct.
Moisture		8.15 per ct.

PARIS GREEN–BORDEAUX MIXTURE.

Arsenious oxide	15.49 per ct.
Water-soluble arsenious oxide	1.72 per ct.
Copper oxide	16.02 per ct.

SMITH'S ELECTRIC VERMIN EXTERMINATOR.

This is a mixture consisting chiefly of carbonate and hydrate of lime.

ANALYSES OF COPPER COMPOUNDS USED IN SPRAYING PLANTS.*

An investigation was undertaken to ascertain whether the copper compounds used in making spraying mixtures are adulterated and whether the special preparations put on the market are pure, properly mixed and economical in price. The following materials were examined: Copper sulphate in the form of crystals, powdered, and dried or anhydrous; copper carbonate as precipitated and "hydrated;" a prepared mixture called "copperdine" in dry form and in solution; and a prepared bordeaux mixture.

The samples of copper sulphate crystals contained 98.1 to 99.6 per ct. of pure copper sulphate. Powdered copper sulphate contained 98.1 per ct. The dried copper sulphate contained about 80 to 90 per ct. of what it should contain if entirely free from water of crystallization.

The samples of copper carbonate contained from 60 to 90 per ct. of pure copper carbonate.

"Copperdine" is a mixture of ammonium carbonate and copper carbonate. It was found to be needlessly high-priced.

A "Prepared bordeaux mixture" was found to contain only three-fourths as much copper as it should.

* Bulletin 41.

HOW TO DETECT IMPURITIES IN COPPER COMPOUNDS.

While the help of a chemist is needed to tell how much copper a substance contains, a few suggestions may be given which will enable anyone to test, in a rough way, samples of copper sulphate, and copper carbonate as well as paris green, in regard to their purity.

1. *Copper sulphate,* if pure, should dissolve completely in warm water, making a clear solution, free from sediment or suspended matter. A solution of copper sulphate should form a clear solution when treated with a sufficient amount of strong ammonia.

2. *Copper carbonate,* if pure, should dissolve completely in nitric acid. It should also dissolve completely, or nearly so, in strong ammonia used in considerable quantity.

3. *Paris green* should, if pure, dissolve completely in strong ammonia used in liberal quantity.

A SPRAYED-GRAPE SCARE.

In September, 1891, the New York city board of health seized and destroyed large quantities of grapes on the ground that they had been sprayed with copper compounds and were dangerously poisonous. Samples of clusters of grapes were selected which were covered with the largest amount of bordeaux mixture obtainable from those vineyards from which the condemned grapes came. Analysis showed that in each pound of grapes (the berries) there was about one-thirtieth of a grain of copper carbonate. To get an amount of copper that would be regarded as serious, if taken in one dose, one would need to eat not less than 3,000 pounds of grapes, skins included. Or, stated in another way, if one were to eat each day one pound of the worst sprayed grapes, including the skins, and if all the copper taken in this way were to accumulate in the body, it would require over eight years to accumulate an amount of copper which would, if taken at one dose, be considered dangerous, not necessarily fatal.

THE COMPOSITION OF COMMERCIAL SOAPS IN RELATION TO SPRAYING.

An investigation was undertaken to ascertain why commercial whale-oil soaps in some cases fail to destroy insects and in some cases cause injury of foliage (Bulletin No. 257, 1904).

A soap is made by treating a fat or oil with an alkali, as caustic soda or potash. A soap is a chemical compound formed by the union of an alkali and the fatty acid or acids contained in a fat or oil. The important constituents of a soap in relation to spraying are (a) water, (b) actual soap and (c) free alkali. In the case of nine samples of commercial whale-oil soap, the percentage of water varied from about 11 to 55 per ct.; of actual soap, from about 15 to 60 per ct.; of free alkali, from nothing to 1.30 per ct. Two different lots of soap from the same factory contained 36.79 and 53.13 per ct. of water and 24.06 and 46.28 per ct. of actual soap. Therefore, in making solutions of different commercial whale-oil soaps, one can not be sure of having a uniform strength of solution, and this lack of uniformity seriously affects their value for spraying purposes.

In order to have a soap of uniform composition, the following formula is suggested: Caustic soda, 6 pounds; fish-oil, 22 pounds; water, 1½ gallons. This will make 40 pounds of soap. These ingredients must be very thoroughly mixed.

Such home-made soap, when used at the rate of one pound in seven gallons of water, gave entire satisfaction in every way on the foliage of apple, pear, plum, currant, cherry and peach trees. The foliage was not injured and the plant lice were destroyed.

To ascertain how much free alkali in a soap will cause injury to foliage, soaps were made so as to contain 1, 2, 5, 10, 20, and 50 per ct. of free alkali. These were used in the same strength of solution and on the same kinds of foliage as before. Injury was done when the free alkali in the soap reaches 10 per ct. Little or no injury was done by the use of soap containing 5 per ct. or less of free alkali.

Caustic soda can be purchased at 4½ cents a pound and fish-oil at 26 to 30 cents a gallon. On the basis of these figures, the cost of the materials used in making one pound of fish-oil soap is about 2¾ cents. The advantages of home-made fish-oil soap are (a) greater uniformity of composition, (2) greater reliability, (3) decreased cost.

TESTS OF SORGHUMS.*

During five years, observations[1] were made on all varieties of sorghum that could be obtained, to determine which were of value in this State for forage, syrup and seed production.

In 1888 sorghums were grown from 162 samples of seed found afterward to include about 100 distinct varities. The next season

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* Abstract by W. P. Wheeler.

[1] Rpts. 7:71–84 (1888); 8:67–70 (1889); 9:162–168 (1890); 10:208–215 (1891); 11:291–294 (1892).

82 varieties were tested including 15 selected from those grown the first year, and in the three years following fewer new varieties were tried each season. Most of the sorghums came from South Africa and different parts of India, a number came from China and some from the Malay peninsula, Java, Algiers and Turkey.

All attempts to determine the yield of seed were finally abandoned owing to the nearly complete destruction on the small areas by English sparrows. A majority of the varieties grown were good seed producers, and a few were heavy yielders of seed of excellent quality, but not many were found to mature early enough for this latitude.

Records were made of the amount of juice capable of extraction from the canes by ordinary means, and of its composition so far as the percentages of cane sugar, glucose and total solids not sugar were concerned. Most of the best sugar producing varieties came from South Africa and a few from India. A few of the very best varieties were considered of too late maturity for safe planting in the greater part of the State. After the five years' tests only six of the varieties were recommended as reliable syrup producers for this latitude. The most encouraging fact in the series of tests was that no mature cane of any of the better varieties was found at any time that failed to contain a good percentage of sugar, seldom less than 12 per ct. of total sugars in the juice, and with the best, usually considerably more.

In one season analyses were made of the juices of canes grown on a number of plats that had been differently fertilized for two years, but no general difference in composition was found that seemed due to effects of the several fertilizing materials used.

In one season 12 varieties from strips in the field treated with carbonate of lime carried an average of about 10 per ct. more sugar than the same varieties from untreated strips. But a more extended comparison the next season on alternate limed and unlimed plats gave almost identical average composition, and no differences in yield and maturity of crop appeared.

THE COMPOSITION AND PRODUCTION OF SUGAR-BEETS.*

From 1897 to 1901, an experimental study of sugar-beets was made. The work being carried on at the Station and also in other parts of the State.

* Bulletins 135, 155 and 205.

Two varieties (Klein Wanzlebener and Vilmorin Improved) were used. The work was undertaken for the purpose of ascertaining the following facts: (1) The yield, (2) the richness in sugar and purity, (3) the cost of production, (4) the possible profit, (5) the influence of fertilizers, and (6) methods of culture.

YIELD.

The yield of sugar-beets, trimmed and washed, varied from 8,670 pounds to 59,000 pounds an acre, the average being 26,720 pounds. In ordinary commercial operations, 20 tons are regarded as a maximum yield. In favorable seasons, an average yield of 10 to 12 tons an acre may be expected in this State.

RICHNESS IN SUGAR.

In 1897, analyses of about 140 samples of beets grown in different parts of the State showed a variation of sugar in the beets from about 12 to 18.5 per ct., with a general average of 15.3 per ct. In 1898, samples of beets grown in sixteen different localities contained 10.1 to 18.5 per ct. of sugar, with an average of 15.5 per ct. Work continued at the Station in 1899, 1900 and 1901 gave sugar varying from 12.3 to 18.5 per ct., with an average of 15 per ct.

PURITY OF SOLIDS IN SUGAR-BEET JUICE.

The efficiency of sugar-beet juice in producing sugar depends largely upon two factors,—the amount of sugar in the juice and the amount of solids other than sugar. The larger the amount of sugar in relation to the other solids in juice, the larger will be the proportion of sugar that will crystallize out in manufacture. This relation is expressed by the "coefficient of purity," which is found by dividing the percentage of sugar in the juice by the percentage of total solids in juice. Experience has shown that for each pound of non-sugar solids, one pound of sugar is not recovered from the juice. The coefficient of purity is low in immature beets, in large beets, in the portion growing above soil and in beets overfed with nitrogenous manures. In the several years of work, the coefficient of purity varied from 72.5 to 90.2, averaging about 83 per ct.

INFLUENCE OF FERTILIZERS.

One ton of sugar-beets takes from the soil, on an average, 4 pounds of nitrogen, 2 pounds of phosphoric acid and 7 pounds of potash. In 1898, numerous coöperative experiments were made in testing the influence of fertilizers upon the yield and quality of sugar-beets. A fertilizer, analyzing 3 per ct. of nitrogen, 5.5 per ct. of available phosphoric acid and 7 per ct. of potash, made from nitrate of soda, dried blood, acid phosphate and sulphate of potash, was applied at the rates of 500 and 750 pounds an acre. The use of 500 pounds of fertilizer proved more profitable in every way than the use of 750 pounds. The percentage of sugar and coefficient of purity were not apparently affected by the use of fertilizer.

Experiments were carried on at the Station during four years in testing the influence of stable manure applied in the spring upon the quality of sugar-beets. Comparisons were made of the quality of beets not manured with those grown with commercial fertilizer (usually 1,000 pounds an acre) and with those grown on land receiving in the spring, before planting the beets, from 20 to 40 tons of stable manure an acre. Beets from at least six varieties of seed were grown during the four years. The results showed that the beets thus grown were of uniformly high quality under all three methods of treatment. The average was somewhat better with the farm manure than with no manure or with commercial fertilizers. The soil is a rather heavy clay, well drained.

THE CHEMISTRY OF HOME-MADE CIDER VINEGAR.

Cider vinegar made by farmers was frequently found to fall below the legal standard of the State, viz., 4.5 per ct. of acetic acid and 2 per ct. of cider-vinegar solids. It was commonly claimed that these vinegars were made from pure apple juice. An investigation was undertaken to ascertain why cider vinegar made by farmers so frequently falls below the legal standard. The work covered a period of some seven years. The details were published as Bulletin 258. The investigation included (1) the composition of apple juice of different varieties of apples, (2) the change in composition that apple juice undergoes during alcoholic and acetic fermentations. (3) conditions affecting these changes and (4) the destructive fermentation of vinegar on long standing.

I. COMPOSITION OF APPLE JUICE.

Analyses of apple juice, representing 122 samples and 83 varieties of apples, all American grown, are summarized in the following table:

TABLE III.— SUMMARY OF ANALYSES OF APPLE JUICE.

AVERAGE OF ANALYSES MADE IN	Specific gravity.	Solids.	Reducing sugars	Sucrose.	Equivalent of total sugar in form of invert sugar.	Ash.	Fixed acid as malic.	No. of analyses of apple juice.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
New York	1.064	15.11	9.28	3.85	13.33	0.23	0.53	13
Pennsylvania	1.056	13.31	7.67	3.61	11.47	0.28	0.58	11
Virginia	1.053	13.31	7.00	3.35	10,41	......	0.52	77
Washington, D. C.	1.054	13.39	6.84	3.48	10.00	0.33	0.51	21
Average of all	1.054	13.52	7.28	3.45	10.91	0.29	0.52	

The constituents of apple juice of most interest in connection with the making of vinegar are the sugars, because they furnish the original material for the final production of acetic acid. The value of apple juice for vinegar-making is mainly dependent upon the amount of sugars contained in it. The percentage of sugars varies greatly in apple juice, ranging all the way from 6.74 to 15.39 in the cases examined. These variations are dependent upon a variety of conditions, among which the following may be mentioned as the most prominent: Variety of apple, stage of ripeness, soil, climate and culture.

Sugar is present in apples in largest quantity only when they are ripe. The sugar decreases when apples become over-ripe. Therefore, green apples and partly decayed apples contain less sugar and produce less acid in vinegar than apples that are in the proper stage of ripeness.

It is a matter of interest to notice that sweet apples are not necessarily richer in sugars than sour apples. The increase of sweetness, apparent to the taste, is due more to the fact that sweet apples contain less malic acid than sour apples. For example, the sample of Red Astrachan apple juice contains 10.16 per ct. of sugars and 1.15 per ct. of malic acid, while Tolman Sweet and Sweet Bough contain about the same amount of sugar, but only 0.10 to 0.20 per ct. of malic acid.

2. ALCOHOLIC FERMENTATION OF APPLE JUICE.

Apple juice left exposed to the air is acted upon by yeast cells everywhere present, the sugar being changed into alcohol and carbon dioxide gas. Theoretically, 100 parts of sugar should yield about 51 parts of alcohol, but in actual practice losses are experienced, reducing the actual yield to 45 to 47 parts of alcohol. The fresh apple juice in sound apples contains no alcohol. When apple juice has undergone partial or complete alcoholic fermentation, it is commercially known as "cider." Under the ordinary conditions of a cellar temperature, most of the sugar is changed into alcohol in five or six months. In studying the alcoholic fermentation at temperatures ranging from 45° F. to 85° F., it was found that the change takes place more rapidly at the higher temperatures. Adding yeast to apple juice tends to hasten the alcoholic fermentation.

3. ACETIC FERMENTATION OF CIDER.

Certain forms of bacteria act upon the alcohol of cider and convert it into acetic acid, the presence of which in sufficient quantity is the object of the maker of vinegar. The conditions most necessary for the acetic fermentation of cider are (a) acetic bacteria, (b) an abundant supply of air, and (c) a temperature between 65° F. and 85° F. Theoretically, 100 parts of alcohol yield about 130 parts of acetic acid, but the actual yield is usually below 120.

At cellar temperatures, the acetic fermentation takes place slowly, requiring about eighteen months. Under the conditions of our work the formation of acetic acid took place most satisfactorily at temperatures between 65° F. and 75° F. The addition of vinegar containing "mother" to cider after the completion of the alcoholic fermentation increases the rapidity of the formation of acetic acid. When the clear portion of cider was separated from the sediment, the acetic fermentation appeared to be favored, especially at lower temperatures. It is possible that different barrels of apple juice, placed side by side, may show quite different behavior in fermentation.

4. LOSS OF ACETIC ACID IN VINEGAR ON STANDING.

Several different organisms have the power of decomposing dilute acetic acid and thus destroying the value of vinegar. These organisms work only in the presence of air. Accordingly, this destructive change in vinegar can be prevented by excluding air, when once the acetic acid has been formed. In practice, this can be done by drawing off the clear vinegar, placing it in a clean barrel, filling it as full as possible and putting the bung in tight.

5. BEHAVIOR OF MALIC ACID OF APPLE JUICE IN VINEGAR-MAKING.

Malic acid was found to decrease during the vinegar-making process. In most cases, only small amounts of malic acid, free or combined, were left when the vinegar had become a commercial product. In decomposed vinegars, malic acid had entirely disappeared. Malic acid added to apple juice also disappeared to a large extent. In sterilized apple juice, the decrease of malic acid was less marked.

The white precipitate formed when lead acetate is added to vinegar has been attributed to the presence of malic acid in the vinegar, and a vinegar failing to give this test is usually regarded as not cider vinegar. While all of our vinegars gave a precipitate with lead acetate, there were several in which no trace of malic acid was present. Such a white precipitate with lead acetate is due, not to malic acid, but to the phosphates in vinegar.

6. THE SOLIDS OF APPLE JUICE AND CIDER VINEGAR.

During the first three months of the alcoholic fermentation at cellar temperature, the solids decreased rapidly. The loss was not uniform in different experiments. There is quite generally a decrease of solids to a point below 2 per ct., but under normal conditions there is a subsequent increase. In old vinegars, standing in barrels with the bunghole open, there is evaporation of water and a consequent increase of solids. In vinegars in which a destructive fermentation of acetic acid has occurred, there is also a marked loss of solids. The amount of vinegar solids may be below 2 per ct when the acetic acid is above 4.5 per ct.

7. CIDER VINEGAR IN RELATION TO LEGAL STANDARDS.

Legal standards for cider vinegar are usually based upon the percentage of acetic acid and cider-vinegar solids. In New York State, the legal requirement is 4.5 per ct. of acetic acid and 2 per ct. of solids. From our work, it appears that where proper fruit is used for cider-making and where the conditions of fermentation are properly controlled, there should be no difficulty in making cider vinegar that contains above 4.5 per ct. of acetic acid in 18 to 24 months.

In respect to the requirement of 2 per ct. of cider-vinegar solids, something depends upon the method of determining solids, since there is as yet no recognized official method. It would be wise for the law to fix the method to be used in estimating solids.

8. CONDITIONS COMMONLY PRODUCING CIDER VINEGAR BELOW STANDARD.

The more common causes responsible for the production of cider vinegar low in acetic acid are the following:—(1) Poor apple juice, due to (a) unripe fruit, (b) over-ripe fruit, (c) watering normal apple juice, (d) second pressing of water-treated pomace, (e) the use of fruit normally poor in sugar. (2) Conditions unfavorable to the necessary fermentation processes, such as (a) dirty fruit, (b) unclean barrels, (c) too low temperature, (d) lack of air from filling barrel too full or stopping the bung-hole. (3) Lack of proper care after the vinegar is made, by leaving the cider standing at too high a temperature with the bung open and the barrels only partly filled.

9. DIRECTIONS FOR HOME MANUFACTURE OF CIDER VINEGAR.

(1) Kind of apples to use. Only clean, sound, ripe apples, giving a juice containing not less than 8.5 per ct. of sugar should be used. (2) Preparation of apple juice. Cleanliness should be observed in grinding and pressing. Avoid the use of juice made from second pressing of pomace. (3) Putting apple juice in barrels. The barrels should be carefully cleaned and thoroughly treated with live steam or boiling water and should be filled about two-thirds or three-fourths full of apple juice. The bung should be loosely placed in the hole or preferably the hole loosely plugged with a stopper of absorbent cotton. (4) Management of alcoholic fermentation. The barrels of apple juice should be kept at a temperature of 65° F. to 70° F., if a fairly rapid fermentation is desired. A further shortening of time may be realized by adding yeast to the apple juice, using one compressed yeast cake for five gallons of juice. (5) Management of acetic fermentation. When alcoholic fermentation is complete, draw off clear portion of liquid, rinse barrel, replace the clear liquid, add 2 to 4 quarts of good vinegar containing some "mother" and keep at a temperature of 65° F. to 75° F. (6) Care of cider vinegar. When the acetic acid amounts to 4.5 per ct. of acetic acid or more, then fill the barrels as full as possible and cork tightly.

METHODS OF ANALYSIS.

Several methods of chemical analysis have been worked out at the Station, some of which have been adopted as official methods by the Association of Official Agricultural Chemists. A mere mention of such methods will suffice for our present purpose.

1. Determination of number of fat globules in milk.[1]
2. Determination of viscosity of milk, cream, etc.[2]
3. Determination of casein in milk, cream, etc.[3]
4. Determination of albumin in milk, cream, etc.
5. Methods for the estimation of the proteolytic compounds contained in cheese and milk.[4]

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[1] Rpt. **4**:266–275 (1885).
[2] Rpt. **5**:316–330 (1886).
[3] Rpt. **12**:487–497 (1893).
[4] Bul. 215.

INVESTIGATIONS OF THE DEPARTMENT OF ENTOMOLOGY.

SUMMARIZED BY
P. J. PARROTT.

The first effort of the Station toward an economic study of the destructive insects of this State was in 1894, when investigations[1] were undertaken to determine means for the prevention of injuries to truck crops on Long Island. The agriculture of this region of the State is largely trucking, on an extensive scale, and serious losses were being sustained by the growers of cucurbits, cabbage and cauliflower. The more prominent pests were the cucumber beetle, squash bug, cabbage worm, cabbage plusia, and cabbage aphis. At this time there was an urgent need for direction in the proper use of insecticides and in the employment of cultural and preventive measures that are calculated to avoid injuries by these agencies. In 1895 attention was also directed to the San José scale,[2] which was first discovered on the Island by the Station entomologists, and to other species of scales. As opportunity has afforded, studies have been extended to other insects of a destructive nature throughout the State and special investigations have been undertaken of unusual outbreaks, which, during their duration, were of much concern to farmers. For convenience, the results of the more important of these studies are reviewed briefly under the names of the insects, which are classified according to their appropriate headings of Garden Insects, Fruit Insects and Field Crop Insects.

STUDIES ON GARDEN INSECTS.

STRIPED CUCUMBER BEETLE.

(*Diabrotica vittata* Fab.)

Squashes, melons and cucumbers are grown to a considerable extent in all sections of the State, especially on Long Island and in the vicinity of New York City where they form very important crops.

[1] Rpt. 13:711 (1894).
[2] Bul. 87 and Ann. Rpt. 14:605–617 (1895).

The insect enemies[3] of these crops are numerous and destructive, and growers have been seriously embarrassed by them. Of these pests the striped cucumber beetle is one of the best known and is much dreaded because of its destructiveness. In Long Island, where cucumbers are planted on a large scale for pickles, the ravages of this insect cause heavy losses every year and the insect is generally regarded as a serious handicap to successful pickle growing. In 1897 and 1898, extensive observations[4] were made on the life history of the beetle and some exhaustive tests were undertaken to determine the value of the remedies that were commonly employed, and, if possible, to develop more efficient methods of control.

It was found that the young striped beetles feed during late summer and fall upon the fruits of the cucurbits, especially damaging musk melons; upon late planted beans, eating both vines and young pods; and upon the flowers of golden rod and aster. They do not mate during the fall, as shown by careful dissections. Most of them pass the winter in little cells which they have burrowed out in the soil below the frost line, while some possibly hide in sheltered positions, where they feel the heat of the spring quicker and make their appearance early in mid-spring. The beetles do not appear in injurious numbers until late in May or early in June.

The beetles feed voraciously for five or ten days before commencing to pair. As they show so little discrimination at this period in their eating, it was found that they are more readily poisoned now than later, when they become more fastidious in their tastes. At all times they show a preference for squash, which habit furnished a suggestion for the better protection of cucumbers and melons.

It was also noticed that egg laying begins about July 20 and lasts one month. The eggs are deposited with little care about the hairs of the leaves, at the growing tips of the vines and on the ground under the leaves or runners. The eggs are light yellow in color, oval in shape, and are but little larger than a pin point.

It was found that the larvae live in the moist earth and in the stems, feeding upon the tissues of the latter, and upon the vines and fruits when they rest in the soil. These larvae require about a month to feed and to develop. They then form little cells below the surface of the ground and emerge as adults in from one to two

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[3] Bul. 75; same in Rpt. **13**:713–728 (1894).

[4] Bul. 158; same in Rpt. **18**:251–288 (1899).

weeks. The new brood begins to appear on Long Island about September 10. There is one brood a year, the old hibernating beetles surviving until some of their progeny have matured. The beetles are present from mid-spring till fall, when the frosts compel them to go into hiding.

In the field work, tests were made of paris green, laurel green, green arsenite and lead arsenate. These were applied dry, in water, in bordeaux mixture, in resin-lime mixture, alone, and in various combinations. Green arsenite dusted over the plants gave the best results. It was found a waste of the poisons to apply them in bordeaux mixture as the blue vitriol in the spray so repelled the beetles that they would not eat the sprayed vines and thus they escaped poisoning. These poisons in water alone are liable to burn or stunt the plants. To poison the beetles it was found necessary to grow trap crops to attract the insects, and to apply the poison to this crop rather than to the vines it is intended to protect. As the squash is the beetle's favorite food plant it was recommended that this vegetable be planted in single rows around the margins of small patches, and in several rows around large fields, about four days before the cucumber or melon seeds are sown. When the trap crops are up and the beetles appear about them it was advised that about one-half of the plants be dusted with an arsenical poison, preferably green arsenite, reserving the remainder of the plants for similar treatment if rains or dews make the poison soluble, killing the vines first treated. When the cucumbers and melons are up, unless they are protected by covers, spraying with bordeaux, and applications of poison to the squashes were recommended. When the beetles commence to pair, the squashes may be largely destroyed, leaving only a few vines for the beetles to feed upon at flowering time as they prefer the squash flowers.

It is believed that beans may be used with some success as a fall catch crop where wild flowers are not too plentiful. They should be planted on the cucumber or melon fields, and when the beetles leave the old vines to feed upon the tender beans the plants should be dusted with poison.

SQUASH BUG.

(*Anasa tristis* Deg.)

This is an old and well known pest to growers of squashes and cucumbers. For years it was unusually destructive, causing severe losses on Long Island, especially about Jamaica when squash was one of the main crops. It also attacks melons and pumpkins. In the work[3] by this Station on this species, tests were made of kerosene emulsion, carbon bisulphide, pyrethrum and other insect powders to determine their values for the treatment of this insect. Kerosene emulsion diluted with four parts of water killed the old bugs but was not regarded as a practical remedy except in severe cases as the emulsion at this strength would endanger the plant. The emulsion diluted with nine parts of water was considered entirely effective and was advised for the treatment of the young bugs. Carbon bisulphide under light covering completely destroyed the adults, and the young bugs, less than half grown, proved much more susceptible, with less time exposure and smaller quantities of the liquid. Pyrethrum and other insect powders failed entirely to affect the bugs. The measures calculated to avoid injuries by this insect are the burning of rubbish and all crop remnants, and fall plowing. The first bugs to appear in the spring should be caught and destroyed. Bits of boards, chips, squash leaves, etc., placed underneath the vines make good traps, from which the insects may be collected and destroyed. Young vines should be carefully examined for eggs which should be burned. Upon the appearance of young bugs the plants should be sprayed with kerosene emulsion diluted with nine parts of water.

SQUASH VINE BORER.

(*Melittia satyriniformis* Hubner.)

This is a well known pest in this State and has been exceedingly destructive, especially on Long Island. It was estimated[3] in 1894 that from one-third to one-half of the vines grown in the vicinity of Jamaica and Brooklyn were more or less affected and that nearly if not quite 50 per ct. of the crop of late squashes was destroyed by this pest. The borer seems to prefer the Hubbard and the Marrowfat varieties. Cucumbers, melons and pumpkins are also liable to attack. The work of destruction is accomplished by the larva which is a fat white grub of about an inch long. The adult moth appears shortly after July and remains for some time, continuing to lay eggs on almost any part of the vine, specimens having been found as late as September 1. It was found that the eggs hatch in about ten or fifteen days and the larvae immediately burrow into the stem or roots. In four weeks the larvae are full grown, and during

[3] Bul. 75; same in Rpt. 13:713–728 (1894).

the latter part of July or first of August, they leave the plants to burrow into the soil where they spin their cocoons. The larvae remain over winter and do not change to pupæ until a short time before emerging in the spring. In the experiments on this pest to determine methods of control, insecticides proved of little value and were abandoned as useless. It was found that in small patches, cutting the borers out as soon as the vines show signs of injury is a practical and thorough remedy. If the wounded part of the vine is immediately covered with earth, no injury attends the operation. Covering the base of the vine as far as the third or fourth joint and capturing the sluggish moths late in the evening and early in the morning are commendable practices. Many farmers delay planting their late squashes as long as possible without endangering the crop and fertilize heavily to stimulate a vigorous growth of the vines. For extensive planting it was ascertained that frequent shallow cultivation in the fall, followed with deep plowing in the spring, are practices which are calculated to reduce the numbers of the moth and permit the growing of squashes with but a small part of the losses that formerly attended the growing of the crop.

BOREAL LADY-BIRD BEETLE.

(*Epilachna borealis* Fab.)

In Bulletin 75, attention was called to the appearance of this species in great numbers on Long Island in 1893. They were especially numerous in the vicinity of Glen Cove but were more or less abundant on the western part of the island. This insect belongs to a family of beetles which fed, both in larval and adult stages, on animal food, as plant lice and eggs of other insects. This particular species has taken to vegetable food, and preys upon some of our most important crops. At Glen Cove the beetle did considerable damage to squash and pumpkin vines. Treatment of the vine with an arsenical proved an efficient remedy.

MELON LOUSE.

(*Aphis gossypii* Glov.)

This species is discussed in Bulletin 75 as a pest on the underside of the leaves and also upon the roots of muskmelons, cucumbers, squashes and other cucurbitaceous plants, which causes the leaves to curl and to shrivel, and stunts the growth of the plant. At the time that the observations and experiments were being made on the insects of cucurbits this species was of minor importance. It occurred in spots in the fields and was usually combated by the uprooting and destruction of affected plants at the first appearance of infestation.

IMPORTED CABBAGE BUTTERFLY.

(*Pontia rapae* L.)

This is the best known cabbage insect and during certain seasons is one of the most destructive pests with which our market gardeners have to contend. As early as 1870 it was estimated by a correspondent of the American Agriculturist that the worm damaged the cabbage crop to the value of a million dollars in the vicinity of New York city alone, and in 1894, when the Station undertook special investigations[5] of the cabbage industry, it was thought that the losses sustained by truckers on Long Island by this one insect would at least approximate or exceed this sum. In sections of the country where only one crop of cabbage is raised in a year, the cabbage worm is not usually considered a serious pest, but in localities where two or three crops are grown every year, as is the case on Long Island, this insect is a formidable obstacle to the successful culture of this crop.

Aside from its prolificness another reason for the growing importance of this insect was the lack of intelligent effort in the use of efficient insecticides. Numerous remedies, like lime, salt and decoctions of weeds, etc., were commonly used, all of which possess little or no value. Many gardeners were, in place of recognized remedies, employing proprietary insecticides which were often unreliable and injurious to the plant. The more successful truckers used paris green and london purple in powder form, and while these poisons could be depended on to kill the caterpillars, injuries often resulted to the foliage from such use. In the study of the insects of the cabbage, it was the endeavor of the Station to ascertain more efficient and safer methods of control.

After conducting several tests with paris green and london purple with various diluents, as water, flour, and road dust, which were usually employed for this purpose, it was demonstrated that the use of arsenicals in liquids was much more effective in controlling the caterpillars; and that there was less likelihood of injuries attending the applications. It was also shown that neither flour nor road dust will prevent free arsenic in paris green or london purple from going

[5] Buls. 83 and 144; same in Rpts. 13:737–766 (1894) and 17:389–413 (1898).

into solution if applied while the dew is present; and if distributed when the plants are dry, the powder adheres only to the upper surface of the leaves. On the basis of these results, one pound of paris green to one hundred and sixty gallons of water, with enough lime to neutralize any soluble arsenic present, was recommended as the spray best adapted for the treatment of the cabbage leaf-eating insects. Attention was also called to the new arsenical, gypsine, now known as arsenate of lead, which by reason of its safe and adhering qualities appeared to be a promising poison for spraying cabbages. Subsequent experiments have shown that arsenate of lead is the most efficient poison for the treatment of plants with smooth foliage, such as cabbage, because of its superior adhesiveness.

With the appearance of the cabbage looper (*Autographa brassicae*) and its growing importance as a cabbage pest, efforts were then directed to compounding a soap[5] to make arsenicals more adhesive to cabbage foliage. The necessity for this addition to the usual spray was that the caterpillars of this species work largely on the undersides of the leaves, where they may remain unnoticed until much damage has been done, and where only very thorough applications of remedies will affect them. They are also active in movements and discriminating in taste so that they quickly abandon feeding places which show traces of poison or other foreign substance. To obtain successful results it was found that the applications of the poison must be made thoroughly so that every portion of the surface of the leaves is protected.

After repeated tests, an excellent material for securing uniform distribution and perfect adhesion was found in a resin-lime mixture. In preparing this mixture it is necessary to make, by slow boiling, a stock solution of five pounds resin, one pound concentrated lye and one pint of fish oil. For use, one gallon of this stock material was mixed with three gallons milk of lime, one-fourth pound paris green and sixteen gallons of water.

The resin-lime mixture received its first test upon cabbages in 1896. The results were an entire success and protection was afforded to the plants to the end of the season, notwithstanding heavy rains. In this experiment, comparative tests were made of the paris green and resin mixture in comparison with bordeaux mixture and paris green, and paris green mixed with flour. It was estimated by the owner that the plats treated with the poisoned

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[5] Buls. 83 and 144; same in Rpts. 13:737–766 (1894) and 17:389–413 (1898).

Unsprayed. Sprayed.

PLATE XI.— RESIN-LIME WASH PROTECTS CAULIFLOWER.

resin mixture yielded 100 per ct. better than the untreated plats and at least 60 per ct. better than those dusted with paris green and flour. The bordeaux mixture even when united with paris green, and the paris green and flour were of little advantage against the loopers, though quite effective against the common cabbage worm.

To make two applications upon ten acres of late cabbage after the plants are two-thirds grown would require materials worth $5.00, time in preparing stock solution 75 cents and 10 days' labor which at $1.50 a day would be $15.00, a total of $20.75 or about $2.00 per acre for treatment, which will insure almost perfect freedom from injury by the worms.

CABBAGE LOOPER.

(*Autographa brassicae* Riley.)

This is a native moth[6] and its injuries on late cabbage are frequently confused with the work of the common cabbage worm. It undoubtedly does more damage to late cabbage and lettuce on Long Island than the latter species, as in this locality it is not checked by parasites. The larva is especially destructive to lettuce when it is transplanted from cold frames or open beds to the forcing house. The caterpillar is not provided with prolegs on the sixth and seventh segments like most Noctuids, so in traveling over the surface of the leaf they loop the body like the "Measuring Worms" or "Geometers." From this habit they are often called "Cabbage Loopers" in distinction to the common cabbage worm. Protection from this pest is afforded by the use of the remedies employed for the preceding species.

DIAMOND-BACK MOTH.

(*Plutella maculipennis* Curtis.)

In some plantations this insect[6] occurs in numbers sufficient to do a great deal of damage to rape and turnips. It is also known to feed on cabbage, cauliflower and Brussels sprouts. The cabbages are injured principally in the early part of the season. Thorough treatment of cabbage as previously described will control this species.

CABBAGE APHIS.

(*Aphis brassicae* L.)

The cabbage aphis[6] or "greenfly," as it popularly is designated, is a serious pest of the cabbage, and in some seasons it is responsible

[6] Bul. 83; same in Rpt. 13:737–766 (1894).

for as much or more damage than the cabbage caterpillars. It injures the cabbage in the seed bed as well as in the field, and causes a large amount of damage to seed cabbage by injuring the seed stalk, so that in some localities no seed is produced. The aphis survives the winter on cabbage stored in cellars and pits, and also on plants stored in pits for seed purposes, which facilitates an early attack on the seed stalks in the spring. To free cabbages of the broods that survive the winter, the use of carbon bisulphide was recommended, and tests were made in 1894 to test the value of this treatment.

With the completion of the tests it was recommended that seedsmen who raise cabbage seed should open the pits a few days before the time to set the cabbage in the fields and fumigate the plants with carbon bisulphide, using one teaspoonful for each cubic foot of space. After the distribution of the liquid the pit should be closed and not opened again for at least two days. For the treatment of infested cabbages in the field, kerosene emulsion diluted with ten parts of water proved the most efficient remedy.

THRIPS.

(*Thrips tabaci* Lind.)

This insect ordinarily causes no marked damage but in some seasons its injurious work is sufficient to cause the outer leaves of the second crop of cabbage to die. Mention[6] was made of this species as a matter of record. The thrips is controlled by the same remedies that are employed for the cabbage aphis.

HARLEQUIN CABBAGE BUG AND OTHER CABBAGE INSECTS.

(*Murgantia histrionica* Hahn.)

In Bulletin 83, on the cabbage insects, attention is directed to the appearance of this southern cabbage pest on Long Island where it was found feeding on radishes, near Jamaica, L. I. Other insects of lesser importance discussed in this bulletin are the zebra-caterpillar (*Mamestra picta* Harr.), the cross-striped cabbage worm (*Evergestis rimosalis* Guen.), the southern cabbage butterfly (*Pontia protodice* Bd.), and the stalk borer (*Papaipema nitela* Guen.).

STUDIES ON FRUIT INSECTS.

CODLING MOTH

(*Cydia pomonella* Linn.)

An important advance in the methols of controlling leaf-eating insects was made when it was demonstrated that the potato beetle (*Leptinotarsa decemlineata* Say.) could be efficiently combated by the use of paris green. The success attending the employment of an arsenical in the destruction of this pest naturally suggested its application to other plants that suffered from insects with similar habits. Among the insects that were thought to be amenable to treatment with paris green was the codling moth, a very destructive pest of the apple crop. As it was desirable to ascertain the merits of an arsenical treatment for this insect, an experiment was conducted by this Station in 1885, to ascertain to what extent the losses usually sustained by the codling moth could be avoided. For the test nine Fall Pippins and two Rhode Island *Greenings* were sprayed, the number of trees having of necessity to be limited, as the spraying machinery in vogue was rather crude and not adapted for large orchard operations. The paris green was used at the rate of a teaspoonful to ten gallons of water, and the applications were made on June 3, 5 and 17, the young apples during the first treatment, as described, being the size of cranberries. Alternate trees were left unsprayed for comparison.

As the apples began to drop in August, the windfalls were collected and examined, under the sprayed trees, and those not sprayed; and the number of sound and wormy fruits counted. On October 5 and 6, the remaining fruit was picked, assorted and counted in the same manner. The results of the examination showed that there was an average of 13 per ct. of wormy apples from the sprayed trees while the untreated trees had an average of 35 per ct. of wormy apples. The percentage of wormy apples from the trees sprayed with paris green was about 22 per ct. less than those not sprayed. The details of this test were published in the Annual Report of this Station[7] for that year, which was the first publication by an official experiment station of results from the use of paris green for the control of the codling moth. The utility of arsenical poisons for this pest has been firmly established, and spraying with arsenicals for the codling moth is now a recognized practice among our most successful fruit growers.

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[7] Rpt. 4:246–248 (1885).

SAN JOSÉ SCALE.

(*Aspidiotus perniciosus* Comstock.)

In 1894, the San José scale was discovered for the first time on Long Island[8] and efforts were immediately directed to discover means of controlling this pest in several nurseries, in which it was found, and which, aside from a few private yards and orchards, were the leading centres of infestation. At this time there was no question but that this species was already distributed in many parts of the State where its presence was unsuspected. As this pest, from its ravages in California, was known to constitute one of the most difficult problems with which fruit growers and nurserymen have to contend, the Station directed special efforts to ascertain other localities where it was present, attention being largely given to nurseries and to orchards of recent planting. It was hoped by this means to retard the spread of the species in the communities in which it was found and to prevent, as methods of control were developed, its further dissemination through infested nursery stock. The studies that were undertaken on this subject may be grouped under the headings: (1) The San José scale in nurseries, and (2) the San José scale in orchards.

San José scale in nurseries.— As fumigation for the treatment of scale insect on citrus trees had proven the most efficient means of destroying the scale in California, experiments[9] were commenced by this Station in 1895 to determine the limits of effectiveness and safe use of hydrocyanic gas upon nursery trees. In the preliminary tests[10] upon dormant nursery stock, fumigation, using the standard amount of potassium cyanide, proved entirely destructive to the scale and safe to the plants; and it was then concluded that this was the cheapest and most reliable treatment for nurserymen who handle and ship fruit trees in large quantities.

Besides treating importations and spraying doubtful stock in the field, an additional safeguard in the nursery to prevent the dissemination of the scale on the premises is an efficient treatment of bud sticks, scions, etc., especially if such are taken from infested plantations. As fumigation was proving well adapted to dormant trees, it was desirable to also extend its use

[8] Bul. 87 Rpt. **14**:350 (1895); *Insect Life*, **7**:284; N. Y. State Mus. Rpt. **3**: No. 13 (1895).

[9] U. S. Dept. Agr. Rpt. 1887; *Insect Life*, **3**:457 (1890).

[10] Rpt. **14**:609–613 (1895); Bul. 136 and Rpt. **16**:467, 468 (1897).

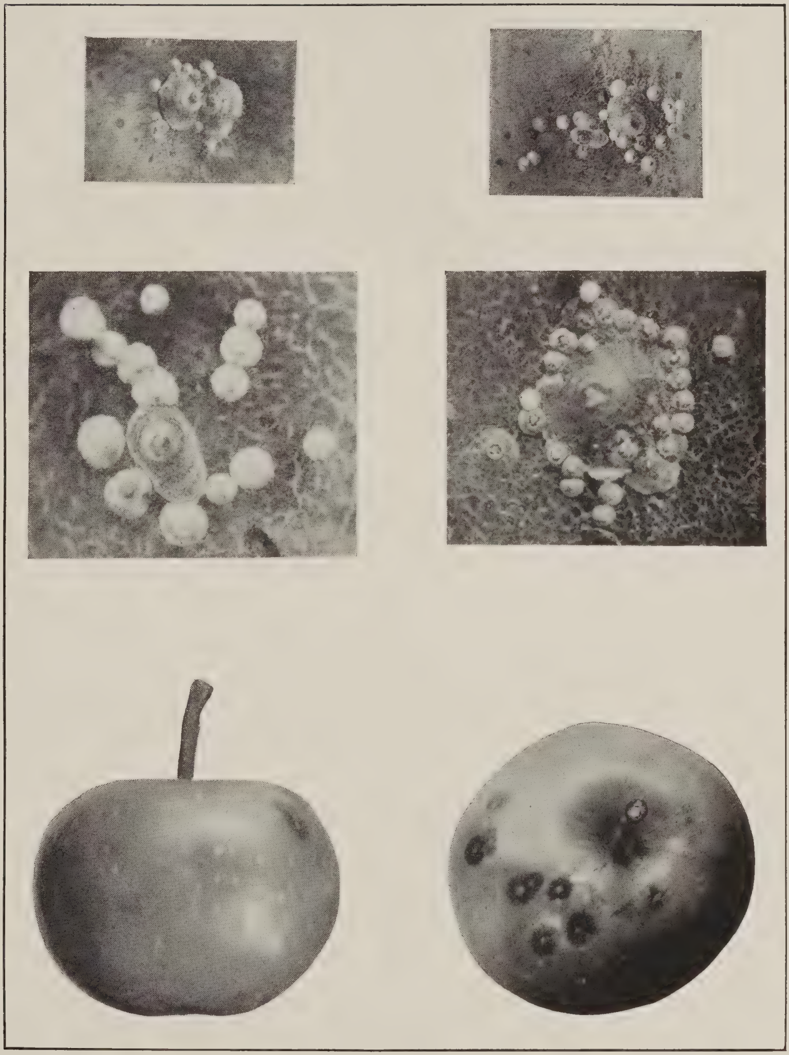

PLATE XII.— SOME CHARACTERISTIC VIEWS OF SAN JOSE SCALE.

in other nursery operations; and to that end, extensive experiments[11] were made to determine the effects of the gas on buds. The results of these tests showed that this treatment was safe and its use was advised. To assist nurserymen in the identification of the various insects upon their stock and to direct them in the methods of fumigation, Bulletins 136 and 174 were published. These contain simple descriptions of the more common destructive species of insects and explain clearly the methods of treating dormant nursery stock, with suggestions as to the location and construction of fumigating houses or chambers.

San José scale in orchards — fumigation of bearing trees.— One of the first problems arising from its discovery in this State was to exterminate the San José scale in the more recent plantings of young orchards, where it was introduced on the nursery trees. If treatment was made in time, it was thought in many instances feasible and well worth the effort to attempt its eradication in order to present its spread in a community in which it was just discovered. As hydrocyanic gas seemed then to be the most practical treatment for this pest, tests[11] were made to determine its utility for orchard use. Fumigation in every instance proved safe to dormant trees and trees in foliage. The interesting observation was also made that while .3 of a gram of potassium cyanide per cubic foot was necessary to kill all of the scales by winter treatment, only .18 of a gram was required to kill every scale when the fumigation was made in early summer.

The sheet tents that were commonly employed in orchard fumigation proved, unless carefully handled, to be destructive to branches because of their weight and the interference by the limbs in adjusting them to their proper position. Moreover, variations in the sizes of the trees made it necessary to estimate the fumigation dosage at each change which could not be as accurately determined as was desirable, owing to the changing shape of the tent, which varied with each tree. To simplify the problem of fumigating small trees, considerable attention was directed to the problem of constructing a practical fumigation box for such work. In the course of the experiments, a box fumigator[12] was designed which is inexpensive and light in weight, and can readily be manipulated by two men. This style of fumigator possesses several advantages

[11] Bul. 202; same in Rpt. **20**:247–291 (1901).
[12] Bul. 181; same in Rpt. **19**:287–291 (1900).

over the sheet tents in that the cubic contents can be accurately computed once for all, thus avoiding the necessity of changing the amounts of the chemicals for each tree and thereby insuring correct treatment with the gas. Moreover the box fumigator does not rest on the trees and is not so apt to break the branches or brush off the buds or fruits. In the field tests with the box fumigators the Station concluded that the use of hydrocyanic acid gas in orchards in this State is only feasible on a few comparatively small trees which can be pruned back to 12 feet in height and 8 feet in diameter before adjusting the fumigator, and was impracticable for general orchard treatment.

Experiments with kerosene.— With the entrance of this pest into the older orchards of New York, kerosene oil, pure or diluted to various strengths, was freely advocated for the treatment of the San José scale. As injuries had attended applications of the oil by fruit growers, it could not be recommended without knowing more definitely both the highest strength which could be used without injury to trees of different kinds and the lowest strength which would kill the scale under different conditions. Experiments[13] were conducted to determine the range of this oil for spraying purposes, and it was concluded that careful spraying of apples and pears at a strength of 40 per ct. in the spring as buds were swelling, was an efficient treatment for the San José scale. For spraying peaches and plums, oil treatment was considered inadvisable as they are very susceptible to injury. For these kinds of fruits, the safer sprays were recommended.

Experiments with crude petroleum.— Following the demonstration that kerosene oil under certain conditions could be used for the treatment of fruit trees, attention[14] was then given to crude petroleum. Much interest had been aroused among orchardists as to the probable utility of this oil for this purpose because of some experiments conducted in other States south of New York, which showed that applications of undiluted crude petroleum, testing about 45° Beaumé oil test, did not injure ordinary fruit trees when sprayed upon them, while an emulsion containing as little as 20 per ct. of oil seemed effective in destroying the scales. These effects upon the trees by the crude petroleum were contradictory to some

[13] Buls. 194 and 213; same in Rpts. **19**:317–331 (1900) and **21**:258–280 (1902).

[14] Buls. 202 and 213; same in Rpts. **20**:247–291 (1901) and **21**:258–280 (1902).

results that were obtained in the eastern part of the State where applications of undiluted oil seriously injured many of the sprayed trees.

In 1901 the Station carried on two extensive series of tests which seemed to show that 40 per ct. of crude oil could be used with safety upon apple, cherry, and pear trees. In the treatment of plums, caution was advised in its use;—to apply the minimum quantity necessary to cover the trees. Oil treatment of peaches was regarded as a dangerous practice as the applications are liable to kill the trees at any strength that will destroy the scale.

Experiments with the lime-sulphur wash.—With the establishment of the San José scale in many orchards, there was a demand on the part of our fruit growers for a cheap, safe and efficient spraying mixture. Whale oil soap, once the recognized remedy, was not satisfactory because of its cost and variable composition. There was also dissatisfaction with kerosene and crude petroleum. While they are the most available and effective sprays, they were not answering the purposes of average fruit growers, because of the difficulty of making thorough applications without causing injuries to the trees, such as are liable to occur from a too free use of these oils. In 1902 it was proposed to introduce the lime-sulphur wash, which was thoroughly tested in a series of experiments[15] on Long Island, in the Hudson Valley and in western New York, to determine its value under our climatic conditions as a remedy for the scale. In California its utility for this purpose had been thoroughly established, but the advisability of using sulphur washes in this State was still a matter of doubt. It was thought that if rains should follow the applications, as is very apt to be the case during the spraying season, the treatment would prove only a partial success. In the experiments that were conducted, frequent rains or snows invariably occurred during the spraying operations or immediately following the completion of the work, and yet withal the results on scale and trees were most satisfactory. Because of its safe and efficient qualities combined with its cheapness, the sulphur wash was regarded as the remedy best adapted to the needs of our fruit growers for the control of the scale and its use has been persistently advocated by the Station. It is now generally employed by orchardists in preference to the oil or soap mixtures. In many localities, while there is a full appreciation of its destructive capacity

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[15] Bul. 228; same in Rpt. **21**:281–348 (1902).

and the danger of neglecting to afford suitable protection to the trees, the San José scale is gradually losing many of the terrors which it formerly inspired; and annual spraying of peaches, plums, pears and apple trees of moderate size for this pest is now an established practice in the yearly routine work of the farm. In general, our fruit growers, by the faithful observance of the details required for the preparation and application of known remedies, experience now no especial difficulty in controlling the scale on small trees. The remaining phase of the scale problem that is not yet satisfactorily solved from the average fruit grower's standpoint is that of affording efficient protection to old apple orchards; but experience, derived from our own experiments and observations of the efforts of commercial fruit growers, demonstrates with increasing emphasis each year that the control of the scale is practicable, and that with careful management, efficient protection can be afforded for about thirty to fifty cents a tree, which is a relatively nominal expense, compared with the productiveness of a well managed orchard.

Sulphur washes as combined insecticides and fungicides.— In the first experiments with these sprays, conducted in 1902, there were indications that the sulphur washes were effective against other pests of the orchard than the San José scale, especially as a fungicide for the peach leaf curl and the apple scab. In 1904 the combined properties of the wash was the subject of considerable inquiry,[16] which showed conclusively the value of this treatment for the prevention of the scab on apple trees. As compared with the checks there was a difference of 22 per ct. less scabby fruit for the trees sprayed with the sulphur washes. These results indicated that in orchards sprayed with the lime sulphur wash for the San José scale, this treatment would take the place of the first application of the bordeaux mixture which is usually made for the prevention of apple scab. This substitution avoids the necessity of one extra spraying and has simplified the methods of orchard treatment, which the scale, upon its introduction, necessitated.

Fall use of sulphur sprays.— With the complete infestation of large orchards much trouble is usually experienced by fruit growers in spraying all of the trees satisfactorily during the dormant season in the spring. In the past, this work has usually been done at this season, but the area now to be sprayed by individual orchardists

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[16] Bul. 262; same in Rpt. **24**:297–324 (1905).

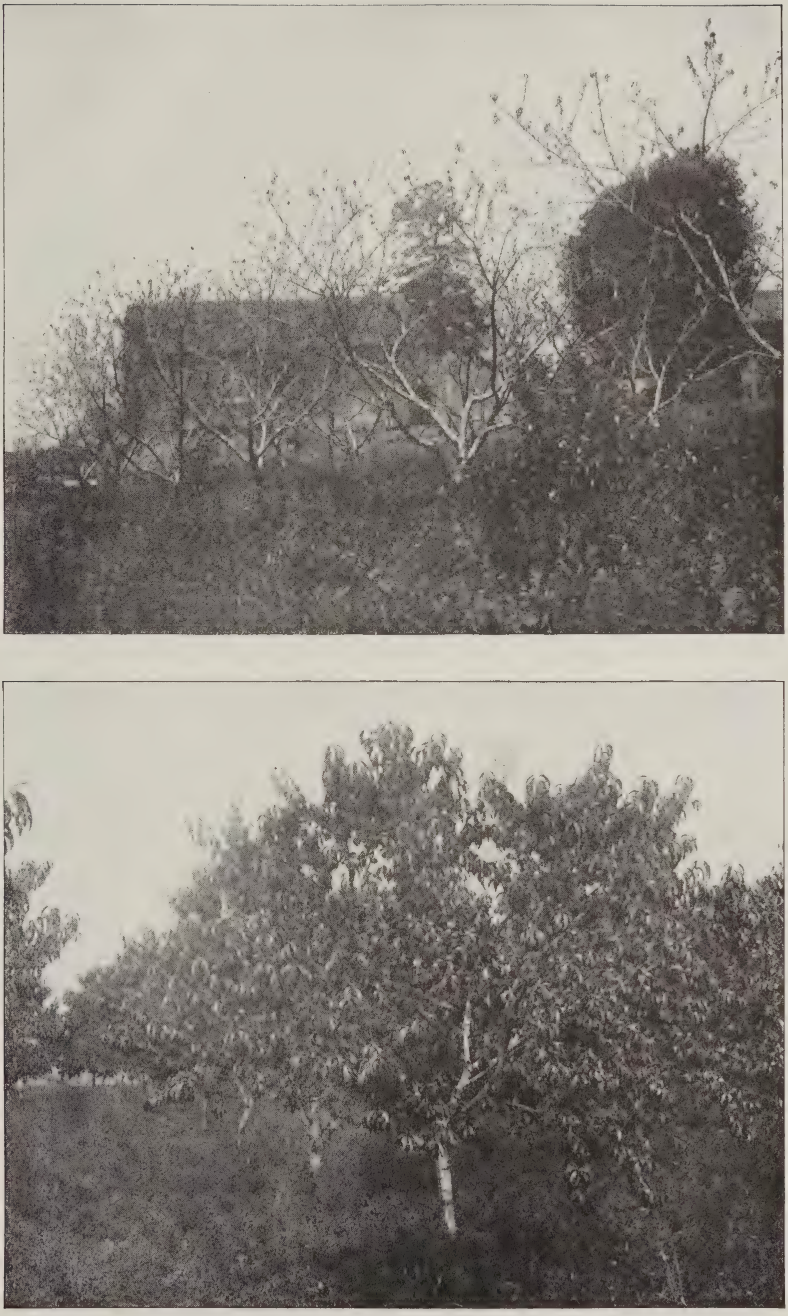

Plate XIII.— Lime-Sulphur Wash Prevents Peach Leaf-Curl.
Upper, unsprayed; lower, sprayed.

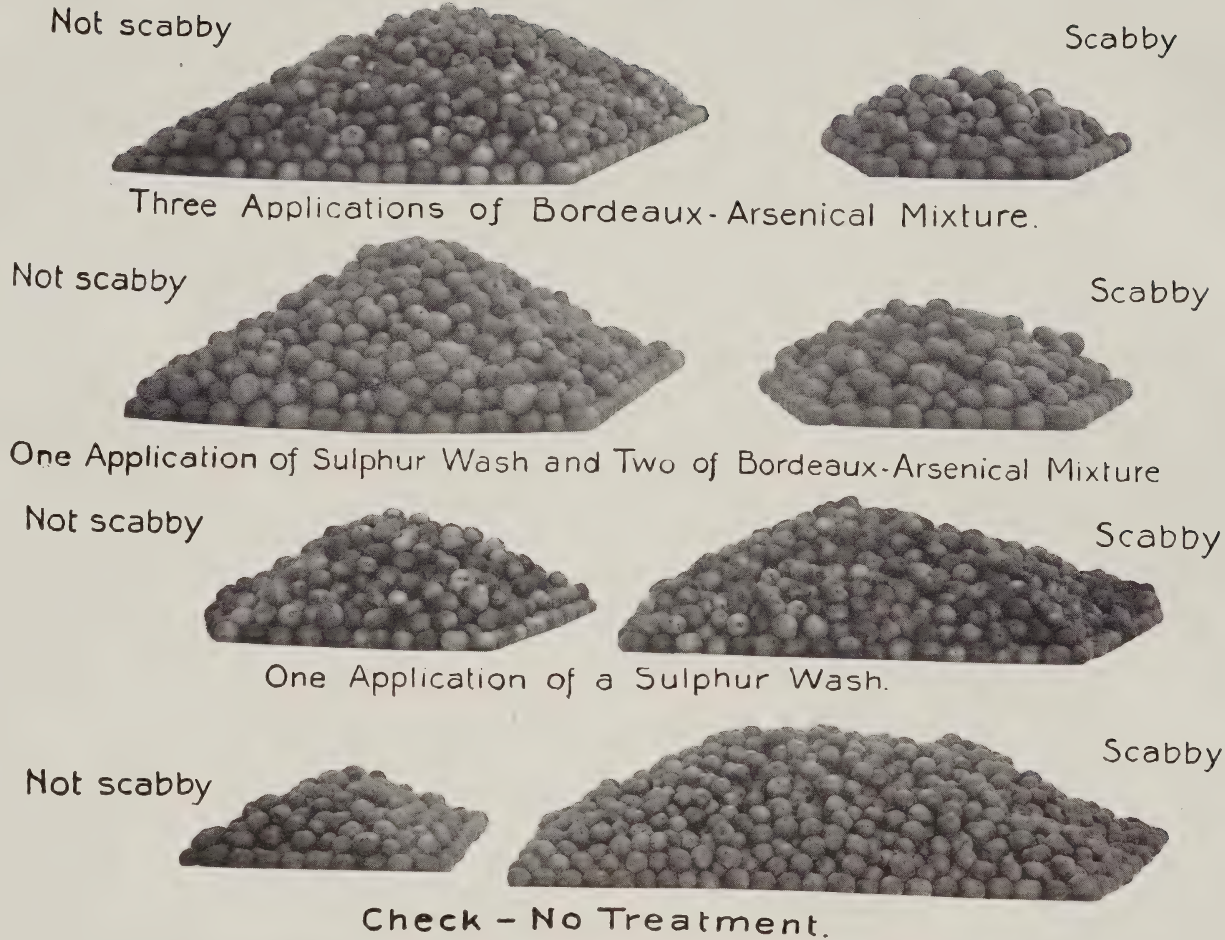

Plate XIV.—Effect of Sulphur Wash on Apple Scab.

is often so extensive that it is desirable to extend the period for these operations, and spray a portion of the orchards in the fall. In 1903–05, experiments[17] were undertaken to determine the effects upon fruit trees and scale of such practice. The work that has been accomplished indicates that the sulphur washes applied in the fall may, under certain conditions, cause injuries, such as sometimes attend the excessive use of these sprays in the spring. Trees that are healthy and possess well ripened wood will usually escape harm, while trees injured by insects, fungi and unfavorable environment may sustain more or less injury, proportionate to their health and the severity of the winter. As plums and peaches are more sensitive to injury it is deemed advisable not to spray these fruits in the fall, but to limit the treatment as far as possible to the more hardy pears and apples.

Miscible oils.—In recent years attention has been directed to determine methods by which crude and refined oils could be treated to get a stable mixture with water. Several compounders of insecticides have interested themselves in this problem and have been successful in their efforts. This has led to the production of so-called water-soluble oils or miscible oils, which are now offered for sale on the market, under various proprietary names as Kil-o-Scale, Scalecide, Water Soluble Petroleum, etc. The best of these preparations emulsify readily in water, and when diluted form uniform white or cream colored liquids, free from sediment or precipitates. The convenience in the preparation of these sprays and their freedom from clogging precipitates have commended them to many fruit growers, especially those having a small acreage, who did not wish to go to the expense of erecting suitable outfits for cooking the sulphur wash, which is more commonly employed. During 1905–7, the Station conducted a number of experiments[18] with these mixtures to determine their value for the treatment of the San José scale and their effects upon the trees. The miscible oils were used according to the manufacturers' directions and stronger preparations were also employed. In these tests applications of the miscible oil at the rate of one part of oil to twenty or twenty-five parts of water as recommended in the printed directions, did not give uniform results on the scale, and when applied during the growing season, caused much damage to the foliage. The stronger mixtures of these sprays were

[17] Buls. 247 and 273; same in Rpts. 23:187–205 (1904) and 24:325–344 (1905).

[18] Bul. 281; same in Rpt. 25:289–298 (1906).

generally much more effective on the scale and when applied to dormant trees in the spring, proved entirely safe. Because of the ease in which they may be prepared, they are very convenient sprays for the treatment of a few trees and small orchards and their use is largely advised for this purpose.

With the establishment of the utility of these sprays for scale treatment, attention is now being given by the Station chemists to determine a formula by which fruit growers may prepare their own miscible oil at a much less cost than the commercial preparations. Formulas for making home-made miscible oils are now known but their use is largely experimental, until the ability of the average orchardist to prepare them or have them properly compounded has been satisfactorily determined.

NEW YORK PLUM LECANIUM.

(*Eulecanium cerasifex* Fitch.)

The sudden appearance of this species as an important fruit pest in 1894 in overwhelming numbers in some of the large plum orchards in western New York, prompted some extensive experiments[19] at Geneva and Hector to determine a practicable method of combating this insect. As kerosene emulsion was the most efficient spray for this purpose, tests were planned to determine its relative merits when applied during the winter, in the spring, and later upon newly hatched scales. The results of the experiments showed, all things considered, that the best time to spray is during the winter, and that kerosene emulsion, diluted with four to six parts of water, can be depended upon to kill the hibernating scales.

PISTOL CASE-BEARER.

(*Coleophora malivorella* Riley.)

In 1896 this species appeared in unusual numbers in the western part of New York where it was causing serious damage to apple orchards. It was thought by some fruit growers to be a new pest of the apple, but examination[20] proved the insect to have been a well known species, which, however, had not caused sufficient damage, except in certain localities, to occasion more than a passing

[19] Bul. 136; same in Rpt. 16:437–469 (1897).

[20] Buls. 122 and 136; same in Rpts. 15:545–557 (1896) and 16:437–439 (1897).

notice. Observations and experiments were made to ascertain the life history of the insect and to determine practicable methods of preventing important injuries. With a knowledge of its habits, it was reasoned that the insect could be controlled by spraying with an arsenical poison, provided the treatment was applied at the proper time, which should be when the buds are swelling and again as the leaves are making their appearance.

With this in mind experiments were undertaken with paris green; and from the first the effect of the treatment was plainly apparent. From these tests it was concluded that the pistol case-bearer can be controlled by thorough applications of an arsenical poison, the treatments being made as the leaf buds begin to swell and when the leaves are unfolding. As bordeaux mixture was coming into general use for orchard treatment, especially for the apple scab, it was considered advisable to employ this spray as a carrier of the arsenical, as neither interferes with the beneficial action of the other.

Some tests were also made with kerosene emulsion, at a strength of one part of the emulsion to ten parts of water. Although the trees under treatment were badly infested with both the pistol case-bearer and a closely allied species, the emulsion seemed to have no effects on either insect. It was thought that a preparation containing larger percentages of oil would have penetrated the cases, but under the circumstances to use this was considered inadvisable because of the risks of injury to the tender foliage and flower buds.

PLANT LICE.

(*Aphididae.*)

In response to the demand for information concerning the nature and habits of these insects, together with the best known methods of combating them, a bulletin[21] was prepared and distributed in 1897. These lice are among the most important of the injurious insects. They infest all kinds of fruits, vegetables and ornamental plants. Although present every year, some seasons are more favorable for their development than others. This season had been one of this kind and various species had caused serious injury to orchard and bush fruits. Experiments with whale oil soap in plum orchards and currant plantations had demonstrated the efficiency of this spraying mixture for plant lice, and were the basis for detailed directions in combating these well known pests.

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[21] Bul. 139; same in Rpt. 16:470–488 (1897).

SPRING CANKER WORM.

(*Paleacrita vernata* Peck.)

The work[22] by the Station on this species was largely in the nature of an experiment, to demonstrate the efficiency of paris green and other arsenicals as a means of controlling cankerworms, and to stimulate fruit growers generally to rely more extensively on these poisons for the protection of their trees. Two methods were employed by fruit growers in combating this insect: (1) Trapping the wingless females as they ascend the trunks of the trees to lay their eggs; and (2) poisoning the larvae by means of arsenical sprays. The former method, though quite successful, could not be depended on to rid an orchard of this pest. The experiments were conducted in 1897 and 1898 at Rushville, and tests were made of paris green in comparison with green arsenite and arsenite of lime, which were newer poisons. The results of these experiments, lasting two years, showed conclusively that the three poisons, each applied three times in May or early June, were equal in efficiency and were almost perfect preventives of damages by cankerworms.

GRAPE FLEA BEETLE.

(*Haltica chalybea* Ill.)

The attention of the Station is frequently called to the work of this insect in the vineyards along the lakes of Keuka, Canandaigua, Ontario and Erie. The beetle derives its importance from its attacks on the buds. During years of unusual numbers of the insects, vineyards are often stripped of their foliage, with the result that no grapes are produced and the vines are much weakened. Observations[23] about Keuka Lake in 1897 and 1898 showed that one of the principal causes of the destructiveness of this insect in this region were the neglected vineyards, which serve as breeding places for large numbers of beetles, which swarm over to adjacent plantings. Vineyardists who are in the habit of carefully spraying their vines often have much of their good work undone by the close proximity of less progressive neighbors. To prevent losses by this insect the use of arsenical poisons for the treatment of buds and leaves was advised, and grape growers were urged to encourage

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[22] Buls. 152 and 170; same in Rpts. **17**:359–363 (1898) and **18**:398–465 (1899).

[23] Bul. 150; same in Rpt. **17**:345–388 (1898).

the more extensive adoption of spraying methods in their respective communities as the means best calculated to reduce the importance of this insect.

APPLE-TREE TENT-CATERPILLAR.

(*Malacosoma americana* Fab.)

This insect, although very easy to control, was probably never more abundant throughout the State than during the summers of 1897 and 1898. The unsightly nests of the caterpillars were very conspicuous along the roadsides of otherwise well kept farms, and comparatively few apple orchards escaped injury. With the appearance of so many caterpillars on the trees, there was an unusually favorable opportunity to ascertain the value of arsenical poisons as a means of protection, which demanded further experimentation. In 1897, tests[22] were made of green arsenite, paris green and arsenite of lime, and it was concluded that standard arsenicals are efficient remedies if applied early enough, the first application being made before the caterpillars are half grown. The results of these experiments were given in Bulletin No. 152, which also contained a complete account of the insect and called attention to various remedial and preventive measures, which should be employed to afford protection to orchards. In those communities suffering from the orchard tent-caterpillars, where spraying has not been practiced, the Station, through its bulletins and at farmers' meetings, has persistently advocated the spraying of fruit trees with the bordeaux mixture containing an arsenical poison, as a means of not only controlling the codling moth and the apple scab, but many insects of minor importance as the tent-caterpillars and case-bearers. Experience has shown that the systematic spraying of fruit trees affords complete protection against many of the insect pests which are so frequently destructive to neglected orchards.

FOREST TENT-CATERPILLAR.

(*Malacosoma disstria* Hubn.)

In the summer of 1899 and 1900 a serious outbreak of the forest tent-caterpillar occurred in central, western and eastern New York. It was not a new insect, but there were no records that it had ever before occurred in such great numbers over so wide an area. The caterpillars were of economic importance over almost the entire State, but in certain communities they were unusually destructive.

This insect feeds on a wide range of plants and is a pest of fruit, shade and forest trees. Its control in woodlands especially is a serious problem. The extensive destruction caused by it created a general interest in this insect. As the species had been under observation for two seasons, bulletins[24] were prepared with the view of aiding in disseminating the desired information.

RASPBERRY SAWFLY.

(*Monophadnoides rubi* Harr.)

This is one of the important pests of the raspberry, blackberry and dewberry in both nurseries and plantations. In some sections of the State it is at times one of the most troublesome insects with which the grower has to contend. Few if any of the numerous species of insects known to attack these important crops are capable of doing more serious injury in a single season.

Studies[25] on the life history of this species showed that the time of the appearance of adults varies with the season, ranging from about May 10 to May 25. Egg laying commences with the appearance of the adults, and incubation lasts for seven to ten days. The larvae feed for ten or more days, devouring oblong or irregular holes in the leaf and finally consuming all of the leaf with the exception of the main rib and larger veins. Some interesting observations were made on the habits of the larvae which showed that some, on leaving the plant, may enter the ground close to the roots, while large numbers may wander two or three feet from the base of the bushes before going into the ground. Also later in the season more of the cocoons were found about two feet from the bushes than close to the base. The cocoons are formed from two to three inches below the surface of the ground. This cocooning habit suggested the value of frequent shallow cultivation as a means for the destruction of the insect.

Aside from the investigations on the life history of the sawfly, experiments were conducted to determine the most efficient methods of combating the insect, which are jarring or brushing from the bushes, fall cultivating and application of an insecticide, either dry or as a spray. Both arsenical poisons and hellebore proved efficacious, but preference is given to the latter because of the preju-

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[24] Buls. 152, 159 and 180; same in Rpts. 17:364–388 (1898); 18:289–317 (1899) and 19:263–286 (1900).

[25] Bul. 150; same in Rpt. 17:345–388 (1898).

dice against the use of arsenicals on rapidly developing small fruits and because hellebore does not disfigure either fruit or leaves.

It was concluded in these experiments, that, although the sawfly is capable of doing serious injury, often ruining the entire crop of fruit, it is not a difficult pest to combat. Special emphasis is laid on the importance of recognizing the presence of the eggs or the young larvae when they first appear, so that the necessary steps can be taken to check the insect by spraying before serious injuries are done.

APPLE AND PEAR MITES.

(*Eriophyes* spp.)

Attention was directed to this group of mites because of the abundance of one species on apple foliage in 1902 at Williamson, where its conspicuous ravages attracted much attention. In succeeding years the mite has increased in importance and marked infestations of many apple orchards in Wayne, Ontario, Monroe, Niagara, Livingston, Wyoming, Seneca and Yates counties have been noted. It is now a common pest in the important apple-growing sections of western New York, where during 1906 it was especially prominent and very destructive.

A somewhat similar trouble upon pears, produced by the leaf blister mite (*Eriophyes pyri* (Pgst.) Nal.) has been known for many years and has been given widespread mention in literature, but there has been some doubt as to the identification of the species thriving on the apple foliage. One of the first objects of this investigation[26] was to establish the identity of the apple mite, which was subsequently shown to be the same species that thrives on the pear. The work of the mite upon the apple and the pear shows differences, which would at first suggest that the causal agent of the diseased foliage was not the same for each fruit. Upon the pear the work of the mite first appears as minute greenish pimples, with a more or less reddish tinge. With increase in size the affected spots become reddish and later with the drying up of the diseased tissue turn to a dark brown or black. The galls are usually arranged in a row on each side of the main rib. The early attacks of the mite on apple are indicated by distinct light colored pimples which later develop to corky spots of a reddish brown color. The galls are of irregular size and are unevenly distributed, though the

[26] Bul. 283; same in Rpt. **24**:297–334 (1906).

larger proportion of them are about the sides and the base of the leaf. The mite that is responsible for these injuries is a small vermiform, four-legged animal, about one one-hundred-and-twenty-fifth of an inch in length and hardly visible to the unaided eye.

The more common food plants are the pear and the apple. Dr. Nalepa has also recorded this species on the foliage of the service-berry (*Amelanchier vulgaris* Monch), the common cotoneaster (*Cotoneaster vulgaris* Lindl.), the white beam tree (*Sorbus aria* Crantz), the European mountain ash (*Sorbus aucuparia* L.), and the white service tree (*Sorbus torminalis* Crantz).

While the leaf blister mite (*Eriophyes pyri* (Pgst.) Nal.) is the most abundant and is responsible for the conspicuous injuries to apple foliage, four other species of mites were found which are of interest as a matter of record. These are *Eriophyes malifoliae* Parr., *Eriophyes pyri* var. *variolata* Nal., *Phyllocoptes schlechtendali* Nal., and *Epitrimerus pyri* Nal. With the exception of the former, which is new, these species were first recorded from Europe. The two latter species have been quite numerous and appear to be more common here than on the Continent.

In the study of the life history of the leaf blister mite it was found that the winter is spent in the buds, preferably under the second and third layers of bud scales. Upon the approach of warm weather, the mites become active and with the maturing of the buds they seek the epidermis of the undersides of the tender leaves, into which they burrow. The irritation produced by these operations in the cellular tissues gives rise to a thickening of the leaf which is known as a gall or blister. Within these galls eggs are deposited and the young find subsistence. During October the mites largely abandon the leaves and swell the numbers already in hiding in the buds and in the pubescence of the bark of the new wood. Hibernation occurs under the bud scales.

In the experiments to determine methods by which the mite could be controlled on apple trees, tests were made with kerosene oil, miscible oil, kerosene emulsion, whale oil soap and the sulphur washes; and of these sprays, kerosene either clear or emulsified, miscible oil and the lime sulphur wash proved the mose efficient remedies for the mite. On account of its safe qualities and cheapness the lime sulphur wash applied during the dormant season, is the most practical remedy for the spraying of apple orchards, when treatment is advisable. The mite may be efficiently controlled upon pear trees by careful pruning and by spraying during the late fall or early spring with kerosene emulsion, miscible oils or the sulphur washes.

MISCELLANEOUS FRUIT INSECTS.

Two bulletins have been issued by the Station which contain miscellaneous notes on various insects. These deal with subjects that were of too little importance at the time to be the objects of extended investigation, but were of too much interest to be laid aside; or with topics upon which immediate information was desired.

The first species discussed in the first bulletin[27] is the fruit bark-beetle (*Scolytus rugulosus* Ratz.). This is a common pest of stone fruits, especially peaches and plums, and was very destructive in 1900, throughout the State. Observations were made on the insect and have been continued to the present as the basis for a more complete treatise. During the same year observations were made on a mealy bug (*Dactylopius* sp.) attacking quince trees in the vicinity of Geneva. Interest was aroused in this occurrence of this insect as it belongs to a genus of scales, of which, in this latitude, there had been no species represented which could be classed as a fruit pest. The quince trees were literally alive with the mealy bugs and there were indications that a new pest of this fruit was in the making. Studies were made of the various stages of the insect and attention was called to methods of treatment by which protection could be afforded the trees. Mention is also made of two apple leaf-miners (*Tischeria malifoliela* Clemons and *Ornix prunivorella* Cham.) which during the same summer caused some little apprehension on the part of fruit growers in the western part of the State. As a matter of record, mention was made of injury to peaches at Rochester by the tarnished plant-bug (*Lygus pratensis* L.).

During the spring of 1900 some observations[28] were made of the palmer worm (*Ypsolopus pometellus* Harr.) which overran many apple orchards in western New York. It was most abundant in Erie, Niagara, Orleans, Genesee, Monroe, Ontario, Wayne and Cayuga counties. The records of the insect show that it appears in large numbers only after long periods of years and usually its disappearance is as sudden as its rise to destructive numbers. Inquiry during the following season disclosed the fact that history had repeated itself and that the species had practically disappeared.

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[27] Bul. 180; same in Rpts. **19**:263–286 (1900).

[28] Bul. 212; same in Rpt. **21**:233–257 (1902).

During 1900 and 1901, the attention of the Station[28] was called to the work of white grubs (*Lachnosterna* sp.) on the roots of extensive plantations of asters. Some observations were made on the habits of the insects, and suggestions were given as to the most satisfactory means of preventing injuries. During the same years, the celery caterpillar (*Papilio asterias* Fab.) was quite numerous in the vicinity of Geneva and observations of its destructiveness to young celery plants in seed beds were recorded.

Because of the general interest in this species, mention[28] was made of the probable appearance of the periodical cicada (*Cicada septendecim* L.) during the spring of 1902 in one of the largest broods, known to occur in the United States. A short account was given of the life history, habits and other interesting facts of this insect. For purposes of record, detailed observations in western New York of the brood of 1899 were included.

SPECIAL BULLETINS ON FRUIT INSECTS.

Two bulletins dealing with the insects of the nursery and insects injurious to fruits have been published by the Station. The former, Bulletin No. 136, was issued largely for the benefit of the nurserymen of this State, to call their attention to the importance of the San José scale as a nursery pest and to assist them in recognizing the various insects attached to their shipments and purchases of stock. The inspection of nurseries was then in its inception and there was much demand for information relating to this subject. The Maryland legislature had recently passed a law, providing that all nursery stock shipped into that State must be accompanied by a certificate, showing that the stock had been duly inspected by an authorized official and pronounced by him to be free of dangerous insects and plant diseases. Other states had followed suit and the question was being discussed in many more. Owing to this agitation and the reputed menace of the San José scale to nurseries, western New York nurserymen found it necessary to have their plantings inspected or be seriously handicapped by the inspection laws of other states. Although there was no evidence of an organized effort on the part of nurserymen to have the work of inspection put on a proper basis, the Station at once undertook to accommodate them and as opportunity was afforded, rendered assistance in this endeavor for two years.

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[28] Bul. 212; same in Rpt. **21**:233–257 (1902).

The latter, Bulletin No. 170, is a complete compendium dealing with the common diseases and insects injurious to fruit trees and small fruits, in which directions are given for fighting them efficiently and economically. Special attention is devoted to spraying methods and emphasis has been given to the advisability of systematic spraying and as far as possible of combating diseases and insects with one general line of treatment. This bulletin was a joint production of the horticultural, botanical and entomological departments.

STUDIES ON FIELD CROP INSECTS.

ARMY WORM.

(*Heliophila unipuncta* Haw.)

In 1896, considerable attention[29] was given to this caterpillar, which was the cause of much alarm in the important agricultural sections during the early summer. The invasion of the army worm was one of the worst in the history of the State, and according to old settlers, no such destruction of crops by this pest had ever before been experienced by them. Complaints of injuries were received from twenty-eight of the leading agricultural counties, and, in reply to these, circulars, letters and telegrams were sent giving explicit instructions and suggestions, to check the migration of the caterpillars and to protect invaded fields. As the army worm is a general feeder, some farmers experienced a shortage of fodder crops for fall and winter feeding. While it was not possible to overcome this deficiency, suggestions were given to farmers for raising certain crops which could be grown at a late season to tide them over the emergency which the army worm had caused.

COTTONWOOD LEAF BEETLE.

(*Lina scripta.*)

During 1894 and 1895 from one-half to three-fourths of the willow crop of Onondaga County was rendered worthless by this pest, which then constituted a serious handicap to the industry of growing basket willows. At the urgent request of the leading growers, the Station carried on experiments,[30] covering two years, to determine more efficient means for the prevention of injuries. At this time there had been various attempts to destroy the beetles by

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[29] Bul. 104 and Rpt. 15:583–605 (1896).

[30] Bul. 143; same in Rpt. 17:323–344 (1898).

the employment of poisons, but the opinion was quite prevalent that arsenicals, applied strong enough to materially check the insects, seriously injured the willows, which discouraged their use. To protect the willows, the growers relied largely on "bug catching" machines, which, while effective on larger plants, were unfortunately not satisfactory for the young willows in the early season, which were often ruined. At the outset, it seemed that the use of arsenical poisons would solve the problem, and so during 1896 and 1897, tests were made at Liverpool to determine the strength of poison that could safely be used on willow foliage with efficient results on the insects. Some experiments were also made to ascertain the comparative cost of spraying as compared with the average expense of operating the machines. Investigations were also made to ascertain the life history of the insect. The results of the field tests were gratifyingly in favor of spraying both as a means of protecting young willows and for its economy, as the cost of spraying one acre was but $2.58 as compared with an expenditure of $4.05 required by the use of machines.

To assist growers in affording better protection to their plantations, Bulletin No. 143 was issued in 1898, which called attention to the habits of the beetle and gave directions for the use of arsenical poisons for the treatment of willows.

ONION CUTWORM.

(*Euxoa messoria* Harris.)

In 1905 the attention of the Station was called to the onion fields of Orange County which were being ravaged by this cutworm. This destructive insect also appeared in 1896 and was computed to have destroyed at least 46 per ct. of the onion crop, besides injuring severely many other garden and market vegetables. During these years, observations were made on the life history and habits of this species, and several lines of treatment were tested by the Station. When the cutworms commenced their work on the onion fields, it was found that the caterpillars migrated from the margins of ditches and driveways, so tests were made of various remedies to determine their value for the protection of the crop and their effectiveness in checking the progress of the worms from the adjacent fields and swampy neglected lands into the cultivated areas. Comparative experiments[31] were made of the resin-lime mixture,

[31] Rpt. 15:628–635 and Bul. 120.

kerosene emulsion, and wet and dry poisoned baits; and of these insecticides the poisoned bran mixture proved the most efficient. This bait proved very acceptable to the cutworms and was deadly in its effects. The results of these tests were published in Bulletin No. 120, and onion growers were advised to use the dry bran bait as an efficient means of protecting their plantings. It is considered as fully as effective as hand picking, which was commonly employed, and is much less expensive. For onions it is in every respect a satisfactory defense against cutworms, and its use is advised for the protection of cabbages, tomatoes and other garden plants.

POPLAR AND WILLOW BORER.

(*Cryptorhynchus lapathi* L.)

In recent years, there have been many complaints of the work of the poplar borer by nurserymen in this State, in extensive and continued injuries that occur in the growing of poplars and willows. In the year 1902, when the attention of the Station was called to the ravages of this species, some blocks of poplars and willows were so badly injured by this insect that some growers contemplated abandoning their culture. In many localities, the native willows along swamps, streams and canals were badly attacked, and injuries were being sustained by certain species of willows planted for ornamental purposes.

Investigations[32] were commenced in 1905 to determine the habits of the insect and practical means of protecting nursery stock. The life history has now been completely studied. It was found that this species has one brood a year. Oviposition occurs in the corky portions of the wood, near a bud or branch or in the overgrowths caused by pruning, and takes place during August and September. The injury to the plants is caused by the larvae which hatch in about eighteen days after the depositing of the eggs and which girdle the trees and so weaken them that they often fall with the wind. The larval period lasts till the following July, when pupation occurs. The beetles commence to appear about July 15, and they may be found until the middle of October.

It was noticed in observing the habits of the beetles that they are external feeders, which suggested the possibility of using

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[32] Bul. 286 (1907).

arsenical poisons as a means of combating this pest in the nursery. To ascertain the effects of these insecticides upon the beetles, a number of experiments were made which showed conclusively that thorough spraying with an arsenical poison of poplar and willow plantations about July 15 will materially reduce the number of beetles and thereby lessen the number of eggs deposited in the trees. Attention of nurserymen was called to these observations and experiments by the publication of Bulletin No. 286, which gives a complete account of this insect and directions for the prevention of injury and the control of the beetles.

WORK WITH FIELD CROPS.

SUMMARIZED BY
F. H. HALL.

Work with field crops is not the corner stone nor even one of the main blocks that uphold the reputation of this Station. In later years, particularly, the problems in other lines of agriculture and horticulture, notably those in dairying and fruit growing, with their incidental demands for the knowledge and technical skill of chemists and bacteriologists, botanists and entomologists, have been deemed of more importance to the State than questions relating to the culture of the staple farm crops of the generations past. This distribution of investigational effort is undoubtedly a proper one; for New York has ceased to rank as a leading wheat and corn State; while problems in the growth of these and similar crops are of supreme importance in the newer states of the West and Northwest and are receiving attention from the stations in those states. New York State lands yield much greater profits when devoted to producing fruit, dairy products, vegetables and other more perishable crops for which there is an ever increasing demand in the nearby markets and which give greater acreage returns but which at the same time require more labor, better care and more expert management to secure the best results than do the grains.

For these and other economic reasons the Station staff has never included an agronomist, and the " farmer " or " agriculturist " has usually found his time too fully taken up with superintendence of labor and general operations to allow the necessary attention to be given to comprehensive or detailed investigations.

In spite of these facts, considerable work has been done with field crops under supervision of the three Directors or their assistants, the horticulturists, chemists, botanists, bacteriologists and other members of the staff. Some of this work has been of high grade and of great practical value, and much of it, especially during early years of the Station's history, was fundamental, leading to the development of correct methods of experimentation which have been of great value to the fifty or more stations established in the

United States since those early days. This feature of the work, as well as the discussions of field crops in which the feeding value or the chemical, botanical, entomological or bacteriological features are most prominent, will be discussed elsewhere in this volume by the members of the staff most interested.

The review here will be of the problems and tests of general cultural methods, tests of varieties, introduction of new crops and similar topics, and the crops will be discussed in their alphabetical order.

ALFALFA.

This plant had been cultivated to a limited extent in New York for at least sixty years previous to the establishment of the Station, and some records indicate that it was known, under the name lucerne, as early as the middle of the Eighteenth Century. However, except in a few scattered localities, it was not grown on large enough areas to be considered more than a curiosity. In its first year the Station took up the culture of the plant and has grown the crop continuously since that time. During the first season the plats of alfalfa and lucerne were regarded[1] as representing different plants, but the practical identity of the two was soon evident and the name alfalfa used and recommended for *Medicago sativa* as grown in the State. The first sowings were not considered especially promising, probably, as we may conclude from the experience of the last decade, because the bacteria necessary for the best growth of the plant were not present in sufficient numbers to secure thorough inoculation. A blight, now known as the leaf blight, also affected the plants, and since it was not then known that cutting the plants was an effective check to this trouble, the plats became very yellow and dwarfed-looking through June and July. With the second growth of that year the plats began to improve and in a few seasons, with sowings made on other plats and fields, convinced the Station observers of the great value of this legume for forage.

Efforts were made by the Station to encourage careful testing of the plant on a small scale in various localities throughout the State to ascertain its adaptability to different soils, conditions and seasons. The plats at the Station gradually increased in size and the forage was increasingly used in feeding the dairy herd and other animals, but no bulletin dealing with alfalfa was published

[1] Rpt. 1:77 (1882).

until 1889, when half of a small bulletin[2] was devoted to notes upon alfalfa from various sources, to a record of the crop cut in 1888, to chemical analyses of the green forage and hay and to a digestion experiment in which alfalfa was fed. In 1894 the first bulletin published in the East devoted exclusively to the growth of alfalfa was issued by this Station, No. 80, which gave the results of feeding trials with alfalfa forage. Previous to 1889, however, favorable mention had been made of the plant in the weekly newspaper bulletins of Station progress, and most of the early annual reports gave notes and data of the test plats. In 1886, in particular, favorable notice was given[3] to the permanence of the plats of alfalfa first seeded. Most excellent crops were reported on these and on plats sown in succeeding years. These good results were secured in spite of unfavorable conditions, for "the seed bed was heavy, cold and retentive, with a very solid clay bed underlying at a depth of about three feet. The alfalfa grew and flourished, although sparingly fertilized, and in 1886 was apparently as strong and vigorous as in 1883, the first cutting in 1886 yielded at the rate of over ten tons per acre of green fodder, and four crops were cut. No changes of weather or temperature seem to have affected this plant thus far as grown here." On another larger plat seeded in 1885 the four cuttings in 1886 gave at the rate of 2½ tons dry hay, 7¼ tons green forage, 5⅞ tons green forage and 4 tons green forage, respectively, per acre. The yields in 1888, as given in Bulletin No. 16, were at the rate of 15½ tons and 14⅜ tons (green) per acre.

The feeding trials given in Bulletin 80 proved conclusively the great value of the alfalfa for milk production. In the succeeding years this crop, with corn silage, has been the main reliance for forage for the herd. It has also been fed with excellent results to horses, sheep, swine (in small amounts) and poultry.

In 1897 a second bulletin[4] on alfalfa was issued which emphasizes the value of the plant and urges that trial of the crop be made in any locality where there is a fair prospect of its growing. This bulletin gives the average yield from five crops of alfalfa, each of four cuttings, as seventeen tons of green forage per acre. This yield exceeds, in total amount, that of any forage or root crop that can be grown in this section, except corn, while the feeding value of the alfalfa is far greater than that of corn because of its large

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[2] Bul. 16:121–129 (1889).

[3] Rpt. 5:134 (1886).

[4] Bul. 118 (1897); same, Rpt. 16:551–560 (1897).

amount of digestible protein (875 pounds per acre, as compared with 300 from corn).

With the publication of this bulletin the Station authorities began an active campaign for the introduction of alfalfa into different sections of the State. This work has been consistently followed, by correspondence and by talks at farmers' institutes. In this institute work and in other ways of commending alfalfa and urging its spread, the Station work has been seconded and supplemented by the efforts of the other institute workers and by the editors of leading agricultural papers. As a result of these efforts the culture of the crop is now spreading rapidly. The United States census of 1900 reports its growth in forty of the sixty-one counties of the State, with a total area of 5,582 acres devoted to the crop. Data collected by the Station indicate that at present alfalfa is grown in every county of the State that has agricultural interests and that the area is now more than 10,000 acres.

The efforts of the Station during later years have been devoted to studies of the conditions necessary for the establishment and best growth of alfalfa, and in control of the pests of the crop. These researches are discussed more in detail elsewhere, but may be said to indicate that the use of lime upon the soil some time previous to sowing the alfalfa seed is profitable in a large proportion of cases, that inoculation with soil from a successful field greatly increases the chances of success, that dodder seed is very commonly found in commercial alfalfa seed, and that this pest when once introduced is very destructive and is hard to eradicate. Sifting the alfalfa seed, by a method worked out by the Station Botanist,[5] is very effective in getting rid of the dodder seeds. Unsuccessful attempts have also been made to grow alfalfa seed upon the Station farm.

BARLEY.

The work with barley has not been extensive nor the results striking. During the first eight years of Station work, variety tests[6] with barley were made several times. These were not continued long enough nor under sufficiently varied conditions to give the results great weight. As with other crops grown during these years, however, careful data were collected showing the characteristics of

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[5] Circ. 8, 1907.

[6] Rpts. **1**:34 (1882); **2**:141 (1883); **3**:398, 400 (1884); **5**:117 (1886); **6**:64 (1887); **8**:288 (1889).

each of the varieties, as to grain and straw, period of growth, vigor, stooling ability, disease resistance, yield and weight per bushel. Botanical studies were also made, based on the above and other characters, and a key[7] worked out to aid in the identification of the different varieties. Of the varieties tested, Chevalier and Manshury appear to be the only ones now in common cultivation.

In connection with these botanical studies, it is interesting to note that a case is recorded[8] in which the progeny of a hybrid barley split up into four distinct varieties, without *intermediate forms or colors.* This was undoubtedly in accordance with Mendel's law. Attention was called to the fact that by growing seed from a single head, an improved strain or a new variety might be developed in two or three years; but no work appears to have been done along this line. Such an observation by Nilsson lies at the foundation of the recent great advance in Swedish barley and oat growing.

In culture, only two experiments are recorded. In one of these,[9] extreme cultivation; i. e. *spading* beside rows sown wide apart and with seeds thinly scattered in the row, did not appear to affect the yield of grain, but reduced the amount of straw very greatly.

In the other test,[10] barley was cut at three different dates, a week apart, to note the effect upon the grain. The late cutting uniformly gave heavier grains than the early cutting, and in a majority of the cases, heavier than the second cutting. In other words, the barley plants should be fully mature when cut and the seeds well ripened, to secure the heaviest yields.

CORN.

During the early years of Station work much attention was paid to corn by the Director. His careful and comprehensive studies on the history and botany of maize form the basis of all recent classifications of the species and varieties of this best known and most valuable American plant. Seed was secured not only from all the leading corn breeders and seedsmen of North America and from different Indian tribes of the West and Southwest, but also from various sources in Mexico, Central and South America, France and Africa. During the years 1883 and 1884 about 125 varieties were grown and studied. These were placed[11] by Dr. Sturtevant in

[7] Rpt. 3:387 (1884).

[8] Rpt. 3:81, 82 (1884).

[9] Rpt. 1:35 (1882).

[10] Rpt. 6:64 (1887).

[11] Rpts. 3:156–188 (1884); 4:64–71 (1885).

six groups: *Zea saccharata,* the sweet corns, including thirty-three varieties; *Zea indurata,* the flint corns, forty-four varieties; *Zea indentata,* the dent corns, forty-seven varieties; *Zea amylacea,* the soft corns, twelve varieties; *Zea everta,* the pop corns, ten varieties; *Zea mays* var. *vaginata,* the pod corns, a few poorly established varieties. In 1885 another group was added to this series, *Zea amylea saccharata,* the starchy sweet corns.

A careful description[12] was secured of each of these varieties, from both botanical and agricultural sides. A most interesting series of observations[13] was also made regarding the tendency of each of the types toward or against cross pollination and the effect of crossing, within the type and with varieties of other types. Upon this work were based ten "propositions" relative to hybridization in corn, most of which hold true to-day, although some of the phenomena are differently explained since we know of Mendel's law and the principle of xenia. Additional work[14] along this line was done in 1885. The scheme of classification was published in the report for 1884, but additional varieties were tested[15] and described in 1888 and 1890.

Seed.— Probably few experiments in field crops ever excited more comment than those[16] carried on at the Station in 1882, '83, '84 and '85, by which it was established that there is practically no difference in germinative ability or crop-producing power between seed at tip, middle or butt of the ear. The criticisms of this work ranged all the way from dogmatic assertions that the experiment was idiotic throughout, in conception, execution and conclusion, to unqualified praise of the Station for demonstrating scientifically a fact that might be made of great practical value to growers of corn. In these tests, which were apparently fairly well guarded by repetition in different years and on different soils, the average yields for four years were: For kernels from butt of ear, 55½ bushels per acre; from center of ear, 57½ bushels, and from tip of ear, 58½ bushels. The tip kernels were superior in twenty-eight out of thirty trials. This experiment has been repeated by practically every station in a corn State, with somewhat varying results, but with a great predominance of evidence to support the conclusion

[12] Rpt. 3:124–188 (1884).

[13] Rpt. 3:145–154 (1884).

[14] Rpt. 4:96–111 (1885).

[15] Rpts. 7:119–121 (1888); 9:287 (1890).

[16] Rpts. 1:46–49 (1882); 2:90–93 (1883); 3:130, 131 (1884); 4:48–50 (1885).

given, that tip kernels make good seed. It may be said, however, that the general introduction of corn planting machinery makes it advisable to reject over-large or over-small kernels, notwithstanding their approximately equal value as seed, so that even planting may be secured. Unevenness of stand has been proven one of the great factors in lowering yields of corn.

Interesting observations[17] were also made upon the use, as seed, of kernels which themselves showed peculiarities in size, shape or color, or which were from ears peculiar in some respect. These studies led to no practical results, but show with what care every variation from the normal was investigated.

Many germination tests[18] of corn were made, as of the seeds of all the other field and garden crops; and the great importance of thus testing the vitality and strength of the seeds to be used on the farm was repeatedly shown. Several simple forms of apparatus[19] were devised for such testing of seed, one of which, the Geneva (or Station) Seed Tester, has been considerably used elsewhere. By means of germination tests the increased value given to seed corn by kiln-drying the seed[20] was brought out, in experiments continued through two years. In the first year's tests, when the drying was done some time before the testing, the kiln-dried corn germinated earlier and better and gave stronger plants than similar corn taken direct from the crib. The kiln-dried kernels also gave much better results than the others when subjected to adverse influences, such as extreme temperatures before the tests. In the second season, when the drying was done immediately before the testing, there was no difference in percentages of germination in the testers, but the kiln-dried kernels gave 80 per ct. of plants when sown in the soil, while the undried kernels gave only 20 per ct.

Attention was repeatedly called to the principles involved and methods used in seed selection and preservation and to the losses resulting from the use of seed from inferior parents and from the absence of hills or plants required by a perfect stand. These factors, emphasized and put into practice by the corn breeders of the Middle West, are to-day astonishingly increasing the yields of maize.

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[17] Rpt. **2**:40–57 (1883).

[18] Rpts. **2**:59, 63, 65 (1883); **3**:118–124 (1884); **4**:84–91, 95 (1885).

[19] Rpt. **2**:58, 67 (1883).

[20] Rpts. **4**:95 (1885); **5**:44–46 (1886).

Some sections of the Annual Report for 1886 read like extracts from the most progressive corn breeders' bulletins of 1906. It was lack of appreciation and utilization, rather than lack of good work in securing them, which led to dearth of results from Station conclusions along some lines of corn growing.

Planting.— Practically all the possible combinations and variations that could be used in planting the seed were tested at some time during the first eight years of the Station's activity. As the results of most of these tests were shown to depend much upon the character of the soil and season, they need not be discussed in detail.

On the heavy soil of the Station the best results were always secured by planting less than four inches deep, and in cool and moist seasons at two inches or even less. The deep planting was injurious through its early effect,[21] preventing germination or emergence of the plants. The stalks that did appear from depths below four inches bore larger individual crops, but their number was so lessened that the total harvest was reduced.

In tests[22] of different treatment of the soil over the seed varying from loose covering to hard packing, the results favor compression of the soil. It was held that in a dry season, the gain from the use of a planter with wheels following the dropper, to compress the soil over the kernels, would be sufficient to justify the purchase of the machine.

The advantage of planting in hills over sowing in drills or broadcast was indicated clearly in several tests,[23] and the best distance, for the Station soil and conditions, was found to be about 3½ feet by 3½ feet, with three or four kernels to the hill. Thicker planting than this was almost without exception followed by deterioration in the quality of the crop more than sufficient to overcome any slight gain in quantity. A smaller number of plants in the hill reduced the yield, though it slightly increased the number of sound ears borne by individual plants. Rather peculiarly, it did not decrease the number of unsound ears, since the few plants produced more suckers bearing soft ears.

Fertilizing and cultivating.— Many tests were made along these lines, but the net result is nothing. Deep or shallow cultivation, frequent or rare stirring of the soil, use or non-use of complete chemical fertilizers or of separate ingredients gave no consistent

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[21] Rpt. **2**:138 (1883).

[22] Rpt. **5**:46 (1886).

[23] Rpt. **2**:135–137 (1883); **3**:101 (1884); **5**:46, 47 (1886); **8**:260–263 (1889).

gains greater than the differences between check plants in the same tests; or the tests, when repeated in other seasons, contradicted the conclusions of previous trials.

The failure to secure satisfactory results in so many of these tests established the unreliability of the system of plat comparisons when the crops under test are sown on square or broadly oblong areas. It is practically impossible to secure on soil of glacial origin adjacent blocks of any considerable size that are uniform in productive power. This series of tests materially influenced the development of the system of plat testing used by younger Stations by which longer, narrower and more numerous plats are used, so that errors due to soil inequality are neutralized or eliminated.

Other factors which prevented satisfactory comparisons were the natural strength and moisture-retaining power of the Station soil. These are so great that in many cases check plats grew as large crops as it was possible for the heat and rainfall of the season to produce, so that the influence of minor factors like the addition of fertilizer or differences in cultural methods was completely obscured.

Two facts were brought out, however: First, that the growth of weeds[24] in corn produces much greater reduction in yield than can be accounted for by the fertilizer elements removed by the weeds. Beside this, the shading of the soil by the weeds reduces the high soil temperature essential to the best growth of corn, the weed roots occupy the feeding ground of the plant roots, and the weeds draw heavily upon the supply of soil moisture, so that the corn often suffers from semi-drought. Second, that root pruning[25] the corn plant is injurious, whether this be done by deep spading beside the plants, by cutting off the roots on one side of the stalks with a lawn edger, by deep cultivation between the rows after the plants were well developed, or even by shallow cultivation close to the rows. The more thorough and deeper the preparation[26] of the soil previous to planting, to give opportunity for deep and wide rooting, the better the results, especially in the production of forage.

Variety and race tests.— The varietal comparisons were usually incidental to more careful studies of characteristics, and were on too small a scale to justify very emphatic recommendation of par-

[24] Rpt. 2:137, 138 (1883); 5:50 (1886).

[25] Rpts. 1:53, 54 (1882); 2:134 (1883); 7:173–178 (1888).

[26] Rpt. 7:171–173 (1888).

ticular varieties for general culture; but during a few years more extensive tests were made. In one[27] carried on during four years ending in 1886, the different races were compared. The flint corns were found to give the greatest yields, 16 tons to the acre, as compared with 15 tons for the dent varieties, 12¾ for the sweet varieties and 12⅔ tons for the pop corns.

The latest test,[28] made in 1889, showed some of the larger dent varieties leading in production, as they were able to mature in the season of 145 days. Some of these, like Hickory King, Blounts' Prolific, Pisa Queen and Burrill & Whitman, gave one-third more corn to the acre than the leading flint variety, Thoroughbred White. Cleveland's Colossal, a sweet corn, yielded better than the flint corns.

In recent years it has been found best to grow the largest dent corn that will mature sufficiently for ensilage, that is, will bring the kernels to the glazing stage before frost.

FORAGE CROPS.

Many forage crops have been tested in plat or field by the Station, and descriptions of new or little known species will be found scattered through many reports. For many years the Station maintained a row of small plats, devoted to the various grasses and forage plants. This was always a source of much pleasure and satisfaction to visitors, and undoubtedly was useful to many farmers through the ready opportunity it gave to compare well-known grasses, clovers and similar plants with new ones recommended by seedsmen or agricultural writers.

Aside from alfalfa and alsike clover, none of these forage crops has gained any prominence in the State as a whole, though soy beans and cowpeas have been grown with some success for forage and soil renovation on the lighter soils in the southern half of the State.

Sorghums of various types have been grown for forage, but more extensively tested for sugar or syrup-making, as noted elsewhere. In quite extensive tests[29] amber sorghum gave larger yields to the acre than corn during two seasons. Much better yields were secured by growing in drills than in hills. Notwithstanding its promise as a forage crop, sorghum has not attracted favorable

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[27] Rpt. 5:51, 52 (1886).
[28] Rpt. 8:266–270 (1889).
[29] Rpt. 3:103, 104 (1884); 7:331 (1888); 8:35, 263–266 (1889).

attention, nor come into general culture. It is similar to corn as a forage crop and but slightly superior to it in this respect, if at all; while it is markedly inferior from the standpoint of grain production. In consequence, it never has, and probably never will displace corn, except in some sections where its drought-resistance makes it valuable.

Among other crops tested and found inferior to corn have been teosinte, pearl millet, kafir corn, millo maize, sachaline and prickly comfrey. Among legumes, several kinds of vetch have been grown, but usually for cover crops and green manure, rather than for forage. Of these the winter vetch or hairy vetch, *Vicia sativa,* has given best results, being more certain for this purpose than crimson clover. The excessive cost of seed, however, has prevented its general use. Tares and various other vetches, serradella, sainfoin, white and yellow lupine, velvet bean, sweet clover, have all proven inferior to more common legumes like red clover or Canada peas, or of use only under particular conditions.

Among some of the grasses grown by the Station, a few have been found worthy of recommendation and are now more or less used for hay mixtures or on lawns. Among these are orchard grass, tall fescue, meadow fescue, sheep fescue, tall meadow oat grass and meadow foxtail.

As with corn, the fertilizer tests on grass have given rather unsatisfactory results, but they show in general the value of light, repeated applications of easily soluble forms of nitrogen. In form of either nitrate of soda or cottonseed meal the spring applications of nitrogen have been profitable, but the other elements applied have not given increased yields sufficient to repay their cost. In storage of forage crops most attention has been given to silage and the possibility of securing a fair article of silage without using a special pit or silo was quite clearly indicated[30] by some early work. It was also shown[31] that silage would keep fairly well in a well-constructed silo, without tramping when filling in the cut forage and without special cover or pressure on the top after filling. However, the Station now fills its silos rapidly, with a man to spread material evenly and tramp it down somewhat, allows silage to settle for a week or more, then fills again, and may repeat this refilling operation. In this way excellent silage is secured, and kept with a very small percentage of loss.

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[30] Rpts. 6:73–75 (1887); 7:326–331 (1888).

[31] Rpts. 4:43–45 (1885); 6:37, 38 (1887).

OATS.

As with the other grain crops, elaborate notes have been taken upon many varieties of oats and a system of classification[32] was soon developed for convenience in arranging and discussing these varieties. This was expanded in 1886.[33] The most careful comparisons[34] made of oat varieties were those reported in 1885. One test included only two varieties, the Welcome, representing the common type, and the White Russian, representing the side-head type. The White Russian yielded one-half more grain than the Welcome and somewhat more straw. The one who reports this test says: "This, it is true, is but a local result. It is within the limits of possibility that in another region the Welcome might have been a superior, yet the trial may stand forth prominently as a test that may be read thus. Some one variety of seed may find better adaptation on a farm than the seed in use, and the cheapest way to secure increase in crop without extra expense in the growing may often be from the change of seed from a less prolific variety to a greater." This in a way sets forth recent belief in regard to variety testing, for, however carefully such work may be done, it can only be suggestive for soils and localities different even in minor points from those of the test, yet every such test emphasizes the necessity of securing those varieties that are particularly adapted to the conditions. What the Station can do is to give unprejudiced, expert judgment as to the good and bad qualities and characteristics of the different varieties grown side by side, upon which the grower may base his choice for the limited selection of varieties he himself will test. In case of the White Russian and Welcome oats, for example, it was the tendency of the latter to lodge, because of weak straw, that reduced its yield. Another useful purpose served by the variety tests early in the Station's history, as in the second test of oats, was to call attention to the unreliability of trade names, since one variety might appear under many names, or varieties really differing greatly be sold under the name of some new or promising kind.

In the report of 1886,[35] notes are given upon sixty-nine so-called varieties; but these are all classified under less than half as many

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[32] Rpt. 3:390 (1884).
[33] Rpt. 5:100 (1886).
[34] Rpt. 4:56–58, 130, 132 (1885).
[35] Rpt. 5:102–114, 119, 120 (1886).

names. It was found in two tests[36] that the character of oat seeds has much to do with the resulting crop. Large seeds germinated better, gave earlier and stronger plants and the plants maintained their advantage through the season. At harvest, the yield of both grain and straw was larger from the large seed, and the grains from the small seed were much smaller in size than those from large seed.

Oats planted at medium depth, one-half to two inches, gave better results[37] than those planted deeper or shallower than this. Those planted one-fourth inch deep, even though carefully covered with fine soil, germinated very poorly and gave weak plants. Surprising as it may seem, seedings as deep as seven inches gave better results than extremely shallow sowings, the principal effect being delay in emergence. The test is taken to indicate that poor results are to be expected from broadcasting oats on light soil, especially during a dry time, but another experiment[38] shows fairly satisfactory results from sowing oats on the snow in early spring. The conclusion is given that "there need be no hesitation on the part of the farmer to sow either oats or barley in late winter or early spring on ground where some fall-sown crop has made a failure." The better results in this case are undoubtedly due to the moist condition of the seed bed caused by the snow. Fall-planted oats[33] all died before spring, though in the south "winter oats" are commonly grown.

With oats, also, fertilizer tests were unsatisfactory, none of the applications made being profitable. It is noted[40] that nitrogen increased the size and deepened the color of the straw and lengthened the growing period; while phosphoric acid apparently hastened the ripening of the crop. Muck, potash and gypsum were without noticeable effect on the appearance of the crops.

ONIONS.

Onions have generally been grown only in garden plats at the Station; but in many parts of the State they are field crops as unquestionably as are potatoes. In order to solve problems connected with this culture on a large scale, experiments have been made on leased fields in Orange county. These tests have included

[36] Rpts. 4:131 (1885); 6:65 (1887).
[37] Rpt. 6:66 (1887).
[38] Rpt. 6:69 (1887).
[39] Rpt. 6:68 (1887).
[40] Rpt. 7:344-348 (1888).

some in treatment of onion diseases, which are discussed elsewhere (p. 140); and one series[41] extending over one season on one farm and four seasons on another, in which various quantities of fertilizer were compared.

It is the practice of onion growers in this section to supply their crops with large amounts of plant-food, in some cases as much as a ton or more of high-grade complete fertilizer annually. Considering any possible demand of the onion crop on the soil, these large amounts appeared wasteful; and the tests proved this to be the case.

On each farm and in each year duplicate tenth-acre plats were left without commercial fertilizer or received, in amounts increasing by 500 pounds, as much as a ton to the acre. The seasons varied from poor to good, so far as onion production was concerned, and accidental interferences, like floods, and insect and fungus pests, affected the different plats to a similar extent so that the tests gave dependable indications of the effect of the different quantities of fertilizer. In each year of the four-year series there was a satisfactory increase and good profit from the use of 500 pounds to the acre, and a slight increase and small profit from the 1,000 pounds and 1,500 pounds applications, but a financial loss from the use of the additional 500 pounds which raised the application to a ton to the acre.

On the other field, in which the test was made for only one year, the ground had grown onions and been well manured for several years. The crops gave only a slight profit from the use of the smallest amount of fertilizer, 500 pounds, and a loss from the use of amounts greater than this.

"The results of these experiments show clearly that the crops were limited more by other conditions than by the extent of the plant food supply. With the best conditions of season and water supply, the smallest amount of fertilizer supported the maximum crop."

POTATOES.

In few, if any, other Stations has as much attention been given to the potato, and along certain lines of investigation the work of the Station is classic. In early years the study of the seed received almost uninterrupted attention for eight or ten seasons, and it would seem that no possible factor was overlooked that might in-

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[41] Bul. 206; same, Rpt. **20**:236–244 (1901).

fluence production. The results in some cases are inconsistent, owing to the lack of uniformity in the soil of the farm and the use of the oblong-plat method of comparison; but so often were the tests repeated and so great was the care used to recognize and to eliminate or neutralize disturbing factors that the conclusions, where these are definitely stated, have been, in the main, confirmed by later tests by other Stations.

In trials of cultural methods and fertilizer tests on Station soil, the handicap of uneven productivity rendered the results with potatoes almost as inconclusive and valueless as those with other crops. In a few lines, however, the indications uniformly pointed to the same conclusion, showing that the factor under consideration was one of real importance in potato growing. In fertilizer tests on Long Island most striking and uniform results were secured during several years' trials; and a means of economizing in the growth of the crop was plainly indicated. Unfortunately this method seems out of line with the general practice on the Island, and growers hesitate to give it a fair trial; so that the tests have not influenced practice as their accuracy and clear-cut teaching merit.

In treatment of blight and rot, the Station work has materially benefited potato growers; not only in the State but in all potato-growing sections. This factor in potato culture is discussed at length on pp. 147 to 151.

Character of seed.— Experiments[42] made in early years of Station history, and repeated, with modifications, after a lapse of twenty years, indicate a decided advantage from the selection of tubers for seed from the productive hills of the parent crop. In 1884 seed thus selected outyielded seed selected from unproductive hills in seven cases out of nine when large tubers were compared and in eight cases out of nine when the comparison was between small tubers of the two classes. In nearly half the cases the small tubers from productive hills gave better yields than large tubers from unproductive ones. In 1885 the tests showed a decided advantage for the seed from heavy yielding hills. In 1887 the comparison was extended to seed from 116 varieties, but the area devoted to each test was small. In two-thirds of the individual comparisons, the advantage was with the seed from productive hills, and the average gain was fourteen bushels to the acre. In this same year

[42] Rpts. 3:301–305 (1884); 4:232–235 (1885); 5:148, 149 (1886); 6:78–86 (1887); Syllabi, Normal Institute Lectures, 1905, 1906.

plat tests on larger areas than were used in testing the varieties showed the advantage to be with seed from productive hills not only when equal numbers of tubers were compared, but when the weights of seed of the two kinds were equal. In 1903, '04 and '05, these comparisons were again taken up, testing seed from heavy and light hills from the same parent crop in rows side by side and repeating the series several times to overcome inequalities in soil conditions. Of the six comparisons, four gave substantial differences in favor of using the seed from heavy hills, one a slight difference in the same direction, and one a slight difference in favor of seed from light hills. In the second year's test with two varieties and in the third year's test with one of them, light yielding hills were selected from crop grown from seed previously selected from similar hills, and heavy hills from crop grown from seed produced in heavy hills in order to ascertain if the differences in favor of seed from heavy hills were cumulative. No such cumulative effect was shown conclusively, but there does appear to be a profitable margin of gain in selecting seed for each crop from the best hills of the preceding crop.

This presupposes that the grower raises his own seed; but some have strongly advocated a "change of seed." Extensive tests along this line have not been made at the Station, but one test,[43] with the same variety grown from Station seed and from seed of the same variety from two other localities, did not favor the practice. The yields were somewhat better from foreign seed grown on similar soil, but much poorer from seed grown on soil of different character.

Preliminary seed treatment.— In some foreign countries, particularly France, the growers of very early potatoes plant only tubers that have been previously started into growth by exposing them to warmth and light. By this means short, thick sprouts are formed, which grow quickly and vigorously when the tubers are carefully planted with the sprouts up. A test[44] of this method was made by the Station in 1888 on four twentieth-acre plats; but no advantage in earliness resulted from the preliminary treatment and difference in yield was exceedingly small. In another test[45] made this same year a disadvantage resulted from the use for seed of potatoes with long sprouts, though this loss was less than was expected. It appeared to make no difference whether the sprouts were broken off

[43] Rpt. 9:383-386 (1890).
[44] Rpt. 7:167, 168 (1888).
[45] Rpt. 7:165-167 (1888).

or not. A laboratory test indicated that potatoes in growing sprouts from one to three inches long lose 2 per ct. of their dry matter.

Size of seed.— Whether it is best and most profitable to use large or small tubers for seed is a question that will probably never be settled until we can limit the terms "large" and "small" by other terms which shall tell whether the small potato is of "good" parentage or the "large" tuber merely an accident in a "poor" family. The early work of the Station nearly all indicated an advantage in the use of large tubers as seed; but a carefully checked experiment[46] was made in 1906, in which small potatoes were compared with equal weights of seed cut from large tubers, gave a different result.

In this test the advantage was plainly with the small tubers. The influence of cutting enters this test, while in most of the early tests the factor of unequal weight of seed pieces makes a complication. In tests[47] in 1884 largest and smallest tubers, selected from productive and from unproductive hills of nine varieties of the crop of 1883, were used for seed. In nearly every case the large tubers gave greater yields of merchantable potatoes than small tubers from the same kind of seed. In case of seed from unproductive hills, the large tubers gave more than 50 per ct. increase in merchantable potatoes. In case of three varieties the influence of size of seed appeared greater than that of productivity of the hills, since the large tubers from poor hills of these varieties gave more merchantable potatoes than the small tubers from productive hills.

In 1887, the computed acre yields of 116 varieties tested on small areas showed an average gain of six bushels to the acre from the use of large rather than small tubers.

In 1890 tubers of different sizes but of uniform weight for each lot were compared. The weights of the tubers used were two, three and four ounces, respectively. Deducting the amounts of seed used, there was still a net gain in favor of the successively larger seed pieces. Rot, however, lessened the yields fully one-half in this experiment.

Cutting seed.—As a result of the first season's test, it seemed that single eye cuttings of very small size were as good for seed as halves or quarters of the potatoes, so in succeeding years comparisons along this line formed a prominent part of the Station's potato program. Not only were single eyes tested against larger pieces, but various ways of cutting the tubers to secure these eyes

[46] Syllabus, Normal Institute Lecture, 1906.

[47] Rpt. 3:301–305 (1884); 6:78–86 (1887); 9:375–379 (1890).

were also compared, and eyes scooped out of the potato, eyes cut from potato parings, and potato shoots were all used as seed. In no season but the first did the tests[48] favor the use of small, single-eye pieces; but there was a chain of evidence extending through tests of seven years that the crop was likely to increase profitably as the size of the seed pieces increased. In some of these tests whole tubers were compared with cuttings. While the results are not *conclusive* in favor of the use of the uncut tubers, as against cuttings of equal size, those in about half the tests showed a decided loss from cutting the tubers. Other tests indicated clearly that it is advisable to allow the cutting to dry out for ten days or less before planting. It seems probable that under certain conditions the exposure of the freshly cut surface to the earth works injury to the seed.

As to the manner of cutting the seed, the tests show a slight superiority for the middle third of the tuber as seed, but not enough to justify rejecting the tip or butt thirds. No advantage was found in the use of the butt half or the tip half of the tuber, either as affecting yield or promoting early maturity. Seed cut diagonally from the tip end of the potato to include as much as possible of the "pith rays," rather than cut toward the tip and across these rays, appeared to give slightly better results; but not enough to be of practical value.

Time and manner of planting.— Only one test[49] is recorded in which the influence of the time of planting is considered, but the results in this case were striking. With the variety White Star, seed planted April 23 yielded at the rate of 251 bushels to the acre, similar seed planted May 24 gave 191 bushels and seed planted June 23, only 79 bushels. This plainly shows that the potato, unlike corn, does best in soils that are not very warm. This was also brought out in other tests along very different lines, as in mulching and cultivation experiments. The depth of planting was considered in a test[50] made in 1882. The results are not very striking or conclusive, but appeared to indicate some advantage for three inches rather than six inches. It was evident that this factor would vary so much in effect with different soils that further tests were not made. Whatever the soil the seed piece must be placed deep enough

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[48] Rpts. **1**:55–66 (1882); **2**:117–122 (1883); **4**:60–63 (1885); **5**:149–152 (1886); **6**:86-90 (1887); **7**:162–165 (1888); **8**:225–238 (1889).

[49] Rpt. **2**:122 (1883).

[50] Rpt. **1**:62 (1882).

to secure a cool, moist bed for the growing roots and leave room above the roots for the development in the warmer soil nearer the surface of a heavy yield of tubers.

Attempts to increase the difference in conditions between soil of roots and soil for tubers by planting in ridges rather than on level ground or in furrows, or by mulching with straw between the ridged rows either gave results unfavorable to these practices because of moist, cool seasons or were contradictory. With straw mulch the growth of weeds is a great detriment, so the final conclusions appear to favor level culture, with maintenance of good soil mulch by shallow cultivation. The recorded tests[51] of varying distances of planting are exceedingly contradictory. They sometimes favor planting as thick as pieces twelve inches apart in rows twenty-two inches apart, while in other tests, to secure any satisfactory results from such thick planting, it was necessary to thin the shoots to one in a hill. The unthinned plants so shaded the ground that the total yield was greatly decreased and the percentage of small tubers greatly increased. In other tests rows forty-four inches apart with plants twelve inches apart in the row have given the best yields.

From recent Station experience, not, however, based on definite distance comparisons, it would seem that for our heavy, productive soil and for varieties like Rural New Yorker No. 2 of which the tubers have a tendency toward excessive size, plants twelve inches apart in rows thirty inches apart would give best results in quantity and quality.

Fertilizer tests.— As already indicated, fertilizer tests on Station soil have generally been inconclusive. The use of fertilizers with potatoes has given increased yields, but these have usually not been profitable nor in proportion to the amounts applied. It was impossible to draw definite conclusions in regard to the separate fertilizer elements, but potash gave some decided gains on Station soil, especially in the form of muriate. In other and more extended tests on Long Island soils, the use of potash in any form or in any quantity did not give consistently profitable returns. For those soils, at least, the very liberal use of potash in the formulas generally applied on potatoes appears to be unwarranted. It is probable "that the physical relations of our soil have a greater influence on [the potato] crop than do the chemical relations." In

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[51] Rpts. 2:125 (1883); 3:73. 74 (1884); 4:63–65 (1885).

two tests,[52] in different years, there was a consistent, though small, advantage from applying fertilizer below rather than above the seed, and in a later test,[53] large quantities of fertilizer applied in the row appeared to injure the vegative power of the seed tubers. Small quantities applied in the row gave better results than similar quantities broadcasted, but when larger quantities were used, broadcasting gave much better results.

In a test[54] on Long Island in 1895, ten brands of commercial "potato" fertilizers were applied on eighth-acre plats, each at the rate of 1,000 and 2,000 pounds to the acre, and one brand also at the rate of 1,500 pounds. (With this brand applications in the row and broadcast were contrasted at each rate. The results of this last comparison have already been given.) Though these brands were all "potato" fertilizers they differed considerably in every ingredient, least in nitrogen and most in potash; but each brand contained in 1,000 pounds more, frequently many times more, than enough of each element to supply the demands for a crop of 200 bushels of potatoes to the acre. This plentiful supply would indicate a liability to great waste, if more than 1,000 pounds to the acre was used, for few soils are so poor that they will not grow something of a crop, and it should be the purpose of a fertilizer to supplement the soil supply, not to furnish all of the ingredients necessary.

The crops in the tests showed that such heavy applications *are* wasteful. In only twelve cases of the twenty-four was the increase sufficient to repay the cost of the fertilizer, and only one of these occurred where more than 1,000 pounds of fertilizer was used. In one case there was a loss from the use of even 1,000 pounds, and in almost every case the loss from using a ton to the acre was greater than the gain from using half a ton.

This experiment was continued[55] the next year on the same plats, to test the residual effect of the fertilizers. The average yield of the plats where 1,000 pounds to the acre had been applied was increased 48.4 bushels the first year and 29.6 bushels the second year; while the use of an additional 1,000 pounds to the acre increased this yield only 4.4 bushels the first year and 14.1 bushels the second year. Taking both years into consideration, the use of 1,000

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[52] Rpts. **7**:168–170 (1888); **8**:253–255 (1889).
[53] Bul. **93**:277, 278; same, Rpt. **14**:35, 36 (1895).
[54] Bul. 93; same, Rpt. **14**:25–36 (1895).
[55] Bul. 112; same, Rpt. **15**:107–118 (1896).

pounds of fertilizer to the acre gave a net gain of $27.58; but the use of 2,000 gave a gain of only $20.46, or a loss, as compared with the use of 1,000 pounds, of $7.12.

Similar tests[56] were carried out in four localities on Long Island during the years 1897 to 1900 with results which strengthen the conclusion that it is bad practice to use, on the ordinary Long Island soils, more than 1,000 pounds to the acre of any good complete fertilizer. In these tests two different brands were compared and the quantities of each used varied by quarter-tons from one-quarter to a full ton. The results were quite consistent year by year, farm by farm and plat by plat; and the averages show undisputably that the use of more than 1,000 pounds to the acre decreases rather than increases the net profit from the crop. The formulas tested were two: One in common use on the island, containing 4 per ct. nitrogen, 8 per ct. phosphoric acid and 10 per ct. potash; and another based more nearly on the chemical composition of the potato crop. This "potato" formula contains more nitrogen, less phosphoric acid and the same amount of potash. Notwithstanding its apparently more rational composition, the "potato" formula gave poorer results on each farm, each year, and, with but one exception in one year, with each quantity used.

Cultivation.— Few tests of cultural methods with the potato have been made, and these[57] give no definite results except in disproving some "freak" beliefs. Pinching off the terminal shoots of the potato tops proved detrimental to the crop as did mowing off the tops or rolling them down in July. Burying the plants when four weeks old by a furrow turned upon the row, and intensifying this treatment by plowing up a second furrow ten days later, were both harmful.

Varieties.—Variety tests[58] have, of course, been carried on in one form or another, and during several seasons in both garden and field, but the varieties of potatoes prove acceptable in only restricted localities, vary so much on different soils, and deteriorate so fast, that tests of them are even less valuable than those with grains and fruits. Merely as a reminder of some that may have

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[56] Buls. 137, 154 and 187; same, Rpts. 16:596–616 (1897); 17:417–429 (1898) and 19:213–230 (1900).

[57] Rpts. 4:238, 239 (1885); 5:55 (1886); 9:386–388 (1890).

[58] Rpts. 1:62 (1882); 2:211–218 (1883); 3:293–305 (1884); 4:230–232 (1885); 5:140–147 (1886); 6:76–81 (1887); 7:158–162 (1888); 8:321–325 (1889).

been favorites of days gone by we give names of a few sorts that have stood at or near the head of the lists in different years: White Whipple, White Star, American Giant, Rose's Invincible, President Arthur, Nott's Victor, Defiance, O. K., Mammoth, Corless Matchless, Buffalo Bill, Putnam's Junks, Burbank, Green Mountain (twice), Grange, Governor Foraker, Stump of the World, Summit, Morning Star and Lombard. Rural New Yorker No. 2 was tested for the first time in 1888, and then led the list; but Carman No. 3, Sir Walter Raleigh, Early Ohio, Irish Cobbler and other favorites of to-day appear in inconspicuous positions on the list or not at all.

SUGAR BEETS.

During the last five years of the Nineteenth Century, New York State farmers were greatly interested in the sugar beet question. The growth of the crop had been found not only possible but profitable in other states whose conditions are not dissimilar to our own; several factories had been established or planned in this State; and the managers of these factories were urgently soliciting farmers to make contracts for growing beets. The conditions for success with the crop were not thoroughly known, however, nor was it possible to estimate the cost of growing, the yields or the profits from any reliable data collected in the State.

The Station accordingly undertook certain lines of investigation; and has grown some beets every season for ten years. In 1897 a comprehensive bulletin[59] was issued, based to some extent upon Station experience, but more largely upon well established principles and facts regarding the growth of the crop. This gave a full discussion of the conditions required for the successful production of sugar beets; with special attention to the factors leading to increase or decrease in the sugar content and coefficient of purity. The outlook for the industry in the State was carefully and conservatively discussed, and farmers were told that "they will not realize unusual profits for any extended periods from sugar-beet growing. The facts appear to justify the belief, however, that this crop may come to rank among those which for some time will be regarded as giving satisfactory returns. It will be a business of moderate profits and one that will not spring into uninterrupted success. If it is a success at all it will become so through education and experience." This conservatism, though somewhat disappointing to the promoters of sugar-beet culture, has proven

[59] Bul. 135; same, Rpt. 16:188–203, 581–595 (1897).

well justified. Though experiments have shown that as good beets and as heavy yields can be grown in New York as in the West, and though the State has encouraged the industry by paying a good ton bounty, culture of the crop is not extending rapidly, if at all; and only one factory remains in operation. Potatoes, cabbage, garden vegetables and well established special crops like peppermint, broom corn, hops, tobacco and celery give such certain returns or such larger profits under favorable conditions that sugar beets have been unable to displace them except in a restricted area.

The work of the Station on its own grounds, either independently or in coöperation with the United States Department of Agriculture, and on outside farms in coöperation with their owners, has shown that sugar beets are well adapted to New York conditions; and if properly managed, a reliable money crop. Indeed, for several years, the Station farm gave a larger amount of sugar to the acre than any other reported in coöperative experiments with the Department at Washington. The experiments of the first year were preliminary. They showed plainly that large crops of beets of good quality could be grown on the Station farm, and indicated that the use of about 1,000 pounds to the acre of a good complete fertilizer would be profitable.

During the next season, coöperative experiments were carried on with about twenty farmers in different localities, and analyses were made of large numbers of beets grown by other farmers. Many useful hints were obtained from this work, which were published in Bulletin No. 155.[60] In tests made by the Station at Geneva and at Fayetteville the use of a small amount of good, complete fertilizer was found profitable, but large quantities gave less satisfactory returns. When more than 1,500 pounds was used the gain in sugar was worth less than the cost of the fertilizer to produce it. Farmyard manure was also used this year and gave good results, though it was not profitable, counting the single season only, in the quantity used, twenty tons to the acre. Contrary to the general teaching, the use of the manure did not injure but improved the quality of the beets.

To test more thoroughly the influence of manure on beets, the trials with it were continued three years more. The results, as reported in Bulletin 205,[61] show the manure as good, if not better than commercial fertilizer for growing beets.

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[60] Same, Rpt. 17:430–457 (1898).

[61] Same, Rpt. 20:223–235 (1901).

During these experiments the Station has coöperated with the United States Department of Agriculture in testing varieties, and later in attempts to grow sugar-beet seed. A large amount of valuable data has been accumulated, but the tests have not yet been concluded, and no results have been published.

TOBACCO.

Some work was done with tobacco soon after the Station was established, but none in recent years. These early tests[62] were, even when first made, considered suggestive only; so it would be profitless to discuss them in detail now.

The use of a layer of pulverized sphagnum moss on the seed bed was found beneficial by checking evaporation and shading and protecting the seedlings. A similar layer of moss beneath a layer of soil did not appear to influence either roots or plants.

Primed plants, alternated with those not primed, gave the greater weight of cured leaf. The largest yield and best quality were given by plants one foot apart in rows three feet apart.

Decided advantage was shown from early planting of vigorous, early maturing plants, so that they could be topped as early as possible. In successive toppings, three days apart, beginning July 31, there was a continuous decrease in the percentage of cured leaf from the second to the last topping. In curing experiments it was found that splitting the stalk so as to hang the plants over laths resulted in rapid drying and great loss of weight; but that partial splitting of stalks to allow stringing on laths caused little more loss than hanging with twine.

The fertilizer tests did not agree in different years, but indicated unfavorable influence of some chemicals, including sulphate of potash in excess, and sulphate of iron. Manure produced a freer burning tobacco than chemical fertilizers.

WHEAT.

The work with wheat[63] has been very unsatisfactory so far as definite results are concerned. The unreliability of ordinary field comparisons was shown more plainly, perhaps, with wheat than

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[62] Rpts. 1:148–154 (1882); 2:227–234 (1883); 3:326–328 (1884).

[63] Rpts. 1:31–34 (1882); 2:140–141 (1883); 3:83–88 (1884); 4:112–128 (1885); 5:72–99, 115, 116, 133, 134 (1886); 6:58–63 (1887); 9:369–372 (1890).

with any other grain; and tests in adjacent rows 18 inches apart and 175 feet long showed the same lack of uniformity. Record was kept of the germination, winter-killing and productivity of forty-four varieties grown in such parallel rows; but the data showed no relationship between these factors. Ten rows of Clawson wheat from the same seed showed similar variation in each of the three factors, with no uniformity in yield. The best row gave three times as much grain as the poorest one.

Under such conditions, any unrepeated tests can be suggestive only, so few lines of experiment have been carried on. The work has indicated that heavy, plump seed is much superior to small, shriveled grains of the same variety; that the ordinary sowing at the usual depth, two inches or less, is better than deeper sowing; and that moderate compacting of the soil, both below and above the kernels, gives the best results.

The most extensive variety tests reported were made in 1885; and in the same report is included a key to the varieties, with careful notes on each.[64]

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[64] 4:112–124 (1885).

HORTICULTURAL INVESTIGATIONS.

SUMMARIZED BY

N. O. BOOTH

ORCHARD FRUITS AND GRAPES.

APPLES.

At the time when the Station was established there was an old apple orchard on the farm. The varieties were the standard sorts, 695 trees all told. It being deemed best by the management to test many of the newer varieties, scions of them were secured and grafted into these trees. The original orchard was in good, vigorous condition and the scions generally made a good growth. It was, however, some years before any fruit was secured. The consequence was that the orchard was hardly in a condition for general experimentation until some eight or ten years after the Station was established. At this time much interest was felt by all fruit growers in the Russian varieties of apples which had been recently introduced by the Department of Agriculture and the Iowa Agricultural Experiment Station. Great claims were made for these varieties as to their hardiness, fine quality, etc. In many instances fruit growers planted large orchards of these untested sorts. The results were disastrous. While New York was more conservative in this respect than many of the newer states, some fruit growers here felt that they were missing something if they did not plant these Russian sorts which, they were told, were better in quality and would be more profitable than varieties already cultivated. In the Eleventh Report of the Station the first report was made on these varieties and for some years this was a prominent feature of the horticultural work and one in which much interest was manifested. While some of the varieties were found to have value, many were worthless and very few were equal to other varieties under cultivation. It was found that these fruits coming from the far north, while many of them were winter apples in Russia, were much earlier in maturing here. Several of the summer and fall varieties are retained and cultivated to a limited extent, but most have been discarded by growers. The reports made on these fruits were quite detailed, were frequently tabulated for yield, blooming dates, etc., so that one variety could be compared with another for these characters. The varieties which were most promising were frequently illustrated. This seems a particularly valuable portion of the work owing to the fact that the varieties were badly mixed. Different shipments had been received from abroad and the same variety had been sent in under different names; conversely two varieties sometimes appeared under the same name. The result was great confusion. Even where errors were found it was almost impossible to correct them. None felt able to say which of two or more names might be the correct one in Russia. Consequently these illustrations enabled the growers of Russian varieties to find out, not if their varieties were correct according to name, but if they were the same as those which the Station had secured under that name. Later the American Pomological Society succeeded in straightening out this nomenclature.

APPLE STORAGE.

It was not until the Station was over twenty years old that anything was published on apples outside of what is already mentioned. The first record published on apples was on the storing of the fruit. The report showed that a complete and very exhaustive study had been made of the subject, a large number of varieties having been tested and much information having been secured by correspondence with buyers and storage men. This bulletin is written primarily from the standpoint of the comparative value of different varieties. The varieties were considered for their keeping qualities both in cold storage and in storage where no refrigeration was used. This comparison seemed particularly valuable because both means of keeping apples are used largely in New York. The information was published mainly in the form of tables; thus it was possible for any grower who desired to run down the list to determine within a reasonable limit of error at what time a variety might be expected to mature, how long it would keep in marketable condition, and a host of lesser points. If any variety had any weakness which would make it less valuable than it otherwise appeared, it was mentioned. Since the fruit house at the Station was quite similar to those on many other farms this work could be directly applied by all those who stored apples. It was found that the length of time a variety would keep depended on several factors:

First, degree of ripeness when picked; second, season; third, manner of picking, packing and handling; fourth, kind of storage; fifth, presence of fungi; sixth, temperature at which the fruit was stored. Some of these evidently the storer of fruit cannot change. It was found by correspondence with many of the large buyers who kept apples in cold storage that they have different temperatures at which they store different varieties; years of experience having shown them that each variety has a certain temperature which might be called its best storage temperature. Storage men do not agree exactly as to these temperatures but their conclusions are very close. A table[1] is given showing the different temperatures at which five of the leading storage men in the United States keep seventy-two different varieties of apples. These temperatures do not vary widely from freezing, the lowest being 30° and the highest, 35°. At the latter end of the bulletin an alphabetical list is given of a large number of varieties including all standard sorts and many others seldom or never marketed. Under each name the variety is discussed solely from the standpoint of storage. Some varieties have certain weaknesses; as the York Imperial which, while a good keeper, is apt to scald in storage. Scalding is a technical term applied to certain changes in the fruit not well understood which give it the appearance of having patches of the surface of the fruit exposed to intense heat. Such changes render fruit much less valuable and in some cases wholly worthless for the market, hence it is a point of importance in estimating the value of the variety.

A valuable discussion is given on the question of treatment of a variety after it is picked so as to make it keep longest. It is stated that "the soil on which a tree grows makes a difference with the keeping quality of the fruit." Baldwins grown on sandy or gravelly soil ripen earlier and must be picked earlier and do not keep so well as those on clay soils, although they have a higher color. The presence of various fungi is mentioned as a frequent cause of decay in fruit. "Except for retarding the development of fungus, apples keep best with considerable moisture in the air," as this prevents them from shriveling as many varieties are apt to do. In recent years cold storage men have come to believe that apples should go into storage as soon as picked. Reports indicate that with many fall varieties, as McIntosh, Oldenburg, and others, it is desirable to go

[1] Bul. 248; same in Rpt. 23:267 (1904).

over the tree two or more times, thus picking the fruit when it is just the proper picking size and when it is the same degree of ripeness.

It was found that with different varieties the effect of cold storage in prolonging the season beyond that of fruit kept in ordinary storage is not the same. Thus Missouri *Pippin* may be kept four months longer in cold storage than under the more common conditions, but York Imperial may be kept only one month longer, the average difference for all varieties being about sixty days, the effect being greater on winter and spring ripening varieties and less on those which mature earlier.

The information secured by corresponding with men who store apples is tabulated. It is quite variable, as might be expected from the fact that the men are operating in different parts of the country. In this table are given the limits to which the various varieties will keep in chemical cold storage, in ice storage, and in cellar storage. The differences in the keeping season under the different methods of treatment are also figured out. Chemical cold storage is evidently everywhere regarded as the best method of keeping apples and the statement is made that " so far as large commercial operations are concerned, ice storage is a thing of the past." With some exceptions the correspondents favor varying the temperature according to the variety. "A general principle can be detected running through and guiding practice in general. It is, that varieties that keep long and go down slowly, are held at about 31° to 32°, while earlier ripening varieties and those that do not keep so well are held one or two degrees higher, that is at 33° or 34°." It is found that the earlier apples do not go down so quickly after coming out of storage if they are held at the higher temperature. Also fruit of a more open texture as Twenty Ounce, freezes at a higher temperature than more solid varieties like Baldwin. One man makes a practice of keeping large fruit one degree higher than medium sized fruit of the same variety.

The temperatures recommended by various storage men are also tabulated. An inspection of this table leads one to suspect that in many instances the difference in treatment of the fruit is governed by the caprice of the storage man, as the differences are slight and many of them do not vary the treatment materially for different varieties. They all agree in accepting a temperature of from 30° to 35° as the best for apples. It seems generally agreed that the keeping quality of apples is affected considerably by the season, a cool

October being commonly regarded as favorable for the keeping of fruit. The kind of growing season that is most favorable is not generally agreed upon. "Various fungus diseases are much worse some seasons than others." On account of the presence of these decay germs it is deemed advisable to get the fruit into storage and have it thoroughly chilled as soon as possible, as this treatment retards the development of the germs. Various kinds of deterioration may precede decay in cold storage. These are scald, loss of quality, change of color, loss of firmness, becoming bitter in skin, shriveling, becoming mealy and bursting. A list of those varieties most susceptible to each of these weaknesses is given, also a list of those which go down very quickly in storage. "Varieties differ greatly in endurance of heat after having been picked and before going into storage." Summer and fall varieties are most affected in this respect and late keeping varieties least. Directions are given for the handling of each variety so as to get best results.

"THE APPLES OF NEW YORK."

Shortly after the publication of Bulletin 248 on the keeping of apples in storage, the horticultural department commenced preparation of the most ambitious work ever attempted by this department, possibly by any Station. This was the publication of the two-volume work entitled "The Apples of New York." It is by all odds the most thorough work of its kind ever published in America. In fact it is not probable that any individual or association of individuals would ever consider it profitable to attempt such a work, all such endeavors being tacitly left to the province of the commonwealth. The expense was supplied by a specific legislative appropriation which provided for the printing of 19,000 copies of each volume.

This work[2] is the culmination of over twenty years of investigation, the studies really coinciding with the history of the Station. It is a summary of all the notes made and information gathered on the subject of apple growing since the horticultural department of the Geneva Station was established. As has already been indicated, from time to time the behavior of various varieties in the Station orchards had been reported in the annual reports; but the work as a whole had never been brought together and summarized. The collection of varieties referred to was started by Professor Goff in

[2] The Apples of New York, in 2 volumes, by Beach, Booth and Taylor, Rpt. 22:pt. 2 (1903).

the year 1883. Each year additions were made to this collection and by 1900 it consisted of over 700 named varieties of apples and crabapples. This report, however, contains not only the records of these various varieties as tested at the Station, but is combined with a mass of information secured by looking up all the available works on the subject of apple growing with particular reference to the value of the different varieties, and also information secured by correspondence with a large number of growers throughout the State and with a smaller number outside the State. In addition acknowledgment is made of assistance of professional associates outside the Station.

The work is divided into two volumes, the first including the introduction and the descriptions of the winter varieties of apples, the second including summer and fall varieties. The division between the two classes is made at the season of the Tompkins King, all those of the same season and later going into the first volume and all of the earlier ones going into the second volume. The introduction contains first a brief discussion of the apple from the botanical standpoint. The apple is stated to be indigenous to the old world but with American relatives, our native crabapples. Three species of North American crabs are given and it is said that in the case of one of them hybrids have been produced with the common apple. The others are sometimes used for preserves but are of no importance in cultivation. The hybrids referred to are considered valuable by us, only in the kitchen or for cider. The native home of the apple is not definitely settled. De Candolle, a French botanist, who has devoted more attention than anyone else to study of the origins of cultivated fruits, and who is generally accepted as an authority, concludes that it is probably indigenous to the region south of the Caucasus but that it has existed in Europe in both the wild and cultivated form since prehistoric times.

A history is given of the cultivation of the apple in New York State. It seems that the earliest settlers planted apple trees and, the region being well adapted to them, these thrived. "In fact, apple culture was carried by Indians, traders and white missionaries far into the wilderness beyond the outermost white settlement." Apple orchards were found, and in some cases remnants still exist, around the sites of the old Indian towns. Most of the trees in the earlier plantings were seedlings, and while it is certain these earlier orchards did not bear the uniformly high-class fruit that we secure to-day, they were of great advantage in that the best of these seedlings were, with the advent of the practice of grafting, taken to topwork other trees and thus became our standard varieties of to-day. It was generally found that European varieties were less well adapted to our American climate than those which originated here. The prevalence of these seedling orchards gave ideal conditions for the selection of varieties better adapted to new world conditions than those secured from the old. Knowledge of the art of grafting, though probably known, was rare until after the Revolutionary War. The first nursery was established in this State at Flushing, L. I., about 1730. Other nurseries were established later, but it was not until about the middle of the nineteenth century that, due to the stimulus of a large demand for grafted trees for planting in commercial orchards, nurseries became common.

It is stated that in the order of their commercial importance, the chief commercial varieties to-day are Baldwin, Rhode Island *Greening* and Northern Spy. The first two of these, it is said, supply two-thirds of the apples grown for the New York market. Other important kinds whose relative value is more difficult to determine are Tompkins King, Roxbury, Golden Russet, Hubbardston, Esopus *Spitzenburg* and others of lesser prominence.

A chapter[3] is given on the adaptation of varieties for particular regions. It is said, and supported by evidence, that practically all of the leading varieties grown in New York State to-day are of New York or New England origin. This may be expressed in the form of a law that varieties are adaptable to regions having about the same latitude as the one in which they originated. Some exceptions are noted, but they are few compared with the number which conform to the rule. Inside of this general law, however, there are many minor differences in the thriftness of trees grown in different neighborhoods, due to differences in the soil, drainage, exposure and smaller differences in the climate. Neighborhoods are instanced in New York State where certain varieties do particularly well. The reason for these slight differences can not be definitely stated.

The definition[4] of the term "variety" is discussed. They are divided into two classes: First, those secured by sexual reproduction, that is, seedlings; second, those which arise from asexual reproduction, that is, bud sports. Practically all of our new varieties were secured by the first method. The propagation of the variety

[3] The Apples of New York, 1:18 (1903).

[4] The Apples of New York, 1:20 (1903).

after it originates is invariably by the second method. The parentage of most of our varieties of apples is unknown, in fact in most cases we do not know from what variety the seed was secured, much less what variety the pollen came from that fertilized the ovule and produced the seed. Speculation is frequently indulged in on this point and varieties are credited with certain parentage on account of their resemblance to the supposed parents, but this is always uncertain. It is said that varieties sometimes originate from bud sports, an occurrence not uncommon among ornamental plants. In spite of the great differences that exist amongst varieties, no two exactly duplicating each other, the writer is of the opinion that many varieties may be grouped together on account of having many points in common. Ten such groups are[5] made, two of which are divided into subgroups. The varieties are most of them well known, and it is said that in like manner many other groups might be made.

A paragraph[6] is given to the discussion of Russian apples. As far back as 1832, Kenrick, one of the early horticultural writers of this country, considers worthy of trial " two highly celebrated Russian apples," the Duchess of Oldenburg and Emperor Alexander, or Alexander as it is called today.

The description of the individual varieties is prefaced by a chapter explaining the technical descriptions of fruit and tree. Incidentally the value of various characters as a means of distinguishing varieties is mentioned. In the descriptions of the varieties the names are arranged alphabetically and under each variety comes, first, a list of all those publications in which the variety is mentioned, or at least all those deemed of any importance. These citations have all been consulted before the description of the variety was written to see if there was any contradiction between the experience of the past as epitomized by standard works and that of the present day as secured at this Station and indicated by correspondence with numerous practical growers. Next is given a list of all the synonyms of that particular variety. It is astonishing, in the case of certain of the older varieties, how many different names can be applied to one sort of fruit. Age alone does not seem to determine this matter. The Baldwin, although over 150 years old, has only nine synonyms. The Newtown Spitzenburg, although probably not over 100 years old, is listed as having twenty-seven. In general, how-

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[5] The Apples of New York, 1:23 (1903).
[6] The Apples of New York, 1:25 (1903).

ever, those varieties which originated after regular nurseries were established and trees generally bought already grafted, have a lesser number of synonyms than the older sorts. The Northern Spy does not seem to have been known by any other name than the regular one, though this is sometimes contracted to Spy.

After the list of synonyms there is a paragraph giving a popular description of the apple, the most striking points in its appearance being mentioned, its general quality, the uses to which it may be best put, and if there are any particular weaknesses which interdict its cultivation these are mentioned. There then follows a brief historical account of the variety, more or less complete, depending on whether such information is known or not. In many cases, even with comparatively recent varieties, the history is obscure. Then follows technical description, first of the tree, then of the fruit. The historical and technically descriptive paragraphs are printed in smaller type than the popular description. Thus arranged one may go through the volume reading the larger print alone and get a good general idea of the value of a variety without burdening oneself with the labor of reading over a mass of technical details, as to whether the buds of a particular variety project or whether they lay close to the twig, or whether the twig itself is gray or olive green, and other points of a similar nature, undoubtedly valuable but not of interest to the casual reader and apt to be very confusing unless separated from the regular text in the manner mentioned.

Three hundred and twenty-two different varieties are described in Volume I and 324 varieties in Volume II. This last number includes twenty-nine crabapples. There are in both volumes 3,417 synonyms given. The illustrations are both half-tones and color plates. In the first volume there are forty half-tone figures of fruits and one general view, and eighty-three color-plate figures of fruits in one general view. The second volume contains thirty-seven half-tone plates, all figures of fruits, and forty-seven color plates, also all figures of fruits, making a total of 209 illustrations. A large part of the expense of issuing these reports and undoubtedly a large part of their value depends on these illustrations. They are all figured from specimens of the variety, those selected being normal specimens. Each volume contains an index, besides which there is a combined index for both volumes at the end of the second volume. Both proper names and synonyms are included in these indices, the proper name being in roman and the synonym in italics.

The volumes were distributed chiefly by the Legislature, 15,000 being divided among the various members of the two houses, 2,000 volumes were apportioned to the Department of Agriculture at Albany, the remaining 2,000 being apportioned to the Experiment Station for distribution. Of this latter number many were already promised to various fruit growers and others who aided in gathering the data that went to make up the volumes.

Many of the demands for the work could not be supplied, and on this account a bulletin was published, entitled "The Apple Districts of New York,"[7] which, while it manifestly could not include all the matter contained in the two preceding volumes, epitomized that which was of the greatest practical interest, and also included other matter designed to aid the fruit grower. The grouping of various varieties of apples, said groups including all varieties apparently similar or known to be related, had been suggested and partly carried out in "The Apples of New York." The object of this grouping, aside from its general interest, is to aid those who wished to plant varieties unknown to them by indicating which of the known varieties they resembled. While it is not claimed that this work will ever be wholly satisfactory, in that many varieties which resemble each other in some particulars do not do so in others, it was hoped to do some good. The characteristics of the group are given, so far as known.

Thus the Reinette group, one of the largest and subdivided into four sections, is characterized as follows: "With few exceptions, rather large in size; of green or yellow ground color, with or without blush, and generally of good quality. Nearly all of the members, with the exception of a few in the Newtown section, thrive in New York. Only a few varieties of this group, however, succeed in the northern district. In the various sections of this group are included Fall Pippin, Holland Pippin, Lowell, Maiden Blush, White Spanish Reinette, Northwestern *Greening,* Rhode Island *Greening,* Sweet Greening, Green Newtown, Grimes, Peck *Pleasant,* Yellow Newtown, Seneca Favorite, Swaar, and many others less well known. Anyone who has any experience with apples is familier with all, or practically all, of these varieties, and if he found a new variety classed with a portion of them, would at once have an idea as to the characteristics of the unknown sort.

In addition to the above there is included in this bulletin a

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[7] Bul. 275; also Rpt. 25:337–397 (1906).

division of the State into nine fruit districts,[8] this division being based on the natural flora of the different districts and the weather records as given by the Government Weather Bureau Stations. Lists of varieties of apples are given for each one of these districts. In each case the list is divided into three classes; first, those worthy of trial, that is, apples whose general characters appear to indicate adaptability to that section; second, those recommended, that is, tried to a limited degree; third, those well recommended, that is, apples tested for a sufficient length of time so that there can be no doubt as to their adaptation. The characters of the various districts, both as to soil and climatic conditions, are indicated in the text that precedes the list of varieties for each district.

There is also presented a list of varieties tested at the Experiment Station and found unworthy of further trial in New York State, and a list of varieties not sufficiently tested to find a place in the descriptions of the apples of New York.

The last pages of this bulletin contain a list of all varieties mentioned, tabulated after the manner made popular by the American Pomological Society. Briefly, this consists of: First, a column giving the name of the variety; second, various columns giving size, form, color, flavor, quality, season, use and origin; third, a column for each apple district in New York State with a star or two stars, opposite a variety to indicate whether it is recommended for trial only or for more general planting. A dash indicates that the variety in question is not recommended for that district. The last, and perhaps most valuable, portion of the table is a column entitled "Remarks." Here there are crowded in, in small type, from three to fifteen words giving the salient features of the variety. For instance we find opposite the Ben Davis variety: "Tree hardy, healthy, vigorous, productive. Lacking in quality." Opposite Esopus *Spitzenburg* is recorded: "Lacks vigor. Uncertain in productiveness. Standard in quality. Adapted to some localities." And so on. Six hundred and twenty-eight varieties of apples and crabapples are thus tabulated, including practically all that any fruit grower would ever have occasion to look up.

THINNING APPLES

The question of thinning fruits is one that has been agitated by fruit growers everywhere; especially has this been the case since

[8] Bul. 275, p. 18.

higher prices and more careful grading have stimulated the growing of fruit of better quality. Commercial peach growers generally follow this practice to-day, and that it is a profitable horticultural procedure is apparently well established. The thinning of apples, however, has never become common. Whether this is due to the fact that an apple tree full of fruit is not benefited to the same extent by having the surplus fruit removed as a peach tree would be or whether it comes from the greater expense of the thinning of the larger trees is not evident.

To test the advisability of thinning apples as a horticultural practice an investigation[9] was started in 1896 and continued for four seasons thereafter. This work was done in a commercial orchard some distance from the Station grounds, the object being to approximate the same conditions as those of the practical fruit grower. The trees were all mature, ranging from twenty-five to forty years in age. In each case where a tree was thinned another tree of the same variety, and as nearly like it as could be found, was taken as a check for comparison. At the close of the experiment the conclusions were as follows: No exact rule for thinning apples can be given, the requirements varying with age, size and season. In general, after all wormy and otherwise inferior specimens were removed and not more than one fruit from each cluster was left, additional fruit should be removed if the apples are less than six inches apart. Early thinning gave best results and the writer advises that the work be done within three or four weeks after the fruits set even if the June drop is not yet completed. No method of raking or jarring the fruit from the trees is recommended.

One of the most valuable things about thinning is that the inferior specimens are removed and this discrimination can only be done by hand. Wherever the trees were well filled with fruit, thinning improved the color and size and consequent market value. The thinned fruit graded higher in all respects than that which was unthinned. There was no material change in either the amount or regularity of fruit production. In this respect the results were rather surprising as it was anticipated that preventing the tree from overbearing would increase the yield on the off years.

It is stated that "the cost of thinning mature trees which are well loaded should not exceed fifty cents per tree and probably would average less than that. Although a given number of fruits can

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[9] Rpt. 15:378 (1896).

be thinned faster than an equal number can be picked when ripe it has required about as much time to thin a tree as it has to harvest the ripe fruit." The thinned fruit, being of a higher grade, is particularly well adapted for marketing in boxes or in any other way appealing to the fancy trade. "Thinned apples can be handled more economically than unthinned apples because they have proportionately less of those grades which form the least profitable part of the crop, namely, the No. 2's, the drops, and the culls.

The general conclusion was that it would pay to thin apples where there is a large crop set and the chance for small fruit very great. Otherwise it would not pay except in those instances where fruit is removed to prevent the breaking of the tree.

WINTER INJURY TO FRUIT TREES.[10]

In a bulletin on this subject are given the results of a study of the injury resulting from the extreme climatic conditions of the season of 1903–4. The writer states that the growing conditions during the summer of 1903 "were not normal and altogether favorable. Insects and fungus epidemics were serious." It was a combination of the unfavorable growing season with the extremely cold winter which followed that injured or killed many trees, the peach and pear suffering more than the others. The writer states that winter injury is usually classified under three heads: Root injury, trunk injury, and branch injury. The first of these, while quite common in some of our western states, is very rare in New York. Trunk injury "may be due to the freezing, causing death or injuries within the trunk or limbs of the active tissue, known as cambium." This cambium, which is the growing part of the tree, is capable of withstanding a great deal of cold. Injury of this kind was, however, quite common in New York State in 1904. Branch injury is the killing back of the twigs and younger branches. It is stated that this occurs commonly every year, the amount of such injury depending largely upon how well the wood ripens in the autumn.

A general discussion is given of the cause of the changes which take place in tissue injured by frost and attention is drawn to the fact that the readiness with which such injury takes place depends largely upon the amount of water in the wood. It is stated that it is impossible to say how much cold any given tree will stand,

[10] Bul. 269; also Rpt. 24:215 (1905).

Unthinned. Thinned.

PLATE XV.— EFFECT OF THINNING ON APPLES.

this depending wholly upon the condition of the tree. At the end of the winter the trees showed no sign of injury, visible from the outside. Upon cutting into the trunk, however, it would be found that both bark and wood were discolored for some depth. Mention is made of the alarm that was felt by fruit growers when this was found to be the case. Their fears were exaggerated, for many of the trees so discolored lived and made a good growth during the summer of 1904. The younger trees generally suffered less than the older trees, and those on higher ground showed less injury from the cold also. With peach trees over seven or eight years old the injury was very serious. Trees that were injured or killed showed the injury in various ways; sometimes it appeared that the winter had killed the trees outright for they showed no sign of life in the spring. In other cases the injury showed itself more gradually. The fruit buds were frequently so seriously injured that there was no crop the following year. Injury of all kinds was particularly noticeable amongst those trees planted in a depression where the water on the surface of the soil would collect and where the cold air would settle.

The opinion of various practical growers is published as to the ability of various varieties to withstand cold. The grower is warned not to cut out trees at once as many times those trees will grow and even bear fruit, although they appear to be very seriously injured in the spring. Many trees were pruned in various manner in the spring to see if this would have any effect on the quantity of fruit borne. It was found that in the case of young peach trees a severe pruning, even to the cutting back of large limbs, was apparently advantageous. The same treatment on old trees was a failure and it was further found that the presence of a crop of fruit seemed to retard the natural healing of the injured trees. It is advised when trees have been injured to prune them at least lightly in all cases, making the pruning more vigorous with young and vigorous trees.

GRAPES.

As has already been indicated, the horticultural department of the Station was considerably hampered during the first few years of its existence by the lack of fruit plantations; this applied especially to grapes. A vineyard was planted in 1882, and almost every year thereafter, new varieties were added. In the Fifth Annual Report[11] the statement is made that ten of these varieties had

[11] Rpt. 5:167 (1886).

fruited. It was some years after this date, however, before the vines became sufficiently mature so that the different sorts might be compared with one another and a proper judgment made of their vigor, quality, fruitfulness and other characters. In the report for 1890 much attention is paid to the grape. This is undoubtedly due in part to the stimulation that had been given to the growing of grapes in America by the recent introduction of the practice of spraying from France. In fact a large part of this report is devoted to the use of fungicides and a description of the various fungus troubles peculiar to the grape.

The bulletin is largely quoted from other publications, especially those of the Department of Agriculture. Descriptions, however, are given of forty-five varieties, which are divided according to their color into black, white and red grapes. These descriptions are popular in their nature, and while they do not describe the variety so that it might be separated from a closely resembling one, they bring out all those characters, good or bad, of importance to the grower, such as vigor or weakness in the vine, susceptibility to certain diseases, quality, if the same is particularly good or particularly bad, and other points of a similar nature. After this time these descriptions became features of the reports. For some years a large number of varieties, including many comparatively unknown, are described in detail. That this work had considerable value to the prospective planter there can be no doubt. Few or none of the newer varieties proved as good as standard sorts, and many that were much advertised were found to be worthless and prospective planters were warned accordingly.

This work soon grew beyond mere variety testing. In the report[12] for 1893 there was included, with the description, the botanical species of each variety. When this was not known absolutely, the reason was usually stated for placing it in a particular class. As will be appreciated by anyone who has studied grape literature, such descriptions as these are of interest to others besides the botanist. Although there are many species of grapes indigenous to North America, only three of them have so far furnished varieties worthy of cultivation in New York, and each of these three shows characters of fruit and vine widely dissimilar.

The Labrusca, or Fox grape of New England, is the only one which has given varieties good for eating. To this species belong

[12] Rpt. 12:617 (1893).

the Concord, Moore Early, Niagara, and many others. The vines grow quite vigorously in our northern states but sometimes winter kill. Practically none of them flourish further south where the summers are longer and the sunshine more intense.

The Riparia, or River Bank grape, is very widely distributed, growing almost all over the United States, and is readily recognized by its thin, almost translucent, leaves, small canes and small dark blue or black berries heavily covered with bloom. None of the pure Riparias are good table grapes but many of them make good wine. In spite of their sour taste the wine maker finds that their juice contains more sugar than the sweeter tasting Labrusca.

The Aestivalis, or Summer grape, as it is commonly called, is like the last in that no varieties which are purely of this species are popular with the public for eating. The juice makes a good wine and the varieties generally are somewhat stronger growing than those of the Riparia class. One of the great advantages of varieties of this species is that the leaves will not sunburn, a point, however, of practically no importance to the New York grower.

Besides these three American species there is the *Vitis vinifera*, or European grape. This species, having been cultivated for thousands of years, furnishes both wine and table grapes. Unfortunately, however, owing to attacks of various mildews and insects, the European grape can not be grown successfully east of the Rocky mountains in North America. It is frequently crossed with American species to improve their quality, usually, however, with the effect of making them less able to resist disease. Thus it will be seen that the question of the species of any variety of grape is a very important one and of horticultural as well as of botanical interest. No description of a variety of grape is considered complete to-day unless the species is given.

TESTING SEEDLING GRAPES.

In connection with this work seedlings were frequently raised, as it was found that in many cases some light could be thrown on the probable parentage, and hence species of a grape, by planting its seeds, the resulting seedlings frequently reverting to ancestral types. In the course of a few years many thousands of seedlings were raised. This was not wholly for diagnostic purposes, but also in the hopes of originating new varieties of value, or at least of finding how such varieties might be produced.

Most originators of varieties of grapes have thought too much of quality of fruit in estimating their seedling grapes and have not given due regard to vigor of vine and freedom from disease. On this account all of the seedlings raised on the Station were, from the time when they were very small, left unsprayed in positions where fungus diseases were prevalent. In the same manner they were left to take their chances in the winter without any protection. Naturally many thousands died, but the surviving ones were able to withstand all vicissitudes incident to the life of a grape in this section.

Besides this natural selection an artificial selection was made of the stronger plants, that is the weaker ones were discarded as soon as they showed their weakness. It was found that it was hopeless to nurture naturally weak plants with the thought that they would become stronger with age. In some cases, for the sake of information, especially weak plants were selected and kept as long as six years with no material improvement. This showed plainly that weakness in seedling grapes was generally, if not always, due to inherent weakness in the constitution of that particular vine and was not due to minor accidents, such as getting a poor start, etc. It was generally found that the larger seeds produced more vigorous seedlings. Certain parents and certain crosses always gave weak seedlings. In a like manner certain other parents and certain other crosses usually gave strong seedlings.

Since seedling grapes have to be six or eight years old before their fruiting capacity can be correctly judged, a report upon this experiment has not yet been made. Many plants were discarded during the first year of their growth, and many others were thrown out later. Of those that showed sufficient vigor and health to be worthy of further trial, 723 are now growing in a separate vineyard on the Station grounds. A detailed record of these will be made some time in the near future.

RINGING GRAPE VINES.

Another bit of grape investigation very valuable in its way, although the results were not positive, was the ringing[13] of grapes. The ringing or girdling of fruit trees or vines is a practice that is very old and frequently advised by amateur horticulturists but not practiced by practical fruit growers in America. This investigation extended through two seasons. The practice of ringing

[13] Bul. 151 and Rpt. 17:510 (1898).

Early ringing. Late ringing. Check.

PLATE XVI.— EFFECT OF RINGING STEMS ON ROOT-GROWTH OF CHRYSANTHEMUMS.

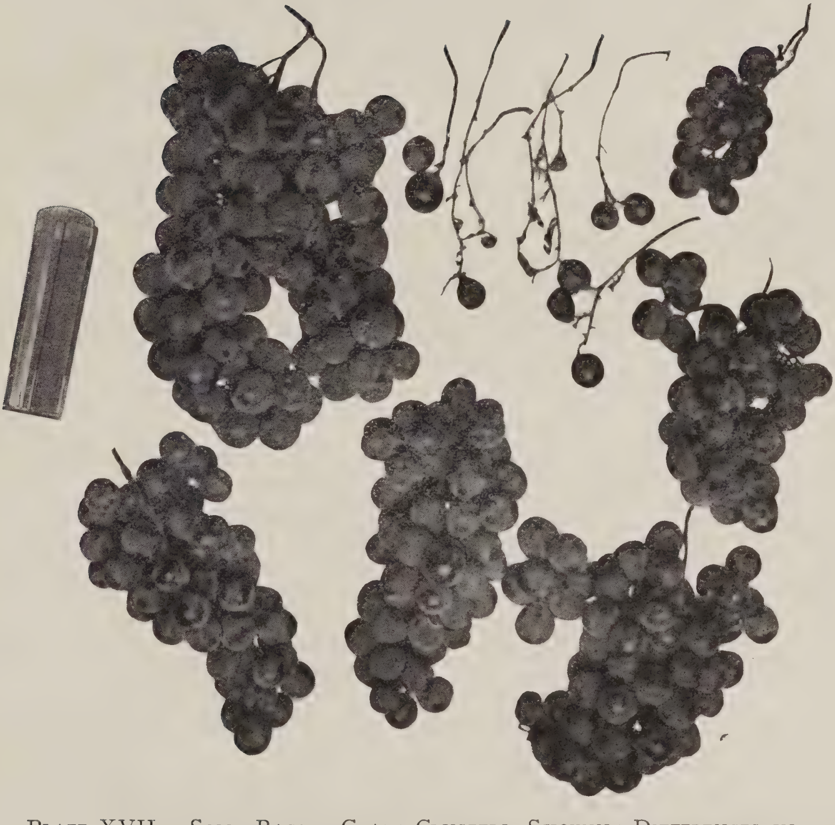

PLATE XVII.—SOME BAGGED GRAPE CLUSTERS, SHOWING DIFFERENCES IN SELF-FERTILITY.

grapevines consists, according to the writer, "in removing a ring of bark from the bearing arm about an inch wide." The effect sought in ringing is to produce earlier ripening of the fruit and larger bunches and berries. An illustration is given of the instrument used and also of that portion of the vine which had been ringed. The general results showed that the differences between the fruit on the ringed and unringed canes were largely a matter of season. "The first season the effect on the fruit of some varieties was very marked. Fruit on ringed vines of Empire State was not only larger in both bunch and berry but began ripening twenty-one days before fruit of unringed vines." Other varieties showed no such differences. The fruit of some varieties showed a lack of quality when ringed and others showed a greater tendency to crack. The writer is of the opinion, while admitting the devitalizing effects of this practice on the vine, that, judiciously practiced, "it need not result disastrously."

The general results are too inconclusive to indicate either that ringing is desirable for those who wish to grow superior fruit, or that it should not be practiced. The results are chiefly of value as furnishing a good answer to the oft-repeated advice to girdle various kinds of fruits with the expectation of securing abnormal crops. While it may be generally taken for granted that any horticultural practice which has been known as long as ringing does not offer any great rewards or it would be more generally used, nevertheless it is sometimes quite difficult to point out to some over-enthusiastic fruit grower wherein his methods fail, or where evidence can be found to prove its exact value.

FERTILITY OF GRAPES.

One of the grape questions taken up by the Station at a comparatively early day was that of self-fertility or self-sterility of varieties. In order to appreciate what this Station did in an investigation on this subject, it would be necessary to recapitulate what was previously known. Engelmann and other botanists who studied the grape had found that both among the wild and the cultivated sorts there were many which were not capable of bearing fruit when standing alone; that is, pollen from another vine is required in order that fruit should be borne. One or two cultivated varieties were known to be self-sterile and others were supposed to be so. No one had ever tested any large number of varieties to determine their capacity in this respect.

The first phase[14] of this work started by this Station was the sacking of clusters on grapevines before blooming time to determine if the variety whose cluster was sacked was capable of bearing fruit without foreign pollen. It was soon found that varieties of grapes could not be divided arbitrarily into two classes, self-sterile and self-fertile, but that there were various degrees of self-sterility and self-fertility. One variety would set a perfect bunch of fruit in the sack, another would set a bunch with many of the berries lacking and the bunch consequently looser than those on the same vine which set outside the sacks. Others, as has already been mentioned, would set no fruit at all if the blossoms were covered.

From the data gathered lists were published in which the grapes are divided into four classes: The first, all those varieties which set perfect bunches in sacks; the second, those which set bunches somewhat loose but not sufficiently so as to be unmarketable; third, those whose bunches were so loose as to be unmarketable; and fourth, those producing no berries or practically no berries from the covered blossoms. "With many varieties the degree of self-fertility is not an unchangeable characteristic even when the vines appear to be in a normally productive condition, but varies under differences of environment. Many other varieties which have been under observation showed practically no variation in this respet. Usually where no variation in self-fertility is observed with a variety it is confined within rather narrow limits."

One hundred and sixty-nine varieties were included in the lists given in Bulletin 157, in which the varieties were divided as above indicated.

It was found in later investigations[15] in which varieties were hand pollinated with the pollen of various other sorts, that varieties which are themselves self-sterile do not make good pollenizers for other self-sterile sorts, and that the value of a variety as a furnisher of pollen for fertilizing is almost identical with its self-fertilizing capacity. The rule was consequently deduced that a strongly self-fertile variety should always be taken as a pollenizer for self-sterile sorts. Thus if one wish to plant Brighton, a quite popular variety in some neighborhoods, although it is practically self-sterile, Wyoming *Red* would not do for a fertilizer because it is also self-sterile and these two varieties planted

[14] Bul. 157; also in Rpt. **17**:518 (1898).

[15] Bul. 169; also in Rpt. **18**:361 (1899).

together and away from other vines would produce no fruit. But if Cottage, Delaware, Diamond, Diana, Moore Early, Niagara, or any other strongly self-fertile sort be planted beside the varieties mentioned, then fruit could be expected.

When the pollen of different varieties was taken into the laboratory, it was found that under the artificial conditions there given, the pollen of the self-sterile sorts would not germinate, while the pollen of the self-fertile sorts always showed a high percentage of germinations, and it was further found that the percentage of germinations was in direct proportion to the capacity of the variety for self-fertilizing itself, as indicated in the previous vineyard tests, that is, all those varieties which were partially self-fertile showed a pollen in which only part of the grains would grow. When examined under the microscope it was found that those grains which were self-fertile were of different shape from those which were self-sterile. From this information we can tell at once whether a variety is self-sterile or self-fertile by examining the pollen, without the necessity of bagging clusters in the vineyards.

As a corollary of this work it was found desirable to note the blooming season of the various varieties since it was evident that two varieties must be in bloom at the same time if it is expected that the one should fertilize the other. Lists were[16] consequently published giving the approximate blooming season of all those varieties included in the previous investigation.

COVER CROPS FOR ORCHARD.

Owing to the fact that in many of the fruit-growing neighborhoods of New York State orchards have been cultivated for years and the humus in the soil more or less exhausted, the renewal of this supply of humus is a vital problem to all fruit growers. Humus, be it understood, is vegetable mold coming from decaying plants and is found in all soils. Soils in which the humus content is deficient are unsatisfactory for the raising of fruit. Supplying the humus by hauling barnyard manure or other vegetable matter upon the land is not only expensive but in many neighborhoods is absolutely impossible owing to the fact that such manure can not be secured. Great interest is consequently felt in the question of cover crops, cover crops being the term implied to indicate any crop growing in the orchard, usually through the latter part of the growing

[16] Bul. 169; also in Rpt. 18:361 (1899).

season, designed for the purpose of allowing the plants either to fall upon the ground when they are killed by the winter, or, if they survive the winter, to be turned under the following spring with the intention of thus creating a continual supply of humus. "Another advantage to be gained by the use of cover crops is that some kinds of plants may be used for this purpose by which the amount of nitrogen compounds in the soil may be increased."

In the Fifteenth Annual Report[17] of this Station the results are given of a series of trials of several crops for this purpose. The crops were as follows: Mixtures of Canada peas and buckwheat, blue peas and buckwheat, cowpeas and buckwheat, or winter vetch and winter rye, and sweet clover, mammoth clover, sainfoin and dwarf Essex rape. Since the object of the cover crop is to add humus to the soil, and since the humus is produced by the decay of the plant itself, then it is evident that the most satisfactory cover crop, other things being equal, is the one which makes the greatest growth, that is, produces the most humus. It follows necessarily from this that the best cover crop in one neighborhood might not be the best in another owing to the plants comprising the cover crop being better adapted to the one section than to the other. There are some other points also that have to be considered. There are certain plants which make a good growth but are barred out of use as cover crops owing to their tendency to become weeds. Sweet clover (*Melilotus alba*) is, in some neighborhoods, in this class. Others, like rye, are sometimes avoided because they form such a dense sod as to render the orchard very difficult of cultivation.

The mixture of Canada peas and buckwheat was found to be very satisfactory, the only possible objection being that the exceedingly rank growth, averaging nearly two and a half feet in the latter part of September, interfered rather seriously with the gathering of the fruit. This was found particularly obectionable on wet days. The plat planted to this crop had been previously planted to crimson clover which had failed.

The plat of blue peas and buckwheat, while not standing quite so thick upon the ground, made fully as good a growth. It is suspected, however, that it is somewhat more difficult to get a stand with the blue peas than with the Canada peas.

The mixture of cowpeas and buckwheat looked quite well, chiefly, however, from the appearance given by the buckwheat since

[17] Rpt. 15:440 (1896).

it is stated that this formed the principal part of the cover crop. The cowpeas killed much earlier in the fall than either the blue peas or Canada peas.

The mixture of winter vetch and winter rye was, in many respects, very satisfactory. A good stand was secured. "This makes an excellent cover crop because it forms a perfect mat of vegetation over the ground and does not grow tall enough to interfere with the gathering of fruit which ripens as late as winter apples."

The sweet clover did not do well under the shade of the trees, the orchard being an old one and the ground considerably shaded.

Mammoth clover was quite satisfactory although the substance furnished was not as great as in the case of most of the preceding mixtures.

Sainfoin makes a short spring growth whose value is probably quite similar to that of mammoth clover.

Dwarf Essex rape made the rankest growth of all, being about two and a half feet with the broad leaves lying close together. As in a previous case this was found disadvantageous in gathering the fruit. It was also found that field mice were inclined to harbor in this abundant vegetation and incidentally to injure the trees.

Of all the cover crops it was decided that the mixture of winter vetch and winter rye was probably the best, all things considered, for bearing orchards; however, the mammoth clover gave almost as good results.

Crimson clover, although not used in this experiment, has been tried at the Station many times. For this neighborhood it is decidedly unsatisfactory; as it is difficult to secure a stand, and the clover does well on dense clay soils and often winter-kills.

SMALL FRUITS.

The raising and testing of small fruits was one of the first investigations undertaken by the horticultural department of this Station. The reasons for this are obvious. It would take some years to raise apple and pear trees large enough for experimental purposes, but small fruit plantations could be established in much less time. In the spring of 1882 plantings were made of raspberries, currants and strawberries. Some of the plants fruited the next year and were reported upon in the Second Annual Report of the Station.

From this time on, notes on small fruits, and in particular, descriptions of varieties, were a regular feature of the Station reports. While these were undoubtedly of great value at the time, many of the varieties described are now out of cultivation and it is consequently difficult to judge of the merit of these reports. There were included in these descriptions blooming and fruiting seasons of the various varieties, usually tabulated, detailed descriptions of the fruit itself very frequently, besides a host of minor investigations as to the value of irrigation for small fruits, comparative merit of row system as compared with hill system for strawberries, etc.

During the first ten years of the Station's existence the greater portion of work on small fruits was on the strawberries, many varieties being reported on every year. Later blackberries, raspberries, currants and gooseberries came more into prominence. The currants and gooseberries were worked up quite thoroughly from the botanical as well as from the horticultural standpoint. In these two fruits we have both European and American species represented in the varieties under cultivation. As in the case of the grapes, the European species show greater susceptibility to fungus attacks than the American ones. This is compensated for in a degree by a superior quality of fruit.

In the first report issued by this Station the subject of huckleberries[18] was taken up, the horticulturist stating " it will hardly be denied that the huckleberry possesses better natural qualities than either the currant or gooseberry, yet the latter have been cultivated for centuries while the former has received very little attention — the reasons for this neglect do not appear." Quotations from correspondence and from newspaper articles are given to prove that it is possible to cultivate huckleberries successfully, the chief difficulty being apparently that the seeds germinate and the plants mature very slowly, not bearing until they are from three to five years old; also, it is said that the dry seeds soon lose their vitality.

There is considerable opportunity for confusion in discussing this subject owing to the fact that there are several plants quite different botanically, which in various portions of the United States pass under the name of huckleberry. Three of these are known botanically as *Vaccinium corymbosum*, *V. pennsylvanicum* and *V. gaylussacia resinosa*. Eight full grown plants of the first two species were transplanted to the Station gardens in the spring of 1882, and five of them grew, one of which blossomed but set no fruit. The next year a good many seeds of the huckleberry were planted and the

[18] Rpt. 1:145 (1882).

older plants made a quite vigorous growth. Two years later it is noted that the bushes in this plantation were still alive and that some fruit was matured. The difficulty was found in growing seedlings, the young plants being very delicate and requiring the most careful treatment. An examination of the flower showed that pollen was present in considerable quantities and that there was nothing in the structure of the flower apparently to forbid artificial crossing. After five years it is stated that no success had been attained in growing huckleberry seedlings, the young plants failing to develop under all methods tried. "The immense natural plantations of the various species of this fruit, which must largely be produced from seed, proved beyond question that when the secret of their culture is once learned there should be no trouble in growing the seedlings."

It is stated that further efforts would be made in this direction but there is apparently no record of the results and there are no plants on the Station grounds to-day to indicate success. Possibly the reason for these repeated failures may lie in the fact that lime is present in the soil in too large quantities for this fruit. Professor Lazenby of Ohio advanced the idea some years ago, which he supported with much evidence, that certain species of huckleberries will not grow in limestone soils or in any soils in which lime is present in large quantities.

AN EXPERIMENT IN SHADING STRAWBERRIES.

During the later nineties the question of the advisability of shading certain crops from the sun by the use of cloth covers was much agitated. On this account an experiment was started to determine the effect of shading on strawberries. This experiment was carried on for two seasons in three localities. The results[19] indicated that under New York conditions, a covering of cheesecloth did not have a very marked effect on the resultant crop. "Only when thin cheesecloth was used was any increase in yield obtained, while with a moderately heavy cheesecloth there was a marked decrease. In no case was the increase in yield sufficient to pay for the added cost of shading which was estimated to be about $350 per acre." The writer states that the results secured by other investigators elsewhere were more favorable than those obtained in this experiment.

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[19] Bul. 246; also in Rpt. 23:229 (1904).

The practice, however, according to the same authority, has never become general.

An estimated account was given of the cost of shading strawberries with mention of the annoyances caused by wind tearing cloth, etc. Tables are appended giving the temperatures for morning, noon and evening of outside air, air under cloth, and of soil three and one-half inches below the surface, under cloth and outside. Investigations showed that there was slightly more moisture in the soil under the cloth than was found in similar positions in the strawberry bed outside, but the difference was very slight. The evaporation was found to be about only one-half as great under the cloth as outside. On this account one of the persons conducting the experiment off the Station grounds advises that if cloth is to be used for this purpose " it be removed after a rain until the leaves had become dried." The protection from frost was quite noteworthy; in one case where frost occurred at the time when the bed was covered, plants outside showed considerable injury, while those underneath the cloth were practically unharmed. In this case the injury was chiefly to the buds, 85 per ct. of those outside showing the effects of the frost, while only 7 per ct. of those covered showed any injury.

In the case of one variety the plat under the cloth was considerably more affected by leaf blight. This variety, the Hunn, is stated to be very susceptible to disease. Mildew was also found, in one locality, to be more prevalent on the shaded plants than those unshaded. It was thought, however, that this can be prevented by withdrawing the cloth after a rain as is mentioned above.

Analysis of the berries showed that those grown under the cloth " were much less sweet, but this was not due to the presence of more acid but of very much less sugar, the acid being slightly less in the shaded than in the unshaded berries."

A discussion is given as to the general effect of shading plants and of the " general applicability of shading as a cultural practice." The writers are of the opinion that the climate of New York State is not such that this would be generally recommended, at least so far as strawberries are concerned. They state that the greatest success has attended the shading of " crops grown for aerial vegetative parts." Tobacco, rhubarb, celery, lettuce, dandelion, swiss chard and asparagus are cited as instances. They state further that a climate, where there " is a high percentage of sunshine and rather light rainfall, and a considerable wind with a consequently high

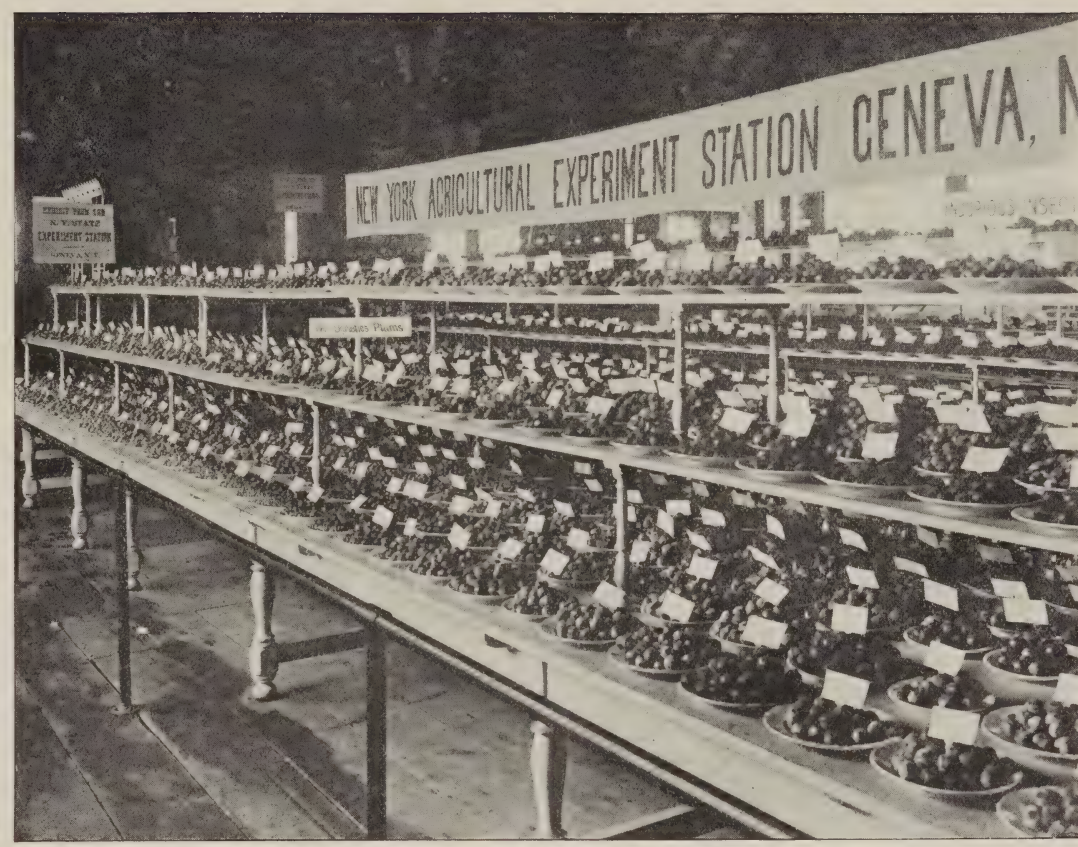

PLATE XVIII.— EXHIBIT OF FRUIT AT STATE FAIR.

rate of evaporation, is one in which the shading of appropriate crops would probably give good results." Such conditions do not prevail in New York.

PLANT BREEDING.

The various problems connected with breeding of plants, such as blooming dates, pollenization and fertilization of blossoms, selection of parents, etc., have occupied the attention of the horticultural department ever since the Station was established. At the close of the second year observations were made tending to show that cross fertilization[20] is exceedingly common in the case of our common varieties of vegetables and flowers. Seeds gathered from plants of the pepper, tomato, bean, balsam, petunia, zinnia, phlox, dianthus and aster growing on the Station grounds, and which had shown themselves to be true to name, showed evidence of mixing when planted the succeeding year. "It seems entirely safe to say that as a rule to which there are few exceptions, different varieties of vegetables are sure to become mixed if grown, for seed, adjacent to each other. In consideration of this fact, we are inclined to wonder that purchased seeds so often produce plants true to type." Such observations are of interest in that they show the necessity of having more or less isolation when it is desired to save the seed. In most cases it would simply mean that the farmer would prefer to buy the seed rather than take the trouble necessary in keeping it pure; this being undoubtedly the cheapest method where only small quantities of seed are desired. It was also found by investigation that there was a great difference in the natural vigor of certain plants, that is, the value of seed would depend largely upon the vigor of the parents from which they were secured. Seed was gathered from two plants of the Little Gem tomato. One of these plants was markedly vigorous, the other equally marked for its lack of vigor. Seed was saved from the resulting progeny for three generations, the offspring of the feeble plant becoming more feeble with each generation until at the close of the experiment they "were scarcely more than one-fourth of the size of the vigorous ones." Equally disastrous results followed the selection of immature seed for the same length of time, the injury appearing, as in the former case, to be cumulative and resulting in ultimate destruction of the plant.

One of the first crossing experiments carried on by this Station was that of the French upright or tree tomato crossed with several

[20] Rpt. 2:222 (1883).

varieties of the spreading type. It was thought that the French upright, owing to its shape and character of growth, had many advantages for a garden tomato, its chief disadvantage being that it ripened so late. The object of the cross, therefore, was to combine the desirable qualities of both types. At the end of the first season it was thought that they were in a fair way to accomplish this end, but disappointment evidently came later. It was noticed that the French upright was more prepotent than the spreading garden type as the majority of the offspring resembled the former type. As this has been taken by investigators later as one of the best plants for illustrating Mendel's Law, it is strange that some thought of the proportions in which the different types were represented in the offspring did not occur to these investigators. However, they were after new and superior varieties rather than demonstrations of any laws of breeding.

One of the fruits crossed by the Station was the strawberry. At different times, the work having extended over several years, 1,700 seedlings, both parents being known in every case, were raised upon the Station grounds and fruited. Most of these were discarded at the close of the first fruiting year. Others were saved for further testing. Ultimately, however, all were discarded, they being deemed less valuable than already existing varieties. The percentage of valuable plants among these seedlings is said to have been very small and peculiarly few of the seedlings resembled their parents.

One of the interesting things in the crossing of plants is what is known as xenia. This is a name given to those instances where pollen of one variety when placed upon the flower of another variety so changes the fruit that it resembles that of the plant from which the pollen came. Instances of this in corn and other plants had been observed many years ago and occasional cases had been noted amongst fruits. In all the various crosses of strawberries, grapes and other plants carried on at this Station, not a single instance had been noted of the occurrence of xenia.

A question that came up incidentally with the preceding investigation was that of the effect of rainfall upon pollination. This was a joint experiment between S. A. Beach of this Station and D. G. Fairchild of the United States Department of Agriculture. In this experiment two Dutchess grapes and two Mt. Vernon pear trees were sprayed continually with a Vermorel nozzle attached to an ordinary garden hose so as to produce an artificial rain. Observations were made from time to time as to the condition of the blossoms. In the case of the pear tree mentioned pollen was found on the stigmas and pollen taken from fresh anthers germinated in artificial solutions. In comparing the sprayed with the unsprayed portions of the tree it was evident that the continuous spraying retarded the development of the flowers very materially. The effect on the foliage was very disastrous. The total length of time which the pear tree was kept wet was nine days and three hours. The tree bore only one fruit. In the case of the grape the effect was similar to that of the pear. The same marked retarding of the development of the flowers was observed and the same injurious effect to the foliage, though in a lesser degree. A microscopic examination of the pollen after eleven days' exposure to the spray disclosed no injury. Unfortunately the spray was not continued during the whole blossoming period so the effect on the resulting crop could only be inferred. It was noticed that the clusters borne by the sprayed vine had more abortive berries than those from the check vine alongside.

Other work done on the crossing of plants was that of the crossing of grapes for which see page 307.

FERTILIZERS FOR HORTICULTURAL CROPS.

Some work had been done by the horticultural department at different times to determine how much and what sorts of fertilizers should be used on various horticultural crops. Years ago numerous analyses were made by the chemical department of fruit trees growing in the nursery, the object being to determine the quantity of each element taken up by the trees during the first few years of growth. The results are published in tabular form.[21] Coincident with these a series of questions was sent out to a large number of nurserymen asking for observations as to the effect of following one nursery stock with another upon the same land; whether it is material as to what stock should follow another; and whether farm crops can be grown successfully upon land from which nursery stock has just been removed. The opinion was practically unanimous that good nursery stock could not be raised upon land which had just been used for that purpose. Pear trees were mentioned as being particularly exhaustive to the soil. However, after an interval of some years the land apparently recovers and can be used

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[21] Rpts. 10:162 (1891); 11:173 (1892).

again. Stone fruits following seed fruits gave much better results than the reverse rotation. In reply to the second inquiry, it was unanimously agreed that excellent grain crops could be raised upon land from which nursery stock had just been removed.

FERTILIZER ELEMENTS IN FRUIT CROPS.

Later, an investigation[21a] was made to determine the amounts of nitrogen, phosphoric acid, potash, lime and magnesia used in one growing season by bearing fruit trees. From one to three varieties of apples, peaches, pears, plums, and quinces were selected for this test. The writers call attention to the fact that the results given by analyses of the plant do not perhaps correctly indicate the actual amount of plant-food required, since excess of any element might be taken up on account of its plentifulness in the soil, and on the other hand, if certain elements were more plentiful in the soil, they might be taken up in larger quantity to the benefit of the plant. They are of the opinion, however, that multiplication of data of this kind is valuable since an approximate idea is gained of the quantity of plant-food required. The different kinds of fruits are considered separately.

Tables are presented giving the analyses of fruit, leaves and new wood in the case of apples, pears and quinces; and fruit pulp, stones, leaves and new wood in the case of peaches; and fruit pulp, stones, stems, leaves and new wood in the case of plums. From these analyses an estimate is made of the amount of fertilizer that should be applied to the ground in which fruit trees are growing each year in order that there will be no depletion of the plant-food in the soil. This information is given in the form of tables, one of which is appended below. The amount of plant-food used by the trees, branches and roots in increasing their size is not included in these analyses. It is stated that if the soil were absolutely destitute of these forms of plant-food, this would be the minimum amount that should be supplied. Since, however, no soils are absolutely lacking in any form of plant-food, account must be taken of the relative amounts of these plant nutrients already in the soil. A statement is made that "we can ascertain what we want to know about the amount of available plant-food the soil can furnish only by rather crude experimenting."

[21a] Bul. 265; same in Rpt. 24:255–275 (1905).

AMOUNTS OF PLANT-FOOD USED PER ACRE.

Variety.	Number of trees an acre.	Nitrogen.	Phosphoric acid (P_2O_5).	Potash (K_2O)	Lime (CaO).	Magnesia (MgO),
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Apple........	35	51.5	14.0	55.0	57.0	23.0
Peach........	120	74.5	18.0	72.0	114.0	35.0
Pear........	120	29.5	7.0	[illegible]3.0	38.0	11.0
Plum........	120	29.5	8.5	38.0	41.0	13.0
Quince........	240	45.5	15.5	57.0	65.5	19.0

FERTILIZERS FOR FORCING HEAD LETTUCE.

This investigation was inaugurated in the autumn of 1895, the object being to determine the comparative value of different soil mixtures in forcing lettuce under glass. This work was continued for several years, reports of progress being made in bulletins and in the annual reports.[22]

"A soil mixture which had been used for forcing lettuce with good results, composed of three parts rotted sod from a clay loam, one part sand and one part stable manure, was at first compared with the other mixtures which were made from it by adding different amounts of sand. In some later tests the amount of sand was still further varied or omitted entirely. In one case sand and stable manure were used without any loam." Commercial fertilizers were also used on some of the soils, both alone and in combination with the stable manure. The effects of the various soil mixtures on the following points were carefully noted: Earliness, texture, shape and size of head; that combination being considered best which gave the best results in all of these particulars. It was found that, all things considered, the clay loam with a heavy application of stable manure gave the best results. A heavy application in this instance means about 30 per ct. stable manure. The addition of nitrate of soda to this soil gave practically no increase in growth. With half this quantity, or 15 per ct. of manure, the use of nitrate of soda did give a slight increase in growth. In every instance the use of barnyard manure on the clay loam increased the crop. This was probably due to the fact that it benefited the soil physically as well as adding plant nutrients. On the other hand, the use of barnyard manure on sandy loam was disastrous in its effects, the poorest crop of all coming from this combination; and the heavier the application of manure, the poorer,

[22] Rpt. 14:108 (1895).

apparently, was the crop. Excellent lettuce, however, was produced on the sandy loam by the use of commercial fertilizers alone. No advantage was gained either on the clay loam or the sandy loam from the addition of sulphate of potash and acid phosphate when the soils had already received a heavy application of stable manure. The clay loam was composed of rotted sod from an uncultivated field; the sandy loam was from the side of a cultivated field where it had been drifted by wind. Analyses showed that the latter soil contained far less plant-food that was the case with the former.

In comparing the various nitrogenous fertilizers in combination with stable manure, it was found that nitrate of soda gave the best result on a sandy loam. Dried blood was next with comparatively little difference in the crop. Sulphate of ammonia gave the poorest crop of all. On the clay loam the sulphate of ammonia gave the best results, with the dried blood the poorest of all. The variation in size of crop with the different fertilizers, however, was not so great on the clay loam as on the sandy loam. The general results were of interest in that they indicated that with light soils it is advisable to use commercial fertilizers, while with heavy soils, stable manure is more satisfactory. Perhaps the lesson that may be drawn from the results is quite as important as the results themselves; that is, that the physical condition of the soil is quite as important a factor in determining the growth of a plant as the quantity of plant-food present.

Later this work was carried further and a comparison made of the respective values of the different forms of nitrogenous commercial fertilizers.[23] Lettuce was planted in boxes filled with the soils already described. To one series was added dried blood, dried blood and nitrate of soda to another, and sulphate of ammonia to a third lot. With each of these acid phosphate and muriate of potash were used. The quantity of each fertilizer was sufficient to exceed the needs of the crop. As compared with check lots in which no commercial fertilizer was used there was a decided increase in yield; but the use of commercial fertilizers alone 'proved inadequate for forcing the lettuce in a sufficiently short time to be profitable.' On the clay loam, with no stable manure, a better yield was generally obtained where nitrate of soda was used than where either sulphate of ammonia or dried blood was used. On the sandy soils the results with dried blood were generally superior to the results with nitrate of soda or sulphate of

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[23] Bul. 208; also in Rpt. **20**:321.

ammonia. With the sulphate of ammonia the results were very variable.

Dried blood, combined with the smaller percentage of manure, gave, in the aggregate, better results than either nitrate of soda or sulphate of ammonia similarly combined.

The best crops were grown where the soil was fertilized with stable manure.

Those portions of soils which received applications of 5 per ct. of manure in combination with the commercial fertilizers always showed a very great increase in yield over corresponding soils which were treated only with the commercial fertilizers. Further increase in the manure, however, was not followed by a corresponding increase in the yield.

When soils similar to those under test are used for the first time for forcing a crop of lettuce, much more manure may doubtless be used with profit than would be profitable where manure has been used abundantly with previous crops.

Where the use of manure is continued year after year on soil originally not rich enough to force good lettuce the optimum amount may be expected to decline first toward 10 per ct., eventually to approach 5 per ct.

The amount of manure which may be used with good economy in forcing lettuce varies with the character of the soil and of the manure, and also with the differences in prices received for fancy lettuce and ordinary lettuce. For these reasons no definite amount can be recommended.

Repeated applications of excessive quantities of manure to the same soil are not good economy. Manure is thus wasted and the yield may be reduced.

Where large amounts of manure were incorporated in the soil for forcing lettuce the yield was increased by compacting the soil. This shows that unfavorable effects which follow excessive applications of manure may be caused, in part at least, by thereby loosening the soil so much as to put it in an unfavorable mechanical condition for the lettuce plant.

The clay loam used in these experiments has always proved superior to the light sandy loam for forcing lettuce when both were fertilized with equal amounts of stable manure.

While these results apply directly only to the forcing of lettuce it is probable that they may be used in a general way in the growing of all crops where the leaves are the edible portion; and it has been proved both by other experiments at this Station and investigations elsewhere that the superiority of commercial fertilizers over stable manure for light soils, and the superiority of the stable manure over the commercial fertilizers for heavy soils holds in a general way for all plants and all localities.

WOOD ASHES AND APPLE SCAB.

The only other investigation[24] to determine the effects of any fertilizer on horticultural crops was an experiment to determine if applications of wood ashes to the soil in apple orchards would prevent or lessen apple scab. The writer states that this experiment was started owing to suggestions on the part of the members of the Western New York Horticultural Society, some of whom were strongly of the opinion that the condition of the soil in which trees were growing was largely responsible for their susceptibility or immunity to apple scab. It is noted that this was contrary to the results of the investigations previously made, which had apparently shown that the prevalence of scab depended on the variety and the weather during the growing season, and particularly during the blooming period.

The varieties treated were Baldwin, Fall Pippin, Rhode Island *Greening*, Roxbury and Northern Spy. This experiment extended over five years. " The results show that with the conditions under which this investigation was made, liberal applications of hardwood ashes to the soil did not increase the immunity of the apples from scab. Whether the results would be the same on soil, which is naturally very deficient in potash, remains to be demonstrated."

Aside from the negative effects of the ashes as a fungus preventive, an improvement was noted in the color of the fruit in practically all the varieties. The effects on the keeping quality were very contradictory and it is impossible to draw any conclusions. The majority of the evidence, however, indicates that the applications of ashes slightly extend the keeping time of the fruit. Some interesting observations are made on the differences in structure observed in the skin of the fruit in resistant varieties as compared with less resistant varieties. The writer says: " Fall Pippin makes itself conspicuous each year by taking front rank among the varieties which are susceptible to this disease, while Maiden Blush, even in a most unfavorable season, has comparatively little of the disease." Other resistant varieties are Ben Davis, Grimes, and

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[24] Rpt. 16:316 (1897).

Tolman *Sweet*. Susceptible varieties are Fameuse, Esopus *Spitzenburg*, and Rhode Island *Greening*. The statement is made that, so far as examination has been made, the resistant varieties have thicker cuticle and thicker walled epidermal cells. The proposition is advanced that these resistant characteristics might be intensified by breeding and selection.

VEGETABLES.

Much time during the first years of the horticultural department's existence was spent in testing vegetables. Many of the so-called varieties of vegetables sent out by our seedsmen are practically identical, although passing under different names. Many others, while not exactly identical, are quite similar. It was with the purpose of correcting this synonymy and arranging the various varieties according to their apparent relationship that this work was started. Something in the nature of a monograph of a particular vegetable is given in each one of the earlier reports of the Station; that is, while notes are given on the current year's tests of vegetables in general, some one particular vegetable is written up in detail. Besides the description of each variety under its name, other information is given in tabulated form with those varieties classed together which, in the opinion of the experimenter, are most closely related. This work has been carried out with a thoroughness and attention to details which would seem to have justified a more widely extended dissemination than the expensive annual reports of the Experiment Station permit.

In the First Report[25] of this Station, beans are treated in the manner indicated, eighty-three or more varieties being tested, the number being considerably reduced, however, in the report by combining those which proved to be identical. Eight varieties failed to mature, including all of the lima beans tested. All the varieties are classified according to a system credited to a German, Martens. The next year this work was extended, 251 varieties being planted. Some of these, however, failed to vegetate and many of the southern varieties matured no crop, some of them not even blooming. It was found that when all varieties which came under different names but which proved to be identical were counted as one, there were 102 distinct varieties under test. A very detailed tabulated life history of each variety is given and the individual varieties are classified and described in the text following the table.

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[25] Rpt. 1:89 (1882).

It is now believed that variations which occurred in the bean crop for 1882, and which were credited at the time to impurities in the seed secured from the seedsmen, were probably due to cross fertilization, being instances of what is known as xenia. This opinion is based on the fact that the crop of 1883 showed unmistakable signs of cross breeding. Fifteen varieties are given in which these variations occurred, with detailed description.

The same year this work was extended and to quote the investigator, "almost the entire list of garden plants offered by our American seedsmen, as well as many others from foreign places" were planted "with other objects in view than the mere comparison of the yields and the qualities." The principal object of the investigation is "to discover how many of the so-called varieties planted are really distinct and how many are only synonyms." Reference is made to similar work[26] having been done by Mr. Fearing Burr, Jr., of this country, and M. Louis Vilmorin of Paris. Lists are given of numerous varieties of twenty-five vegetables, with the date of planting, date of appearance above ground, and length of time elapsing before edible portion of plant was fit for use, also the yield. The synonyms are given under each vegetable separately. The author indicates that, in some instances at least, it is not easy to determine whether two given varieties are strictly identical or merely similar. The varieties tested are particularly numerous and the subsequent discussion particularly full in the case of tomatoes and peas.

In the case of tomatoes the test included sixty-four named samples. The tomatoes were found particularly difficult for the detection of synonymy. Certain varieties were found to be "exactly similar in appearance" but with a different ripening period.

The "trial list of peas embraced seventy so-called varieties." Seven names are believed to be synonyms, and one or two other varieties resemble each other so closely as to leave the writer in doubt whether they are not identical. This test of peas includes an investigation "to ascertain how much may be gained in the earliness of peas by selecting the earliest pods for seed." It was found that there was a 14½ per ct. increase in the germinations of the earlier ripening peas as compared with the later ones. The earlier ripening peas were also fit for the table earlier by an average of five

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[26] Garden Vegetables and How to Cultivate Them, by Fearing Burr, Jr., 1866.

days and they also gave a slightly larger yield. "This difference was more noticeable while the plants were growing than after they had ripened their crop."

In the Third Report[27] a monograph is given of the garden peas. In the introduction we are told that there are three botanical species to which our agricultural peas may be credited: First, *Pisum sativum,* the common garden pea which may be known by its white or bluish white flowers and by a thin but tenacious lining to the pods. Second, *P. macrocarpon,* frequently called sugar pea, but inappropriately, since these peas really contain less sugar than those of the previous species. There is no lining to the pods as in the *P. sativum* and consequently varieties of this species are frequently eaten, pod and all, after the manner of string beans. Third, *P. arvense,* the field pea, having reddish purple or variegated flowers and a parchment-like lining to the pods similar to the *P. sativum.* The first species mentioned is of greatest importance horticulturally, its varieties being much more numerous than the others. The varieties of this species are subdivided first, according to stature, whether dwarf or standard; second, according to color of seed; and third, according to whether the seed be wrinkled or smooth. Ninety-eight varieties are included, many of which are now either out of cultivation or passing under different names.

The next year the vegetable[28] selected for study was lettuce. The treatment here is quite similar to that given peas. Of 200 differently named varieties tested during three seasons, eighty-seven are described as being apparently distinct. The writer states: "We scarcely hope the classification and descriptions which we here present will enable one unacquainted with the characters of the lettuce plant to name a given variety with ease and certainty. The most we dare to hope is, that with the help of these it may be possible to decide with some degree of certainty whether or not a given lettuce is true to the name which it bears." It is said that in work of this kind it is quite necessary that the plants be some distance apart so that each may assume its own individual character as distinct varieties are frequently difficult to separate when the plants are crowded together. This work seems particularly valuable in that before the description of each variety a list of synonyms is given with the name of the seedsman using each synonym.

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[27] Rpt. 3:228 (1884).

[28] Rpt. 4:156 (1885).

In the Fifth Report[29] of the Station attention was concentrated on the cabbage. As in the cases previously mentioned the entire list of varieties offered by American seedsmen and many of the varieties offered by foreign seed houses were secured for planting. There were 196 supposedly different varieties in the list. The real number planted, however, was greater, since seed of the same variety was planted from different seedsmen. The seeds were planted at different periods according to their season of ripening, the early varieties being planted during the first week in March, while certain of the later sorts were planted as late as the second week in May. Much of the information secured was tabulated as in the case of the other vegetables.

Much difficulty was found in classifying the varieties in spite of the fact that the number of varieties was not so great as with some of the other vegetables previously tested. This was due to the extreme variability often shown in the plant from the same sample of seed. The heading cabbage, in particular, was extremely variable. This variability may be due in part to impurity in the seed, but it is not thought to be wholly so. The writer objects to those varieties in which the characters are not fixed. He says: "We find in the writings of a prominent grower of and writer on cabbages, 'in the Wakefield cabbage the conical and flat are both normal.' The same author in speaking of the Stonemason cabbage says: 'The color of the leaves varies from a bluish green to a pea green and the structure from nearly smooth to much blistered.' Another well known seed grower says of the Early Jersey Wakefield cabbage: 'It must be admitted it presents many conditions; it is early, late, pointed, round, rough, and smooth leaved.' Admissions like these would seem to prove beyond question that the cabbage under consideration is either very poorly fixed or else from having been grown under very unfavorable conditions or through mixture with other varieties it has been permitted to deteriorate — the seed grower should certainly have an ideal for his varieties and this ideal should include not simply the part for which the plant is grown but the secondary characters as well."

The heading cabbages are divided into two main classes, the first including those varieties in which the leaves are smooth or only slightly blistered; the second, those varieties in which the foliage

[29] Rpt. 5:179 (1886).

is much blistered. These in turn are subdivided according to the shape of the head. Each of these is further divided according to color of foliage.

The next year there is a continuation of this work. The vegetables covered with more or less thoroughness were *beets, carrots, radishes, turnips, onions, celeriac, celery, spinach, cucumbers, squashes, pumpkins, egg-plant and tomatoes.* The notes on the different vegetables varied from a very few brief remarks in regard to a very few varieties to a test sufficiently complete to justify calling its discussion a monograph upon the vegetable. In view of the great patience and labor that such investigations require, it is to be regretted that their value is so transient.

In many cases the study of Professor Goff along this line included not only the test in the field but also an investigation of the literature of the subject tracing the history of the plant from the earliest time. In this volume he gives for the tomato a mass of botanical references running as far back as the sixteenth century. It seems probable that for this phase of the work he availed himself of Doctor Sturtevant's library, one of the best, if not the best, libraries of that kind in this country. If any criticism could be made of this work, either of its conception or the manner in which it was carried out, it would be that neither the head of the department nor his subordinates apparently had any idea of the amount of labor required to complete any contemplated line of investigation. Statements were made of intended investigations which would have taken all the time of a much larger force than was then available to the department.

From this time on the vegetable work was continued in a somewhat different manner. While many varieties were tested each season, no effort was made to concentrate the attention of the department on any one vegetable. Various methods of culture were tried and compared with each other and an effort was made to secure the newer varieties offered by seedsmen and compare them with the older standard sorts. Some general experiments were carried out in the early nineties to demonstrate the feasibility of forcing vegetables for the local market. It was found that, under the conditions existing in Geneva, there was a ready sale for such produce at prices that would apparently pay good profit above the cost of production.

SEED STUDIES.

Early in the history of the Station's existence the investigators became interested in the subject of seeds. Starting in with some very simple tests to determine the viability of seeds, the investigation ultimately assumed multitudinous phases. The initial experiment along this line was one by Doctor Sturtevant[30] to determine if what he calls Goethe and Hilaire's Law, that nature spares in one direction in order to spend in another, applies to seeds. If this be true, he says that "in gaining potency in fruit, we should expect weakness in seed; in exaggeration of bulb, a deficiency in leaf, etc." Any such law, if it were proved to be correct, would undoubtedly be of tremendous importance to all persons engaged in plant raising in whatever line. It would mean that in order to secure large fruit we should select undersized seed. To get perfect fruit, we should take more or less imperfect seed, etc. To test this point, a very large number of weights were made of the fruits and seeds of various cultivated plants. The resulting figures showed that the assumption is wholly incorrect. Plants which produce large fruit sometimes produce small seed and sometimes large seed, and the same is true of plants which produce small fruits. Goethe and Hilaire's Law, even if it be true in a general way, cannot be thus applied.

For the purpose of testing the vitality of seeds it has been the common custom with botanists and others for many years to use some sort of an artificial germinator. The conditions necessary for the germination of seeds are: First, presence of moisture; second, the presence of air; third, a temperature at which the seed to be tested will germinate, this varying with different seeds. If the seeds were planted in the ground, either outside or in the greenhouse, the conditions demanded would be fulfilled, but owing to the greater inconvenience this is seldom done, artificial germinators being used instead.

This Station at first used the saucer and blotting paper germinators. These were not wholly satisfactory. A later and more convenient apparatus was devised consisting of a copper box with a sliding glass cover with a ledge on the inside just below the top, the ledge supporting copper or glass rods which extend across the box. A long piece of cloth of the same width as the box and with tucks or hems sewed in at intervals completes the apparatus. The rods are run through these tucks or hems in the cloth and

[30] Rpt. 1:78 (1882).

the intervening cloth hangs down between the rods within about an inch and a half of the bottom of the box. The end of the cloth is left sufficiently long to reach the bottom of the box. The seeds are placed in the folds between the rods. About half an inch of water is poured in the bottom of the box to supply moisture. This apparatus is still popular with those who test seeds and is known as the Geneva Germinator. It is convenient, durable, and easily sterilized to remove any invading germs of decay.

The question was raised as to the accuracy of such germinators in testing the value of seeds, or rather the accuracy of seed testing; *i. e.,* whether 50 or 100 seeds selected from a large quantity and tested give a correct indication of the value of the lot To determine this point duplicate tests were made from the same batches of seed and the results compared. In the case of seed which was low in vitality either from age or any other cause, the results were very variable, ranging from 0 to 40 per ct. The greatest difference found in two tests of seed not more than one year old was 21 per ct. and the average difference for seeds, grown the previous season, of different varieties of twenty-four different kinds of vegetables was only 4.7 per ct. Later this work was carried farther to determine if a portion of these discrepancies might not be eliminated by increasing the number of seeds.

With watermelon seed four years old it was found where 50 seeds were used in each lot tested the "variation was 20 per ct.; with 100 seeds, just 20 per ct.; with 200 seeds, it was 6 per ct.; with 300 seeds, it was 5 per cent.; with 400 seeds, it was 2 per ct.; and with 500 seeds it was 6 per ct." With onion seeds where 50 seeds were used the "variation in germination between duplicates is expressed by 24 per ct.; with 100 seeds, by 15 per ct.; with 200 seeds, by 6 per ct.; with 300 seeds, by 4 per ct.; with 400 seeds, by 3 per ct.; with 500 seeds, by 2 per cent." It may thus be seen that increasing the number of seed does to a large degree remove the error arising from the seeds not running even, that is, not all being of a like degree of vitality.

It was found both in the investigations outlined above and in the regular garden work of the horticultural department, that much of the seed on the market is defective. This applies to seeds from all sources, and while criticism is not made of any individual seedsman the statement is made that our "experience justifies the reflection that our seedsmen scarcely exercise the proper care in the sending out of their seeds and in assuring quality in their varieties. * * * Our experience with 'grocery seeds,' that is the packages from boxes distributed to be sold on commission, has been so extremely unsatisfactory that we are fain to believe that it is only the ignorance of the purchaser that retains this abominable system of sale."

The statement is made[31] that "in the early spring we could not but notice the variation that existed between the germinative property of our seeds as tested in our apparatus and the vegetative property under the circumstances of actual planting. We hence devised a series of trials for testing the relations, if any, between germination and vegetation — by germination meaning the vitality sufficient to form a radicle, and by vegetation the vitality required to form a plant." Seed from the same package was taken, a portion of which was tested in the seed germinator and the remainder planted in clean sand at what was supposed to be the proper depth for the seeds in question. The results indicate that in the same seeds germinative capacity and vegetative capacity may exist in quite different amount. It was found that of the seeds which germinated the percentage forming mature plants was very variable, ranging from 4 per ct. up. Wherever there was a low percentage of vegetation as compared with germination, the seeds were invariably more than one year old. The results are very pointed in indicating that with old seed germinating power alone is not a true index of vitality.

In the light of our present day knowledge these results do not seem particularly surprising. In the case of old seeds it is manifest that if time in any way had injured the cotyledons or endosperm, making the stored plant food less available, if the embryo were uninjured, this would not necessarily lessen the percentage of germinations, although since the young plant could not properly utilize the food stored in the seed its chances of reaching maturity would be materially lessened. And if the germ itself had been slightly injured in the long storing process, even though strength sufficient might remain for germination it is probable that it would soon die.

The question how long seed may be kept without impairment of the germinating power is one of importance. In the early eighties a series of experiments was inaugurated along this line, the seed being furnished by different standard seed houses of the country. A part of the table showing results is appended below.

[31] Rpt. 5:56 (1886).

Germination Tests.

	Years age	No. of trials	No. of seed	Germinated Per ct.
Asparagus	1	15	450	86
	2	3	150	65
	3	2	100	40
	9	1	50	0
Beans	1	6	340	96
	2	6	240	69
	3	1	50	98
Beets	1	26	1900	71
	2	31	2750	71
	3	4	400	38
	4	3	250	69
	5	1	50	88
	6	4	400	62
	7	1	50	34
	9	4	300	33
	10	2	200	14
	12	2	100	40
	13	2	200	27
	14	1	50	10
	15	4	400	18
Broccoli	1	5	500	79
	2	12	1200	64
	3	2	200	59
	4	7	700	35
	5	2	200	31
	7	2	200	43
	11	2	200	3
Brussels sprouts	1	9	900	66
	2	2	200	80
	3	2	200	83
	9	2	200	0
Cabbage	1	76	7150	86
	2	82	6400	75
	3	47	3800	62
	4	10	1000	54
	6	5	500	14
	7	6	600	9
	8	1	100	0
Carrot	1	44	4400	86
	2	34	3400	34
	3	11	1100	20
	4	3	300	7
Cauliflower	1	44	4400	86
	2	26	2600	84
	3	17	1700	61
	4	15	1500	54

	Years age	No. of trials	No. of seed	Germinated Per ct.
Celery	1	11	1100	46
	2	9	900	23
	3	1	100	0
Cucumber	1	23	1122	85
	2	2	150	57
	3	4	108	95
	4	3	100	72
	5	2	50	60
	13	1	50	40
	19	1	50	14
Egg-plant	1	8	700	50
	3	2	100	39
	4	1	50	46
	6	1	50	28
	9	2	200	15
Kale	1	3	400	95
	2	2	200	93
	3	3	200	65
	4	1	50	16
	5	2	200	64
	7	2	100	58
Kohl Rabi	1	10	1000	80
	2	3	200	76
	3	1	100	94
	4	4	400	51
	5	2	100	44
	17	2	200	0
	20	2	200	0
Lettuce	1	22	2200	84
	2	47	4700	79
	3	34	3400	83
	4	27	2700	71
	5	15	1500	65
	6	10	1000	29
Melon, Musk	1	26	1120	88
	2	6	362	92
	3	4	200	77
	4	32	1492	79
	6	2	200	90
	7	5	300	90
	8	4	200	92
	9	1	50	36
	10	1	46	85
	14	2	100	49
Melon, Water	1	39	968	58
	2	19	611	65
	3	11	377	60

	Years age	No. of trials	No. of seed	Germinated Per ct.
Melon, Water	4	1	25	80
	6	1	25	80
	8	1	100	2
	9	2	100	20
	11	4	150	8
	12	4	150	10
Mustard	2	4	400	90
	3	9	900	92
	4	3	150	73
	10	2	200	5
	11	2	100	4
Onion	1	252	21157	74
	2	123	12300	57
	3	31	3000	28
	4	7	650	5
	7	1	100	0
Parsley	1	18	1800	57
	2	3	300	50
	3	4	400	8
	4	5	500	10
Parsnip	1	7	650	28
	3	6	386	9
	4	1	50	0
	6	2	90	0
Pea	1	20	1232	87
	2	70	3844	87
Pepper	1	17	1700	62
	2	24	2150	54
	3	11	647	41
	4	2	200	62
	5	6	600	19
	6	1	50	4
	8	2	150	3
	9	4	350	10
	10	5	500	.06
	13	2	200	.05
Radish	1	143	12700	77
	2	42	3100	61
	3	18	1450	50
	4	6	350	54
	5	4	350	37
	6	2	200	12
	7	1	100	3
	8	2	200	14
	12	2	200	0
Salsify	1	4	400	91
	2	4	150	73
	3	4	400	20

	Years age	No. of trials	No. of seed	Germinated Per ct.
Savoy Cabbage	1	10	1000	92
	2	8	800	86
	3	4	400	86
	5	1	100	33
	6	2	200	43
	7	3	300	23
	8	2	200	6
	10	1	100	0
	11	2	200	0
Squash	1	20	542	73
	2	16	595	76
	3	12	417	72
	4	2	100	63
	6	1	30	10
	10	3	67	6
	14	1	50	0
Tomato	1	19	1400	85
	2	32	2250	86
	3	15	1400	89
	4	11	1100	79
	5	11	1100	81
	6	2	200	96
	7	5	400	74
	8	12	950	76
	9	5	500	83
	10	11	600	75
	11	2	150	63
	12	4	400	86
	13	3	300	44
	14	4	300	74
Turnip	1	77	4100	88
	2	50	3400	94
	3	28	1900	94
	4	30	2150	79
	5	6	600	67
	6	3	300	58
	7	11	1000	56
	8	2	200	65
	12	2	100	49

Some of the lessons that may be drawn from this investigation are as follows: The manner in which seed is kept is quite as important a factor in determining its value as its age. Some plants are much more apt to give poor seeds than others. In raising certain crops it is hardly necessary to pay much attention to the securing of seeds which will grow, for practically all the seed on the market of that kind germinates readily while with other plants it is necessary at all times to exercise great care in order to get seeds that have been properly selected, properly kept, and that are not too old. Thus asparagus seed after the second year is evidently questionable in value and had better be avoided. Beet seed of less than five years of age need not be discarded on account of age alone. Cabbage seed apparently loses value rapidly after the fourth year. Celery seed is difficult to germinate even when fresh and care should be taken to get seed not more than one year old. Cucumbers, watermelons, and muskmelons may be classed together as having seed that is very resistant to the destructive influences of age and that even show better germinating power when five or six years old than when fresh. This has been corroborated by the practical experience of gardeners elsewhere. In the case of egg-plant the investigator calls attention to the importance of removing all abortive seeds, as with this and some other plants furnishing small seeds "the difference in the percentage of germinations is due rather to the percentage of empty seed cases present than to any lessened vitality of the true seeds. Lettuce furnishes a seed, which, although it is small, will keep four or five years under ordinary conditions without deterioration. Onion seed should in all cases be fresh as it loses vitality very rapidly after the first year. Tomato seed is apparently one of the most enduring of all seeds, deteriorating but little after ten or fifteen years of storage, and turnip seed has keeping qualities almost if not quite as good. By consulting such tables as these the planter can determine whether it is probably best to plant old seed on hand or secure a fresh supply. However, as is mentioned above, the answer depends partially upon how the seed has been kept.

A seed question in which much interest has been expressed at various times is that of the comparative value of large and small seeds. Possibly a more intelligent view may be obtained of this subject by a brief statement of what constitutes a seed. From the standpoint of the botanist or vegetable physiologist a seed consists of: 1st. The rudimentary plantlet, commonly called the germ or embryo. 2nd. The endosperm or stored food on which the plantlet lives until its roots are established in the soil and its leaves exposed to the sunlight. In the case of many plants the endosperm is not separate from the plantlet, stored food being contained in what are known as the cotyledons or seed leaves. 3d. The seed coat, a covering of the parts already mentioned, varying in density and character with different seeds but probably designed in all cases to protect the inner portions of the seeds from mechanical injury, excess of moisture and germs of decay. Thus it was found in experiments[32] at this Station that the seed coat evidently retarded germination. This is probably due to its keeping out a portion of the water which would otherwise be absorbed, the taking up of moisture being the first stage of germination. In all cases where this seed coat was artificially broken the seeds germinated in less time than similar seeds in which the seed coat was intact. A coat of tar or tallow increased the length of time necessary for germination.

In comparing the large with the small seed it is evident that the difference in size must be due to one of three causes; either the embryo of the one must be larger than that of the other, the endosperm greater, or both embryo and endosperm may be of an increased size in the larger seed. It seems probable that this greater size, whether it be due to embryo or endosperm, or both, would be of advantage to the seedling at least in the early stages of growth. Whether this advantage would continue after the plant had formed its own leaves and roots is not so apparent. To determine this point many tests were made with different kinds of seeds.[33] The tests were faulty in that the seeds were usually divided into large and small by the use of sieves, whereas weight would have been a more correct criterion. Of two seeds of different sizes the larger is generally the heavier, but this is not invariably the case. At different times seeds of the following plants were divided into two lots according to size. The plants were turnip, onion, cabbage, cauliflower, beans, corn, and oats.

In the turnip the small seed gave a slightly larger root than the large seed, the difference being only a fraction of an ounce. With the onion there was a slight difference in the crop in favor of the large seed. Of the nine varieties tested, one variety gave bulbs from the larger seed more than double those from the smaller seed. If this variety had been eliminated from the test the results would have been slightly in favor of the small seed. The results from the sowing of eleven packets of savoy and twenty-one packets of smooth cabbage seed exactly balanced each other, with the savoy the heavier heads coming from the small seed, while with the smooth cabbage the reverse was the case. In the test of large and small cauliflower

[32] Rpt. 3:328 (1884).
[33] Rpt. 1:80 (1882); 2:71 (1883).

seed the heads from the small seed averaged an inch larger in size and sixteen days later in maturing than those from the large seed.

In the case of beans the test was more thorough than with the other vegetables and carried through two years. The large and small beans were separated from two quarts of the commercial product. In both of the two years in which the experiment was carried on the crop from the large seed was greater than that from the small seed. The differences while not very great were sufficiently so to be decisive. Some of the notes in connection with this experiment are of interest. These are: 1st. That the large seed was slower in vegetating during the early stages of growth which is credited by the investigator "to the larger amount of dry matter to be acted upon by the moisture in the soil and for the chemical and other changes necessary to cause germination." 2nd. The plants from the large seed were found to be more vigorous after germination than those from the small seed which is considered to be due to the fact "that the larger amount of dry matter contained in the large seed after it becomes converted into available food for the young plant furnishes them with greater power to overcome any adverse condition attending vegetation." 3d. "That the number of seeds germinating or vegetating in the first few days is not a correct measure of the vitality of the seed." 4th. It would seem advisable in testing the germinating power of seeds to take into consideration the weight of the seed as well as their age.

Waushakum corn kernels were divided into two lots according to size. The resulting crop did not show that there was any material difference in the producing capacity of large as compared with small seed corn.

The test of large and small oat seed gave the most tangible and satisfactory results of all the seeds tested. The seeds were planted in alternate rows. The seeds used in this experiment were from the farm granary, 1,000 of the smallest and an equal number of the largest being carefully selected. It was noticed during the growing season that those rows from the large seed were vegetating more rapidly than the others. They ripened slightly in advance of the plants from the small seed. The respective crops were eleven pounds fourteen ounces of grain and thirty-four pounds twelve ounces of straw from the large seed plat, and eight pounds fifteen ounces of grain and thirty-two pounds six ounces of straw from the small seeded plat. It was found, also, that the individual oat grains from the large-seeded plat were slightly heavier than those from the small-seeded plat.

Corn which was kiln-dried before planting had greater value for seed purposes than the best selected corn of the same variety from the crib. This drying is preferably done some time before planting. The percentage of germinations is greater and the plants themselves were more vigorous. It was rather curious that this difference only showed in the field. There were two lots of 500 seeds each, one of which had been dried over a radiator and the other was fresh from the crib. When tested in the seed germinator both lots gave the same result, 94 per ct. of germinations, but when planted in the open ground the kiln-dried corn gave 80 per ct. of vegetation, while the corn from the crib gave but 20 per ct. of vegetation. This experiment was carried through several years with results which always pointed in the same direction.

Unfortunately this line of investigation seems to have been dropped and seeds of other plants were not tested in a similar manner. If the percentage of moisture in seeds at the time when planted influences the germinative and vegetative vigor of the plant it seems possible that to this cause may be credited the variable results secured from seeds of the same age and apparently similar condition.

It was found that the portion of the plant on which the seed was borne seemed in some cases to have an influence on the resulting seedlings. In Red Top Strap-Leaf turnip the seeds from the terminal blooms were distinctly larger than those from the lower branches. Sunflower seeds "taken from axillary flowers had narrower leaves and were of a lighter green than plants from seeds taken from terminal flowers." Sorghum seed which ripens from the summit downward sprouted more plants from the terminal seed than from the central or lower portion of the head.

This experiment was later repeated with three varieties of turnips with similar results. With cabbages, however, the results were wholly negative, no differences appearing between the seedlings produced by seed from different parts of the plant.

Certain plants furnish seeds of two different colors. Cases in point amongst the vegetables are endive, broccoli, brussels sprouts, collards, salsify, cabbage and kale. Seed was taken from all these plants and the light colored divided from the dark colored. It was found in every instance that the dark colored seeds were heavier than the light colored seeds from the same plant. When planted the dark colored seeds gave generally a higher percentage of germinations than those of the lighter shade.

Tests showed that a seed will stand repeated drying during the germination process without fatal injury. The seed used was of different varieties of different species of corn. Where this was repeated four or five times in succession, the drying period lasting usually seven days, the percentage of germinations was reduced very low and sometimes the seed was absolutely destroyed. The vitality of seeds in this respect is quite remarkable. Certain plants during the first few days or weeks of their existence evidently have a capacity to withstand drying conditions not possessed by the same plants later in life.

The value of green seeds is an important point with gardeners as well as seedsmen since it frequently happens that they find it necessary to use seed not fully matured. Investigations[34] were made at various times and with various kinds of plants to determine the value of green as compared with ripe seeds. The results from the different kinds of seeds do not agree. The seeds taken from a plant before maturity did not give as high a percentage of germinations as those which were allowed to remain until ripe. The plantlets themselves were also less vigorous. The yields were very variable, in some instances the plants from the green seeds giving the largest yields and in some instances the opposite was true.

In the case of peas seed gathered at the time when the peas were in the best eating stage gave only 3 per ct. of germinations and did not ripen the succeeding crop noticeably earlier than that from mature seeds. "A small percentage of the seeds taken from a tomato not fully developed in size and which had not commenced to change color toward maturity vegetated and developed into plants." These plants ripened their fruit earlier than the plants from mature seed. The percentage of germinations from the green seed was considerably lower and the plants themselves less vigorous than those from well ripened seed. Where green seeds were again taken from those plants which had come from green seed the vigor was still more reduced, the weakening effect being apparently cumulative, increasing with each generation until the plants had not sufficient vigor to make a good growth or resist any of the various diseases to which tomatoes are subject. In the case of radishes it appeared that when the plant itself was pulled up while the seed was green and hung inside, seed which was allowed to remain on the plant gave 81 per ct. of vegetations while the seed from pods removed from the plant at the time when the plant was taken indoors vegetated only 3 per ct. It is evident that a certain portion of the

[34] Rpt. 4:130, 133, 182 (1885).

maturing process in the seed will continue so long as the seed is on the plant even though the plant itself be removed from the soil.

The last phase of seed investigation carried out by this Station was "Seed Selection According to Specific Gravity."[35] The specific gravities were determined by the use of salt solutions of various strengths, the seeds being immersed in the salt solution and those rising to the surface being skimmed off, while those which sank were placed in a stronger salt solution. This method of determining specific gravity is, we are informed by the investigator, an old one used by gardeners in China and Japan for 250 years. Previous investigations have presented very contradictory verdicts as to the effect of this method of seed selection upon the resulting crop. As the results of the investigation here were different for almost every kind of seed used it does not seem strange that this should have been the case. As was shown in earlier investigations at this Station, and has been demonstrated elsewhere, with some plants heavier seeds will produce more vigorous seedlings than those of lighter weight.

The writer thinks it possible that in many instances the grading of seed according to specific gravity is practically the same as grading according to weight; that is, the heavier seeds have the greater specific gravity and the lighter seeds the lesser specific gravity, so that the results might be wrongly credited to a greater specific gravity rather than to a greater weight of seed where these characters appear together.

Seeds of the following plants were tested: Mustard, timothy, clover, peas, carrot, turnip, cauliflower, cabbage, egg-plant and pepper.

In the case of the mustard it was found that the specific gravity varied from 1.01 to 1.21 with the most of the seed ranging on either side of 1.15. The earlier and apparently stronger germinations ranged from 1.12 to 1.19. The seeds of neither very light specific gravity nor very heavy specific gravity gave as good germinations as those of medium specific gravity. In the case of timothy, the seed of which ranged from 1 to 1.26, the best seed apparently in every respect was that of the heavier specific gravity, the percentage of germinations being greater and the plants more vigorous. Clover ranged generally from less than 1.17 to above 1.30, and seeds of medium specific gravity gave the best results, those from 1.23 to 1.26 being the best of the lot. Champion of

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[35] Bul. 256; also in Ann. Rpt. 23:335, 1904

England peas ranged from 1 to 1.31, the most of these being at the upper end of the series, 1.25 being an average for the lot, the best germinations coming a little higher, about 1.28. Here, as with the other seeds, there were many exceptions, sometimes a seed of lowest specific gravity giving a quite vigorous plant. In the case of the Swedish turnip, the seed of which varied from 1 to 1.18, those seeds which varied in specific gravity from 1 to 1.03 gave roots of an average weight of 9 ounces, those which varied from 1.03 to 1.12 gave roots with an average weight of 19 ounces; while from those seeds in which the specific gravity ranged from 1.12 to 1.18 the roots averaged 42 ounces.

These are the most striking results secured. The investigator cautions us, however, in accepting them in their entirety since there were no seeds sifted and it might be that those seeds of greatest specific gravity were also the larger ones. It does not seem, however, that this should make any difference to the man who would desire to select seed in this fashion for planting, since if the results were secured it will be immaterial whether they came from selecting larger seed or selecting seed of a higher specific gravity.

In the test of cauliflower seed the seeds were divided by the eye into small seed and large seed. The seed varied in specific gravity from 1 to 1.15, yet strange to say the small seed ranged from 1.12 to 1.15 but the large seed, even though of lower specific gravity, averaged much larger heads. The test of cabbage seed indicated very clearly that "the percentage of germinations among very small seeds is low, also that such seeds as do germinate produce small plants — the heaviest yielding plants were those from the large dark seed." In the case of the egg-plant it was found that practically all of those seeds with a specific gravity less than water did not germinate while the remainder practically all germinated. As egg-plant seed is generally low in percentage of germinations the investigator recommends this as a means of getting rid of the poor seed. In the peppers, the seeds of which vary in color as well as in size, it was found that the large white seeds gave much the best results. With one exception, in which case the plant grew from a medium white seed, every large fruit was from a large-sized white seed. Plants from dark seed were worthless, bearing in all cases small fruits and the plants themselves being feeble. The plants from brownish seed were somewhat better but not satisfactory. The small white seed produced plants which were very feeble and either failed to fruit at all or else produced small fruit. Those from medium sized white seed were fairly satisfactory, but the best results, as indicated above, came from the use of large white seeds.

An effort was made to determine the causes for the differences in specific gravities found in different seed of the same kind. The writer gives a list of the various chemical compounds found in the seeds with the specific gravity of each. This list is as follows:

	Specific gravity.
Fats	0.91–0.96
Legumin	1.285
Protein	1.297
Starch	1.53
Cellulose	1.53
Ash, about	2.50

It will be seen from this list that fat is the only component which is lighter than water. It is evident that all those seeds which are lighter than water must owe this property either to containing a large amount of fat or else to the presence of imprisoned air. The writer says, "it is well known that seeds vary very greatly in their composition." Wheat is reported as ranging from 8.58 per ct. to 17.15 per ct. in proteids, 66.67 per ct. to 76.05 per ct. in carbohydrates, etc.

These differences in composition may be due to differences in soil, climate, fertilization, or methods of culture. It is also stated that the specific gravity may depend on the ripeness of the seed. Wheat and rye have a lower specific gravity when dead ripe than when in the milk stage, while with peas the specific gravity increases with the approach of maturity. In many seeds with a rigid seed coat such as grape, squash, etc., the internal portion will, if for any reason it be not properly developed, shrink away from the outer hull forming an air space. In such cases a specific gravity test would be a test of proper development. From what has been stated it may be seen that determining the specific gravity is by no means an infallible method of indicating the quality of seeds. It is of doubtful practical use and certainly only to be applied to certain kinds of seeds. It may, however, be found of great service in removing impurities from seeds, whether these impurities be foreign matter or other kinds of seeds.

ROOT DEVELOPMENT.

Investigations[36] were made at various times during the history of the Station as to the root system of various plants. This work was started by washing out the roots from the soil to determine their position and extent. It was found that strawberry plants washed out about the middle of August had roots extending "nearly vertically downward to the depth of 22 inches. The horizontal roots were few and short, the largest being traceable but 6 inches." Nearly all of the fibrous roots were found directly beneath the plant.

Similar investigations disclosed that "the roots of the tomato plant are in their manner of growth opposite to those of the strawberry plant," the greater part of the roots extending horizontally and being situated about eight inches below the surface. The writer draws the deductions that in the case of the strawberry, since the feeding roots are situated almost directly beneath the plant covering an area scarcely larger than the leaves, "there is little danger of injuring the roots of strawberry plants by cultivation between the rows, even if the soil is disturbed to a considerable depth," the inference being that in the case of the tomato the opposite is the case.

The cauliflower was found to be a deep-rooting plant, the roots extending downward to a depth of three feet and horizontally about two and one-half feet. It thus appears that the cauliflower draws its sustenance from a greater area and depth than the tomato plant. The fibrous roots, however, are less numerous in the upper layers of the soil."

This was continued in subsequent years. Its importance is perhaps best indicated by the statement of the investigator in one of his introductions "that it would seem that before we can give an intelligent opinion as to the best system of cultivation to be observed, or the best method of applying fertilizers, for any crop, we should know something of the character of the roots that sustain the plants, and the position that these occupy in the soil. If the fibrous roots through which the plant receives its nourishment grow very near the surface, it is certain that any but the most shallow cultivation must lacerate these to a great extent. If, on the other hand, the fibrous roots chiefly lie deeper than the ordinary plow

[36] Rpt. 2:219 (1883); 3:305 (1884); 4:233 (1885); 5:157 (1886); 6:90 (1887); 7:171 (1888).

reaches, it may be advisable, in preparing a soil for such crops, to plow deeper than we usually do, and thus mellow and fertilize the soil at the point where the roots can be more directly benefited by culture and fertility." The writer states that this "is only preliminary work in what seems to be a most important and fertile field."

Observations were made on the root system of the pea, lettuce, endive, spinach, asparagus, onion, radish, beet, swiss chard, parsnip, carrot, muskmelon, cabbage, kohl rabi, and celery. These results show that all of the plants secure their nutriment from a much larger area than is generally supposed. The writer says that "it is obvious that the effects of hill manuring must be chiefly upon the young plant and that where no fertilizer is applied beyond the limits of the hill, it seems probable that the plant receives little benefit from the manure at the time when it is completing its growth and maturing its seed."

The writer speculates as to the probable use of the deeply penetrating roots of vegetables, particularly in the case of the pea, parsnip, etc. "Certainly they are not required for the purpose of sustaining the plant against wind. If they were in search of food they would hardly penetrate in this direction, for we have many examples in which the roots of plants have extended toward their food with a directness that seems almost like instinct. The fact that the fibrous roots are almost always most numerous in the upper layers of the soil would seem to indicate that a dearth of moisture had not existed here."

The root system of various other plants was examined later. The table below presents in a concise form the results of the investigation:

Name.	Greatest depth. In.	Maximum depth. In.	Horizontal length. In.
Orchard grass	36	21	21
Tall meadow oat grass	30	21	24
Kentucky blue grass	37	18	12
Meadow fescue grass	32	12	9
Red top grass	40	22	9
Medium red clover	34	21	12
Meadow fox tail	34	18	18
Bokhara clover	33	18	18
Bent grass	25	20	24
Yellow trefoil	20	....	15
White clover	24	15	9

Name.	Greatest depth. In.	Maximum depth. In.	Horizontal length. In.
Sheep fescue	27	12	9
Alsike clover	28	12	9
Timothy grass	34	15	12
Cucumber	18	12	48
Potato	19	8	30
Long red mangel-wurzel	26	16	39
Scarlet runner bean	30	....	48
Boston dwarf wax bean	24	....	24
Corn salad	12	....	12
Black Pekin egg-plant	24	....	24
Okra	24	....	36+
Parsley	30+	18	30
Yellow scallop bush squash	....	....	102
Purple top globe turnip	18	....	18
Montreal nutmeg muskmelon	24	....	60
Onion	18	12	12

It is not to be expected nor did the investigator think that the same results would be shown on all soils. It is stated that generally "fibrous roots having an abundance of food nearby are more concentrated" than where the opposite is the case. The soil on which these plants were grown is a fertile clay loam to the depth of from six to ten inches, resting on a tenacious subsoil of gravelly clay. "In roots which penetrate the soil it is only the youngest parts with their delicate root hairs and papillae that absorb nutriment for the use of the plant. The rates of growth of these roots are probably largely influenced by temperature and moisture and hence we should anticipate a non-accordance of observations made during different seasons or in different climates."

Carrot and parsnip seeds were planted in four-inch drain tiles so as to prevent the formation of all except vertical roots. These tiles were placed upright in the ground, the top flush with the surface soil. It was found that roots grew straight down until they came to the bottom of the tile (fourteen inches) where a portion of the roots continued their downward course and the remainder grew upward along the outside of the tile, branching more and more until within three to six inches of the surface where they extended out into the soil in the usual manner. When fertile soil was taken from the surface and placed around the bottom of the tile the roots did not rise to the extent that they did in the former trials. On this point the investigator says: "Botanists tell us that a certain degree of warmth, moisture and oxygen are indispensable to the development of roots and that when these are present the rapidity of growth and the number of branches are dependent upon the amount of available plant-food. In that stratum of the soil in which the balance of these four conditions is on the whole most favorable to root growth, the roots develop fastest and this is doubtless one law that governs their distribution."

"Market gardeners find transplanting young plants of cabbage, tomato, etc., while growing in a cold frame to be of great advantage in assisting them to endure the final removal to the open ground. The question arose as to the cause of the benefit thus ascribed to a process that would appear to be in itself detrimental." An investigation "indicated that the benefit chiefly arises from the longer roots being broken in transplanting which causes a compact growth of fibres near the base of the plant. This mat of fine roots carries the inclosed soil with it in the final transplanting and thus many of the feeding parts are in a condition to commence absorption at once in their new home. The experiments showed that precisely the same result may be secured by sowing the seeds thinly in the frame and then severely root-pruning the young plants from time to time. Whether this checking of the root growth by transplanting or root pruning is in itself beneficial" was not determined, the results of the investigation being inconclusive. "In experiments with young plants of cabbage and corn, root pruning seemed to increase the proportionate development of the root as compared with that of the top, but on the whole to retard growth. In every case where the root pruning was performed in dry weather the results appeared injurious to growth."

A mulching experiment showed "that mulching the surface tends to bring the fibrous roots" upward, the proportion of fibrous roots in the first two inches of soil being greater for the mulched than for the unmulched plants. It was noted that normally in cultivated fields roots are much closer to the surface than is generally imagined. A numerous supply of roots was found in August between the rows in a field of sweet corn within an inch of the surface. A microscope showed that these roots were covered with root hairs; that is, they were feeding roots. Practically the same conditions were found in field corn and tobacco. In the language of the investigator the results of this investigation are:

1st. "The chief feeding ground of the roots of our hoed crops including both those of field and garden is in the stratum of soil lying from three to ten inches below the surface. Several plants, particularly the legumes, the cabbage family, lettuce, parsley, parsnip, beet, and perhaps a few others, doubtless obtain a considerable amount of their nourishment below ten inches, but judging from the locality in which the fibrous roots are most numerous we may infer that even these secure more of their food above than below that depth."

2nd. "In general terms the plants make the largest development of stem and foliage during summer, as corn, sorghum, tobacco, and the cucurbitae, are those of which the feeding ground is shallowest in the soil."

Later an attempted application of these results was made in the field. It was found with corn that root pruning, such as would be caused by ordinary cultivation, seriously retarded the growth of the young plants, and that this lessened growth was detrimental to the crop harvested the following autumn. That this injury came from the root cutting alone independently of the effects of stirring the soil was demonstrated by using a lawn edger in place of the ordinary cultivator, the soil being stirred as little as possible, no cultivation being given throughout the growing season except scuffle hoeing and weed pulling. The results were the same as before, the root-pruned plants yielding decidedly less than those in which the roots were not pruned. A wet growing season seems to lessen the injury arising from this cause.

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