State of New York—Department of Agriculture

TWENTY-SIXTH ANNUAL REPORT

OF THE

BOARD OF CONTROL

OF THE

NEW YORK

Agricultural Experiment Station

(GENEVA, ONTARIO COUNTY)

FOR THE YEAR 1907

With Reports of Director and Other Officers

ALSO

INDEX TO FIRST TWENTY-FIVE ANNUAL REPORTS

TRANSMITTED TO THE LEGISLATURE JANUARY 15, 1908

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1908

STATE OF NEW YORK.

No. 29.

IN ASSEMBLY,

JANUARY 15, 1908.

TWENTY-SIXTH ANNUAL REPORT

OF THE

BOARD OF CONTROL OF THE NEW YORK AGRICULTURAL EXPERIMENT STATION.

STATE OF NEW YORK:

DEPARTMENT OF AGRICULTURE,

ALBANY, N. Y., *January* 15, 1908.

To the Assembly of the State of New York:

I have the honor to herewith submit the Twenty-sixth Annual Report of the Director and Board of Control of the New York Agricultural Experiment Station at Geneva, N. Y., in pursuance of the provisions of the Agricultural Law.

I am, respectfully yours,

CHARLES A. WIETING,

Commissioner of Agriculture.

NEW YORK AGRICULTURAL EXPERIMENT STATION.

GENEVA, N. Y., *January* 1, 1908.

Hon. CHARLES A. WIETING, *Commissioner of Agriculture, Albany, N. Y.:*

DEAR SIR.— I have the honor to transmit herewith the report of the Director of the New York Agricultural Experiment Station for the year 1907, in accordance with the provisions of chapter 439, Laws of 1904.

Yours respectfully,

T. B. WILSON,

President, Board of Control.

ORGANIZATION OF THE STATION 1907.

BOARD OF CONTROL.

Governor CHARLES E. HUGHES, Albany.
Commissioner CHARLES A. WIETING, Albany.
STEPHEN H. HAMMOND, Geneva.
LYMAN P. HAVILAND, Camden.
EDGAR G. DUSENBURY, Portville.
THOMAS B. WILSON, Halls Corners.
[1] MILO H. OLIN, Perry.
IRVING ROUSE, Rochester.
ALFRED G. LEWIS, Geneva.
[2] WILLIS G. JOHNSON, New York.

OFFICERS OF THE BOARD.

[3] STEPHEN H. HAMMOND,
[4] THOMAS B. WILSON,
President.

WILLIAM O'HANLON,
Secretary and Treasurer.

EXECUTIVE COMMITTEE.

STEPHEN H. HAMMOND, LYMAN P. HAVILAND,
THOMAS B. WILSON.

STATION STAFF.

WHITMAN H. JORDAN, Sc. D., LL.D., *Director.*

GEORGE W. CHURCHILL,
Agriculturist and Superintendent of Labor.
WILLIAM P. WHEELER,
First Assistant (Animal Industry).
FRED C. STEWART, M. S.
Botanist.
G. TALBOT FRENCH, B. S.,
[5] JOHN G. GROSSENBACHER, Pd.B.,A. B.,
Assistant Botanists.
LUCIUS L. VAN SLYKE, Ph. D.,
Chemist.
[6] ALFRED W. BOSWORTH, B. S.,
Associate Chemist.
ERNEST L. BAKER, B. S.,
[7] ARTHUR W. CLARK, B. S.,
[8] ANTON R. ROSE, B. S.,
MORGAN P. SWEENEY, A. M.,
[9] PERCY W. FLINT, B. S.,
[10] JAMES T. CUSICK, B. S.,
[11] OTTO MCCREARY, B. S.,
Assistant Chemists.
HARRY A. HARDING, M. S.
Bacteriologist.
MARTIN J. PRUCHA, Ph. B.,
JAMES WILSON, B. S.,
Assistant Bacteriologists.

GEORGE A. SMITH,
Dairy Expert.
FRANK H. HALL, B. S.,
Editor and Librarian.
PERCIVAL J. PARROTT, M. A.,
Entomologist.
HAROLD E. HODGKISS, B. S.,
WILLIAM J. SCHOENE, B. Agr.,
Assistant Entomologists.
ULYSSES P. HEDRICK, M. S.,
Horticulturist.
NATHANIEL O. BOOTH, B. Agr.,
RICHARD WELLINGTON, B. S.,
[12] MAXWELL J. DORSEY, B. S.,
Assistant Horticulturists.
ORRIN M. TAYLOR,
Foreman in Horticulture.
[13] F. ATWOOD SIRRINE, M. S.,
Special Agent.
FRANK E. NEWTON,
JENNIE TERWILLIGER,
WILLARD F. PATCHIN,
Clerks and Stenographers.
ADIN H. HORTON,
Computer and Mailing Clerk.
JULIA H. HOEY,
Junior Clerk.

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[1] Died May 20, 1907.
[2] Appointed July 27, 1907.
[3] Resigned Presidency August 6, 1907.
[4] Elected President August 13, 1907.
[5] Appointed June 1, 1907.
[6] Promoted from assistant chemist.
[7] Resigned; reappointed after a short absence.
[8] Absent on leave from October 1, 1907.
[9] Appointed February 25, 1907; resigned November 1, 1907.
[10] Appointed June 10, 1907.
[11] Appointed June 10, 1907.
[12] Appointed June 15, 1907.
[13] Riverhead, N. Y.

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Twenty-Sixth Annual Report

OF THE

Board of Control of the New York Agricultural Experiment Station.

TREASURER'S REPORT.

Geneva, N. Y., *October* 1, 1907.

To the Board of Control of the New York Agricultural Experiment Station:

As Treasurer of the Board of Control, I respectfully submit the following report for the fiscal year ending September 30, 1907:

Maintenance Fund — Necessary Expense.

APPROPRIATION, 1906–1907.

Receipts.

1906.			*Dr.*
Oct.	1.	To balance on hand..................	$0 04
		Amount received from Comptroller....	20,000 00
			$20,000 04

Expenditures.	*Cr.*
By building and repairs..............	$844 20
By chemical supplies	519 01
By contingent expenses	3,850 00
By feeding stuffs	1,099 59
By fertilizers	134 29
By freight and express..............	427 86

By furniture and fixtures	$870 51
By heat, light and water	622 33
By library	822 09
By live stock	516 00
By postage and stationery	1,783 29
By publications	2,651 29
By scientific apparatus	55 31
By seeds, plants and sundry supplies	2,335 08
By tools, implements and machinery	80 93
By traveling expenses	2,501 03
Balance, October 1, 1907	25 89
	$20,000 04

GENERAL EXPENSE — HEAT, LIGHT, WATER, APPARATUS, REPAIRS, ETC.

Receipts, 1906–1907.

1906.		*Dr.*
Oct. 1.	To amount on hand	$44 51
	To amount received from Comptroller	4,000 00
		$4,044 51

Expenditures.	*Cr.*
By buildings and repairs	$1,525 32
By contingent expenses	19 50
By feeding stuffs	50 20
By furniture and fixtures	283 80
By heat, light and water	1,916 54
By postage and stationery	1 25
By publications	130 96
By seeds, plants and sundry supplies	35
By tools, implements and machinery	80 93
Balance, October 1, 1907	35 66
	$4,044 51

Special Fund — Horticultural Investigation.

Receipts, 1906–1907.

1906.		*Dr.*
Oct.	1. To amount on hand	$217 52
	To amount received from Comptroller	8,000 00
		$8,217 52

Expenditures.	*Cr.*
By contingent expenses	$1,272 32
By freight and express	16 15
By library	49 25
By postage and stationery	1 90
By publications	540 56
By salaries	5,359 72
By seeds, plants and sundry supplies	356 54
By tools and machinery	7 20
By traveling expenses	613 37
Balance, October 1, 1907	51
	$8,217 52

Fertilizer Inspection.

Receipts, 1906–1907.

1906.		*Dr.*
Oct.	1. To balance on hand	$2,916 19
	To amount received from Comptroller	14,000 00
		$16,916 19

Expenditures.	*Cr.*
By building and repairs	$865 42
By contingent expenses	5 15
By feeding stuffs	3 35
By freight and express	122 68
By heat, light and water	546 33
By postage and stationery	16 61
By publications	974 12

	By salaries	$6,267 82
	By scientific apparatus	228 85
	By seeds, plants and sundry supplies	3 20
	By traveling expenses	633 41
	Balance, October 1, 1907	7,249 25
		$16,916 19

CONCENTRATED FEEDING STUFFS INSPECTION.

Receipts, 1906–1907.

1906.		*Dr.*
Oct. 1.	To balance on hand	$1,107 90
	To amount received from Comptroller.	3,500 00
		$4,607 90

Expenditures.

		Cr.
	By chemical supplies	$282 23
	By contingent expenses	6 60
	By freight and express	107 47
	By heat, light and water	45 30
	By postage and stationery	15 90
	By salaries	2,745 09
	By seeds, plants and sundry supplies	6 35
	By tools, implements and machinery	50
	By traveling expenses	789 32
	Balance, October 1, 1907	609 14
		$4,607 90

SALARIES.

Receipts, 1906–1907.

1906.		*Dr.*
Oct. 1.	To balance on hand	$835 70
	To amount received from Comptroller.	28,000 00
		$28,835 70

Expenditures.	*Cr.*
By salaries	$26,935 37
Balance, October 1, 1907............	1,900 33
	$28,835 70

LABOR.

Receipts, 1906–1907.

1906.		*Dr.*
Oct.	1. To balance	$2,000 99
	To amount received from Comptroller.	13,000 00
		$15,000 99

Expenditures.	*Cr.*
By labor	$13,824 54
Balance, October 1, 1907............	1,176 45
	$15,000 99

INSURANCE MONEY.

1906.		*Dr.*
Oct.	1. To balance	$22 0[illegible]

	Cr.
By balance on hand, October 1, 1907..	$22 0[illegible]

UNITED STATES APPROPRIATION.

Receipts, 1906–1907.

	Dr.
To receipts from the Treasurer of the United States, as per appropriation for fiscal year ended June 30, 1907, as per act of Congress approved March 2, 1887	$1,500 00

Expenditures.	*Cr.*
By salaries	$1,500 00

ADAMS' FUND.

APPROPRIATION, 1906–1907.

Receipts.

	Dr.
To receipts from the Treasurer of the United States, as per appropriation for fiscal year ended June 30, 1907, as per act of Congress approved March 16, 1906.	$700 00

Expenditures.	*Cr.*
By chemical supplies	$112 50
By salaries	587 05
By postage	45
	$700 00

All expenditures are supported by vouchers approved by the Auditing Committee of the Board of Control and have been forwarded to the Comptroller of the State of New York.

WILLIAM O'HANLON,

Treasurer.

DIRECTOR'S REPORT FOR 1907.*

To the Honorable Board of Control of the New York Agricultural Experiment Station:

GENTLEMEN.— I have the honor to submit for your consideration the report of this institution for the year 1907. In this report I have endeavored to set forth the important facts relating to the existing status of the Station, its policy, its needs for maintenance and progress, and a review of the principal facts and conclusions published in the bulletins of the year.

ADMINISTRATION.

STAFF.

Several appointments have been made to the staff during 1907.

John G. Grossenbacher, PD. B., A. B., a graduate of the University of Missouri and during the year 1906-7 a fellow in Harvard University, was appointed as Assistant Botanist with especial reference to plant pathology, to fill the position vacated in 1906 by Mr. H. J. Eustace.

Maxwell J. Dorsey, B. S., a graduate of the Michigan Agricultural College and for the year 1906-7 an instructor in Horticulture at the University of Maine, was appointed Assistant Horticulturist.

The following gentlemen were elected to the position of Assistant Chemist:

Morgan P. Sweeney, A. M., and James T. Cusick, B. S., graduates of Colgate University, the former having pursued a year's post-graduate work at the same institution in 1906-7; Otto McCreary, a graduate of the University of Michigan, and Percy W. Flint, a graduate of South Carolina College and at the time of his appointment an assistant chemist in the Pennsylvania State College Experiment Station. Mr. Flint has since resigned in order to take up further studies at the University of Illinois.

*Reprint of Bulletin No. 295.

MAINTENANCE FUNDS.

The maintenance funds appropriated by the Legislature of 1907 for the use of the Station during the fiscal year 1907-8 were the same amounts that were available during the year 1906-7, as follows:

Salaries	$28,000
Labor	13,000
Expenses of various departments of research	20,000
General expense, heat, light, water, apparatus, repairs, etc	4,000
Horticultural investigations	8,000
Fertilizer inspection	10,000
Feeding stuffs inspection	3,500

In accordance with a recent action of your Board, the following are the sums that the coming Legislature is to be asked to appropriate for the maintenance of the Station during the fiscal year 1908-9:

Salaries	$33,000
Labor	14,000
Maintenance expenses of departments of research	20,000
Horticultural investigations	8,000
General expense, heat, light, water, apparatus, repairs, etc	4,000
Fertilizer inspection	10,000
Feeding stuff inspection	3,500

THE MAILING LIST.

Early in the year the number of names listed to receive our bulletins and other publications aggregated approximately 44,900. A recent revision of the list for the purpose of removing from it the names of persons who had died or changed their place of residence, reduced the above number to about 43,200, a decrease of 1,700. It should be said that no additions are made to our mailing list except the names of those persons who express a desire to receive our publications. These are free to all the citizens of the State who ask for them. It is assumed that a bulletin will be of little benefit to a person who makes no effort to secure it.

The belief seems to be somewhat prevalent that the Station bulletins are issued monthly or at certain regular intervals during the year. Such is not the case. Bulletins are published only as fast as results are reached that are deemed of sufficient importance to print. The number ranges from twelve to twenty per year. Often the statement comes to us by letter "Why is my name removed from your mailing list? I have received no bulletins for three months." No name is ever discontinued except by request or because of some other necessary cause, such as death or change of residence.

The following is a summary of the list as it now stands:

POPULAR BULLETINS.

Residents of New York	34,800
Residents of other states	2,540
Newspapers	776
Experiment stations and their staffs	1,305
Miscellaneous	115
Total	39,536

COMPLETE BULLETINS.

Experiment stations and their staffs	1,305
Libraries, scientists, etc.	184
Foreign list	270
Individuals	3,338
Miscellaneous	115
Total	5,212

THE TWENTY-FIFTH ANNIVERSARY OF THE STATION'S ESTABLISHMENT.

On August 29th, 1907, exercises were very successfully held on the Station grounds celebrating the twenty-fifth anniversary of the Station's establishment. The institution was honored by the presence of the Chief Executive of the State, Governor Charles Evans Hughes, and other distinguished guests.

Addresses were made by Hon. A. P. Rose, Mayor of Geneva, Governor Hughes, Congressman Sereno E. Payne, Senator John Raines, President William Oxley Thompson of the Ohio State University, Hon. George L. Flanders of the State Department of Agriculture, Dr. L. H. Bailey, Director of the New York State College of Agriculture, Hon. F. N. Godfrey, Master of the New York State Grange, and Hon. J. A. Woodward, a member of the first Board of Control of the Station. Approximately 3,500 persons gathered to listen to the addresses. The day was fine and the spirit of the occasion was all that could be desired. The pleasures of the day were enhanced by the presence of some of the early members of the Station staff who have attained distinction, notably Dr. S. M. Babcock of the University of Wisconsin, Dr. J. A. Arthur of Purdue University, and Prof. H. H. Wing of Cornell University. The officers and friends of the Station are under great obligations to the Mayor and citizens of Geneva and especially to Capt. Stacey and the military company under his command, for their kind co-operation in making the celebration a success. Especial thanks should be tendered to the Governor of the State and to the other speakers, who gave inspiring and helpful addresses.

ADDITIONS TO THE BUILDING EQUIPMENT.

Dwelling houses.— The Legislatures of 1906 and 1907 made appropriations for new dwelling houses, an electrical lighting plant and other minor construction at the Station. The appropriation for 1906 was for two houses. When it became probable that additional houses would be provided for in 1907, it was decided to wait and carry on the construction under one contract. After the 1907 appropriation was secured, the State Architect kindly hastened the plans and bids were invited for the construction of the five houses, so that, if the bids had been satisfactory, their erection could have been begun late in September. Unfortunately the bids greatly exceeded the funds available and as the plans agreed upon by your Board called for houses as inexpensive as in your judgment should be built, it was decided to suspend operations and present the situation to the Legislature of 1908. In order to erect the five structures as planned, $10,000 additional should be provided. It is not asked that elaborate or ornate dwellings shall be erected but it is deemed essential that they shall be substantially built and shall be of modern construction and equipment. Anything less than this would not be creditable to a State institution.

Lighting and motor plant.— Construction has not yet begun on the electrical equipment authorized by the Legislature of 1907, but it is hoped that specifications will be received from the State Architect so that the plant can be installed in the early spring.

An auditorium.— My report to you for 1906 contained the following statements: "So far in its history the Station has suffered the disadvantage quite unusual to institutions of this class, of not having on its grounds an auditorium where audiences of any considerable size can meet. Such assemblages as have met with us have held their sessions either in the open air, or as was the case on one occasion, under a large tent. This fact has placed limitations upon our relations to the public and in view of the enlarging responsibilities of the institution constitutes a disadvantage that is increasingly evident. There are several agricultural organizations in the State that would meet with us occasionally and probably some would be glad to make our grounds a permanent meeting place. The means are few by which we could more effectively bring the public into an intelligent touch with our work. This is true not only of agriculture but of the educational efforts of the schools to which, I believe, this Station will in time come to sustain much closer relations."

The Legislature of last winter was asked to appropriate sufficient money to build an auditorium but the request was not granted. The reasons why such a structure should find a place on the Station grounds still exist and it is gratifying to know that your Board is not to cease its endeavors to secure this addition to our building equipment.

The function of the Station.— The question of the work the Station should undertake to do is an ever recurring one. Theoretically its primary office is to establish facts and principles that shall serve as a safe guide for conducting and developing agricultural practice. The effort cannot stop with this, however. It is equally the duty of such an institution to suggest new applications of knowledge, verify conclusions in their relations to agricultural practice, and disseminate the results of its investigations. All this the Station does in some measure. It must be confessed, however, that its efforts are not as closely confined to its real function as is essential to maximum efficiency. This is a time of the strenuous exploitation of agricultural knowledge and the agricultural public is demanding,— an attitude that has been assiduously cultivated by the leaders of agriculture,— that those connected with agricultural institutions shall be almost constantly acting as popular teachers, a service that is undoubtedly productive of great good. The experiences of the past year make it clear, however, that because of the continuous demands made on the members of the Station staff for speaking and exhibition work of an educational character, the management of the Station will find it necessary to determine just how far the institution shall be allowed to de-part from the real purpose for which it was organized. It is very certain that the members of the staff cannot successfully carry on important investigations and experiments unless they can give to such work their uninterrupted attention through a large portion of the year, a fact that is not fully appreciated by those without experience in studying scientific problems. It cannot be truly said that popular teaching is more important than the discovery of facts and principles, for indeed there could be no teaching without knowledge and no well established knowledge without careful and severe inquiry.

It needs but a glance at the progress of agriculture in the United States during the past twenty-five years to show that nothing has so powerfully promoted it as a few important discoveries. The experiment station workers who have established truths of general agricultural importance stand in the forefront of the benefactors of agriculture. So long, then, as so many important problems are not solved and the experiment station is the recognized research agency for each state, why should it assume the functions of the college or the school and become largely an agency for popular education? In this connection I take the liberty of referring to the remarks I made at the time of our twenty-fifth year celebration which are to be printed elsewhere. (Twenty-fifth Anniversary Report. Part III of the Twenty-sixth Annual Report of this Station.)

Requests for service of special kinds.— There come to the Station each year numerous requests for services of special kinds, such as the analysis of soil, drinking water, samples of feeds, fertilizers, seeds, milk, vinegar, mineral substances, stomachs of animals supposed to be poisoned, etc. Many persons evidently suppose that it is the rightful business of the Station to analyze anything that may be sent to it. These persons do not understand that to comply with these requests in an indiscriminate way would largely waste the funds of the Station and the time of its staff. The Station must necessarily hold itself pretty closely to activities that serve the interests of its constituents in a more or less general way.

The following explanations are offered with the hope that they will clear up misunderstandings in several directions.

Many requests come to us from manufactures of fertilizers and feeds and dealers in the same, for analysis of the products they manufacture or sell. In many cases there is expressed a willingness to pay for the service. The answer to these requests is that the Station does no commercial work and under no conditions whatever can it assume the burden of the chemical or other expert work of the trades.

Frequently farmers mail samples of feeds or fertilizers, asking for an analysis. In most cases these are samples of brands that are inspected by the State and it is unwise to duplicate work, especially when samples sent by consumers are liable, because of inexperience in sampling, not to represent fairly the goods from which they are taken. Users of feeds and fertilizers should utilize the official reports as a guide to the character of these materials. It would be impossible to make special analyses for each farmer in the State, but what is granted in one case cannot rightfully be refused in another.

It is often possible by the mere physical inspection of a sample of feed for us to determine what are the materials out of which it is made. This sort of an examination consumes little time and it can often be made the basis of useful advice to a prospective buyer. Such examinations we are glad to make.

It should be stated, however, that when an association of farmers makes a contract for the purchase of a large lot of feed or fertilizer on the basis of a guaranteed composition, the Station is always willing to make free analyses to determine whether the goods are according to the guarantee. This we have done in many cases.

Many samples of water are sent to us that we may determine their sanitary quality. Examinations of this kind are not undertaken by the Station as they properly belong to the State Board of Health, which is located at Albany.

Inquiries are frequently received by us as to the purity of samples of seeds. Such inquiries can be answered with comparatively little effort and our replies often serve to warn the farmers of a community against injurious adulterations, such as dodder and trefoil in alfalfa seed.

Requests are not infrequently received at the Station to have some member of the staff visit a particular farm or orchard or other agricultural operation in order to give expert advice as to the business management that should be followed. Such requests are made in good faith and with the best of motives and are a gratifying evidence of confidence in the Station, but they show something of a misconception of the kind of aid the institution can render to farmers. The Station staff is not made up of expert farm managers but of scientific specialists who are studying problems that are important to agriculture. To illustrate, the botanists study plant diseases and their remedies; the bacteriologists investigate soil and dairy conditions that involve the action of germ life; the entomologists inquire into the life history of injurious insects and the methods for preventing their ravages; the horticulturists deal with such questions as plant breeding, orchard culture, and varieties of fruit, and the chemists and other members of the staff take up questions relating to plant and animal nutrition, dairy methods, barn sanitation and poultry production. All this effort is largely in the direction of seeking new knowledge, which, when obtained, we endeavor to adjust to agricultural practice. We do not endeavor to adjust all knowledge, experience and business conditions to the management of a given farm, for this is the owner's problem and for us to take it out of his hands, even if it were possible, would do him more harm than good. We can and do give advice freely on specific points connected with farm management when the questions involved are definitely brought before us.

The Station publications as a source of information.— Modern agricultural literature may be divided in a general way into two classes, first, that which is placed on the market by publishing houses and is largely the literature of compilation with a view to a comprehensive discussion of the subject under consideration, and second, the literature issued in their official capacity by members of government departments and experiment stations. Without desiring to criticize policies that may prevail elsewhere, I wish to express the conviction that an experiment station endowed for the maintenance of research, cannot wisely act as a bureau of compilation to prepare and publish books on all sorts of agricultural subjects. It is often necessary, to be sure, to do more or less compiling in order to adjust existing information with results obtained at the Station. Such organization of knowledge on a given subject is legitimate to an investigating agency and even necessary. There is a broad difference, however, between an exhaustive treatise on the growing of corn or potatoes or any other crop and a bulletin setting forth the results of an investigation on the stage of growth of corn that yields the most nutritive value, or on the influence of seed selection on the amount and character of the product. It is the belief of the writer that when a station has set forth the results of its work in a clear manner and their relation to pre-existing knowledge accompanied by sufficient demonstration of the relation to practice, it has fulfilled its duty to the agricultural public. These explanations are made because my office is in almost constant receipt of requests for agricultural literature of the most general kind covering all phases of farm methods and management. Such requests cannot be met. Our bulletins are free to all who ask for them and we take pleasure in answering specific inquiries up to the limit of our time and knowledge.

The Grapes of New York.— In accordance with a previous announcement, copy for a volume to be known as the Grapes of New York will be submitted as a part of our annual report for 1907. It is hoped that the Legislature will provide for printing of this part of our report more than the usual number of copies.

The Graduate School of Agriculture.— In my report for 1906 it was stated that the Graduate School of Agriculture had been invited to hold its 1908 session in New York under the joint auspices of the New York State College of Agriculture and this institution. That invitation was accepted by the Association of Agricultural Colleges and Experiment Stations and plans are now being perfected for holding the school during the month of July, 1908. A good share of the work done at this school relates to experiment station aims and methods, which justifies the support our stations give to such an effort.

INVESTIGATION.

The following paragraphs are not intended to summarize the activities of any of the Station departments during 1907. They present only the outlines and conclusions of experiments reported in the bulletins of the year.

DEPARTMENT OF BACTERIOLOGY.

Chloroform as an aid in the study of milk enzyms.—Among the factors which combine to produce the ripening of cheese there is none more difficult of study than the enzyms which are secreted with the milk. Any results in this field are open to question unless it can be shown that the activity of bacteria has been suppressed during the period of study.

The adaptability of chloroform for this purpose has been studied. It was found that fat and proteid each associate with chloroform in such a way as to take it out of the general solution. When there was present an excess above the requirements of these two components of the milk the germicidal action of the chloroform was prompt and satisfactory.

DEPARTMENT OF BOTANY.

Potato spraying experiments.— During the season of 1906 the potato spraying experiments begun in 1902 were continued along practically the same lines as in previous years. In the ten-year experiment at Geneva five sprayings increased the yield 63 bushels per acre, while three sprayings increased it 31.75 bushels. In the duplicate of this experiment at Riverhead, Long Island, the gain due to five sprayings was 53.25 bushels per acre and to three sprayings 21.5 bushels. In fifteen farmers' business experiments, including 225.6 acres, the average gain due to spraying was 42.6 bushels per acre; the average total cost of spraying $5.18 per acre; and the average net profit, $13.89 per acre. Sixty-two volunteer experimenters, spraying 598 acres, reported gains averaging 44.5 bushels per acre.

One-half the time during which this series of experiments is expected to run has now passed. Thus far the results are highly favorable to the practice of spraying. In the ten-year experiments at Geneva, the average gain for five years from spraying every two weeks has been 132 bushels to the acre, and from spraying three times during the season 103.3 bushels; at Riverhead the corresponding gains have been less, but still decided, being 66.3 bushels and 35.3 bushels respectively.

In forty-eight business experiments made in four years the average gain due to spraying has been 52 bushels to the acre, the average total expense of spraying, $4.85 per acre, and the average net profit from spraying $20.51 per acre. In 153 volunteer experiments reported in three years the average gain from spraying was 58 bushels to the acre.

DEPARTMENT OF CHEMISTRY.

Effect of treating milk with carbon dioxide under pressure.— In connection with some work done in making kumiss from cows' milk, it was learned that carbon dioxide gas under pressure has the power of delaying the souring of milk. The suggestion thus obtained was utilized in studying the effect of treating milk with carbon dioxide under pressure, the milk being carbonated in precisely the same way that soda water is made. Fresh skim milk and whole milk, pasteurized and unpasteurized, were treated with carbon dioxide gas under pressures of 70, 150 and 175 pounds per square inch and then kept at temperatures varying from 35 to 70° F. Pasteurized milk, carbonated, kept for five months with little increase of acidity. Fresh, whole milk, carbonated, kept, under high pressure, about the same length of time. Milk carbonated under a pressure of seventy pounds comes from the bottle as a foamy mass; it has a slightly acid, pleasant flavor, due to the carbon dioxide, and tastes somewhat more saline than ordinary milk. It might easily become a popular beverage. Among the several possible useful applications which may be made of carbonated milk, the following can be mentioned: On steamships, in hospitals and elsewhere as a food for invalids, in feeding children, in case of certain ailments and as a common beverage.

Analyses of miscellaneous materials.— During the past years of the Station's activity, there have accumulated the results of a large number of analyses which have been made gratuitously for individual farmers. These analyses include many interesting materials and it has seemed desirable to publish such representative cases as would be of interest. The materials included are ashes, dried blood, nitrate of soda, meat meal and tankage, potash salts, muck soils, fertilizer constituents of miscellaneous materials, constituents of feeding stuffs, molasses refuse, commercial gruels, poultry foods, maple sugar, home-made cider vinegar and dried apples.

Some of the first chemical changes in cheddar cheese and the activity of the water-extract of cheddar cheese.— Before we can control intelligently and completely the changes taking place in cheddar cheese, especially those changes which affect the most important commercial qualities of cheese, flavor and texture, we must learn in detail what chemical changes the material undergoes from the time rennet is added to milk until the cheese is ready for consumption. Some of these changes are known, but only in a very incomplete manner. Of special importance appear those changes occurring in the cheese-vat and cheese-press, because the character of change at this time may affect the later changes. One change which has heretofore been completely overlooked occurs within a dozen hours after the cheese is put in press. The insoluble proteid of fresh cheese curd (calcium paracasein) changes rapidly into a form soluble in a 5 per ct.

solution of common salt and then changes into another form insoluble in such a solution, this latter change taking place rapidly at first and then slowly. Proteids in water-soluble form do not appear to any extent until after the second change above noted has taken place. The exact manner in which these changes are brought about and their direct bearing upon the practical problem of cheese-making have not yet been fully worked out. The changes appear to be connected with the formation of lactic acid during the cheese-making process and with its action upon the calcium phosphate compounds of the milk. Thus, the calcium and phosphoric acid compounds of cheese, insoluble in water at the start, becomes soluble until about 80 per ct. of the calcium and all of the phosphates become soluble in water. About 20 per ct. of all the calcium in the cheese is found in the salt-soluble portion.

The acidity of the water-extract of normal cheddar cheese is largely due, not to the presence of free lactic acid but to acid calcium phosphate. The lactic acid formed during cheese-making acts upon the phosphates, forming acid calcium phosphate and calcium lactate.

Chemical studies of camembert cheese.— This work was begun by A. W. Bosworth, assistant chemist, before he came to this Station. He has continued the work here. It is shown that bacteria are responsible for the most important chemical changes which take place in this kind of cheese during its early history, such as the formation of lactic acid from milk-sugar, the combination of this acid with some of the insoluble calcium present in certain compounds, forming calcium lactate and soluble phosphates, the conversion of calcium paracasein into a compound completely soluble in a 5 per ct. solution of common salt, the conversion of this soluble into an insoluble compound. The acidity of camembert cheese is due mainly to proteids and to acid calcium phosphate. One of the characteristic differences in the making of cheddar cheese and camembert cheese seems to be the proper control of the production of the salt soluble compound and of the subsequent change in this compound. Molds are responsible for that part of the ripening in which the compact insoluble curd is changed in texture and becomes a soft, creamy mass almost entirely soluble in water. This is due to enzyms produced by the molds.

DEPARTMENT OF ENTOMOLOGY.

The willow borer as a nursery pest.— The willow borer (*Cryptorhynchus lapathi* L.) is an insect of growing importance to the nursery interests of this State. Native willows along streams, swamps and canals are also frequently badly attacked, and injuries are being sustained by certain species of willows planted for ornamental purposes. The species of plants observed to be conspicuously injured are *Populus monilifera, Salix lucida, S. caprea, S. cordata, S. sericea, S. alba* and *S. amygdaloides.*

Investigations 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 overgrowths caused by pruning, and takes place during August or September. The injury to the plants is caused by the larvæ which girdle the trees, and so weaken them that they often fall with the wind.

It was noticed in observing the habits of the beetles that they are external feeders, which suggested the possibility of employing arsenical poisons as a means of combating this pest in the nursery. To ascertain the effects of these insecticides upon the beetles, numerous experiments were made which showed conclusively that thorough spraying, with an arsenical poison, of poplar and willow plantations about July 15th will materially reduce the number of beetles and thereby lessen the number of eggs deposited in the trees. Experiments are now being conducted to determine the actual value of this treatment for field use.

DEPARTMENT OF HORTICULTURE.

Bordeaux injury.— Under some conditions bordeaux mixture injures the fruit and foliage of fruit trees sprayed with it. A study of bordeaux injury of this fruit in the State at large showed: That in 1905, 70 per ct. of the orchards sprayed had been injured; that an excess of lime did not prevent the injury; that in some orchards spraying did more harm than good; that there had been similar losses in past years; that the use of power machinery increased the injury; that wet weather gave favoring conditions for injury; and that some varieties are more susceptible to injury than others. Experiments on the Station grounds proved that bordeaux mixture causes the trouble known as "spray injury." In these experiments injury seems to follow the first shower of rain. The toxic substance passes, for most part, through stomata and the basal cells of plant hairs into the cellular tissue of fruit and leaves. Small black specks characterize the first stage of the injury. As the fruit grows, the epidermis is lacerated because the dead cells are unable to bear their share of the surface tension. It is these dead cells that give the russetted appearance.

An experiment to show whether wet or dry weather gave favoring conditions for the injury proved that wet weather gives the favoring condition for the trouble. Bordeaux mixture containing an excess of lime, in these experiments, did not prevent nor lessen bordeaux injury. An experiment to show the effects of bordeaux mixtures made with varying qualities of copper sulphate and lime showed that the more copper sulphate the greater the injury; and that, in general, the stronger the solution, as to copper sulphate, the better the control of the scab fungus. From the experiments it was believed that what is known as the 3-3-50 solution can be used to check the fungus and yet cause a minimum amount of injury.

Practical suggestions for spraying without injury are: Use less copper sulphate; spray in moderation; use the bordeaux mixture in dry weather, as far as possible; use equal amounts of lime and copper sulphate. Some varieties of apples may be sprayed without much fear of injury. Others must be sprayed with great care. Many varieties are nearly immune to attacks of apple scab. These need only light applications of bordeaux mixture.

Ringing herbaceous plants.—The objects of ringing plants are: To cause unproductive plants to set fruit; to increase the size of the fruit; and to hasten the maturity of the fruit. Experiments were made in the Station forcing houses in ringing the tomato and the chrysanthemum. In ringing these plants a wound was made through cortex and the bast and a band of bark of greater or less width removed. The plants were ringed during the period when the bark peels most readily from the wood.

The theory upon which ringing is founded is: That unassimilated food passes from the roots of the plant to the leaves through the outer layer of the woody cylinder. The assimilated food is distributed through the cortex of the inner bark. When plants are ringed the flow upward continues, but that downward is checked and the top of the plant is thus supplied with food at the expense of the parts below the ring.

With the tomatoes ringed there were no differences to be noted in regard to either the color, the maturity or the flavor of the fruits from the ringed plants. The average loss in weight per plant due to the ringing was about 14 per ct. The roots of ringed plants were less well developed, fewer in number and smaller in size. The foliage was more or less abnormal.

With the chrysanthemum, ringing decreased the height of the plant, produced abnormal foliage and stems; the first ringing hindered the opening of the buds, but the second ringing, two weeks later, slightly hastened the maturity of the buds. The size of the blossoms of all varieties was greatly reduced; the earlier the ringing the greater the injury.

These two plants were chosen because they seemed to be typical of a great number of herbaceous plants. From the experiments conducted with them, it seems to be very doubtful if ringing can be made beneficial to herbaceous plants. The loss to the plant is great, and there seems to be little or no compensating gain.

The effect of wood ashes and acid phosphate on the yield and color of apples.—An experiment was begun in 1893 to ascertain the effects of potash, phosphoric acid and lime as found in wood ashes and acid phosphate on the yield and color of apples. This test continued for twelve years, being completed in 1904. The seat of the experiment is a 55-year old orchard on the Station grounds, located on a medium heavy clay soil. Throughout the experiment the orchard was given clean cultivation until August 1st and was then seeded to a cover crop of oats, barley or clover. There were ninety-four trees in the test representing five varieties. The orchard was divided into eight plats, four treated and four untreated.

Wood ashes were applied to the treated plats at the rate of 100 pounds per tree; acid phosphate at the rate of 8½ and lime at 32 pounds per tree. Analyses showed that 169 pounds per acre of actual potash were applied each year; 129 pounds of phosphoric acid; and 1,536 pounds of lime. These amounts are excessive for all three of the fertilizers.

From a financial standpoint the results were negative. The estimated increase in value of crop on the treated plants for a hypothetical five acres is $99 and the estimated value of the fertilizers for the above area is $74.50. This gives a difference of $24.50 which does not pay for handling the fertilizers.

Results as to color of fruit lack uniformity and were not decided enough in a sufficient number of the twelve seasons to enable the experimenters to state that the fertilizers applied improved the color of the apples. The only practical application of the results obtained by this experiment is, that fruit growers should not apply manure in quantity until good evidence has been obtained that some of the food elements are needed and if any, as to which ones.

INSPECTION.

FEEDING STUFFS.

The following is a summary of the results of the inspection of feeding stuffs as based upon the analyses of the samples sent to the Station by the Commissioner of Agriculture. The composition of the samples may be seen in Bulletin No. 291.

NUMBERS AND KINDS OF BRANDS INSPECTED.

It is interesting and suggestive to note the number of brands of each class of feeding stuffs that were found on the market. These are shown below, together with the number of samples analyzed of each class.

	Brands inspected No.	Sampled analyzes No.
Cottonseed meals	13	18
Linseed meals	14	19
Gluten feeds	13	16
Corn brans	6	6
Dried distillers' grains	17	24
Malt sprouts	30	34
Dried brewers' grains	15	17
Hominy feeds	21	23
Compounded feeds	114	139
Animal products	35	39
Poultry foods (compounded)	30	33
Beet sugar wastes	2	2
Barley by-products	4	4
Oat by-products	3	3
Miscellaneous feeds	11	11
	328	388

The above figures are suggestive as showing the present status of the feeding stuff market. About 31 per ct. of the brands inspected are feeds carrying a relatively high proportion of protein and which, in most cases, bear names that are indicative of their character. The hominy feeds and animal products are also materials having a fairly definite composition and concerning the nutritive value of which an approximate estimate may be made. On the other hand about 44 per ct. of the feeds examined is made up of brands compounded from a variety of materials that bear names in many cases savoring of quackery. These brands, in a majority of cases, are simply a means of selling at grain prices inferior by-products that could not be floated on the market unless disguised in some way. The extensive sale of such mixtures is not creditable either to the intelligence or the business judgment of the purchasing public. It is no exaggeration to state that at the present time the conditions of the feeding stuff market are bad and are inimical to the financial interests of the farmers and other consumers.

COMPARISON OF THE ACTUAL WITH THE GUARANTEED COMPOSITION.

While the inspection of feeding stuffs under the sanction of law indirectly serves certain ends such as acquainting farmers with the character of the goods in the market, its chief purpose is to secure conformity between the manufacturer's claims and the goods he offers for sale. To this end the State Department of Agriculture selects samples in the open market and forwards them to the Experimental Station for analysis.

In the table which follows the results of these analyses are summarized; but the comparison between the actual and guaranteed composition of the separate brands must be sought in the bulletin.

NUMBER OF BRANDS AND SAMPLES FOUND TO BE MATERIALLY BELOW THE GUARANTEE.

	Below Guarantee		
	No. of brands	No. of samples	Per cent.
Cottonseed meals	6	8	46
Linseed meals	3	4	21
Gluten feeds	6	7	46
Corn brans	2	2	33
Dried distillers' grains	12	15	70
Malt sprouts	4	4	13
Dried brewers' grains	3	3	20
Compounded feeds	19	19	17
Animal products	5	5	11
Poultry foods (compounded)	1	1	3
Miscellaneous feeds	1	1	9
Total	62	69	

It seems that sixty-two brands or about 19 per ct. of the whole number of brands examined fell below the guaranteed composition to a serious extent.

THE QUALITY OF THE COMPOUNDED FEEDS.

It is unfortunate for the feeding stuff trade and especially for the consumer that inferior materials have come into such extensive use in compounding commercial feeds. The substances chiefly in evidence in this connection are oat hulls and ground corn cobs; although other materials like ground alfalfa are associated with grain products in order to sell at grain prices what is really a coarse fodder.

The presence of low grade materials in a mixture may be discovered in many cases either by microscopical examination or by chemical analysis. For instance, several brands of feeds have been offered for sale that consist of mixed wheat offals adulterated with ground corn cobs. With these mixtures the microscope reveals the corn cob tissues and chemical analysis shows a protein content too low and a fibre content too high for pure mixed wheat offals. In the case of many other feeds their low percentage of protein and high percentage of fibre characterizes them as made up in part of inferior ingredients. Any supposed grain mixture with only 8½ per ct. of protein or less, with 12 per ct. of fibre or more, may safely be considered as made up in part of some low grade by-product. No mixture of straight farm grains would have so little protein or so much fibre. Indeed a grain feed with protein as low as 9 per ct. should be regarded with suspicion.

A careful survey of the results of the inspection herewith reported shows that approximately eighty, or 70 per ct., of the 114 brands of compounded feeds contain low-grade products. In many instances these mixtures bear names that to the ordinary mind are deceptive and to all intents and purposes are dishonest.

It will be well for prospective buyers of feeds to study carefully the published analyses of compounded feeds and avoid the purchase at grain prices of any feed carrying 8½ per ct. of protein or less or over 12 per ct. of fibre. A feed is especially to be avoided if the protein is low and the fibre high.

In view of the character of a majority of the compounded feeds now offered in our markets and the ease with which, by ingenious methods of mixing, purchasers of feeds may be deceived as to the quality of what they are buying, wise consumers will avoid compounded feeds and mix their own rations from such standard feeds as the oil meals, distillers' and brewers' by-products, gluten meal and gluten feed, wheat-offals, hominy feed, farm grains and other feeds having characteristic composition and quality. It is the height of folly for buyers to allow manufacturers to palm off upon them at grain prices inferior materials like oat-hulls and corn cobs that are no more valuable than the roughest, poorest farm products such as straw, corn stalks and the like.

FERTILIZERS.

The Station continues to analyze samples of fertilizers collected in the State under the direction of the Commissioner of Agriculture. These number several hundred annually. This work involves the preparation of evidence to be submitted in those cases prosecuted by the State Department for the violation of the fertilizer law. The amount of work required by these analyses and the various duties related thereto, is very large.

PUBLICATIONS ISSUED DURING 1907.

BULLETINS.

No. 285. January. Report of analyses of samples of fertilizers collected by the Commissioner of Agriculture during 1906. Pages 61.

No. 286. February. The poplar and willow borer. W. J. Schoene. Pages 22, plates 6. Popular edition. Pages 8, plate 1.

No. 287. March. Bordeaux injury. U. P. Hedrick. Pages 85, colored plate 1, plates 7. Popular edition. Pages 16.

No. 288. April. Ringing herbaceous plants. U. P. Hedrick, O. M. Taylor, and Richard Wellington. Pages 17, plates 4. Popular edition. Pages 4.

No. 289. April. The effect of wood ashes and acid phosphate on the yield and color of apples. U. P. Hedrick. Pages 25, diagram 1. Popular edition. Pages 8.

No. 290. June. Potato spraying experiments in 1906. F. C. Stewart, H. J. Eustace, G. T. French, and F. A. Sirrine. Pages 85, plates 2. Popular edition. Pages 12.

No. 291. August. Inspection of feeding stuffs. Pages 47.

No. 292. August. Effect of treating milk with carbon dioxide gas under pressure. L. L. Van Slyke and Alfred W. Bosworth. Pages 14, plates 3. Popular edition. Pages 4.

No. 293. October. Analyses of miscellaneous materials. L. L. Van Slyke. Pages 11.

No. 294. December. Report of analyses of samples of fertilizers collected by the Commissioner of Agriculture during 1907. Pages 81.

No. 295. December. Director's report for 1907. W. H. Jordan. Pages 22.

TECHNICAL BULLETINS.

No. 4. April. I. Some of the first chemical changes in cheddar cheese. II. The activity of the water extract of cheddar cheese. L. L. Van Slyke and Alfred W. Bosworth. Pages 22.

No. 5. June. Chemical studies of camembert cheese. Alfred W. Bosworth. Pages 17.

No. 6. December. Chloroform as an aid in the study of milk enzyms. H. A. Harding and L. L. Van Slyke. Pages 42.

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No. 8, new series. January 20. Dodder in alfalfa seed. F. C. Stewart and G. T. French. Pages 4, plates 2.

REPORT

OF THE

Department of Bacteriology.

H. A. Harding, *Bacteriologist.*

M. J. Prucha, *Assistant Bacteriologist.*

James K. Wilson, *Assistant Bacteriologist.*

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REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

CHLOROFORM AS AN AID IN THE STUDY OF MILK ENZYMS.*

H. A. HARDING AND L. L. VAN SLYKE.

SUMMARY.

I. Solubility.—At 20° C. (68° F.) skim-milk is saturated by 6.55 per ct. of chloroform by volume. Normal milk containing 5 per ct. of fat requires an additional 1.0 per ct. of chloroform to produce saturation.

II. Germicidal action.— Skim-milk containing 3 per ct. of protein requires 0.2 per ct. by volume of chloroform to destroy the vegetative bacteria gradually and 0.4 per ct. to destroy them within 24 hours. In normal milk containing 5 per ct. of fat, 1.0 per ct. of chloroform destroys the vegetative forms gradually, 1.5 per ct. destroys them within 24 hours, while 2.0 per ct. accomplishes this result within 4 hours. The spores are not immediately destroyed even with excessive amounts of chloroform.

In chloroformed cheese the germicidal action is slightly variable and a uniform destruction of the vegtative forms was not obtained with less than 10 per ct. by weight of chloroform.

III. Action on milk enzyms.— In skim-milk, digestion progressed at a uniform rate in the presence of chloroform varying from 0.2 to 0.7 per ct. by volume. With increasing percentages of chloroform there was a decrease in the rate of digestion, which in the presence of 2.5 per ct. of chlorofrom amounted to 12 per ct. of that occurring in the presence of 0.7 per ct. of chloroform.

* Reprint of Technical Bulletin No. 6.

Increasing the percentage of chloroform from 2.5 to 30 per ct. did not retard the rate of digestion much more than did 2.5 per ct.

IV. Action on milk proteids.— Chloroform above the amounts required to saturate the milk settles to the bottom carrying down a portion of the casein. This is observable as a white, opaque layer.

INTRODUCTION.

The announcement in 1897 by Babcock & Russell (1)[1] that an enzym inherent in milk, later called by them galactase,[2] was a considerable factor in cheese-ripening pomptly attracted the attention of all students of this problem. The work of other investigators[3] has apparenly confirmed what Babcock & Russell early suggested, namely, that milk contains a mixture of enzyms. A record of our attempts to determine the action of chloroform when used in the study of these enzyms is given in this bulletin.

In 1899 the problem of cheese-curing was assigned to the co-operative activities of the Dairy, the Chemical and the Bacteriological departments. The results of their investigations have appeared in a series[4] of bulletins of which this is a continuation. The action of chloroform was briefly discussed in Bulletin 203, which also included some observations on the action of ether.

Early in their study of milk enzyms, Babcock & Russell (3) tested the action in milk of benzol, chloroform, toluol, xylol, analin, arsenious acid, oil of organum, thymol, sodium fluoride, phenol, phenol and sodium chloride, oil of cloves, oil of cassia, oil of Ceylon cinnamon, turpentine and oil of mustard. They recommended only four of these substances — chloroform, ether, benzol, toluol — for the study of milk enzyms and of these they preferred chloroform. While we have used ether or formalde-

[1] The numbers in parenthesis refer to the bibliography at the end of the bulletin, in which the names of authors are arranged alphabetically, with different articles by the same author numbered consecutively.

[2] Babcock, S. M., Russell, H. L., & Vivian, A. Properties of galactase, a digestive ferment of milk. Wis. Agr. Exp. Sta. Rept., **15**: 77–86. 1898.

[3] Vandevelde, A. J. J. Les enzymes du lait de vache. *Revue genérale du Lait*, **6**: 361–370; 385–397; 414–422. 1907. Good bibliography.

[4] N. Y. Agr. Exp. Station Bulletins 203, (1901); 214, 215, 219 (1902); 231, 236, 237 (1903); 245 (1904); 261, 263 (1905); Technical Bulletins 3 (1906); 4, 5 (1907).

hyde in a few experiments as a check upon the action of chloroform, practically all of our enzym study has been carried on with the aid of the latter agent. We chose chloroform for our work for the following reasons: 1. It is an active germicide. 2. It does not prevent a vigorous action of the enzyms. 3. It apparently has but little action upon the proteids of the milk. 4. It is efficient in small quantities and does not markedly affect the dilution. 5. Its presence can be quantitatively determined. 6. It is not inflammable. 7. It tends to submerge the fat and thereby assists in sampling.

Before undertaking a discussion of the relation of enzyms to cheese-ripening it has seemed best to treat the action and utility of chloroform in such a study in a separate bulletin. Much of the data here given is closely associated in origin and significance with that in a bulletin to follow upon the relation of milk enzyms to cheese-ripening.

In the study of any enzym one of the first requisites is a substance which will repress those lower forms of life that so readily attack digesting solutions. An ideal agent for this work would be one which totally eliminates the organized ferments without, at the same time, exerting any influence upon either the enzym acting or the proteid acted upon. Unfortunately we know of no such substance for use in connection with milk. It is therefore of vital interest in our study of chloroform to note its germicidal action, its effect upon the enzym and its effect upon the proteids.

ACKNOWLEDGMENTS.

The data upon which this bulletin is based have been gradually accumulated during the past eight years and several persons have been concerned in their production. Most important among these was E. B. Hart, now connected with the Wisconsin Agricultural Experiment Station, who was associated with us in the study of this problem up to four and one-half years ago. A. J. Patten, now with the Michigan Agricultural College and Station, and J. A. LeClerc, now with the Department of Agriculture at Washington, D. C., each assisted in some of the chemical work. During the past two years A. W. Bosworth has done the detailed chemical work. L. A. Rogers, now with the Department of Agriculture, at Washington, D. C., and J. F. Nicholson, now with the Oklahoma Agricultural College and

Station each in turn took charge of the determinations and of the details of a number of experiments, as assistants in the bacteriological laboratory; and later M. J. Prucha and J. K. Wilson have rendered similar services efficiently in the same capacity. The Station Dairy Expert, Geo. A. Smith, has frequently assisted us in the preparation of material for various experiments.

HISTORY.

Although chloroform is commonly used in connection with enzym studies, discussions of its effects and limitations in such work are not numerous. The mere addition of a small quantity of an antiseptic to a digesting solution is often given as a sufficient proof of the elimination of organized ferments. The criticism of the work of Stoklasa by Mazé[5] indicates that more extended proof of the absence of germ action in such cases would be desirable.

The germicidal effect of chloroform seems to have been first observed in 1850 by Robin (1). He reported that pieces of meat plunged into chloroform or exposed to its vapors did not decompose. The humidity of the air was thought by Robin to be the cause of decomposition. As the result of the work of Pasteur and others, Müntz (1) in 1875 had a clearer conception of the causes of fermentation. He made use of chloroform in distinguishing between the organized and unorganized ferments and he observed that a prolonged exposure of germs to the action of chloroform caused their death. It is interesting to note that he added 5cc. of chloroform to 200cc. of milk and stated that the mixture did not curdle during four months. Two years later, with the aid of chloroform, Schloesing and Müntz (1) were able to establish the important fact that nitrate formation in the soil is due to the activity of germ life.

Taking advantage of marked improvements in bacteriolgical technique, Salkowski (2) in 1888 contributed an important paper dealing with the applicability of chloroform to enzym study. He gave the results of a study of its germicidal effect on a number of bacterial species. His results may be summed up in the following statement: So far as his observations went during some years of work, chloroform prevented all fermenta-

[5] Mazé P. Sur l'isolement de la zymase des végétaux et des tissus animaux. *Ann. Inst. Pasteur,* **18:** 535-544. 1904.

tive processes dependent upon the metabolism of living organisms, as the alcoholic fermentation, the fermentative splitting of hippuric acid, the lactic fermentation and bacterial proteid decomposition; while it did not destroy the activity of the unorganized soluble ferments (enzyms), as, for example, ptyalin, pepsin, trypsin, invertins, diastases, etc. Salkowski found that 0.5 per ct. by volume of chloroform destroyed cholera and anthrax bacilli promptly but that it had little germicidal effect upon anthrax spores. He called attention to the necessity of closely confining the chloroform which would otherwise soon be lost by evaporation.

At the same time the germicidal action of chloroform was being extensively tested by Kirchner (1). His study was carried out with a view to an improved method of sterilizing blood-serum. He worked principally with blood-serum but in some case also used bouillon, milk and water. Part of his work was done with saturated solutions of chloroform but he commonly compared solutions containing 0.25, 0.50, 0.75 and 1.0 per ct. by volume of chloroform. As test objects he used pure cultures of *Bacillus prodigiosus*, *B. anthracis*, *B. typhosus*, *B. subtilis*, *B. zoppfi*, *Sarcina aurantiaca*, *Staphylococcus pyogenes aureus*, *Spirillum asiaticae cholerae*, "*Wurtzel*" bacillus and a bacillus and coccus obtained from decomposing blood-serum and also mixed cultures as they occur naturally in river water, decomposing blood, human and bovine feces and garden soil. The action of the chloroform was determined by aerobic and anaerobic cultures and the results were often expressed quantitatively. His findings were in accord with those of Salkowski. Kirchner found that all classes of vegetative bacteria were destroyed by a 0.25 per ct. solution of chloroform in a short time varying from a few minutes with *Spirillum asiaticae cholerae* to a few days with *Staphylococcus pyogenes aureus*. However, even an excess of chloroform was not immediately fatal to spores. Kirchner believed that chloroform had no effect upon them until such time as they germinated, when they were immediately destroyed. He observed that when an excess of chloroform was present the germicidal action was more marked in bouillon than in blood-serum and attributed the difference to the higher percentage of chloroform actually in solution in the bouillon than in the blood-serum. He again emphasized the necessity for a well-stoppered container on account of the ease with which chloroform may escape by evaporation. Reference has already been made to the extensive work of Babcock and Russell.

The work of Smith (1) emphasizes the necessity of a well-closed receptacle since he pointed out that in a cotton stoppered test-tube an abundance of liquid chloroform in the bottom of the tube would not inhibit the growth of bacteria in the upper layers of the supernatant liquid medium. In such cases evaporation of the chloroform at the upper surface of the media seemed to take place faster than the solution of the same at the lower surface.

While the earlier work was principally concerned with finding substances which would prevent germ action, attention was later given to the effect of such substances upon the activity of the enzyms. The results of these physiological studies have varied widely, depending upon variations in the conditions attending the experimental work. Unfortunately, these variations were not always recorded, since the worker was naturally often unaware of the existence of important factors. Good examples of these differences are seen in the conflicting reports regarding the curdling of milk in the presence of chloroform and in the controversy which was waged regarding the coagulating action of chloroform upon albuminous substances.

Green (1, 2) reported the sterilization of vaccine lymph within eight days by saturating it with chloroform vapor. He found this treatment effective against *Bacillus proteus, B. prodigiosus, B. pyocyaneous, B. fluorescens, B. coli, B. typhosus, B. diphtheriae, B. mallei, B. pestis, B. tuberculosis* and *Spirillum cholerae.* He stated that this method of applying the chloroform did not impair the activity of the vaccine, while the addition of liquid chloroform markedly reduced it. His conclusions have been tested by Carini (1) and by Nijland (1). Both found that vegetative bacterial forms were promptly destroyed by this treatment but that spores survived. Neither considered the treatment with chloroform superior to the former method of handling lymph with glycerin, since in some cases the activity of the vaccine was quickly destroyed and in general chloroform vaccine lost its virulence more quickly on standing than did vaccine treated with glycerin.

QUANTITATIVE METHOD OF DETERMINING CHLOROFORM.

The method used in determining the amount of chloroform present in milk or cheese is as follows:

We place 5 grams of milk or cheese in a pressure bottle with about 100cc. of alcohol and 5 grams of caustic potash. The bottle is then heated in an autoclave for half an hour at 230° F. (110° C.). The resulting chloride is determined by titration as for chlorine in sodium chloride.

CURDLING OF MILK IN PRESENCE OF CHLOROFORM.

In studying enzym action in milk, considerable interest attaches to the interval before curdling and also to the character of the curd. The appearance of sour, curdled milk is so familiar as to need no description. This is the characteristic result of germ action, and, where an inefficient antiseptic is added, curdling will occur within a few days. Acid formation is practically an invariable accompaniment of such change.

When the antiseptic is efficient, the milk remains unchanged for two to three months, depending somewhat upon the temperature. The milk then changes to a soft jelly which is readily broken up on shaking. This soft coagulum differs so markedly from the ordinary curd due to germ action that it often escapes observation. Müntz, who was studying the influence of chloroform, in an effort to distinguish between organized and unorganized ferments, held milk four months under the influence of chloroform and did not note that it curdled. Salkowski (2) did observe that after some time (rather regularly, three months) chloroformed milk changed to a soft jelly, which could be broken up by vigorous shaking. He also stated that Meissner had observed the same change in sterile milk and had ascribed it to a slow-acting rennet ferment.

Again, when sterile milk stands undisturbed for a year or more, the solids gradually settle leaving a thin layer of serum at the top. This seems to be merely a mechanical separation, and on being shaken the milk resumes its usual appearance.

SOLUBILITY OF CHLOROFORM.

It seems fairly evident that, to be efficient as a germicide, chloroform must be in solution. Salkowski (2) noted that, when a drop of the culture which was being tested remained on the side of the tube above the level of the liquid, the germs escaped the action of the chloroform. This was also shown in the experiments of Smith (1), where the presence of a body of chloroform at the bottom of the tube of culture medium did not prevent germ growth in the upper layers of the same tube.

In Thorp's Dictionary of Applied Chemistry the solubility of chloroform is given as 1 volume in 200 volumes of water. Salkowski (2) gives it as 5cc. or 7.5 grams to the litre of water. Kirchner (1) found that a litre of blood-serum dissolved only 4cc. or 6 grams.

METHODS OF EXPRESSING SOLUBILITY.

Since the specific gravity of milk is approximately 1 and that of chloroform is 1.48 there is a marked difference between percentages expressed by weight and by volume. As a matter of convenience, mixtures of chloroform and milk are usually made upon a volumetric basis, and, in the literature of the subject, percentages by volume are usually given. Accordingly, in the present publication all percentages given are to be taken as percentages by volume unless the contrary is specifically stated.

SOLUBILITY IN MILK.

In milk it is difficult to distinguish between solution and emulsion when chloroform is added. When working with milk containing 4 to 5 per ct. of fat, 25cc. or 2.5 per ct. of chloroform is readily taken up by a litre; but when 50cc. is added, a portion settles to the bottom. Repeated shaking causes the chloroform to enter into intimate relation with the milk. In extended trials with both centrifugally-skimmed milk and with normal milk having a fat content of 4 to 5 per ct., chloroform was thus incorporated with the milk in practically all percentages up to equal volumes of chloroform and milk. In a part of these tests the chloroform was added in portions of 2 to 5cc. in 200cc. of milk, while in other cases the additions were at the rate of 25 to 50cc. In these tests the chloroform did not separate from the milk even after standing some weeks.

In the case of the larger percentages, it was very evident that something more than an ordinary solution was formed. The lower portion of the flasks was filled with a heavy, white, opaque layer, the thickness of which was proportionate to the amount of chloroform present. The tendency of chloroform to submerge fat is well known and this layer of fat tends to hide the other layer in normal milk unless the percentage of chloroform is relatively high. The relation of the chloroform to the fat, as well as the nature of this white layer, will be discussed later.

Taking advantage of the tendency of solutions to come to an equilibrium, duplicate bottles of milk were prepared containing various percentages of chloroform and, after ten days to two weeks, the chloroform actually in solution in the body of the milk was determined. The following table gives the results of two such sets of determinations, one with a milk containing 5 per ct. of fat, and the other with similar milk from which the fat had been removed. In each case the bottles were shaken sufficiently to mix the chloroform and the milk thoroughly, and were allowed to stand, at approximately 20° C. (68° F.), for some days preceding the chemical analysis in order to ensure a settling out of the chloroform not in solution.

Table I.— Solubility of Chloroform in Milk.*

Chloroform Added.	Milk containing 5 per ct. of fat.	Skim-milk.
	Chloroform in solution.	Chloroform in solution.
Per ct.	*Per ct.*	*Per ct.*
1.0	0.280	0.486
2.0	0.582	0.589
3.0	0.582	0.572
4.0	0.566	0.550
5.0	0.476	0.557

* Determined by Mr. Bosworth.

With the exception of the bottles of milk containing 5 per ct. of fat, which received 1.0 per ct. of chloroform, the percentage of chloroform found in solution in the milk in these experiments is entirely independent of the amount added. The average of the solubility found in these 9 cases, representing 18 bottles, is 0.55 per ct. by volume.

In the two bottles of normal milk received 1.0 per ct. of chloroform there was not sufficient chloroform to saturate both the fat and the milk. The percentage of chloroform given in the table is higher than the true percentage of chloroform in the milk-serum, since in these battles there was 1.4 per ct. of fat combined with chloroform present in the body of the milk.

The close agreement between the solubility as here determined for milk (0.55 per ct.) and the figures already given for the solubility of chloroform in water, suggests that the chloroform dissolves in the water of the milk as it does in pure water, while the 3 per ct. of proteids present unites with about 0.05 per ct. of chloroform in addition.

When the chloroform present is sufficient to saturate the milk and the fat, the excess associates with some of the casein and goes to the bottom, forming there the white layer referred to above. While the formation of this layer can be observed within a few minutes in the presence of a marked excess of chloroform, the material of which it is composed does not all separate quickly from the milk and may enter as a disturbing factor in determinations of the solubility of chloroform in milk, as the following experience will show. At the time that the samples of milk containing 5 per ct. of fat were drawn for analysis one of the bottles containing 1.0 per ct. of chloroform was accidentally overturned, somewhat mixing its contents. This bottle was allowed to stand 20 hours, after which samples were drawn and analyzed. These samples showed the presence in the body of the milk of 0.79 per ct. of chloroform. After standing quietly for a week an examination of this same bottle showed that its real percentage of chloroform in solution was like that of its duplicate, 0.28 per ct.

That this variation in the two determinations was really due to this material in suspension is made fairly certain by the results obtained from an examination of 4 bottles of skim-milk which had been shaken 24 hours before examination. Duplicate bottles had received 5 and 10 per ct. of chloroform 10 days before the examination and should have shown 0.55 per ct. of chloroform in solution. The results of the examination made 24 hours after shaking varied from 0.90 to 0.94 per ct. with an average of 0.924 per ct.

SOLUBILITY OF MILK-FAT.

The solvent power of chloroform upon fat is well known, but in the case of milk this expresses itself in such a way as to have a distinct influence upon the germicidal value of the chloroform. This is well illustrated by the results of an experiment in which ten well-stoppered bottles, each holding 150cc. of milk containing approximately 5 per ct. of fat, received successive additions of 0.5cc. of chloroform. There was no visible effect from the addition of 0.6 per ct. of chloroform, the fat rising to the top in a sharply defined layer; but, when the amount reached 1.0 per ct., and more particularly 1.3 per ct., there was sufficient fat diffused through the milk to give it a yellow tinge, and the thickness of the cream layer was noticeably reduced. With 1.7 per ct. of chloroform the cream layer at the top of the milk disappears and the fat collects at the bottom of the bottles. In bottles of similar milk containing 1.5 per ct. of chloroform there was a thin but evident cream layer at the top of the milk. Deducting from this value the 0.55 per ct. found necessary to saturate the milk, it is seen that approximately 1.0 per ct. of chloroform is required to saturate 5 per ct. of fat.

In connection with the experiment already quoted, where the solubility of the chloroform was determined in the presence of 5 per ct. of fat, the distribution of the fat was determined after the bottles had stood for some time. In the case of 1.0 per ct. of chloroform, while there was a well-marked cream layer at the top of the milk, analysis showed that 1.4 per ct. of fat was present in the body of the milk. In the presence of 2 per ct. or more of chloroform, the fat was entirely removed from the body of the milk and collected at the bottom of the bottles.

From this it will be seen that there is a strong tendency on the part of the fat and the chloroform to enter into a solution relationship which takes the chloroform out of contact with the body of the milk. The specific gravity of this solution evidently depends upon the relative amounts of fat and chloroform composing it. The effect of the formation of this solution upon the germicidal power of the chloroform will be treated under a subsequent heading.

GERMICIDAL VALUE OF CHLOROFORM IN MILK AND IN CHEESE.

As has been noted, Müntz(1) observed that 2.5 per ct. by volume of chloroform prevented the curdling of milk during four months. Salkowski(2) also observed that milk thoroughly shaken with chloroform continued its original neutral or faintly alkaline reaction. He referred to similar observations by Meissner, but without reference to where they were recorded. Kirchner(1) held flasks of chloroformed milk for four months and quantitative cultures showed that bacterial growth was inhibited. Babcock and Russell(3) showed that the efficiency of antiseptics in milk had been generally overrated, and they also found that variations in its fat content influenced the germicidal value, especially of ether, benzol, oil of cloves, and oil of Ceylon cinnamon.

EFFECT OF SOLIDS IN MILK OTHER THAN FAT.

In order to determine more closely the influence of this factor upon the action of chloroform, the following determinations were made.

Duplicate bottles containing 200cc. of sterile peptone bouillon and 0.1, 0.2 and 0.3 per ct. of chloroform, respectively, were inoculated with 1cc. of a twenty-four hour bouillon culture of *B. subtilis.* The bottles were kept at 37° C. and shaken daily. At the end of one month no turbidity or sediment had been formed and there was no other evidence of growth. Cultures made from the bottle containing 0.1 per ct. of chloroform showed 330 germs per cc., which undoubtedly represented the spores present. A sterile cotton plug was inserted in place of the rubber cork and the bottle returned to the incubator. On the following day the bouillon was turbid and an examination showed the presence of immense numbers of *B. subtilis.* The remaining bottles were left for a month with their rubber stoppers in place and they remained without any evidence of growth. While 0.1 per ct. of chloroform was enough to prevent growth, the evaporation which occurred after the rubber stopper had been replaced by the cotton plug promptly reduced the concentration of the chloroform below the point where it was efficient. In this experiment the amount of solids was slight and the germicidal effect of the chloroform was at its maximum.

The influence of added proteid is shown in the following test with skim-milk which contained 3 per ct. of proteids.

Twenty litres of skimmed milk was mixed with 250cc. of slime from a centrifugal separator and there resulted a germ content of 672,500 per cc. Duplicate bottles of this mixture received 0.1, 0.3, 0.5, 0.6, 0.8, 1.0, 1.5, 2.0, 10.0 and 20 per ct. of chloroform. The bottles were held at 32.5° C. (80° F.). The effect of the chloroform upon the germ content is shown in Table II.

TABLE II.—GERMS PER CUBIC CENTIMETER IN CHLOROFORMED SKIM MILK.*

INTERVAL.	PERCENTAGE OF CHLOROFORM BY VOLUME.									
	0.1	0.3	0.5	0.6	0.8	1.0	1.5	2.0	10.	20.
Initial 672,500										
3 hrs........	241,000	62,500	4,000	10,500	1,000	1,000	10,000	10,000	19,000	7,500
	227,000	34,500	3,000	38,000	2,000	1,200	2,000	3,000	......	.....
1 wk........	181,000,000	100	1,000	100	200	1,700	140	30	100	100
	21,000,000	1,000	40	20	100	200	100	100	......	.....
1 mo........	72,200	24	21	31	14	13	13	9	13	12
	4,500	17	268	26	9	22	10	11	40	22
3 mo........	40	39	27	60	15	12	8	10	8	3
	100	62	8	20	12	68	7	3	3	7
6 mo........	20	30	37	89	30	25	75	32	19	38
	11	67	20	33	36	89	19	26	19	24

*Determined by Mr. Nicholson.

The results are given in pairs representing the duplicate bottles. In this experiment 0.1 per ct. of chloroform did not hold the germs in check, although at first it destroyed a portion of them. These bottles curdled after two and four days respectively. Apparently, the chloroform entered into some combination with the solids present, so that the growth was not prevented, as is shown by the high germ content at the end of a week. Before three months the number fell to as low a point as in the other bottles, probably on account of the accumulation of decomposition products. The germ content in the bottles containing 0.3 per ct. and more of chloroform fell promptly to a point that undoubtedly represented little, if anything, more than spores present. The bottles containing 0.3 per ct. or more of chloroform all curdled after about two months with a curd characteristic of enzym action.

These results were tested by a second series of bottles.

The milk used in this experiment was twice passed through the centrifugal separator and the fat reduced to 0.015 per ct. The milk contained 408,500 germs per cc. Chloroform was added to duplicate, well-stoppered bottles at the rate of 0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0, and 2.5 per ct. The bottles were kept at 21° C. (60° F.). The numerical results of cultures made at the end of one, three, and six months are given in the following table.

TABLE III.— GERMS PER CUBIC CENTIMETER IN CHLOROFORMED SKIM-MILK.*

INTERVAL.	PERCENTAGE OF CHLOROFORM BY VOLUME.								
	0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.0	2.5
1 mo.	Curdled	48	38	36	30	33	46	35	46
	"	44	35	50	15	25	43	44	42
3 mos.	Too many	33	30	39	25	12	26	15	25
	to count	43	30	38	15	19	12	16	3
6 mos.	189,000	18	18	12	14	21	10	10	13
	....	14	34	14	6	8	4	12	7

*Determinations made by Mr. Nicholson.

This table shows that while 0.1 per ct. of chloroform was not sufficient to preserve this skim-milk, 0.2 per ct. reduced the germ content as successfully as a larger amount. It should be noted, however, that the first determination was made after an interval of one month.

The bottles containing 0.1 per ct. of chloroform curdled after four and seven days respectively with a curd characteristic of acid action, while all the remaining bottles curdled after slightly less than two months with a soft curd, characteristic of enzym action.

In considering the action of a germicide in connection with enzym studies, it is important to know the rate at which the germs present in the digesting solution are destroyed, as well as the final limits of the destruction, since it is conceivable that in the interval sufficient enzym may be elaborated to affect the results markedly.

Accordingly, in December, 1906, an experiment was carried out in which duplicate bottles of milk, which had been twice passed through the centrifugal separator to remove the fat more completely, received chloroform at the rate of 0.1, 0.2, 0.3, 0.4, and 0.5 per ct. respectively. The results of subsequent examinations are given in Table IV.

TABLE IV.— GERMS PER CUBIC CENTIMETER IN CHLOROFORMED SKIM-MILK.*

Interval.	Percentage of chloroform by volume.				
	0.1	0.2	0.3	0.4	0.5
Initial content		166,000			
6 hours	210,000	177,000	60,000	10,200	5,300
	290,000	205,000	81,000	18,200	4,000
24 hours	Too many	85,200	11,400	280	45
	to count	54,000	18,500	520	220
3 days	250,000	21,500	4,800	30	120
	324,000	27,000	8,100	95	500
11 days	....	6,900	2,300	24	23
	....	16,700	2,700	18	....

*Determinations made by Mr. Frucha.

From these results it will be seen that all amounts above 0.1 per ct. produced a steady decline in the germ content of the milk. In the case of 0.4 and 0.5 per ct., this decline was so sharp that within twenty-four hours the numbers present could hardly represent more than the spore content of the milk. In the case of 0.2 and 0.3 per ct., the decline, while evident, was so gradual that at the end of eleven days vegetative forms were still present in comparatively large numbers.

From the above results, it would seem evident that while bouillon with 0.5 per ct. of proteid was at once protected from germ action by the presence of 0.1 per ct. of chloroform, skim-milk with 3 per ct. of proteids required 0.4 per ct. of chloroform to give it an equivalent protection.

EFFECT OF FAT UPON THE GERMICIDAL VALUE OF CHLOROFORM.

Babcock and Russell (1) found that while 15 per ct. of ether would preserve milk containing 4 per ct. of fat, heavy cream required an equal volume of ether in order to prevent germ action. In this case the fat appears in some way to reduce markedly the germicidal value of the ether. The effect of fat upon the action of chloroform has been studied in the following experiments.

Bottles of normal milk containing 5 per ct. of fat received 0.1, 0.2 and 0.3 per ct. of chloroform respectively and were kept at 37° C. (99° F.).

Table V.— Germs per Cubic Centimeter in Chloroformed Milk Containing 5 per ct. of Fat.*

Interval.	Percentage of chloroform by volume.		
	0.1	0.2	0.3
Initial	780,000	313,000	720,000
1 hour	97,000	222,000	255,300
2 hours	147,000	390,700	212,000
4 "	583,000	2,884,000	447,000
7 "	5,245,000	18,312,000	Too many to count
24 "	451,970,000	Too many to count	Too many to count
32 "	Too many to count	Too many to count	Too many to count
48 "	Curdled	Curdled	Curdled

*Determinations made by Mr. Nicholson.

These results show that 0.3 per ct. of chloroform is not sufficient to saturate 1 per ct. of fat in addition to the other solids and leave enough excess to destroy the germ life. Accordingly, further tests were made with larger proportions of chloroform.

In this case milk was obtained from the cow under such precautions that the germ content was only 31 per cc. Duplicate bottles received 0.3 and 0.5 per ct. of chloroform and were held at 37° C. (99° F.). The two bottles which contained 0.3 per ct. curdled on the second day, while both bottles containing 0.5 per ct. curdled on the third day.

Duplicate bottles were prepared with milk containing 5 per ct. of fat, to which chloroform was added at the rate of 0.5, 0.8, 1.0, 1.5 and 2.0 per ct. The milk was held at 15.5° C. (60° F.). The germ content after various intervals is shown in Table VI.

TABLE VI.—GERMS PER CUBIC CENTIMETER IN CHLOROFORMED MILK CONTAINING 5 PER CT. OF FAT.*

INTERVAL.	PERCENTAGE OF CHLOROFORM BY VOLUME.				
	0.5	0.8	1.0	1.5	2.0
Initial germ content			77,200		
6 hours	95,700 76,300	97,200 64,900	44,700 60,000	17,300 6,600	680 2,130
24 hours	Too many to count		12,000 15,000	860 1,800	330 430
1 month	Too many to count		250 270	78 99	110 110

* Determinations made by Mr. Prucha.

From this it is seen that while 1.0 per ct. of chloroform is sufficient to reduce the germ content gradually, so that curdling occurs only after the interval alloted for enzym action, 1.5 per ct. reduces the numbers to approximately the spore content within 24 hours.

It is interesting to observe that, in this test, the germicidal action with 1.5 per ct. is approximately equal to that observed with 0.4 per ct. of chloroform in similar milk from which the fat had been skimmed. Thus the presence of 5 per ct. of fat neutralizes the germicidal action of about 1.0 per ct. of chloroform.

In our study of the solubility of chloroform in milk it was shown that 1.0 per ct. of chloroform was required to saturate 5 per ct. of fat. Accordingly, it would seem plain that the chloroform which is absorbed in the fat layer at the bottom of the milk is for all germicidal purposes removed from the milk.

We frequently used chloroform in the study of enzyms in cheese where the fat content amounted to 20 to 30 per ct. Accordingly two experiments were planned to determine the effect of 10 and 20 per ct. of fat upon the germicidal action of chloroform. As they were in perfect accord, but one of them is here given.

In order to obtain high percentages of fat, normal milk was enriched with fat in the form of melted butter, from which the casein had been removed by filtration, and the water and salt by decantation. The chloroform was useful in bringing this large amount of fat into an emulsion. Percentages of chloroform below 2.5 per ct. were not used since, with this percentage, a good emulsion was not produced and satisfactory sampling was thereby made difficult. The bottles were arranged in two series, one containing 10 per ct., and the other 20 per ct. of fat, and in each series there were duplicate bottles containing 2.5, 10.0 and 20 per ct. of chloroform. The bottles were held at 15.5° C. (60° F.). The germ content before the addition of the chloroform was 17,120 per cc.

TABLE VII.— GERMS PER CUBIC CENTIMETER IN CHLOROFORMED MILK CONTAINING ADDED FAT.*

INTERVAL.	10 PER CT. FAT. Percentage of chloroform.				20 PER CT. FAT. Percentage of chloroform.			
	2.5	5	10	20	2.5	5	10	20
2 mo.	209	113	255	244	....	82	...	163
	...	...	...	86	....	...	...	....
4 mo.	236	20	84	246	34	107	142	....
	44	64	194	126	....	...	...	....
6 mo.	74	90	62	98	34	34	46	200
	60	116	182	52	176	52	30	156
9 mo.	166	170	251	249	126	116	194	268
	211	250	261	215	144	280	64	274
12 mo.	308	352	412	276	2,546	308	360	207
	201	397	391	334	643	240	297	272

* Determinations made by Mr. Rogers.

It will be seen that the germ content remained high in all of the bottles even at the end of a year. This is probably due to the large number of spores in the melted butter. The numerical results are quite irregular since the fat globules transferred to the culture plates closely resembled colonies and made accurate counting difficult, with a tendency to too high results. None of the bottles curdled until after the usual interval required for enzym action. The last analysis of the bottles containing 2.5 per ct. of chloroform and 20 per ct. of fat indicates that germ growth was then taking place. At this time the quart bottles were nearly empty and evaporation into the air space had further reduced the amount of available chloroform. It is probable that 2.5 per ct. is close to the limit of chloroform required to preserve milk containing 20 per ct. of fat.

RATE OF GERMICIDAL ACTION IN MILK.

From the data already given, it is evident that the destruction of bacteria by chloroform is not an instantaneous matter, but rather a progressive one, being dependent upon the amount of chloroform which is active, and upon the length of exposure to its influence. Under such circumstances, it is conceivable that, while the chloroform might ultimately destroy the germs in the milk, it might do this so tardily that in the interval there would be sufficient enzym formed to produce observable changes in the compounds present. In order to obtain more exact information of the rate at which the germs were destroyed by different percentages of chloroform, duplicate series of bottles were prepared, containing normal milk with 5 per ct. of fat and varying amounts of chloroform. Each bottle contained 300 cc. and was held at approximately 22° C. (72° F.) during the period of examination. Plates upon lactose agar were made in triplicate at short intervals and the results from these plates are given in Table VIII.

TABLE VIII.— GERMS PER CUBIC CENTIMETER IN CHLOROFORMED MILK CONTAINING 5 PER CT. OF FAT.*

INTERVAL.	PERCENTAGE OF CHLOROFORM BY VOLUME.					
	0.0	0.5	1.0	1.5	2.0	2.5
10 min.	34,600 41,300	24,500 27,500	33,200 24,500	19,800 16,000	12,000 5,980	0† 0†
80 min.	36,700 30,000	27,600 28,800	23,100 18,800	3,500 5,220	796 973	20 30
4 hrs.	10,000 118,800	67,700 53,300	6,810 9,980	1,360 1,710	73 163	33 114
6 hrs.	112,800 138,500	28,700 26,900	6,430 11,210	795 1,220	85 90	43 44
10 hrs.	5,070,000 4,145,000	143,000 151,200	4,100 3,650	400 354	38 28	641 591
22 hrs.	....	2,042,000 1,585,000	3,540 3,090	115 242	33 32	37 25
27 hrs.	....	6,613,000 5,860,000	3,436 3,480	48 75	31 18	21 27
50 hrs.	curdled "	45,467,000 43,600,000	1,360 1,100	66 123	29 43	27 19

* Determinations made by Mr. Prucha.
† No colonies appeared upon plates with dilutions of 1-70, 1-200 and 1-1000 respectively.

The results are given in pairs representing the duplicate bottles. The two control bottles increased in germ content so rapidly that the plates made at the end of 22 hours and subsequently were too thickly seeded to be counted satisfactorily.

These bottles were both curdled at the end of 48 hours. While 0.5 per ct. was not sufficient to destroy the germs, it retarded their growth so that curdling did not take place until after six and nine days, respectively. The remaining bottles curdled simultaneously at the end of two months.

In the case of 1 per ct., there was a gradual and decided decrease in the germ content. This did not seem to be so much the result of the extinction of given species as of the reduction of all the species present. After an exposure to the chloroform for 50 hours, the flora was made up of non-spore-bearing lactic forms, a few yellow cocci, and a few spore-bearing organisms.

With 1.5 per ct. of chloroform, the reduction was more rapid. After 10 hours the flora was made up largely of spore producers with a few colonies of yellow cocci and a few acid producers. Plates made after 27 and 50 hours contained few but spore-bearing forms.

The presence of 2.0 per ct. of chloroform cut the flora in 80 minutes to spore-bearing forms and a few yellow cocci. Later examinations showed practically all spore-formers. The results with 2.5 per ct. of chloroform were the same, except that its action was quicker. The destruction was so prompt that no colonies appeared on the plates made at the end of 10 minutes. This does not indicate that the germs were all destroyed, but rather that they were so reduced that they were excluded by the dilution used, which in this case was 1-70, 1-200 and 1-1000. Plates made at the end of 80 minutes produced colonies with a dilution of 1-10, but not with a dilution of 1-50. Evidently, something irregular occurred in connection with the plates made at the end of 10 hours since the non-spore-bearing yellow coccus appeared among the spore-forming colonies on the plates only at this examination and the numbers on these plates were too high to harmonize with the results obtained either before or after this time.

From these results, it is seen that with 2.5 per ct. of chloroform the destruction of the vegetative forms is so complete and so prompt that it is extremely improbable that they would have time to exert any influence before their death. Likewise it is very doubtful if the occasional spore which remains alive is sufficiently active to exert any influence, since the first start toward germination would result in instant destruction. The same reasoning holds with 1.5 and 2.0 per ct., except that the interval between the addition of the chloroform and the death of the vegetative forms is measurable. With 1.0 per ct. of chloroform the case is somewhat different, since vegetative forms persist for many hours.

Since many of the forms present were lactic germs, a sensitive test of their activity was the reaction of the milk. Accordingly, at the end of 25 days the milk was titrated, using phenolphthaleïn and decinormal sodium hydroxide. The bottles containing 1.0 per ct. of chloroform showed an acidity equal to 25.6cc. of normal acid to the litre; with 1.5 per ct. chloroform, an acidity of 22.8cc.; and with 2.0 and 2.5 per ct., an acidity of 21cc. of normal acid to the litre. While these differences are slight, they are suggestive that, so long as vegetative forms are present, there may be a minimum amount of bacterial action in the presence of an amount of chloroform which is producing a constant diminution of the germ content.

EFFECT OF PROTEIDS AND FAT IN CHEESE.

It was shown on page 40 that the presence of 3 per ct. of proteids prevented the germicidal action of 0.3 per ct. of chloroform, and on page 43 that the presence of 5 per ct. of fat rendered 1.0 per ct. of chloroform inactive. In average green cheddar cheese we have approximately 24 per ct. of proteid and 34 per ct. of fat, so that the need of a considerable percentage of chloroform in order to prevent germ action is evident. Calculated on the basis of the above results, the proteid should absorb 2.4 per ct. and the fat 6.8 per ct. of chloroform by volume. In the case of cheese, it is manifestly more convenient to handle percentages by weight than by volume and the above, expressed as percentages by weight, would be 3.55 per ct. and 10.06 per ct. respectively. It should be noted that the change which takes place in the physical condition of the proteid in passing from milk to cheese is so great that these values may be subject to wide variations. That these figures are too high is rendered more than probable by the results given on page 59, where it was shown that 3 per ct. of proteid and 20 per ct. of fat was protected by 2.5 per ct. of chloroform when 4.4 per ct. was indicated by these figures.

In preparing chloroformed cheese, the chloroform was added to the milk and the ordinary operations of cheese-making carried out as usual. The milk used was of the quality ordinarily used for cheese-making, except that used in cheese 6.2, which had been obtained with special precautions to avoid undue contaminations. The chloroform was always added in quantities greater than would be readily absorbed by the milk and, owing to its high specific gravity, the excess of chloroform settled toward the bottom of the vat, but the stirring which accompanied the process of manufacture tended to keep it distributed. A considerable amount of chloroform was retained in the finished cheese. When 2 per ct. by volume was placed in the milk, there was found approximately 6 per ct. by weight of chloroform in the cheese; while, with 5 per ct. by volume in the milk, 15 per ct. by weight remained in the cheese. Thus about 20 per ct. of the chloroform added to the milk was recovered in the cheese.

The cheese remained in the press 18 to 24 hours, when it was removed and sampled for analysis. The above-mentioned amounts of chloroform were present at this time. The cheese was now placed in a container supplied with chloroform and held at 15.5° C. (60° F.). This container consisted of a bell jar or carefully soldered galvanized-iron can inverted over the cheese and fitting into a broad groove in a heavy wooden base. This base had been boiled in paraffin to fill all of the pores and melted paraffin was used to seal the cover into the groove in the base, thus reducing the loss of chloroform and moisture to insignificant amounts. At regular intervals the container was opened and samples taken for analysis with a sterilized cheese-trier. To replace the small amount which had been lost by leakage and evaporation, chloroform was added to a dish within the container at the time of each examination.

The results of such examinations of a number of cheeses are given in Table IX.

TABLE IX.— GERMS PER GRAM IN CHLOROFORMED CHEESE.

INTERVAL.	6.2		6.7 I		6.7 II		6.11 I		6.11 II	
	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.
2 days	21.6	612	15.11	4,345	15.50	725	14.9	......	13.5	.....
2 weeks	26.9	780	......	7,300	......	1,788	......	......	......	......
1 mo	18.1	413	14.33	448	13.30	451	14.7	310	13.1	199
3 mo	19.4	480	16.50	891	15.50	605	14.7	342	12.7	360
6 mo	8.6	1,587	12.70	178	12.30	200	15.2	350	14.8	130
9 mo	9.0	24,897	15.20	200	14.40	2,360	14.6	......	15.4	......
12 mo	......	......	......	253	......	262	14.0	840	14.6	231

TABLE IX.— (Continued.)

INTERVAL.	6.12 I		6.12 II		6.14 IV		6.14 V		6.14 VI	
	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.
2 days	11.9	4,467	11.9	2,280	10.8	724	12.4	268	12.0	268
2 weeks	9.1	4,105	9.1	4,100	10.9	294	9.6	......	10.8	......
1 mo	11.0	3,700	10.4	3,500	12.0	680	12.6	1,197	14.0	504
3 mo	......	2,320	......	3,240	12.6	209	12.4	110	12.8	1,220
6 mo	11.6	1,420	10.4	1,320	12.0	126	12.6	200	13.2	220
9 mo	......	472	......	997	14.2	220	14.2	500	14.0	130
12 mo	......	420	......	220	15.6	160	15.8	136	18.0	368

TABLE IX.— (Continued.)

INTERVAL.	6.17 I		6.17 II		6.17 III		6.17 IV		6.17 V	
	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform	Germs per gram.	Chloroform.	Germs per gram	Chloroform.	Germs per gram.
2 days	5.2	2,500	5.9	66,180	10.6	210	9.6	230	9.8	2,300
2 weeks	6.3	189	5.9	188	10.4	......	9.8	......	10.4	......
1 mo	4.9	500	6.1	84,460	9.6	430	9.6	100	10.2	336
3 mo	10.8	160	8.8	0	12.4	90	11.6	209	10.2	280
6 mo	6.3	450	6.4	120	11.0	80	10.4	100	11.0	100
9 mo	7.0	30	7.2	180	12.0	70	10.8	75	11.6	210
12 mo	......	150	......	100	......	593	......	520	......	65

TABLE IX.—(Concluded.)

INTERVAL.	6.17 VI		6.17 VII		6.17 VIII		6.17 IX	
	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.	Chloroform.	Germs per gram.
2 days	8.9	......	6.6	2,400	6.7	200	13.2	520
2 weeks	11.2	110	6.4	190	6.5	560	13.2	few
1 mo	10.2	80	5.8	260	8.4	60	16.0	84
3 mo	12.0	140	8.0	160	9.6	90	16.5	240
6 mo	13.2	220	8.5	308	9.0	258	15.8	80
9 mo	13.0	100	8.8	2,645	......	90	16.0	100
12 mo	......	250	......	500	8.9	2,140	......	......

It will be noted that in all cases the germ content is markedly below the numbers found in normal cheese. The high numbers found at the first examinations can be attributed at least in part to spores. The milk used in cheese 6.12 I and cheese 6.12 II was of particularly poor quality with a correspondingly high germ and spore content.

The first chloroformed cheese was 6.2 and in this case the percentage of chloroform was excessive. The germ content was reduced to what could be regarded as hardly more than the spore content and it remained in this condition until at the end of six months. At this time the form of container which was described had not been fully developed and through an accident the larger part of the chloroform was lost. At this time the germ content rose to 1587 and at the end of 9 months it was 24,900 per gram. It seemed a natural inference from these results that more than 9 per ct. of chloroform was necessary in order to prevent germ growth in cheese.

Cheeses 6.7 and 6.11 carried approximately 15 per ct. of chloroform and the counts were satisfactory except in case of 6.7 I at 2 days and 2 weeks and 6.7 II at 9 months.

Cheese 6.12 and 6.14 contained approximately 11 per ct. of chloroform and, while the results with the 6.14 series were very satisfactory, those with 6.12 frequently gave excessive numbers. The latter cheeses were made from some purchased milk which proved to be of poor quality with correspondingly high germ and spore content. This would seem to indicate that the results obtained from the use of chloroform in this work were at least in a measure dependent upon the germ content of the milk itself.

The 6.17 cheeses were all made from heated milk, that of 6.17 I being heated in the autoclave to 120° C., while the milk used in the remainder of the series was heated in a continuous pasteurizer to temperatures varying from 95° to 99° C. in the case of different cheeses. In this series the chloroform varied from 5 to 15 per ct. in different cheeses. In all of these cheeses, the germ content was low except in the case of occasional analyses, freuently in the first taken just as the cheese was coming from the press.

It is difficult to formulate a satisfactory explanation for these relatively high numbers found at certain examinations. In the case of cheese 6.17 I the milk should have been practically sterile, while in the remainder of this series it should not have had a germ content of more than 200 per cc. Had all of these germs been retained in the curd, it would not have accounted for more than 2,000 per gram, on the pasteurized cheeses. The analyses give 2,500 per gram from the practically sterile milk and as high as 66,000 per gram from the pasteurized milk.

Troili-Petersson,[6] Gorini,[7] Rodella,[7a] and Harrison[8] have shown that the growth of bacteria in cheese takes place in the form of distinct colonies. In the chloroformed cheese these colonies appear to be so widely separated that one is not often included in a sample. Observe that while the examination of 6.17 II gave 66,180 germs at 2 days and 84,460 at 1 month, it gave only 188 at 2 weeks and the plates at 3 months, containing one-twentieth and one-fortieth of a gram of cheese respectively, remained sterile. In some instances, where unusually large numbers were found at the regular examinations, plates made a few days later gave the usual small numbers.

It may be suggested that these colonies are the remains of the growth which occurred in the milk previous to the addition of the chloroform. While this may be possible, it does not seem probable that colonies formed in the milk would remain intact and alive while passing through the pasteurizer, the paddles of which revolve 300 times per minute. Further our study of the efficiency of this same pasteurizer, as given in Bulletin 172, would indicate strongly that this does not occur. The chloroform was added within a few minutes after the heating and our previous results have shown that the amount of chloroform present was sufficient to inhibit growth promptly in the milk. The conclusion seems almost unavoidable that, at least in the 6.17 series, these colonies were formed in the cheese in the presence of the chloroform. It should be noted that even in these cases they appeared only in the cheese with small percentages of chloroform.

It is regrettable that while the germicidal action of chloroform in cheese is so marked there should be the occasional production of colonies as indicated in the above results. The most satisfac-

[6] Troili-Petersson, Gerda, Studien ueber die Mikroorganismen des Schwedischen Güterkäses. *Cent. Bakt. u. Par.*, II Abt., **11**: 120–143; 207–215. 1903.

[7] Goroni, C. Sur la distribution des bacteries dans le fromages de Grana. *Rev. gen. du Lait*, **3**: 287–293. 1904.

[7a] Rodella, A. Einiges über die Bedeutung der direkten microscopischen Praparate für das Studium des Käsereifungsprozesses. *Cent. Bakt. u. Par.*, II Abt., **15**: 143–153. 1905.

[8] Harrison, F. C. The distribution of lactic acid bacteria in curd and cheese of the cheddar type. *Rev. gén. du Lait*, **5**: 409–415. 1906.

tory method of estimating the possible significance of such colonies is by a discussion of the relative chemical changes in cheese in which they did, and in which they did not appear. This will be presented in a later bulletin upon the relation of enzyms to cheese-ripening.

EFFECT OF CHLOROFORM UPON ENZYM ACTION.

Since so little is known regarding the constitution of enzyms, it is not to be expected that the mode of action of the chloroform upon enzyms will be clearly understood. Our knowledge here rests principally upon observed variations in the rate of action of enzyms under different circumstances. In such cases it is often impossible to determine whether these variations are due to the action of the chloroform directly upon the enzym or indirectly by changes induced in the substance upon which the enzym acts.

INFLUENCE OF OXYGEN UPON THE ACTION OF CHLOROFORM.

Malfitano(1) found that the influence of chloroform upon enzym action was markedly affected in some cases by the absence of oxygen. Thus the autodigestion of bacteria was stimulated by the addition of a drop of chloroform to a cotton stoppered tube containing a suspension of the organisms, while this digestion did not take place if the air was removed and the tube sealed at the time the chloroform was added. He reasoned that this difference in digestion was due to the absence of oxygen, since the same inhibition of the enzym action occurred when the culture tube was filled with hydrogen before sealing.

In the case of pancreatic juice under similar conditions, chloroform noticeably hindered the action of the enzym and, in the absence of oxygen, practically stopped digestion. While the presence of chloroform weakened the action of pepsin, there was no appreciable difference in its rate of digestion in the presence and in the absence of oxygen. Fibrin in a physiological salt solution digested rapidly and quite completely in the presence of oxygen and an excess of chloroform, while a second portion of the same fibrin under parallel conditions, except that the container was sealed after the removal of the air, digested but little.

In our study of milk enzyms we have necessarily conducted our experiments in sealed containers, since the rate of action was slow and, unless closely confined, the chloroform would evaporate, leaving the milk or cheese open to the action of bacteria.

It is interesting to observe that, in the light of Malfitano's results with the bacteria, the action of such bacterial enzyms as might be present in the milk or cheese would be hindered, if not prevented, by the conditions under which our experiments were conducted. It should be remembered, however, that he worked with an almost entire absence of oxygen. The results obtained by Babcock and Russell with pancreatin and trypsin (see page 55), indicate that the amount of oxygen inclosed in a bottle may be enough to supply the needs of these enzyms.

EFFECT OF CHLOROFORM UPON DIFFERENT ENZYMS.

The prevailing opinion regarding the effect of such substances as chloroform upon enzym action, as expressed by Grützner(1) is that "if one works with large quantities of the ferment, one can use the antiferments, substances which destroy the organized ferments, as thymol, chloroform, etc., without affecting the ferment action in a noticeable manner. Where the amount of ferment is small or where the aim is to discover traces of ferments, one must not use these antiferments." This inhibiting effect of given chemicals does not appear to be equal toward all enzyms.

Salkowski(6) was able to demonstrate the presence of a diastatic enzym in the liver in the presence of chloroform and he found that the digestion of fibrin proceeded in the presence of 0.5 per ct. of the same agent. As has been already cited, Malfitano(1) stated that an excess of chloroform did not prevent a practically total digestion of fibrin. According to Jacobson(1) the action of emulsion upon hydrogen peroxide is only slightly diminished by the presence of 10 per ct. of chloroform.

Bertels(1) found that a saturated water solution of chloroform retarded the action of Finzelberg's pepsin but did not have a similar action upon a solution prepared from the fresh stomach of a pig. Dubs(1), in going over the same ground, found that chloroform in 0.23 to 0.36 per ct. concentration accelerated the action of scale-pepsin, while a saturated watery solution retarded its action. He attributed this variation in the results of its action to the presence of proteids in the solution.

Work at the Wisconsin Station[9] showed that pepsin in the proportion of 1-25000 would not attack amphoteric, boiled milk in the

[9] Babcock, S. M., Russell, H. L., Vivian, A., & Hastings, E. G. Action of proteolytic ferments on milk with special reference to galactase, the cheese-ripening enzyme. Wis. Agr. Exp. Station Report, 16: 157–174. 1899.

presence of 2 per ct. of chloroform but, when 0.2 per ct. of hydrochloric acid was added to the mixture, the pepsin became active. At the end of 56 days, 46 per ct. of the nitrogen of the milk was in a soluble form.

Grützner(1), in working with the pancreatic ferment, found that its action was checked by chloroform water even when diluted 10 to 20 times.

At the Wisconsin Station commercial pancreatin in the proportion of 1-25000 parts of amphoteric, boiled milk in 2 per ct. of chloroform acted so energetically that 52 per ct. of the nitrogen of the milk was soluble at the end of 56 days. Two tests with commercial trypsin in the same concentration and under similar circumstances gave 86 per ct. and 87 per ct. of soluble nitrogen respectively at the end of 56 days.

The ability of milk enzyms to produce a digestion of the milk in the presence of chloroform and similar substances was announced by Babcock and Russell(1) in 1897 and evidence on this point has been furnished in a number of papers. These results have been substantiated by von Freudenreich,[10] Jensen[11] and others. An observation of Salkowski's(4) stands in such sharp contrast to their results that it deserves mention. He reports that two samples of normal milk containing 0.3 per cent. of chloroform showed no demonstrable evidence of proteolysis after standing 13 years.

In our own experience covering a large number of experiments and extending over 8 years, every sample of milk in the presence of chloroform has undergone a gradual but well-marked proteolysis. Further discussion of the enzyms of milk is not given here, since it is proposed to devote a bulletin to this subject later.

EFFECT OF CHLOROFORM UPON MILK ENZYMS.

For the purposes of this study, it seemed desirable to remove the fat from the milk, and accordingly the milk used in these experiments was twice passed through a centrifugal separator. In so doing, the amount of enzyms was unavoidably reduced and the resulting action was less rapid than would have been the case in normal milk.

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[10] von Freudenreich, Ed. Ueber das in der Milch vorhendene unorganisierte Ferment, die sogenannte Galactase. *Land. Jahrb. Schweiz,* **14**: 49–55. 1900.

[11] Jensen, Orla. Studien ueber die Enzyme im Käse. *Landw. Jahrb. Schweiz,* **14**: 197–233. 1900.

In order to determine accurately the inhibiting effect of chloroform, the standard of comparison should be the action which takes place in the absence of the substance being tested. In the case of milk, this is not possible, since, unless there is sufficient chloroform present to repress the bacteria, they will promptly induce such profound changes as to obscure the action of the inherent milk enzyms. This took place in the case of some of our bottles containing the lower percentages of chloroform where the bacteria were not repressed. The first experiment was designed to test the range from amounts which would not hold the bacteria in check up to 2.5 per ct., which was the percentage ordinarily used in our studies of the milk enzyms.

In this experiment duplicate bottles of milk received 0.1, 0.2, 0.3, 0.5, 0.7, 1.0. 1.5, 2.0. and 2.5 per ct. of chloroform, respectively. Each bottle contained 1 litre, the milk coming from our own herd and normally containing 5 per ct. of fat, but in this case the fat had been removed until only 0.015 per ct. remained. The bottles were held at approximately 15.5° C. (60° F.). The results of the chemical and bacterial examinations are given in Table X.

TABLE X.— SOLUBLE NITROGEN IN CHLOROFORMED SKIM-MILK.*

INTERVAL.	PERCENTAGE OF CHLOROFORM.								
	0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.0	2.5
Soluable nitrogen expressed in percentage of total nitrogen.									
Initial	14.16	14.16	14.16	14.16	14.16	14.16	14.16	14.16	14.16
1 mo	....	35.55	37.42	37.50	35.38	31.50	26.52	25.45	25.63
		35.54	38.06	36.14	35.27	33.69	30.18	25.81	28.07
3 mos	45.72	45.53	49.18	49.10	45.66	39.96	39.77	35.60	38.67
	44.73	44.20	48.98	48.18	46.74	38.93	35.49	34.92	34.02
6 mos	41.70	51.50	50.58	50.42	50.64	43.88	39.96	43.29	35.07
	47.20	48.26	50.01	48.35	50.00	43.48	42.06	39.85	40.23
Bacteria per cubic centimeter found in these milks.									
Initial	162,000	.....	......	......	......	......	......	......	......
1 mo	Curdled	48	38	36	30	33	46	35	46
		44	35	50	15	25	43	44	42
3 mos	Too many to count	33	30	39	25	12	26	15	25
		43	30	38	15	19	12	16	33
6 mos	188,700	18	18	12	14	21	10	10	13
		14	34	14	6	8	4	12	7

* Chemical determinations by Mr. Hart and bacteriological by Mr. Nicholson.

Since the first demonstrable effect of enzyms in milk is to bring nitrogen into solution, the percentage of nitrogen in this form has been used as a measure of enzym action.

The bacteria were not held in check in the bottles containing 0.1 per ct. of chloroform and this milk curdled at the end of four and seven days, respectively. There were many thousands of bacteria per cc. present at the end of three months but the colonies developed so thickly on the plates that accurate counting was not possible. Plates were prepared from only one of the bottles at the end of six months and 188,700 per cc. were found. It was difficult to obtain satisfactory samples for chemical analysis from the curdled mass and these results were therefore somewhat irregular. While the total digestion was not greater than in the bottles where the bacteria were destroyed by the chloroform, it was characterized by the presence of measurable amounts of ammonia.

No ammonia was found in any of the other bottles; the germ content was uniformly low and the milk did not curdle until after about two months. From these facts, it seems a justifiable assumption that, in the case of these bottles, the action of germ life was excluded. This must certainly have been the case with the bottles containing 0.5 per ct. or more of chloroform.

The determinations of the soluble nitrogen show that, in the bottles containing chloroform in percentages ranging from 0.2 to 0.7 per ct., the rate of enzym action was practically uniform, and at the end of 6 months there was approximately 50 per ct. of the nitrogen in the soluble form. The digestion in the bottles containing 1.0 per ct. or more of chloroform was less rapid from the beginning and this retardation of the enzym action increased with the increase in the percentage of chloroform present. In the bottles containing 2.5 per ct. of chloroform, the average content of soluble nitrogen at the end of 6 months was but 38 per ct. of the total nitrogen.

This observed decrease of 12 per ct. in the activity of the milk enzyms, when comparing their action in the presence of 0.7 and 2.5 per ct. of chloroform, respectively, was undoubtedly due to the unfavorable action of the higher percentage of chloroform.

In view of these results, it is important to know the effect of such higher percentages of chloroform as were used in the cheese work. Accordingly, duplicate bottles were prepared containing 2.5, 5, 10, 20 and 30 per ct. of chloroform, respectively, in skimmed milk. The milk had been twice passed through a centrifugal separator and contained only 0.025 per ct. of fat. One litre of the mixture was put into each bottle and the bottles were held at 15.5° C. (60° F.).

The soluble nitrogen and the germ content of the bottles at the end of various intervals are given in Table XI.

TABLE XI.— SOLUBLE NITROGEN IN CHLOROFORMED SKIM-MILK.*

INTERVAL.	PERCENTAGE OF CHLOROFORM.				
	2.5	5.0	10.0	20.0	30.0
Soluble nitrogen expressed in percentage of total nitrogen.					
7 days	10.59	9.63	9.85	9.97	13.33
	9.00	11.19	12.49	11.85	8.08
21 days	16.09	13.47	13.87	13.76	12.73
	10.94	17.77	15.90	18.42	15.85
49 days	22.58	22.82	22.08	22.31	24.32
	16.17	21.99	22.72	20.26	21.12
112 days	31.71	31.94	30.29	37.74	32.23
	21.65	34.59	32.00	28.09	32.76
192 days	42.18	38.83	34.79	35.82	36.40
	35.41	39.54	37.76	38.88	35.01
336 days	51.81	47.52	42.19	44.47	45.40
	43.89	52.54	46.97	47.04	42.92
Bacteria per cubic centimeter found in these milks.					
7 days	34	60	25	22	18
	23	33	27	28	....
21 days	39	30	25	22	31
	45	41	26	31	29
112 days	8	....	11	6	8
	....	....	11	5	3
192 days	....	14	7	6	....
	13	....	....	....	....
	2	8	6	6	2
336 days	10	8	8	12	6

* Chemical determinations by Messrs. Le Clerc, Patten and Hart, and bacteriological by Mr. Rogers.

The large percentages of chloroform promptly reduced the bacteria to numbers which represented only the most resistant spores in the original milk.

A comparison of the results here given in case of 2.5 per ct. of chloroform with those obtained under similar conditions as given in Table X shows that in the two experiments the digestion progressed at approximately the same rate under similar conditions.

In this table the analyses of the pairs of bottles are given each time in the same order and it will be noticed that there are distinct differences in the rate of digestion in the different bottles. Thus the soluble nitrogen in one of the bottles containing 2.5 per ct. of chloroform is high during the entire experiment, while, at the same time, in its duplicate the percentage of soluble nitrogen was among the lowest in the entire series.

While the differences are not marked, there is indication of a slight retarding action with the increasing percentages of chloroform, but this is by no means so well marked as with the range from 0.7 to 2.5 per ct.

In attempting to reason from these results to the probable action of the chloroform upon the enzyms in cheese, it should be remembered that there is a marked difference in the physical condition of the material in the two cases. With milk, the chloroform settled to the bottom in all bottles containing 5 per ct. or more of chloroform, while in the cheeses it remained more evenly distributed throughout the mass. This is in a measure offset by the fact that the percentages of chloroform tested in the milk were much higher than in the case of cheese, and that there was little increased retarding action shown by these higher percentages of chloroform over that shown by 2.5 per ct.

EFFECT OF CHLOROFORM UPON PROTEIDS.

The effect of chloroform upon the rate of digestion through its action upon the milk proteids is so closely related to its action directly upon the enzym that in our studies we have not attempted to differentiate them but have measured the combined effect and given the results in Tables X and XI. There are, however, other phenomena in connection with the use of chloroform which can be directly observed and which deserve notice.

In an early communication Salkowski(2) called attention to the coagulation which takes place when blood is preserved with chloroform and Formanek(1), Kruger(1) and Salkowski(7) have more recently discussed its action as a precipitant for haemoglobin.

Kirchner(1) observed that blood serum coming in contact with the drops of chloroform turned a grayish white and, during the years that chloroform has been used as a means of preserving proteid solutions, it has been a matter of common observation that a white accumulation commonly forms on standing.

In discussing the solubility of chloroform, attention was called to the formation of a heavy, white, opaque layer at the bottom of the milk. This layer is most easily studied in skim-milk, though it is equally abundant in normal milk, in the latter case being partly obscured by the submerged fat.

Observations have shown that it is formed in skim-milk in noticeable quantities after the addition of 0.7 per ct. of chloroform and steadily increases in amount in proportion to the amount of chloroform added. In case of the smaller percentage it readily mixes with the milk upon shaking and does not reappear until after standing some hours. With larger amounts of chloroform it forms promptly and, while it mixes with the milk on shaking, it promptly settles out. Measurements of the depth of the layer formed after the addition of 40 per ct. of chloroform showed it to be as deep at the end of 4 hours as after 10 days. Where it is present in considerable quantities, the volume of this opaque material is approximately equal to the volume of the chloroform which has been added. Where chloroform is added in large quantities, the milk standing above this opaque layer becomes noticeably more translucent, indicating that a portion of the casein has been carried down.

Mr. Bosworth siphoned the milk from above such a layer in a bottle of milk which had contained 10 per ct. of chloroform. The chloroform layer with a little of the milk was transferred to a separatory-funnel and allowed to stand over night. In the morning one-half of the chloroform layer was drawn off into another separatory-funnel and to this was added some water and the mixture well shaken for a half hour or more. It was then allowed to settle and after a distinct separation of the two liquids all of the chloroform and one-half of the water were drawn off. The remaining half of the water was transferred to a beaker. The solution was of a milky appearance and upon the addition of a slight amount of 1 per ct. acetic acid a precipitate settled out, which upon examination proved to be casein.

From these observations it would seem clear that the chloroform, in excess of what passes into solution in the serum of the milk, settles to the bottom and carries down with it a portion of the casein. The casein is apparently not altered by entering into this relation with the chloroform since, upon being shaken with an excess of water, it passes in suspension into the water from which it can be precipitated by acid in the same form in which it is normally thrown down from the milk.

CONCLUSIONS.

Solubility.— The solubility of chloroform in skim-milk is approximately 0.55 per ct. by volume. In normal milk the solubility of chloroform depends largely upon the percentage of fat present. Five per ct. of fat dissolves approximately 1.0 per ct. of chloroform. The affinity of chloroform for fat is marked and the resulting saturated solution is heavier than the milk, collecting at the bottom of the container.

Germicidal value of chloroform.—All determinations of the action of chloroform must be carefully guarded against loss of chloroform by evaporation. In working with small percentages the air space in the container must be small.

Vegetative germs are very susceptible to the action of chloroform while spores are extremely resistant.

In peptone bouillon, 0.1 per ct. of chloroform by volume is sufficient to prevent growth. In skim-milk this is sometimes accomplished by 0.2 per ct., but 0.3 per ct. is often required while 0.4 per ct. destroys the vegetative forms within 24 hours.

In normal milk containing 5 per ct. of fat, 1.0 per ct. of chloroform produces an immediate reduction of the germ content, 1.5 per ct. destroys the vegetative forms within 24 hours, while 2.0 per ct. kills them within 4 hours and 2.5 per ct. accomplishes this within 10 minutes.

The chloroform which dissolves in the fat and settles to the bottom is, for all germicidal purposes, removed from the milk. The explanation for the observed increase in the germicidal action, on the addition of chloroform above that required for the saturation of the fat and the milk serum, is not clear, since this excess of chloroform also tends to settle to the bottom. However, during the short period in which it manifested its activity, it was largely in suspension, due to repeated shaking of the milk.

The results with chloroformed cheddar cheese were somewhat variable, indicating the action of factors which have not been recognized and measured. The lowest percentage tested, 5 per ct. by weight, prevented growth with the exception of the formation of occasional colonies. Similar colonies were occasionally found in cheese containing as much as 10 per ct. of chloroform by weight.

Effect upon enzym action.—With percentages of chloroform so low that acid formation is not prevented, the digestive action of milk enzyms is less rapid than when more chloroform is used. This is undoubtedly due to the inhibiting effect of the acid rather than to any stimulating action of higher percentages of chloroform. In skim-milk a retarding action upon the enzyms becomes evident with amounts between 0.7 and 1.0 per ct. This retardation practically reaches its maximum with 2.5 per ct. of chloroform, when it amounts to 12 per ct. of the amount of digestion that occurred in the presence of 0.7 per ct. or less of chloroform.

Action upon milk proteids.— The chloroform above that required to saturate the fat and the milk-serum carries down casein in quantities roughly proportional to the excess of chloroform present. This combination is readily observed as a heavy, white, opaque layer. The casein does not appear to be changed by this solution in the chloroform since it can be separated from the chloroform by vigorous shaking with water and when thus separated responds to reagents as does ordinary milk-casein.

General.— Chloroform is a fairly satisfactory agent for repressing germ life in connection with the study of milk enzyms. Quantitative studies of the action of such enzyms should receive a correction of at least 10 per ct. where 2.5 per ct. of chloroform or more is used.

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REPORT

OF THE

Botanical Department.

F. C. Stewart, *Botanist.*

H. J. Eustace, *Assistant Botanist.*

G. T. French, *Assistant Botanist.*

J. G. Grossenbacher, *Assistant Botanist.*

F. A. Sirrine, *Special Agent.*

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REPORT OF THE BOTANICAL DEPARTMENT.

POTATO-SPRAYING EXPERIMENTS IN 1906.*

F. C. STEWART, H. J. EUSTACE, G. T. FRENCH AND F. A. SIRRINE.

SUMMARY.

The fifth year of the ten-year series of potato-spraying experiments begun in 1902 is now completed. During 1906 the work was carried out along the same lines as in 1904 and 1905. Eighty separate experiments are reported in this bulletin.

TEN-YEAR EXPERIMENTS.

At Geneva, five sprayings increased the yield 63 bushels per acre, while three sprayings increased it 31.75 bushels. The gain was due chiefly to the prevention of late blight. There was no rot. At Riverhead, the gain due to five sprayings was 53.25 bushels per acre and to three sprayings 21.5 bushels. Here, the chief enemies were the flea beetle and late blight, but there was no rot.

FARMERS' BUSINESS EXPERIMENTS.

In fifteen experiments, including 225.6 acres, the average gain due to spraying was 42.6 bushels per acre; the average total cost of spraying, $5.18 per acre; the average cost of each spraying, 98.5 cents per acre; and the average net profit, $13.89 per acre.

VOLUNTEER EXPERIMENTS.

Sixty-two volunteer experimenters, spraying 598 acres, reported gains averaging 44.5 bushels per acre, the largest being 132.6 bushels and the smallest no gain at all.

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*A reprint of Bulletin No. 290.

POTATO TROUBLES IN 1906.

On the whole, the potato crop suffered less from blight and rot in 1906 than in any previous season since these experiments began. It is roughly estimated that flea beetles and early blight caused an equal amount of loss, while late blight was responsible for as much damage as flea beetles and early blight combined. There was no rot of any importance anywhere in the State.

SPRAYING IS PROFITABLE.

Judging from the experiments thus far made it appears that spraying for blight is an operation which no potato grower in New York can afford to neglect. Forty-eight farmers' business experiments made during the past four years show an average net profit of $20.51 per acre due to spraying.

DIRECTIONS FOR SPRAYING.

Commence spraying with bordeaux when the plants are 6 to 8 inches high and repeat at intervals of 10 to 14 days throughout the season, making, in all, five or six applications. When bugs or flea beetles are numerous add paris green or other poison. For further details see page 134.

INTRODUCTION.

Does it pay to spray potatoes in New York? Potato growers have been asking this question for fifteen years or more. It is well known that in seasons when blight is destructive spraying will check the blight and considerably increase the yield; but the majority of potato growers have doubted that spraying is profitable on the average. They argue that blight does not appear every year. In some seasons it causes but little if any damage, yet the spraying must be done regularly because it is impossible to foretell the appearance of blight. The result is that in some seasons spraying is profitable while in others it is unprofitable and they doubt that it is profitable on the average.

This Station has set out to find an answer to the above question. The investigation was begun in 1902 and is to be continued until 1912. During ten consecutive years numerous potato spraying experiments will be made each year and at the end of the period the results will be averaged. The experiments are of three kinds: (1) Station ten-year experiments; (2) farmers' business experiments; (3) farmers' volunteer experiments.

The Station ten-year experiments were begun in 1902. Each year there are two of them — one on the Station grounds at Geneva, the other near Riverhead, Long Island. The object of these experiments is to determine how much the yield can be increased, on the average, by spraying with bordeaux mixture. Two methods of spraying are being compared as to their efficiency: Some rows are sprayed regularly every two weeks while others are sprayed only three times during the season. The rows sprayed every two weeks alternate with those sprayed only three times and with others not sprayed at all, so that every third row is an unsprayed one.

The farmers' business experiments were begun in 1903 and have been continued each year since. The object of these experiments is to determine the net profit in spraying potatoes in different ways under actual farm conditions. In 1906, fifteen farmers coöperated with the Station in making business experiments.

The collection and tabulation of the results of volunteer experiments made by farmers all over the State was begun in 1904. Sixty-two such experiments made in 1906 are reported in this bulletin. While the most important feature of the volunteer experiments, taken as a whole, is the increase in yield due to spraying, several of them contain, also, other points of special interest.

Bulletins previously published are as follows:

No. 221. Potato Spraying Experiments in 1902;
No. 241. Potato Spraying Experiments in 1903;
No. 264. Potato Spraying Experiments in 1904;
No. 279. Potato Spraying Experiments in 1905.

SUMMARY OF RESULTS OBTAINED IN TEN-YEAR EXPERIMENTS PRIOR TO 1906.

RESULTS IN 1902.

TABLE I.—YIELD BY SERIES AT GENEVA IN 1902.[1]

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	lbs.
I..........	1, 4, 7 and 13.....	July 10, 23 and Aug. 12............	317	41
II..........	2, 5, 8 and 14.....	June 25, July 10, 23, 30, Aug. 12, 26 and Sept. 10....................	342	36
III..........	3, 6, 9 and 15	Not sprayed......................	219	4

[1] Rows 10, 11 and 12 omitted because of probable error.

Gain due to spraying three times, 98½ bu. per acre.

Gain due to spraying seven times, 123½ bu. per acre.

The unsprayed rows died two weeks earlier than the sprayed rows, owing chiefly to a severe attack of late blight. They were also somewhat injured by flea beetles, but there was no early blight. On unsprayed rows the loss from rot was 7½ per ct.; on sprayed rows only an occasional tuber.

TABLE II.—YIELD BY SERIES AT RIVERHEAD IN 1902.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	2, 5, 8 and 11.....	May 26, June 20 and July 12........	295	20
II..........	1, 4, 7 and 10.....	May 26, June 3, 20, 30, July 11, 23 and Aug. 5....................	312	35
III..........	3, 6, 9 and 12.....	Not sprayed.....................	267	40

Gain due to spraying three times, 27⅔ bu. per acre.
Gain due to spraying seven times, 45 bu. per acre.

In this experiment there were only traces of early blight and no late blight. The larger yield on sprayed rows was due to partial protection against flea beetles which were rather plentiful at times. There was no rot.

RESULTS IN 1903.

TABLE III.—YIELD BY SERIES AT GENEVA IN 1903.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7, 10 and 13..	July 14, 28 and Aug. 26............	262	—
II..........	2, 5, 8, 11 and 14..	July 7, 21, Aug. 7, 21 and Sept. 3....	292	10
III..........	3, 6, 9, 12 and 15..	Not sprayed.....................	174	20

Gain due to spraying three times, 88 bu. per acre.
Gain due to spraying five times, 118 bu. per acre.

Three sprayings prolonged the life of the plants 11 days; five sprayings, 18 days. There was no early blight and the injury from flea beetles was only slight. Late blight was again the chief enemy. The loss from rot was even less than in 1902.

TABLE IV.—YIELD BY SERIES AT RIVERHEAD IN 1903.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7 and 10.....	June 5, July 22 and Aug. 7..........	246	45
II..........	2, 5, 8 and 11.....	June 5, 24, July 7, 22 and Aug 7.....	263	10
III..........	3, 6, 9 and 12.....	Not sprayed......................	207	10

Gain due to spraying three times, 39½ bu. per acre.
Gain due to spraying five times, 56 bu. per acre.

The sprayed rows outlived the unsprayed by several days. Late blight and flea beetles were the chief enemies. Early blight, also, caused slight damage. On the unsprayed rows the loss from rot was 2 per ct.; on the sprayed, practically nothing.

RESULTS IN 1904.

TABLE V.—YIELD BY SERIES AT GENEVA IN 1904.

Serie .	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7, 10 and 13..	July 13, 27 and Aug. 15............	344	30
II..........	2, 5, 8, 11 and 14..	July 8, 22, Aug. 1, 15 and 29........	386	40
III..........	3, 6, 9, 12 and 15..	Not sprayed......................	153	25

Gain due to spraying three times, 191 bu. per acre.
Gain due to spraying five times, 233 bu. per acre.

Spraying prolonged the life of the plants 25 days. Late blight was the only trouble. Both on sprayed and unsprayed rows there was a little rot at digging time. In storage, the sprayed potatoes rotted most. Spraying materially improved the cooking qualities.

TABLE VI.—YIELD BY SERIES AT RIVERHEAD IN 1904.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7 and 10.....	June 14, July 21 and Aug. 9........	257	58
II..........	2, 5, 8 and 11.....	June 14, 27, July 11, 26, Aug. 9 and 22	297	45
III..........	3, 6, 9 and 12.....	Not sprayed......................	201	25

Gain due to spraying three times, 56½ bu. per acre.
Gain due to spraying six times, 96⅓ bu. per acre.

The larger yield on sprayed rows was due chiefly to partial protection against flea beetles which were unusually abundant.

Both early and late blight also present. The loss from rot was 3 per ct. on Series I, 1 per ct. on Series II, and 6 per ct. on Series III.

RESULTS IN 1905.

TABLE VII.—YIELD BY SERIES AT GENEVA IN 1905.[2]

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	4, 7, 10 and 13....	July 3, August 7 and 25............	228	45
II..........	5, 8, 11 and 14....	June 29, July 13, 27, Aug. 12 and 24..	241	15
III..........	6, 9, 12 and 15....	Not sprayed......................	121	52

[2] Rows 1, 2 and 3 omitted because of error.

Increase in yield due to spraying three times, 107 bu. per acre.
Increase in yield due to spraying five times, 119⅓ bu. per acre.

From the combined attack of flea beetles, tip-burn and late blight the unsprayed rows died fully two weeks earlier than the sprayed ones. Spraying reduced the loss from rot at the rate of 41 bushels per acre. There was no subsequent rot in storage.

TABLE VIII.—YIELD BY SERIES AT RIVERHEAD IN 1905.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7, 10 and 13..	June 14, July 18 and Aug. 11.......	253	—
II..........	2, 5, 8, 11 and 14..	June 14, 30, July 14, 28 and Aug. 11..	303	41
III..........	3, 6, 9, 12 and 15..	Not sprayed......................	221	38

Increase in yield due to spraying three times, 31⅓ bu. per acre.
Increase in yield due to spraying five times, 82 bu. per acre.

Late blight caused no injury in this experiment and there was not even a trace of rot. Flea beetles and early blight were the enemies fought.

DETAILS OF THE TEN-YEAR EXPERIMENTS IN 1906.

SOIL, PLANTING, CULTIVATION, ETC.

At Geneva.—The plat of land used was the same as that used for this experiment in 1904. The soil was a heavy clay loam containing some gravel. The surface drainage was good. During the season of 1905 it was seeded with red clover. It was plowed in the fall of 1905 and again in the spring of 1906.

Seventeen rows 290½ feet long were marked out three feet apart. Immediately before planting the furrows were opened with a plow. Commercial fertilizer at the rate of 500 pounds per acre (ten pounds per row) was scattered in the furrows by hand. The soil was fine and in excellent condition for planting which was done May 26. The seed pieces were placed 15 inches apart in the row and covered about 4 inches deep by means of hoes.

The seed was of the variety Rural New Yorker No. 2 selected from the sprayed rows in the experiment of 1905. On May 21 the seed tubers were given the formalin treatment for scab. The following day they were cut into pieces of hen's egg size in such manner that each piece contained at least one good eye.

During the season the plants were harrowed twice, cultivated three times and hoed once. Up to about August 15 the weather conditions were favorable but after that date the potato crop was considerably injured by heat and lack of rain.

At Riverhead.— The land used at Riverhead was a level plat of sandy loam on the farm of H. H. Hallock. The soil was of about the same character as that used for the experiment in 1905. The previous crop was potatoes. A mixture composed of 1500 pounds of commercial fertilizer (4-10-5 formula) and 500 pounds flowers of sulphur (for scab) was applied to the land at the rate of 2000 pounds per acre by means of a fertilizer drill which opened a furrow about two inches deep. Furrows for planting were made by deepening the drill furrows with a shovel plow.

The seed potatoes were of the variety Green Mountain and came from an unsprayed field in which there was considerable rot. After the formalin treatment for scab the seed tubers were cut and dusted with sulphur. The seed pieces were planted April 26, 15 inches apart in the row, at the rate of 20 bushels per acre, and covered by means of a horse hoe. The experiment included 15 rows 290½ feet long.

Cultivation was sufficiently thorough to keep the field entirely free from weeds throughout the season.

PREPARATION AND APPLICATION OF THE BORDEAUX MIXTURE.

Both at Geneva and Riverhead the bordeaux mixture used was made by the 1-to-8 formula, approximately, and applied very thoroughly as in former years. At Geneva, the first spraying of Series I and the first two sprayings of Series II were made with a barrel spray dump, all others with a knapsack. At Riverhead all of the spraying was done with a knapsack.

DATES OF SPRAYING, ETC.

At Geneva: Series I.— The rows of this series, 1, 4, 7, 10 and 13 were sprayed three times with bordeaux mixture — July 9, August 10 and 30. At the time of the first spraying the plants were 12 to 15 inches high. Bugs were numerous but had not yet done material damage. Paris green was applied with the bordeaux at the rate of one pound to fifty gallons. After this there was no further trouble with bugs so the second and third sprayings were made with bordeaux alone.

Series II.— This series consisted of rows 2, 5, 8, 11 and 14. The plants were sprayed five times with bordeaux mixture — July 6, 20, August 6, 20 and 21. Following the fourth spraying on August 20 there came a heavy shower (3.10 inches) before the bordeaux was dry and washed it off to such an extent that it was considered necessary to repeat the spraying the next day. After August 21 the weather was so dry and hot that the blight made no progress and further spraying was thought to be unnecessary.

At the time of the first spraying the plants were 10 to 14 inches high. It was the intention to begin somewhat earlier than this, but circumstances prevented. Subsequent events indicate that no loss resulted from the delay. "Bugs" were hatching in considerable numbers. A few were about half grown but the majority were just hatched. Paris green, which was used with the bordeaux in the first spraying at the rate of 8 ounces to 50 gallons, seemed to kill the "bugs" satisfactorily, but it was necessary to use poison a second time in the second spraying; whereas, on Series I and III treated July 9 with double this quantity of paris green one application was sufficient.

Series III.— Series III consisted of rows 3, 6, 9, 12 and 15. No bordeaux mixture was used on this series. One application of paris green in lime water (one pound paris green, two pounds lime and fifty gallons water) applied July 9 was sufficient to keep the plants free from "bugs" during the entire season.

At Riverhead: Series I.— This series consisted of five rows, Nos. 1, 4, 7, 10 and 13. They were sprayed with bordeaux mixture three times (June 12, 18 and August 6) and treated with paris green in lime water twice besides (June 26 and July 12). Paris green was also used with the bordeaux in the first spraying.

Series II.— This series consisted of five rows, Nos. 2, 5, 8, 11 and 14. They were sprayed with bordeaux mixture five times

(June 12, 25, July 10, 25 and August 6). Paris green was used with the bordeaux in the first three sprayings.

Series III.— This series, also, consisted of five rows, Nos. 3, 6, 9, 12 and 15. No bordeaux was used on these rows, but they were treated with paris green in lime water twice, June 26 and July 12.

It will be observed that on Series I and II paris green was applied three times; while on the check rows, Series III, it was used but twice. From this it would appear that the sprayed rows had an unfair advantage, but such was not the case. The use of poison on Series I and II in the first spraying was entirely unnecessary. There were no bugs in sight at this time but they were expected to appear in a few days and it was thought best to be ready for them. However, it was two weeks before they became numerous enough to require treatment. Whenever paris green was used in this experiment it was applied at the rate of one pound per acre.

RESULTS OF THE TEN YEAR EXPERIMENTS IN 1906.

AS SHOWN BY THE CONDITION OF THE FOLIAGE.

At Geneva.— Up to August 6 there was no difference between the sprayed and unsprayed rows. At this time the plants were looking well. They were freely touching between the rows, but not yet covering the ground completely. There had been no injury from "bugs" and there was no early blight, *Alternaria solani.* Only a little injury from flea beetles was evident and there was only a trace of late blight, *Phytophthora infestans.* Some leaves with brown margins were to be found on all of the rows.

By September 6 there was considerable contrast between sprayed and unsprayed rows. There was also a noticeable difference between Series I and II, the latter showing fewer brown leaves.

About September 15 the rows of Series III were dead while the rows of both sprayed series were still partly green. The contrast was greater now than at any other time during the season, but much less than in any of the previous four seasons during which the experiment has been in progress.

Late blight, *Phytophthora infestans,* first appeared in the experiment field August 4. Soon after this the weather conditions became unfavorable to its spread and it did not do much damage.

The most serious disease was one which caused the leaves to turn brown around the margin. Its nature was not definitely determined, but we incline to the opinion that it was due chiefly to excessive heat and dry weather. The early blight fungus, *Alternaria solani*, was responsible for only a small part of the trouble. Whatever the cause, the sprayed rows suffered less than the unsprayed ones.

At Riverhead.— In the experiment at Riverhead the principal enemies were late blight and flea beetles, there being a moderate attack of both. Early blight was not sufficiently abundant at any time to cause material injury.

On July 20 the sprayed series (I and II) presented a somewhat better appearance than the unsprayed series (III), but there was not a marked contrast. The greatest difference probably occurred about August 1 when the condition of the sprayed series was decidedly superior to that of the unsprayed.

AS SHOWN BY THE YIELD.

At Geneva.— The potatoes were dug by hand October 8. The product of each row was carefully sorted into two grades — marketable tubers and culls — and weighed. According to our usual method all sound tubers larger than a hen's egg were graded as marketable.

TABLE IX.—YIELDS IN THE EXPERIMENT AT GENEVA IN 1906.

Section.	Row.	TREATMENT.	YIELD PER ROW.[1]		YIELD PER ACRE.			
			Marketable.	Culls.	Marketable.		Culls.	
			lbs.	lbs.	Bu.	lbs.	Bu.	lbs.
A.	1	Sprayed 3 times	275	23	229	10	19	10
	2	Sprayed 5 times	304	17	253	20	14	10
	3	Unsprayed	224	29	186	40	24	10
B.	4	Sprayed 3 times	255½	22	212	55	18	20
	5	Sprayed 5 times	281	16	234	10	13	20
	6	Unsprayed	237½	18½	197	55	15	25
C.	7	Sprayed 3 times	277½	17	231	15	14	10
	8	Sprayed 5 times	324	13½	270	—	11	15
	9	Unsprayed	244	17	203	20	14	10
D.	10	Sprayed 3 times	292	12½	243	20	10	25
	11	Sprayed 5 times	326	17	271	40	14	10
	12	Unsprayed	238½	15	198	45	12	30
E.	13	Sprayed 3 times	264½	19½	220	25	16	15
	14	Sprayed 5 times	317	19	264	10	15	50
	15	Unsprayed	230	19	191	40	15	50

[1] Rows 290.4 feet long by three feet wide making the area of each row exactly one-fiftieth acre. Concerning the loss from rot see page 77.

Comments on the table.— (1) In every section the five-sprayed row outyielded the three-sprayed row.

Fig. 1.— Showing condition of the experiment field on August 23.

Fig. 2.— Sorting and weighing the crop.

Plate I.— The Ten-Year Experiment at Geneva.

(2) In every section both of the sprayed rows outyielded the unsprayed row.

(3) In different sections the yields of the rows treated in the same way varied considerably. This has happened also in all four of the previous experiments. It can not be avoided. In order to obtain reliable data in experiments of this kind sprayed and unsprayed rows must be alternated and repeated several times to get average yields.

(4) The average yield of culls was greater on the sprayed rows than on the unsprayed, being 16 bu. 37 lbs. per acre on the unsprayed rows, 15 bu. 40 lbs. per acre on the rows sprayed three times and 13 bu. 45 lbs. per acre on the rows sprayed five times. This is in harmony with the results obtained in previous years excepting 1905, when the yield of culls was greater on the sprayed rows.

Yield by series.— The five rows sprayed three times constitute Series I and the average yield of these rows makes the yield for Series I. The yields given for Series II and III have been computed in the same manner. The yield by series is shown in the following table:

TABLE X.—YIELD BY SERIES AT GENEVA IN 1906.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13	July 9, August 10 and 30	227	25
II	2, 5, 8, 11 and 14	July 6, 20, August 6, 20 and 21	258	40
III	3, 6, 9, 12 and 15	Not sprayed	195	40

Increase in yield due to spraying three times, 31¾ bu. per acre.
Increase in yield due to spraying five times, 63 bu. per acre.

It appears that the last two sprayings of Series II (really one double spraying) on August 20 and 21 very nearly doubled the gain.

Loss from rot.— Only four rotten tubers were found in the entire experiment.

At Riverhead.— In the experiment at Riverhead the potatoes were dug on September 1 and sorted into two grades, marketable tubers and culls, in the same manner as at Geneva.

TABLE XI.—YIELDS IN THE EXPERIMENT AT RIVERHEAD IN 1906.

Section.	Row.	TREATMENT.	YIELD PER ROW.[1]		YIELD PER ACRE.			
			Marketable.	Culls.	Marketable.		Culls.	
			Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A.......	1	Sprayed 3 times.......	221	19	184	10	15	50
	2	Sprayed 5 times.......	276	14	230	—	11	40
	3	Unsprayed...........	167	15	139	10	12	30
B.......	4	Sprayed 3 times.......	203	18	169	10	15	—
	5	Sprayed 5 times.......	228	10	190	—	8	20
	6	Unsprayed...........	193	23	160	50	19	10
C.......	7	Sprayed 3 times.......	191	17	159	10	14	10
	8	Sprayed 5 times.......	233	10	194	10	8	20
	9	Unsprayed...........	187	18	155	50	15	—
D.......	10	Sprayed 3 times.......	206	18	171	40	15	—
	11	Sprayed 5 times.......	248	12	206	40	10	—
	12	Unsprayed...........	187	18	155	50	15	—
E.......	13	Sprayed 3 times.......	211	15½	175	50	12	55
	14	Sprayed 5 times.......	237½	14	197	55	11	40
	15	Unsprayed...........	169	25½	140	50	21	15

[1] Rows 290.4 feet long by three feet wide making the area of each row exactly one-fiftieth acre.

Comments on the table.—As in previous years, the gain from spraying in this experiment was smaller than in the experiment at Geneva. On the average, five sprayings gave more than twice the gain from three sprayings. In each section both of the sprayed rows outyielded the unsprayed row and the row sprayed five times outyielded the row sprayed three times.

TABLE XII.—YIELD BY SERIES AT RIVERHEAD IN 1906.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I..........	1, 4, 7, 10 and 13..	June 12, July 18 and August 6......	172	—
II..........	2, 5, 8, 11 and 14..	June 12, 25, July 10, 25 and Aug. 6	203	45
III..........	3, 6, 9, 12 and 15..	Not sprayed.....................	150	30

Increase in yield due to spraying three times, 21½ bu. per acre.
Increase in yield due to spraying five times, 53¼ bu. per acre.

Loss from rot.— There was no rot on any of the rows in this experiment.

SUMMARY OF RESULTS OBTAINED IN THE TEN-YEAR EXPERIMENTS, 1902–1906.

The following table shows the results obtained in the ten-year experiments during the first five years:

Table XIII.— Summary of the Ten-Year Experiments for Five Years.

Year.	At Geneva.		At Riverhead.	
	Gain per A. due to spraying every two weeks.	Gain per A. due to spraying three times.	Gain per A. due to spraying every two weeks.	Gain per A. due to spraying three times.
	Bu.	*Bu.*	*Bu.*	*Bu.*
1902	123½	98½	45	27½
1903	118	88	56	39½
1904	233	191	96	56½
1905	119	107	82	31⅔
1906	63	32	53	21½
Average	132	103⅓	66⅓	35⅓

FARMERS' BUSINESS EXPERIMENTS.

OBJECT OF THE EXPERIMENTS.

Many farmers question the reliability of the results obtained in experiments like the Station ten-year experiments described in this bulletin. They doubt that such results can be obtained in ordinary farm practice. The common objections to the experiments are: (1) They are on too small a scale (three-tenths of an acre); (2) the spraying is done more thoroughly than farmers would do it; (3) it is difficult to determine accurately the expense of the spraying; (4) the idea is prevalent that the Station potatoes are given extra good care in order that large yields may be obtained.

To satisfy this demand for experiments of a more practical kind the Station decided to conduct a series of farmers' business experiments so managed as to show the actual profit in spraying potatoes under farm conditions. This work was commenced in 1903 with six experiments. In 1904, fourteen such experiments were made, in 1905 fourteen and in 1906 fifteen. The results have been of such general interest, that it has been decided to make several of these business experiments each season during the remaining five years in which the potato spraying experiments are to be continued.

METHODS.

The methods employed in 1906 were essentially the same as in previous years. In the spring of 1906 the Station arranged with fifteen farmers in different parts of the State to keep an account of their spraying operations on potatoes. An accurate record was kept of all the expense of the spraying, including labor, chemicals and wear of machinery. In each experiment strips of three to seven rows were left unsprayed for comparison. These rows received no bordeaux mixture but were treated with poison to protect the plants from bugs.

In six of the experiments there was but a single unsprayed strip; in five experiments there were two unsprayed strips; and in four experiments three unsprayed strips. Hence, so far as concerns the increase in yield due to spraying, the fifteen experiments really included 28 separate tests.

In the fall, the tubers on one or more of the unsprayed rows were carefully weighed. The same was done with one or more sprayed rows on either side. In this manner it was determined how much the yield had been increased by spraying. In all cases a representative of the Station was present when the test rows were dug and assisted with the weighing. The length and width of the rows were carefully measured, the Station representative assisting with this, also. Accordingly, we can vouch for the accuracy of the yields reported. Each of the experiments was visited twice or three times during the season for the purpose of taking notes.

The experiment fields varied in size from five to forty-five acres, the total acreage of the fifteen experiments being 226 acres. As far as practicable they were placed in localities where the potato is a leading farm crop. In ten of the experiments the test rows were in plain view from a public road so that the results could be seen by passersby.

The method of spraying in the Hebron experiment was one we call the two-hose-and-three-men method. In the other fourteen experiments the spraying was done with horse sprayers of several different kinds, covering four to seven rows at each passage.

THE CHAFEE EXPERIMENT.

This experiment was made by R. M. Howell, Chafee, Erie county. He sprayed 10.4 acres of potatoes five times at intervals of about ten days, commencing July 10. The spraying outfit consisted of a Spramotor barrel pump mounted on a low, two-wheeled cart with a Spramotor nozzle-carrier attachment at the rear and drawn by one horse. The pump was operated by a gearing on one of the wheels. Four rows were sprayed at each passage with one nozzle per row.

The bordeaux mixture was prepared from six pounds of copper sulphate and five pounds of prepared lime in fifty gallons of water and applied at the rate of about thirty-seven gallons per acre, the total quantity used during the season being thirty-nine barrels of fifty gallons each. The poison used for "bugs" was arsenite of soda prepared by boiling one pound of arsenic and four pounds of salsoda in one gallon of water. This was mixed with the bordeaux in the proportion of three quarts of the poison to fifty gallons of bordeaux.

The potatoes were in two fields of about five acres each, both situated about fifty rods from the water supply. In each field four rows were left unsprayed but treated twice with arsenite of soda in lime water to protect them from bugs. The potatoes were of the variety White Giant in Field No. 1, and Rochester in Field No. 2.

The items of expense of spraying the 10.4 acres five times were as follows:

234 lbs. copper sulphate @ 7¢	$16.38
195 lbs. prepared lime @ 1½¢	2.92
90 qts. arsenite of soda solution @ 2⅓¢	2.10
70 hrs. labor for man and horse @ 30¢	21.00
Wear on sprayer	6.50
Total	$48.90

The total expense of spraying was $4.70 per acre or 94 cents per acre for each application.

In Field No. 1, on August 1, the unsprayed rows were plainly inferior to the sprayed rows on either side. This was due to three causes: (1) They had been slightly more injured by "bugs;" (2) they had been slightly injured by the arsenite of soda applied for "bugs;" (3) they had been considerably injured by a large kind of flea beetle,[5] while the sprayed rows were but very slightly injured. To us, this flea beetle is new as a potato pest. It has not appeared in any of our experiments in previous

[5] *Systena hudsonias* Forst. Identified by P. J. Parrott.

years. It is nearly one-fourth inch long, shiny black and jumps like the common flea beetle.[6] Its injury to potato foliage is similar to that of the common flea beetle except that the gnawed areas are considerably larger. At this time there were very few of the common flea beetles, no early blight and no late blight; but later in the season some late blight appeared on the check rows.

In Field No. 2, on August 1, the unsprayed rows were distinguishable from the sprayed rows only by a slight browning of the foliage due to injury from arsenite of soda. There were no common flea beetles and only a few of the larger kind. Early blight and late blight both were entirely absent; however, during the last month of their growth the plants on the unsprayed rows became slightly affected with late blight.

In both fields the test rows were dug with a potato digger on October 25 with the following results:

Field No. 1.— In this field the test rows were 849 feet long by 34 inches apart. The yields were as follows:

Second sprayed row on the east, 595½ lbs. marketable tubers.
Second sprayed row on the west, 690½ lbs. marketable tubers.
Average of two sprayed rows, 643 lbs. marketable tubers.
One of middle two unsprayed rows, 357½ lbs. marketable tubers.
Yield, sprayed, 194 bu. 5 lbs. marketable tubers per acre.
Yield, unsprayed, 107 bu. 54 lbs. marketable tubers per acre.
Gain, 86 bu. 11 lbs. marketable tubers per acre.

Field No. 2.— In this field the test rows were 626 feet long and 34 inches apart. The yields were as follows:

Second sprayed row on the north, 473½ lbs. marketable tubers.
One of the middle unsprayed rows, 440½ lbs. marketable tubers.
Yield, sprayed, 193 bu. 44 lbs. marketable tubers per acre.
Yield, unsprayed, 180 bu. 14 lbs. marketable tubers per acre.
Gain, 13 bu. 30 lbs. marketable tubers per acre.

There was no loss from rot in either field. Combining the results obtained in the two fields we have an average gain of 49 bu. 50 lbs. marketable tubers per acre. At the time of digging the test rows the market price of potatoes in Chafee was 40 cents per bushel. Thus the value of the increased yield was $19.93 per acre. Subtracting $4.70, the expense of spraying, there remains *a net profit of $15.23 per acre.* Probably the actual profit was not quite as great as this. The lower yield of the unsprayed

[6] *Epitrix cucumeris* Harr.

rows was partly the result of injury from arsenite of soda applied in lime water. Arsenite of soda is a cheap and effective insecticide and may be used with safety on potatoes if applied with bordeaux mixture at the rate of not more than two quarts of the arsenite to fifty gallons of bordeaux. It should be used only with bordeaux mixture.

THE SILVER SPRINGS EXPERIMENT.

This experiment was conducted by F. J. Austin, Silver Springs, Wyoming County. Twenty-two acres of potatoes, all in one field, were sprayed six times with a two-horse, four-row Aspinwall potato sprayer. The first two sprayings were made with one nozzle per row while in the last four sprayings two nozzles per row were used. (We believe this to be a good practice.) The dates of spraying were as follows: July 5-6, 14-16, 25-26, August 6-7, 13-16 and September 5.

Prepared lime was used in making the bordeaux. The water required was taken from a creek and drawn to the potato field in barrels on a stone boat a distance of about forty rods. The man who drew water also prepared the bordeaux and employed the remainder of his time in hoeing.

The potatoes were of two varieties, Carman No. 3 and Sir Walter Raleigh mixed. They were planted on clover sod between May 25 and June 7 in drills fifteen inches apart in the row and thirty-three inches between the rows.

Four rows were left unsprayed for a check. "Bugs" were kept under complete control on these rows by two applications of arsenite of soda in lime water. On the sprayed portion of the field arsenite of soda was used three times at the rate of three pints of the stock solution to fifty gallons of bordeaux. Mr. Austin states that there was no difficulty whatever in controlling "bugs" with this amount of poison.

We examined this experiment twice — July 31 and August 31. At the time of our first visit the check rows were in no way different from the sprayed rows except that the foliage of some plants was very slightly injured by the arsenite of soda. There were no insect enemies and no blight of any kind. The plants were looking well but did not yet quite cover the ground.

At the time of our second visit late blight was beginning to appear all along the check rows, especially at the east end where the rows ran down to the foot of a hill. The checks were now somewhat inferior to the sprayed, but the contrast was not marked. On the sprayed portion of the field the vines completely covered the ground making a very fine showing.

During September the late blight made considerable progress on the check rows and the lower yield of these rows is chiefly due to its ravages.

The items of expense for spraying 22 acres of potatoes six times were as follows:

850 lbs. copper sulphate @ 6¾¢	$57.37
12 sacks lime @ 45¢	5.40
4 sacks lime @ 30¢	1.20
20 lbs. arsenic @ 8½¢	1.70
75 lbs. sal soda @ 1½¢	1.13
6 days' work for two men and two teams @ $8	48.00
Wear on sprayer	10.00
Total	$124.80

Thus the total expense of spraying was $5.67 per acre or 94 cents per acre for each application.

The test rows were dug October 5 with a potato digger. The rows were 1,237 feet long, but owing to lack of time the test was confined to 700 feet at the east end. Had the entire length of the rows been included the difference in favor of the sprayed rows would probably have been less because of less damage from blight toward the west end. Although the rows were supposed to be thirty-three inches apart measurement showed them to be only 2.7 feet. Accordingly, the latter figures have been used in computing the yields, which were as follows:

Second sprayed row on the north, 916 lbs. marketable tubers.
Second sprayed row on the south, 935 lbs. marketable tubers.
Average of two sprayed rows, 925½ lbs. marketable tubers.
Average of two unsprayed rows, 717 lbs. marketable tubers.
Yield, sprayed, 355 bu. 24 lbs. marketable tubers per acre.
Yield, unsprayed, 275 bu. 20 lbs. marketable tubers per acre.
Gain. 80 bu. 4 lbs. marketable tubers per acre.

There was no loss from rot. The yield of culls was at the rate of ten bushels per acre for the sprayed rows and 11 bu. 8 lbs. for the unsprayed rows.

At 35 cents per bushel, the market price of potatoes in Silver Springs on October 5, 80 bu. 4 lbs. of potatoes would be worth $28.02. Subtracting $5.67, the expense of spraying, there remains *a net profit of $22.35 per acre.*

THE BATAVIA EXPERIMENT.

This experiment was conducted by J. H. Miller, Batavia, N. Y. The experiment field contained eighteen acres of potatoes of the variety Champion planted the last week of May in hills 34 inches apart each way.

The sprayer used was a new style "Standard" purchased new in the spring of 1906. The entire field was sprayed six times with bordeaux mixture on the following dates: July 11-12-13, 23-24, August 2-4, 14-15-16, 22-23-24 and September 1-3-4. The bordeaux was made with six pounds of copper sulphate to fifty gallons of water and sufficient lime added to satisfy the yellow-prussiate-of-potash test. The facilities for making the bordeaux were inconvenient. The prepared mixture was drawn to the field in the sprayer a distance of about forty rods. The work was all done by one man, who mixed and applied the bordeaux at an average rate of fifty gallons per hour. In the first spraying six rows were covered at each passage, in the next three sprayings, five rows, and in the last two sprayings, four rows; the quantity of bordeaux applied varying from 50 gallons to about 65 gallons per acre at each application.

Seven rows near the center of the field were left unsprayed. They were not even treated with poison. There were so few "bugs" that probably treatment for them was unnecessary, yet on the sprayed rows arsenite of soda was applied with the bordeaux in the second spraying.

On the unsprayed rows in this experiment there was a little early blight, a few flea beetles and just a trace of late blight, but the injury from all these agencies combined was so slight that the average observer would have pronounced it immaterial.

The items of expense for spraying eighteen acres of potatoes six times were as follows:

720 lbs. copper sulphate @ 7¢	$50.40
10 bu. lime @ 30¢	3.00
119 hrs. labor for team @ 15¢	17.85
119 hrs. labor for man @ 15¢	17.85
11 lbs. arsenic @ 10¢	1.10
44 lbs. sal soda @ 2½¢	1.10
Wear on sprayer	8.00
Total	$99.30

The total expense of spraying was $5.52 per acre or 92 cents per acre for each application.

The test rows were dug October 18 with a potato digger. They were 694 feet long by 34 inches wide, 22.15 rows being required to make an acre. Practically all of the tubers were of marketable size and many were larger than is desirable. There were so few small potatoes that sorting was unnecessary. The yields were as follows:

Third sprayed row on the east, 524 lbs. marketable tubers.
Third sprayed row on the west, 545 lbs. marketable tubers.
Average of two sprayed rows, 534½ lbs. marketable tubers.
Middle unsprayed row, 481½ lbs. marketable tubers.
Yield, sprayed, 197 bu. 19 lbs. marketable tubers per acre.
Yield, unsprayed, 177 bu. 45 lbs. marketable tubers per acre.
Gain, 19 bu. 34 lbs. marketable tubers per acre.

The market price of potatoes being 45 cents per bushel, 19 bu. 34 lbs. of potatoes would be worth $8.80. Subtracting $5.52, the expense of spraying, there is left *a net profit of $3.28 per acre.*

THE AVOCA EXPERIMENT.

This experiment was conducted by G. A. Fox, Avoca, Steuben County. Thirteen acres of potatoes were sprayed five times with a two-horse, four-row "Watson" potato sprayer carrying one nozzle per row. There were four different varieties of potatoes. They were planted about May 25 in hills 34 inches apart each way. The soil was sandy loam. The field was nearly level and so situated in a valley that a part of it was subject to overflow in times of high water.

The bordeaux mixture was made by the following formula: Six pounds of copper sulphate, seven pounds of prepared lime and fifty gallons of water, the latter being obtained from a pump at one side of the field. In the first three sprayings arsenite of soda solution was used with the bordeaux at the rate of three pints to fifty gallons of bordeaux, but as this did not control the "bugs" satisfactorily one additional application of paris green in water was made. The quantity of bordeaux mixture applied was a little less than fifty gallons per acre at each spraying. One man and team, with a boy to help in the preparation of the bordeaux, sprayed the entire thirteen acres in ten hours. The dates of spraying were July 3-5, 12, 24, August 1 and 15.

A four-row check was left in the variety White Carlisle. These rows were kept free from "bugs" by three applications of paris green in water.

In this experiment there was no trouble of any kind except a severe attack of late blight, *Phytophthora infestans*, which began to appear on the unsprayed rows the latter part of July and during August became very destructive. Even the sprayed portion of the field was considerably injured. Just why the spraying was not more effective is not clear. However, the spraying proved profitable.

The items of expense for spraying thirteen acres of potatoes five times were as follows:

372 lbs. copper sulphate @ 6¢	$22.32
535 lbs. prepared lime @ 1¢	5.35
58½ qts. arsenite of soda solution	1.46
5 days' labor for man and team @ $3	15.00
5 days' labor for helper @ $1	5.00
Hire of sprayer	12.50
Total	$61.63

The total expense of spraying was $4.74 per acre or 95 cents per acre for each application.

The test rows were dug by hand on September 26. Owing to a washout across the middle of the field it was necessary to confine the test to 300 feet at the east end of the rows. The yields were as follows:

South sprayed row, 103 lbs. marketable tubers.
North sprayed row, 134 lbs. marketable tubers.
Average of middle two unsprayed rows, 85 lbs. marketable tubers.
Yield, sprayed, 103 bu. 9 lbs. marketable tubers per acre.
Yield, unsprayed, 74 bu. marketable tubers per acre.
Gain, 29 bu. 9 lbs. marketable tubers per acre.

In spite of the severe attack of blight there was no loss from rot among the tubers. The yield of small potatoes was at the rate of 6 bu. 32 lbs. per acre on the sprayed rows and 4 bu. 21 lbs. per acre on the unsprayed rows.

On the day the test rows were dug the market price of potatoes in Avoca was 40 cents per bushel. At this price 29 bu. 9 lbs. of potatoes would be worth $11.66. Subtracting $4.74, the expense of spraying, there is left *a net profit of $6.92 per acre.*

THE ODESSA EXPERIMENT.

This experiment was conducted by O. S. Benson, Odessa, Schuyler County. One field of 2½ acres was sprayed five times on the following dates: June 26, July 2, 18, August 6 and 17. Another field of five acres was sprayed on the same dates and once besides on August 25.

The bordeaux mixture used was of the 6-4-50 formula, the water being obtained mostly from the outlet of a ditch at one corner of the five-acre field.

The sprayer was a cheap, home-made outfit consisting of a one-horse, two-wheeled cart carrying a Pomona spray pump mounted in a fifty gallon barrel. One man drove and worked the pump while another sat on the rear of the cart and directed the spray nozzles which were attached at the ends of two short pieces of hose.[7] In the first four sprayings one nozzle per row was used and in the last two sprayings two nozzles per row.

In each field a strip of three rows was left unsprayed but treated three times with paris green in water to control "bugs." In both fields arsenite of soda was used with the bordeaux in the first spraying, but as the "bugs" were not satisfactorily controlled paris green was the poison used during the remainder of the season. On the five-acre field it was applied three times with bordeaux and once in water, while on the 2½-acre field it was applied twice with bordeaux and once in water. "Bugs" injured the unsprayed rows no more than the sprayed rows.

Neither flea beetles nor early blight entered into this experiment. Because both fields were situated on rather low ground and nearly level, it was expected that there would be a severe attack of late blight if the weather conditions were at all favorable and such was actually the case. The unsprayed rows were severely injured and the sprayed ones also suffered slightly. The increased yield of the sprayed rows was due entirely to protection against late blight.

The items of expense for spraying five acres six times and 2½ acres five times and making one extra application of paris green on both fields were as follows:

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[7] Instead of having the nozzles held in the hands they might have been fastened to the cart and considerable expense for labor saved.

174 lbs. copper sulphate @ 7½¢	$13.05
2 bu. lime @ 35¢	.70
arsenite of soda	.27
8 lbs. paris green @ 28¢	2.24
21 lbs. paris green @ 35¢	7.35
60½ hrs. labor for two men @ 30¢	18.15
60½ hrs. labor for horse @ 10¢	6.05
Wear on sprayer	1.00
Total	$48.81

The expense of spraying was at the rate of $1.15 per acre for each application or a total of $6.90 per acre for six sprayings.

At digging time it was found that the test rows in the 2½-acre field had been so much damaged by water as to make the results wholly unreliable; accordingly the test was confined to the five-acre field. The test rows were 699 feet long by 2.87 feet wide, 21.71 rows being required to make an acre. They were dug with a potato digger on September 24. The yields were as follows:

Second sprayed row on the west, 496 lbs. marketable tubers.
Second sprayed row on the east, 553½ lbs. marketable tubers.
Middle unsprayed row, 393½ lbs. marketable tubers.
Yield, sprayed, 189 bu. 52 lbs. marketable tubers per acre.
Yield, unsprayed, 142 bu. 23 lbs. marketable tubers per acre.
Gain, 47 bu. 29 lbs. marketable tubers per acre.

There was no loss from rot. The yield of small potatoes was at the rate of 6 bu. 9 lbs. per acre on the sprayed rows and 5 bu. 36 lbs. per acre on the unsprayed rows.

At 40 cents per bushel, which was the market price at time of digging the test rows, 47 bu. 29 lbs. of potatoes would have a value of $19. Subtracting $6.90, the expense of spraying, there remains *a net profit of $12.10 per acre.*

THE NICHOLS EXPERIMENT.

This experiment was conducted by Daniel Dean, Nichols, Tioga County. Seventeen acres of potatoes were sprayed nine times with a "Watson" potato sprayer drawn by two horses and spraying four rows at each passage with one nozzle per row in the first three sprayings and two nozzles per row in the later ones. The potatoes were in two fields. One field, containing 6.5 acres, was planted with a variety Irish Cobbler, while in the other field, containing 10.5 acres, the two principal varieties were Rural New Yorker No. 2 and Uncle Sam. In the larger field, a strip of four rows in the variety Rural New Yorker No. 2 was left unsprayed. This portion of the field was planted May 26. The sprayed rows on both sides of the unsprayed strip were sprayed with bordeaux mixture nine times on the following dates, — July 6, 18, 21, 31, August 10, 22, 29 and September 4 and 11. The bordeaux contained six pounds of copper sulphate to fifty gallons of water with lime in moderate excess of the amount required to satisfy the litmus paper test. Water for making the bordeaux was obtained from the Susquehanna River at a point 50 rods from the smaller field and 130 rods from the larger one. The sprayer was driven directly into the river where the water was about two feet deep and the tank filled by means of a cistern pump. Upon arrival at the potato field about one-third of the water was pumped from the spray tank into the lime barrel. To the remainder, six pounds of copper sulphate in stock solution were added and the spray tank refilled with lime water. Whenever "bugs" became numerous paris green was added to the bordeaux while on the unsprayed rows "bugs" were controlled by four applications of paris green in lime water. Frequent showers about July 20 made it difficult to manage the "bugs."

On August 2 Mr. Dean notified us that blight was developing rapidly on the unsprayed rows. When we examined the experiment on August 9 late blight was well established on the unsprayed rows and there were traces of it also on the adjacent sprayed rows. On August 17 Mr. Dean reported that the blight was then spreading very slowly and on August 30 he wrote that there appeared to be but little difference between the sprayed and unsprayed rows. During the first ten days of September the blight was more active than at any other time and the contrast between the sprayed and unsprayed rows became pronounced. Spraying prolonged the life of the plants about two weeks. Late blight was the only important disease in this experiment and there were very few flea beetles.

The items of expense for spraying 17 acres 9 times were as follows:

860	lbs. copper sulphate @ 6.2¢	$53.32
	Freight on copper sulphate	1.22
71½	lbs. paris green @ 25¢ to 32¢	20.55
	Litmus paper	.10
1	bbl. lime	1.25

2 bbls. lime @ $1.45	$2.90
¾ bbl. lime @ $1.40	1.05
175¼ hrs. labor, man and team, @ 30¢	52.50
11½ hrs. labor for extra man @ 10¢	1.15
Wear on sprayer	10.00
Total	$144.04

The total expense of spraying was $8.47 per acre or 94 cents per acre for each application.

The test rows were dug October 10. They were 670 feet long[8] by 3.5 feet wide, 18.45 rows being required to make an acre. The yields were as follows:

Second sprayed row on the south, 687 lbs. marketable tubers.
Second sprayed row on the north, 702 lbs. marketable tubers.
Average of middle two unsprayed rows, 599.5 lbs. marketable tubers.
Yield, sprayed, 213 bu. 34 lbs. marketable tubers per acre.
Yield, unsprayed, 153 bu. 36 lbs. marketable tubers per acre.
Gain, 59 bu. 58 lbs. marketable tubers per acre.

There was no loss from rot except a few rotten tubers on the unsprayed rows. The yield of small potatoes was at the rate of 20.6 bushels per acre for the sprayed rows and 21.2 bushels per acre for the unsprayed.

At the time of digging the test rows potato buyers at Litchfield Station, one mile distant, were offering 45 cents per bushel for potatoes.[9] At this price the gain in this experiment would have a value of $26.98. After deducting the expense of spraying, which was $8.47 per acre, there remains *a net profit of $18.51 per acre.*

THE CORTLAND EXPERIMENT.

This experiment was conducted by G. H. Hyde, Cortland, N. Y., who made a similar experiment for the Station in 1905. The

[8] Mr. Dean thinks that a mistake was made in the length of the rows. He states that in the deed the width of this field is given as 40 rods. When the test rows were dug, about one rod at one end was rejected. This would make the length 39 rods or 643.5 ft. instead of 670 ft. and the gain from spraying somewhat larger. There being no opportunity to remeasure the length of the rows it has been thought best to use the original figures.

[9] Most of Mr. Dean's neighbors sold their potatoes in Sayre, Pa., five miles distant, at 50 cents per measured bushel, which is equal to about 52 cents by weight. Mr. Dean also sold 900 bushels there in winter but was unable to do so at digging time for lack of time to handle his crop of 3,500 bushels.

experiment field contained eight acres of potatoes of the variety World's Superior. The soil was a gravelly clay loam sufficiently rolling to give fair surface drainage. The potatoes were planted about May 15.

Three rows were left unsprayed for a check and the remainder of the field sprayed five times with bordeaux mixture of the 6-6-60 formula. The sprayer used was the same one used in the 1905 experiment, viz., a one-horse, four-row Watson potato sprayer. In the first two sprayings one Vermorel nozzle per row was used while in the last three sprayings when the vines were large two nozzles per row were used. The water required in the preparation of the bordeaux was conveniently obtained from a well a short distance from the field. The dates of spraying were July 3, 14, 31, August 9 and 21. Paris green was used with the bordeaux in the first two sprayings at the rate of one pound to sixty gallons. On the same dates, the unsprayed rows were treated twice with one pound of paris green in sixty gallons of lime water. So far as treatment for "bugs" is concerned the sprayed and unsprayed rows received identically the same care.

Late blight was the principal enemy fought in this experiment. It was well established on the unsprayed rows as early as August 7 and before the close of the season injured them considerably. The contrast between the sprayed and unsprayed rows was so marked that even after the foliage was all dead the unsprayed rows were distinguishable at a considerable distance.

The items of expense for spraying eight acres of potatoes five times were as follows:

323 lbs. copper sulphate @ 7¢	$22.61
1½ bbl. lime @ $1.30	1.95
15 lbs. paris green @ 25¢	3.75
30 hrs. labor for man @ 15¢	4.50
30 hrs. labor for horse @ 10¢	3.00
Wear on sprayer	5.00
Total	$40.81

The total expense of spraying was $5.10 per acre or $1.02 per acre for each application.

The test rows were dug with a potato digger on September 18. They were 1,243 feet long by 3 feet wide, 11.68 rows being required to make an acre. The yields were as follows:

Second sprayed row on the west, 1056½ lbs. marketable tubers.
Second sprayed row on the east, 915½ lbs. marketable tubers.
Middle unsprayed row, 892 lbs. marketable tubers.
Yield, sprayed, 191 bu. 56 lbs. marketable tubers per acre.
Yield, unsprayed, 173 bu. 38 lbs. marketable tubers per acre.
Gain, 18 bu. 18 lbs. marketable tubers per acre.

These figures misrepresent the actual effect of spraying in the experiment; since the average yield per acre for the field was 262.5 bushels, which is 70 bushels per acre more than the yield of the sprayed rows in the test. From the striking contrast in the appearance of the foliage on sprayed and unsprayed rows, we expected a difference of 60 bushels per acre or more; and were surprised to find the gain so small. There was evidently some unknown factor to influence the yield on the test rows.

Only three rotten tubers were found in the test rows.

The yield of small potatoes was at the rate of 10 bu. 10 lbs. per acre for the sprayed rows and 17 bu. 11 lbs. per acre for the unsprayed rows.

The market price of potatoes being fifty cents per bushel, 18 bu. 18 lbs. would be worth $9.15. After deducting the expense of spraying, $5.10, there remains *a net profit of $4.05 per acre.*

THE MEMPHIS EXPERIMENT.

This experiment was conducted by Michael Bowes, Memphis, Onondaga County. Mr. Bowes sprayed 9½ acres of potatoes four times with bordeaux mixture, using a home-made, four-row sprayer pumped by hand and drawn by one horse. The pump used was a common force pump and the nozzles (one for each row) were of the Vermorel type. Water for making the bordeaux was drawn to the field in barrels a distance of 130 rods. One man prepared the bordeaux while another did the spraying. The dates of spraying were July 12, August 2, 16 and 30. The quantity of bordeaux applied in each spraying was about 40 gallons per acre.

"Bugs" became numerous before the spraying materials arrived. This necessitated going over the entire field once with paris green in water before spraying was begun. As this had nothing to do with the spraying for blight the expense is not included in the expense of spraying. The treatment was so successful that no further use of poison was necessary.

There were two unsprayed strips of four rows each. In the latter part of the season these unsprayed rows appeared somewhat inferior to the adjacent sprayed rows, but there was no marked contrast. Apparently, there was no blight of any importance.

The items of expense for spraying 9½ acres of potatoes four times were as follows:

108 lbs. copper sulphate @ 7¢	$7.56
135 lbs. lime	2.00
3¾ days' labor for horse	4.00
7½ days' labor for man	9.50
Wear on sprayer	4.00
Total	$27.06

The total expense of spraying was $2.85 per acre or 71 cents per acre for each application.

The test rows were dug with a potato digger on October 16. In both tests the rows were 825 feet long by 3 feet wide, 17.6 rows being required to make an acre. For want of time the potatoes were not sorted. Accordingly, the yields given are total yields. Inasmuch as there are usually more small potatoes on the unsprayed rows it is safe to assume in this experiment that the difference in yield of marketable tubers was as great, at least, as the difference in total yield. The yields were as follows:

West test.— Second sprayed row on the east, 710 lbs.
Second sprayed row on the west, 717 lbs.
Average of middle two unsprayed rows, 666½ lbs.
Yield, sprayed, 209 bu. 17 lbs. per acre.
Yield, unsprayed, 195 bu. 30 lbs. per acre.
Gain, 13 bu. 47 lbs. per acre.

East test.— Second sprayed row on the east, 726 lbs.
Second sprayed row on the west, 646 lbs.
Average of middle two unsprayed rows, 600½ lbs.
Yield, sprayed, 201 bu. 14 lbs. per acre.
Yield, unsprayed, 176 bu. 9 lbs. per acre.
Gain, 25 bu. 5 lbs. per acre.

There was no loss from rot in either test.

In the east test the rows on the east side of the unsprayed strip were sprayed with soda bordeaux while those on the west side were sprayed with lime bordeaux. It appears that the rows sprayed with soda bordeaux outyielded those sprayed with lime bordeaux at the rate of 23 bu. 28 lbs. per acre. So far as we can learn the test was a fair one except that a greater amount of copper sulphate was used with the soda bordeaux. It was made by the formula, six pounds of copper sulphate, nine pounds of sal soda and fifty gallons of water, while the lime bordeaux was made with four pounds of copper sulphate, five pounds of lime and fifty gallons of water. These results should not be considered conclusive proof of the superiority of soda bordeaux. In more thorough tests made at the Experiment Station soda bordeaux proved inferior to lime bordeaux.[10]

Combining the results obtained in the two tests we have an average gain of 19 bu. 26 lbs. per acre, worth, at forty cents per bushel, $7.77. Subtracting $2.85, the expense of spraying, there remains *a net profit of $4.92 per acre.*

THE OGDENSBURG EXPERIMENT.

This experiment was conducted by Andrew Tuck, Ogdensburg, N. Y. It included two fields of potatoes, one of 4 acres and another of 2½ acres. In both fields the surface drainage was good and the soil a sandy loam. The variety of potato was Rural New Yorker No. 3. The smaller field was planted May 29 and 30 and the larger one June 12 and 13.

Both fields were sprayed with bordeaux mixture five times,—July 18, 25, August 13, 20 and September 4. The sprayer used was a new style Aspinwall potato sprayer drawn by one horse. Four rows were covered at each passage with one nozzle per row. The bordeaux mixture was made with six pounds of copper sulphate to fifty gallons of water and sufficient lime added to satisfy the litmus paper test. Water was obtained from a nearby well.

An unsprayed strip of three rows was left in each field. These rows were kept free from "bugs" by four applications of paris green in lime water. On the sprayed portions of both fields paris green was used with the bordeaux mixture in the first four sprayings at the rate of from two to four pounds to fifty gallons of bordeaux. During the season sixty-four pounds of paris green were used on the 6½ acres. This free use of paris green was the cause of the expense running so high in this experiment.

Both early and late blight were factors in this experiment. During the first two weeks in September there was considerable contrast between the sprayed and unsprayed rows owing to the greater amount of blight on the latter.

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[10] See N. Y. Exp. Sta. Bul. 264:187; and Bul. 279:215.

The items of expense for spraying 6½ acres five times were as follows:

200 lbs. copper sulphate @ 7¢	$14.00
Lime	1.00
64 lbs. paris green @ 20¢	12.80
40 hrs. labor for man and horse @ 25¢	10.00
Wear on sprayer	1.25
Total	$39.05

The total expense of spraying was $6 per acre or $1.20 per acre for each application.

The test rows were dug with a potato digger on October 16. In both fields they were 465 feet long by 2.4 feet wide, 39 rows being required to make an acre. The yields were as follows:

In the 2½-acre field.—

Second sprayed row on one side, 281 lbs. marketable tubers.
Middle unsprayed row, 221 lbs. marketable tubers.
Yield, sprayed, 182 bu. 39 lbs. marketable tubers per acre.
Yield, unsprayed, 143 bu. 39 lbs. marketable tubers per acre.
Gain, 39 bu. marketable tubers per acre.

The yield of small potatoes was at the rate of 12 bu. 21 lbs. per acre for the sprayed row and 14 bu. 18 lbs. per acre for the unsprayed row.

In the four-acre field.—

Second sprayed row on the east, 379 lbs. marketable tubers.
Second sprayed row on the west, 376 lbs. marketable tubers.
Average of two sprayed rows, 377½ lbs. marketable tubers.
Middle unsprayed row, 309 lbs. marketable tubers.
Yield, sprayed, 245 bu. 22 lbs. marketable tubers per acre.
Yield, unsprayed, 200 bu. 51 lbs. marketable tubers per acre.
Gain, 44 bu. 31 lbs. marketable tubers per acre.

The yield of small potatoes in this test was at the rate of 24 bu. 3 lbs. per acre for the sprayed rows and 27 bu. 18 lbs. per acre for the unsprayed row.

There was no loss from rot in either test. Combining the results obtained in the two tests we have an average gain of 41¾ bu. per acre, worth, at fifty cents per bushel, $20.87. Subtracting from this sum $6, the expense of spraying, there remains *a net profit of $14.87 per acre.*

THE CHATEAUGAY EXPERIMENT.

This experiment was conducted by Oliver Smith and Son, Chateaugay, Franklin County, who made a similar experiment for the Station in 1905. A field of 25 acres of potatoes, variety Uncle Sam, was sprayed all over three times and 20 acres of it a fourth time. The sprayer used was the same one used in the 1905 experiment, viz., a one-horse "Iron Age" potato sprayer. Four rows were sprayed at each passage with two nozzles per row,— one a "Vermorel" and the other a "Bordeaux." The quantity of bordeaux applied varied from 41 gallons per acre in the first spraying to 60 gallons per acre in the last spraying, the total amount used during the season being 4,825 gallons. The dates of spraying were as follows: 1st, July 6, 7, 10; 2d, July 17, 18, 19; 3d, August 6, 8, 9; 4th, August 22, 23.

The bordeaux used was of the 6-6-50 formula. Water was obtained from a brook at one end of the field. By means of a small gasoline engine the water was pumped through 240 feet of iron pipe into a 75-gallon mixing tank on a platform. This arrangement greatly lightened the labor connected with the preparation of the bordeaux mixture and also saved a considerable amount of time. One man, doing all the work including the mixing of the bordeaux, could spray the entire 25 acres in from 14 to 15 hours.

Three strips of three rows each were left unsprayed. The unsprayed rows received three applications of paris green in water to control "bugs." The sprayed portion of the field also was treated three times for "bugs." In the second spraying paris green was used with the bordeaux at the rate of two pounds to fifty gallons, while in the last two sprayings arsenite of soda was used at the rate of two quarts of the stock solution to fifty gallons of bordeaux.

Early blight was abundant in this experiment and was only partially controlled by the spraying. In the latter part of the season late blight, also, became a factor. No damage was done by flea beetles.

The items of expense for spraying 25 acres three times and 20 acres a fourth time, which is equivalent to spraying 95 acres once, were as follows:

200	lbs. copper sulphate @ 5¼¢	$10.50
	Freight on copper sulphate	.45
390	lbs. copper sulphate @ 6½¢	25.35
	Freight on copper sulphate	.70
14	lbs. paris green @ 18¢	2.52
20	lbs. paris green @ 30¢	6.00

30	lbs. arsenic @ 10¢	$3.00
60	lbs. sal soda @ 4¢	2.40
2½	bbls. lime @ $1.10	2.75
3	gals. gasoline @ 20¢	.60
52	hrs. labor for man and horse @ 25¢	13.00
	Wear on sprayer	10.00
	Total	$77.27

From the above it appears that the expense of spraying was 81 cents per acre for each application or $3.24 per acre for four applications.

All three sets of test rows were dug with a potato digger on October 17 and 18 with the following results:

West test.—Rows 414 feet long by 3.1 feet wide; 33.94 rows per acre.

Second sprayed row on the west, 252 lbs. marketable tubers.
Second sprayed row on the east, 311 lbs. marketable tubers.
Middle unsprayed row, 230 lbs. marketable tubers.
Yield, sprayed, 159 bu. 14 lbs. marketable tubers per acre.
Yield, unsprayed, 130 bu. 6 lbs. marketable tubers per acre.
Gain, 29 bu. 8 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was 13½ bu. per acre for the sprayed rows and 17½ bu. per acre for the unsprayed.

Middle test.—Rows 1274 feet long by 3.1 feet wide; 11 rows per acre.

Second sprayed row on the east, 764 lbs. marketable tubers.
Second sprayed row on the west, 847 lbs. marketable tubers.
Middle unsprayed row, 546 lbs. marketable tubers.
Yield, sprayed, 147 bu. 40 lbs. marketable tubers per acre.
Yield, unsprayed, 100 bu. 6 lbs. marketable tubers per acre.
Gain, 47 bu. 34 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was 9 bu. per acre for the sprayed rows and 12 bu. per acre for the unsprayed.

East test.—Rows 1274 feet long by 3.1 wide; 11 rows per acre.

Second sprayed row on the east, 790 lbs. marketable tubers.
Middle unsprayed row, 516 lbs. marketable tubers.
Yield, sprayed, 144 bu. 50 lbs. marketable tubers per acre.
Yield, unsprayed, 94 bu. 36 lbs. marketable tubers per acre.
Gain, 50 bu. 14 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was 7⅔ bu. per acre for the sprayed rows and 8 bu. per acre for the unsprayed.

Summary.— Combining the results of the three tests gives an average gain of 42 bu. 19 lbs. marketable tubers per acre. The market price of potatoes being 40 cents per bushel at the time of digging the test rows the gain would have a value of $16.92. Subtracting $3.24, the expense of spraying, there remains *a net profit of $13.68 per acre.*

THE PERU EXPERIMENT.

This experiment was conducted by D. Clark, Peru, Clinton County, who made similar experiments for the Station in 1904 and 1905. One field of four acres was sprayed four times and another of five acres five times. The four-acre field was planted June 14 and 15, the other June 8. In both fields the variety was Green Mountain.

The sprayer was the same as that used in previous experiments; namely, an "Aroostook" potato sprayer which is drawn by two horses and covers six rows at each passage with one nozzle per row. The bordeaux used was of the usual 6-4-50 formula. About 25 gallons per acre were applied in each spraying. Water was obtained from a well near the smaller field and about 50 rods from the other one.

The checks consisted of one unsprayed strip of three rows in the four-acre field and two unsprayed strips of three rows each in the five-acre field. In the four-acre field the check rows were treated once (July 31) with paris green in water, while on the sprayed portion of the field poison was used with the bordeaux in all four sprayings. In the five-acre field the checks received two applications of paris green in water for "bugs" while the sprayed rows received poison in all five sprayings. "Bugs" were plentiful and caused considerable injury in both fields. The check rows, not being properly protected, were more injured than the sprayed rows, so that a part of the difference in yield between the sprayed and unsprayed rows is due to "bugs" and cannot be credited to spraying. It is a question whether this experiment should be included in making up the averages.

Early blight, late blight and flea beetles were all factors in this experiment, late blight being the most destructive of the three. However, there was not at any time a very marked contrast between the sprayed and unsprayed rows.

The items of expense for spraying four acres four times and five acres five times were as follows:

123 lbs. copper sulphate @ 8¢	$9.84
82 lbs. lime @ 1¢	.82
14 lbs. paris green @ 25¢	3.50
20 lbs. arsenate of lead @ 20¢	4.00
23 hrs. labor, man and team, @ 30¢	6.90
Wear on sprayer	5.00
Total	$30.06

The average total cost of spraying was $3.34 per acre or 73 cents per acre for each application.

The test rows were dug October 19 with the following results:

Four-acre field.— The rows were 851 feet long by 3 feet wide, 17.06 rows being required to make an acre. The yields were as follows:

Second sprayed row on the east, 591 lbs. marketable tubers.
Second sprayed row on the west, 507 lbs. marketable tubers.
Middle unsprayed row, 477 lbs. marketable tubers.
Yield, sprayed, 156 bu. 6 lbs. marketable tubers per acre.
Yield, unsprayed, 135 bu. 38 lbs. marketable tubers per acre.
Gain, 20 bu. 28 lbs. marketable tubers per acre.

There was some rot in this experiment, but the rotten tubers were not measured. It was estimated that the loss from rot was 17 bushels per acre on the unsprayed row and about 4 bushels per acre on the sprayed rows. The yield of small potatoes was at the rate of 18.8 bu. per acre for the sprayed and 8.5 bu. per acre for the unsprayed.

Five-acre field; west test.— The rows were 295 feet long by 3 feet wide, 49.22 rows being required to make an acre. The yields were as follows:

Second sprayed row on the west, 208 lbs. marketable tubers.
Second sprayed row on the east, 222 lbs. marketable tubers.
Middle unsprayed row, 164 lbs. marketable tubers.
Yield, sprayed, 176 bu. 22 lbs. marketable tubers per acre.
Yield, unsprayed, 134 bu. 32 lbs. marketable tubers per acre.
Gain, 41 bu. 50 lbs. marketable tubers per acre.

There was no loss from rot. The yield of small potatoes was at the rate of 6.1 bu. per acre for the sprayed rows and 9.8 bu. per acre for the unsprayed.

Five-acre field; east test.— The rows were 409 feet long by 3 feet wide, 35.5 rows being required to make an acre. The yields were as follows:

Second sprayed row on the west, 353 lbs. marketable tubers.
Second sprayed row on the east, 342 lbs. marketable tubers.
Middle unsprayed row, 293 lbs. marketable tubers per acre.
Yield, sprayed, 205 bu. 36 lbs. marketable tubers per acre.
Yield, unsprayed, 173 bu. 21 lbs. marketable tubers per acre.
Gain, 32 bu. 15 lbs. marketable tubers per acre.

There was no loss from rot. The yield of small potatoes was at the rate of 10.6 bu. per acre for the sprayed rows and 15.4 bu. per acre for the unsprayed.

Combining the results obtained in the three tests we have an average gain of 31 bu. 31 lbs. marketable tubers per acre. The market price of potatoes being 40 cents per bushel the value of the gain would be $12.60. After deducting $3.34, the expense of spraying, there remains *a net profit of $9.26 per acre.*

THE HEBRON EXPERIMENT.

This experiment was conducted by W. B. Shaw, Hebron, Washington County, who made a similar experiment for the Station in 1905. The experiment field had an area of about five acres. It was in a rather low situation and a small stream divided it into three irregular plats. In two of the plats the soil was sandy loam and in the third slaty loam. All three plats were planted with an unknown variety of late potatoes.

The spraying outfit was similar to the one used in the 1905 experiment. It was a home-made rig consisting of an Empire King barrel spray pump mounted in a fifty-gallon barrel on a two-wheeled, one-horse cart. The total cost of it was about $20. One man on the cart drove and worked the pump while two other men walking behind the cart directed the nozzles attached at the ends of two long leads of hose from the spray pump. Four rows were sprayed at each passage through the field. This method of spraying is known as the two-hose-and-three-men method. The bordeaux used was of the 6-6-50 formula and the water required in making it was obtained from the brook which ran through the field. The field was sprayed three times — July 13-14, 31 and August 13-14. In the first spraying the quantity of bordeaux applied was about 50 gallons per acre; in the second and third sprayings about 67 gallons per acre. A check of three unsprayed rows was left in each of the plats.

On August 22 there was not even a trace of late blight in this experiment. It seems to have been lacking throughout the season. There was some early blight. Flea beetles were very numerous and destructive. "Bugs," also, were very troublesome. Although the check rows were treated four times with paris green applied by means of a powder gun they were somewhat more injured by "bugs" than were the sprayed rows which received paris green twice only.

The items of expense for spraying 5 acres of potatoes 3 times were as follows:

110 lbs. copper sulphate @ 6.9¢	$7.59
130 lbs. lime @ 1¢	1.30
5 lbs. paris green @ 25¢	1.25
1 lb. paris green @ 30¢	.30
48 hrs. labor for man @ 15¢	7.20
16 hrs. labor for horse @ 10¢	1.60
Wear on sprayer	2.00
Total	$21.24

The total expense of spraying was $4.24 per acre or $1.41 per acre for each application. The test rows were dug by hand on October 23 with the following results:

Test No. 1.— The rows were 313 ft. long by 32 in. wide, 52.19 rows being required to make an acre. The yields were as follows:

Second sprayed row on the south, 169 lbs. marketable tubers.
Second sprayed row on the north, 152 lbs. marketable tubers.
Middle unsprayed row, 72 lbs. marketable tubers.
Yield, sprayed, 139 bu. 36 lbs. marketable tubers per acre.
Yield, unsprayed, 62 bu. 38 lbs. marketable tubers per acre.
Gain, 76 bu. 58 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was at the rate of 21.3 bushels per acre for the sprayed rows and 30.4 bushels per acre for the unsprayed.

Test No. 2.— The rows were 260 ft. long by 32 in. wide, 62.82 rows being required to make an acre. The yields were as follows:

Second sprayed row on the west, 131 lbs. marketable tubers.
Second sprayed row on the east, 116 lbs. marketable tubers.
Middle unsprayed row, 64 lbs. marketable tubers.
Yield, sprayed, 129 bu. 18 lbs. marketable tubers per acre.
Yield, unsprayed, 66 bu. 59 lbs. marketable tubers per acre.
Gain, 62 bu. 19 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was at the rate of 16.7 bushels per acre for the sprayed rows and 24.8 bushels per acre for the unsprayed.

Test No. 3.— The rows were 374 ft. long by 32 in. wide, 43.66 rows being required to make an acre. The yields were as follows:

Second sprayed row on the south, 167 lbs. marketable tubers.
Second sprayed row on the north, 182 lbs. marketable tubers.
Middle unsprayed row, 54 lbs. marketable tubers.
Yield, sprayed, 126 bu. 58 lbs. marketable tubers per acre.
Yield, unsprayed, 39 bu. 18 lbs. marketable tubers per acre.
Gain, 87 bu. 40 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was at the rate of 16 bushels per acre for the sprayed rows and 25.5 bushels per acre for the unsprayed.

By combining the results of the three tests the average gain is found to be 75 bu. 39 lbs. marketable tubers per acre. Spraying increased the yield 134 per ct. At 40 cents per bushel, the market price at time of digging the test rows, the gain would have a value of $30.26. After deducting $4.24, the expense of spraying, there remains *a net profit of $26.02 per acre.*

THE WOODBURY EXPERIMENT.

This experiment was conducted by A. and F. Van Sise, Woodbury, Long Island. It included two fields of potatoes, one of 3.75 acres and another of 5 acres. The potatoes were of the variety Green Mountain. Both fields were sprayed with bordeaux mixture three times — June 11, 25 and July 14. The spraying outfit used was a home-made one consisting of a Spramotor hand pump mounted in a 50-gallon barrel on a two-wheeled, one-horse cart. The eight nozzles (two for each of four rows) were carried on a Spramotor telescoping-pipe attachment at the rear of the cart. One man did both the pumping and the driving. Another man assisted with the preparation of the bordeaux mixture. The water required for making the bordeaux was obtained from a pond adjoining the smaller field but about sixty rods from the larger one. About 85 gallons of bordeaux mixture per acre were applied in each spraying.

Four unsprayed rows were left in each field. These were kept free from "bugs" by two applications of paris green in water made on June 11 and 25. On the same dates paris green was applied to the adjacent sprayed rows with the bordeaux mixture in the first two sprayings. Messrs. Van Sise were of the opinion that the paris green was more effective where used with water than where used with bordeaux. The writers did not see the experiment at the time when this point could be determined, but from observations on numerous other experiments we have reached a directly opposite conclusion.

On July 17 a thorough examination was made of both fields. In the smaller field the plants almost completely covered the ground and were looking well. They were thoroughly covered with bordeaux showing that the spraying of July 14 had been well done. It was evident that "bugs" had done no damage to the unsprayed rows. There was no early blight whatever and only a trace of late blight. In walking the entire length of the unsprayed rows only four leaves affected with late blight could be found. Flea beetles were very numerous and were just beginning to injure the plants. They had injured the unsprayed rows slightly more than the sprayed ones, but this was the only observable difference between the sprayed and unsprayed rows at this time.

In the larger field the vines did not yet cover the ground. The sprayed and unsprayed rows were practically alike in general appearance. Both had been considerably injured by flea beetles which were very numerous. On the unsprayed rows there was a little early blight and a little late blight. Twenty-five leaves affected with the latter disease were found. The sprayed rows were entirely free from both diseases. No damage had been done by "bugs."

Subsequently, there was much damage done by flea beetles and considerable by late blight in both fields. We are of the opinion that a fourth spraying made about July 25 would have largely increased the net profit in this experiment, but the owners were unable to make it owing to the pressure of other work.

The items of expense for spraying 8.75 acres three times were as follows:

174 lbs. copper sulphate @ 6½¢	$11.31
1 bbl. lime	1.35
28 lbs. paris green @ 25¢	7.00
29 hrs. labor for man and horse @ 30¢	8.70
20 hrs. labor for extra man @ 15¢	3.00
Wear of sprayer	2.25
Total	$33.61

The total expense of spraying was $3.84 per acre or $1.28 per acre for each application.

The test rows were dug November 3 with the following results:

In the smaller field.— The test rows were 433 ft. long by 3 ft. wide, 33.53 rows being required to make an acre. The yields were as follows:

Second sprayed row on the north, 440 lbs. marketable tubers.
Second sprayed row on the south, 429.5 lbs. marketable tubers.
Average of middle two unsprayed rows, 347.25 lbs. marketable tubers.
Yield, sprayed, 242 bu. 57 lbs. marketable tubers per acre.
Yield, unsprayed, 194 bu. 3 lbs. marketable tubers per acre.
Gain, 48 bu. 54 lbs. marketable tubers per acre.

There was no loss from rot. The yield of small potatoes was at the rate of 15.5 bu. per acre for the sprayed rows and 24 bu. per acre for the unsprayed.

In the larger field.— The test rows in this field were 590 ft. long by 3 ft. wide, 24.61 rows being required to make an acre. The yields were as follows:

Second sprayed row on the north, 467 lbs. marketable tubers.
Second sprayed row on the south, 350.5 lbs. marketable tubers.
Average of the middle two unsprayed rows, 351 lbs. marketable tubers.
Yield, sprayed, 167 bu. 39 lbs. marketable tubers per acre.
Yield, unsprayed, 143 bu. 58 lbs. marketable tubers per acre.
Gain, 23 bu. 41 lbs. marketable tubers per acre.

There was no loss from rot. The yield of small potatoes was at the rate of 19.4 bu. per acre for the sprayed rows and 24.6 bu. per acre for the unsprayed. We are unable to account for the low yield of the second sprayed row on the south. This row was handicapped in some way, but just how it has been impossible to discover. Probably this test is unreliable and it is a question whether the results should be included.

Summary.— Combining the results of the two tests we have an average gain of 36 bu. 18 lbs. marketable tubers per acre. At the time of digging the test rows the market price of potatoes in New York was $2 per barrel of 156 lbs. After deducting 30 cents per barrel for expense of marketing, the net price would be $1.70 per barrel, which is about 65 cents per bushel. At this price 36 bu. 18 lbs. of potatoes would have a value of $23.60. Subtracting $3.48, the expense of spraying, there remains *a net profit of $19.76 per acre.*

THE RIVERHEAD EXPERIMENT.

This experiment was conducted by Ira M. Young, Riverhead, Long Island. Mr. Young sprayed 45 acres of potatoes all over four times and one lot of nine acres a fifth time. The potatoes were of the variety Green Mountain. The soil was sandy loam. The sprayer used was a Hudson four-row sprayer drawn by one horse. The entire acreage lay within a short distance of the wells from which was obtained the water required in the preparation of the bordeaux. A part of the water used (75 barrels) was purchased at three cents per barrel.

Unsprayed strips of four rows each were left in three different lots. The sprayed rows adjacent to the unsprayed strips were sprayed on the following dates: In Lot I, June 13, 29, July 25 and 31; in Lot II, June 15, July 19, 27 and August 6; in Lot III, June 12, 27, July 21, 26 and August 1. In all three lots poison was applied to the unsprayed rows on the same dates on which the sprayed rows received bordeaux and poison. "Bugs" were kept under complete control on the unsprayed rows as well as on the sprayed.

After spraying was begun we saw this experiment only once, namely, on July 20. At that time the conditions were as follows: In Lot I the vines did not yet cover the ground. Early blight and late blight were both entirely absent. There were some flea beetles but not many. The sprayed rows were indistinguishable from the unsprayed ones.

In Lot II the vines covered the ground well over the west third of the test rows. Here late blight was commencing on the unsprayed rows and there were traces of it, also, among the sprayed plants. Over the east two-thirds of the test rows the soil was lighter and the vines smaller. Here there was no blight, but flea beetles were becoming injurious. However, there was nowhere any material difference in appearance between the sprayed and unsprayed rows. There was no early blight in this lot.

In Lot III the vines were very large and covered the ground completely throughout the entire length of the test rows. There was no early blight here and only a few flea beetles, but late blight was thoroughly established on the sprayed as well as on the unsprayed rows, the latter being somewhat the more affected. At a distance the field looked well, but a close examination revealed the fact that the lower leaves were considerably affected with blight. It was plain that this field had been neglected. It had been sprayed twice (June 12 and 27) and should have had a third spraying about July 7, but owing to the pressure of work in haying time it was postponed until July 21.

The items of expense for spraying 45 acres four times and 9 acres a fifth time (which is equivalent to spraying 189 acres once) were as follows:

1,002	lbs. copper sulphate @ 6.25¢	$62.63
500	lbs. lime	3.55
80	lbs. paris green @ 24¢	19.20
75	lbs. arsenic @ 6.25¢	4.69
300	lbs. sal soda	2.25
75	bbls. water @ 3¢	2.25
277½	hrs. labor for horse @ 10¢	27.75
185	hrs. labor for man @ 15¢	27.75
Wear on sprayer		5.00
	Total	$155.07

The total expense of spraying was $3.44 per acre or 82 cents per acre for each application.

The digging of the three sets of test rows showed the following results:

Lot I.— The test rows were 896 ft. long by 3 ft. wide, 16.2 rows being required to make an acre. They were dug September 6. The yields were as follows:

Second sprayed row on the west, 674.5 lbs. marketable tubers.
Second sprayed row on the east, 650 lbs. marketable tubers.
Average of middle two unsprayed rows, 614.5 lbs. marketable tubers.
Yield, sprayed, 178 bu. 48 lbs. marketable tubers per acre.
Yield, unsprayed, 166 bu. 10 lbs. marketable tubers per acre.
Gain, 12 bu. 38 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was at the rate of 28 bu. per acre on the sprayed rows and 29.7 bu. per acre on the unsprayed.

Lot II.— The test rows were 600 ft. long by 3 ft. wide, 24.2 rows being required to make an acre. They were dug September 6. The yields were as follows:

Second sprayed row on the south, 450 lbs. marketable tubers.
Second sprayed row on the north, 477 lbs. marketable tubers.
Average of middle two unsprayed rows, 458 lbs. marketable tubers.
Yield, sprayed, 187 bu. 37 lbs. marketable tubers per acre.
Yield, unsprayed, 184 bu. 44 lbs. marketable tubers per acre.
Gain, 2 bu. 53 lbs. marketable tubers per acre.

There was no rot. The yield of small potatoes was at the rate of 15.7 bu. per acre on the sprayed rows and 18.1 bu. per acre on the unsprayed.

Lot III.— The test rows were 686 ft. long by 3 ft. wide, 21.16 rows being required to make an acre. There is some doubt regarding the accuracy of the yields given below. No representative of the Station was present when the potatoes were dug and stored. About a month later when the weights were taken no one but the hired man knew how the potatoes were arranged. With so much late blight as there was in this lot it would seem that a larger gain in favor of spraying might be expected. The yields were as follows:

Two sprayed rows, 948 lbs. marketable tubers.
Middle two unsprayed rows, 909 lbs. marketable tubers.
Yield, sprayed, 167 bu. 10 lbs. marketable tubers per acre.
Yield, unsprayed, 160 bu. 17 lbs. marketable tubers per acre.
Gain, 6 bu. 53 lbs. marketable tubers per acre.

The average gain in the three tests was 7 bu. 28 lbs. marketable tubers per acre. At 55 cents per bushel, the market price at digging time, the value of the gain would be $4.10 per acre. After deducting $3.44, the expense of spraying, there remains *a net profit of 66 cents per acre.*

THE SAGAPONACK EXPERIMENT.

This experiment was conducted by Paul Roesel, Sagaponack, Long Island. Mr. Roesel sprayed 21 acres of potatoes, of the variety Green Mountain, ten times with a two-horse, five-row Brown potato sprayer carrying one nozzle per row.

The bordeaux used in this experiment was what is known as soda bordeaux, because the copper sulphate is neutralized with sal soda instead of lime. It was prepared by the following formula:

Copper sulphate	6 pounds
Sal soda (washing soda)	7½ pounds
Water	50 gallons

Water for preparing the bordeaux was obtained from a well at one side of the field. One man drove the sprayer while another pumped water and prepared the bordeaux. The quantity of bordeaux applied averaged about fifty gallons per acre in each spraying. The time required to spray the 21 acres varied from 7½ to 9 hours. The dates of spraying were as follows: June 21, 25, 29, July 5, 10-11, 16-17, 23, 26, 31 and August 4. Paris green for "bugs" was used with the bordeaux in the sprayings of June 21 and July 5; and for flea beetles in the spraying of July 31.

Two unsprayed strips of four rows each were left for checks. These rows were treated with paris green applied in dry form by means of a Leggett powder gun on June 22 and July 6 which was sufficient to control "bugs" thoroughly.

On July 12 traces of late blight were found on some unsprayed early potatoes adjoining the experiment field, and a few days later it appeared on the check rows in the experiment. A thorough examination of the experiment was made July 19. At this time there was no early blight, no flea beetles and no evidence of injury by "bugs;" but late blight was quite plentiful throughout the entire length of both unsprayed strips. On the north side of the field there was so much blight on the unsprayed rows that they were readily distinguishable from the sprayed rows. However, there was some blight on the sprayed rows also. Eventually, there was a marked contrast between the sprayed and unsprayed rows. Most of this difference was due to the greater ravages of late blight on the unsprayed rows, but flea beetles, which appeared in the latter part of July, were also a factor.

The items of expense for spraying 21 acres of potatoes 10 times were as follows:

1,243 lbs. copper sulphate @ 6.5¢	$80.80
1,675 lbs. sal soda @ 1.25¢	20.94
175 lbs. paris green @ 25¢	43.50
76 hrs. labor for man and team @ 40¢	30.40
76 hrs. labor for extra man @ 15¢	11.40
Wear of sprayer	15.00
Total	$202.04

The total expense of spraying was $9.62 per acre or 96 cents per acre for each application.

One set of test rows was dug on September 14, the other on October 6. The results were as follows:

East test. The rows were 690 ft. long by 3 ft. wide, 21.04 rows being required to make an acre. The yields were as follows:

Two sprayed rows (second one on each side), 1,768 lbs. marketable tubers.
Middle two unsprayed rows, 710 lbs. marketable tubers.

Yield, sprayed, 196 bu. 7 lbs. marketable tubers per acre.
Yield, unsprayed, 124 bu. 29 lbs. marketable tubers per acre.
Gain, 71 bu. 38 lbs. market tubers per acre.

There was no rot, even on the unsprayed rows. The yield of small potatoes was at the rate of 19.7 bu. per acre on the sprayed rows and 17 bu. per acre on the unsprayed.

West test. The rows were 962 ft. long by 3 ft. wide, 15.1 rows being required to make an acre. The yields were as follows:

Two sprayed rows (second one on each side), 1,768 lbs. marketable tubers.
Middle two unsprayed rows, 1,052 lbs. marketable tubers.
Yield, sprayed, 222 bu. 28 lbs. marketable tubers per acre.
Yield, unsprayed, 132 bu. 23 lbs. marketable tubers per acre.
Gain, 90 bu. 5 lbs. marketable tubers per acre.

There was no loss from rot either on the sprayed or the unsprayed rows. The yield of small potatoes was at the rate of 8.4 bu. per acre on the sprayed rows and 9.2 bu. per acre on the unsprayed.

By combining the results obtained in the two tests, the average gain in this experiment is found to be 80 bu. 51 lbs. per acre. At the time of digging the east test the market price of potatoes in Bridgehampton was 60 cents per bushel, but when the west test was dug it had dropped to 55 cents. In computing the value of the gain an average price of 57½ cents per bushel has been used which makes it $46.49. After deducting $9.62, the expense of spraying, there remains *a net profit of $36.87 per acre.*

Although the profit in this experiment was remarkably large, the experiment is believed to have been a perfectly fair one in all respects.

SUMMARY OF BUSINESS EXPERIMENTS IN 1906.

The principal features of the fifteen farmers' business experiments are shown in the following table:

TABLE XIV.— SHOWING RESULTS OF BUSINESS EXPERIMENTS IN 1906.

EXPERIMENT.	Area sprayed.	Number of times sprayed.	Increase in yield per acre.	Total cost of spraying per acre.	Cost per acre for each spraying.	Net profit per acre.
	A.		Bu.			
Chafee	10.4	5	49.8	$4 70	$0 94	$15 23
Silver Springs	22	6	80.1	5 67	94	22 35
Batavia	18	6	19.6	5 52	92	3 28
Avoca	13	5	29.1	4 74	95	6 92
Odessa	7.5	5–6	47.5	6 90	1 15	12 10
Nichols	17	9	60	8 47	94	18 51
Cortland	8	5	18 3	5 10	1 02	4 05
Memphis	9.5	4	19.4	2 85	71	4 92
Ogdensburg	6.5	5	41.7	6 00	1 20	14 87
Chateaugay	25	4	42.3	3 24	81	13 68
Peru	9	4–5	31.5	3 34	73	9 26
Hebron	5	3	75.6	4 24	1 41	26 02
Woodbury	8.7	3	36.3	3 84	1 28	19 76
Riverhead	45	4–5	7.5	3 44	82	66
Sagaponack	21	10	80.8	9 62	96	36 87

Total area sprayed in fifteen experiments, 225.6 acres.

Average increase in yield per acre, 42.6 bushels.

Average total cost of spraying per acre, $5.18.

Average cost per acre for each spraying, 98.5 cents.

Average net profit per acre, $13.89.

SUMMARY OF BUSINESS EXPERIMENTS, 1903–1906.

The following table shows the results of the farmers' business experiments for four years, 1903 to 1906, inclusive:

TABLE XV.— SHOWING RESULTS OF BUSINESS EXPERIMENTS, 1903–1906.

YEAR.	Number of experiments.	Total area sprayed.	Average increase in yield per acre.	Average total cost of spraying per acre.	Average cost per acre for each spraying.	Average net profit per acre.
		A.	Bu.			
1903	6	61.2	57	$4 98	$1 07	$23 47
1904	14	180	62.2	4 98	93	24 86
1905	13	160.7	46.5	4 25	98	20 04
1906	15	225.6	42.6	5 18	9 85	13 89

Average net profit for four years $20.51 per acre.

VOLUNTEER EXPERIMENTS.

In 1904 the Station began collecting and recording the results of potato-spraying experiments made by farmers in all parts of the State. As these experiments are carried out entirely by the farmers themselves we call them volunteer expriments. It is probable that, in some cases, the yields, expense of spraying and other data given for the volunteer experiments are not as accurate as are those given for the farmers' business experiments. Nevertheless, they are valuable. They supplement the regular business experiments. By bringing together the results of a large number of business experiments and volunteer experiments extending over several consecutive seasons the Station hopes to be able to answer definitely the question, Does it pay to spray potatoes in New York? We are under obligations to the many farmers who have assisted in this work and take this opportunity to express our appreciation of their services. The experiments are to be continued at least five years longer and it is hoped that we may continue to have the hearty coöperation of potato growers throughout the State. All who spray potatoes with bordeaux mixture are requested to leave a few rows unsprayed in order that it may be determined how much the yield is increased by spraying. The product of unsprayed and sprayed rows adjacent should be *weighed or measured* and the length of the rows measured so that the yields may be accurately determined. We cannot use experiments in which the yields have been only estimated. Neither can we use experiments in which the application of poison to the unsprayed rows has been neglected.

In 1904, forty-one volunteer potato-spraying experiments were reported to the Station and the results published in Bulletin 264; while in 1905 fifty experiments were reported and published in Bulletin 279. The following table shows the principal features of the sixty-two volunteer experiments reported in 1906:

Table XVI.— Showing Results of Volunteer Experiments in 1906.

Experiment.	Location.	Name.	Area sprayed.	Times sprayed.	Yield per acre. Sprayed.		Not sprayed.		Gain per acre due to spraying.		Cost per acre each spraying.	Price of potatoes.	Kind of sprayer.
			A.		Bu.	lbs.	Bu.	lbs.	Bu.	lbs.		Cts.	
1	Gainesville......	C. M. Dennis....	13	5	287	51	155	14	132	37	$1.05	40	2-horse, home-made, 6-row (2 nozzles per row).
2	West Rush.....	T. E. Martin....	18	15	401	5	273	36	127	29	.80	40	1-horse, home-made, 6-row, geared.
3	Cutchogue......	Edward Burns..	20	9	360	—	240	—	120	—	.59	60	Hudson, 1-horse, 4-row.
4	Plattsburgh.....	Pardy Bros.....	9.5	6	235	12	122	41	112	31	.95	50	Aroostook, 2-horse, 6-row.
5	Constableville...	G. P. Bernholz..	1	4	244	20	140	29	103	51	2.30	40	5-gallon, compressed air.
6	Riverhead......	W. L. McDermot	35	6	241	31	140	14	101	17	......	55	Iron Age, 1-horse, 4-row (2 nozzles per row).
7	Lisbon.........	S. Miller........	1	3	254	44	154	—	100	44	.76	......	1-horse, home-made.
8	Churubusco.....	J. La Clair......	4	5	317	43	219	58	97	45	......	45–47	Watson, 1-horse, 4-row.
9	Phelps.........	N. L. Rockefeller	13	7	275	31	179	39	95	52	......	40	E. C. Brown Co., 2-horse, 6-row.
10	Cutchogue......	R. W. Sterling..	7.5	7	293	20	205	20	88	—	......	50–60	Hudson, 1-horse, 4-row.
11	Dewittville.....	G. A. Kirkland..	5	6	246	7	158	7	88	—	1.27	50	Spramotor, 1-horse, 4-row (3 nozzles per row).
12	Cassville........	P. S. Doolittle...	13	6	256	31	169	24	87	7	.87	45	Aspinwall, 1-horse, 4-row.
13	Avoca..........	C. Sager........	16	7	269	45	186	8	83	37	.81	40	Watson, 2-horse, 4-row.
14	Bridgehampton..	E. E. Halsey....	32	7	189	6	105	44	83	22	......	55	E. C. Brown Co., 2-horse, 5-row.
15	Bridgehampton..	F. C. Howell....	15	9	226	35	144	44	81	51	......	60	Peppler, 1-horse, 6-row (2 nozzles per row).
16	Canandaigua....	H. Van Voorhis.	14	4	185	17	111	56	73	21	.90	40	Home-made, 2-horse, 6-row geared.
17	Schuyler Lake...	D. C. Williams..	3	4	240	33	168	15	72	18	1.32	40	5-gallon knapsack.
18	Constableville...	C. H. Zimmer...	1.5	6	306	—	235	—	71	—	1.77	40	4-gallon, compressed air, auto-spray No. 1.
19	Andover........	E. R. Crandall..	6	6	198	19	129	37	68	42	.67	40	1-horse, 4-row.
20	Berkshire.......	G. W. Brown...	4	6	150	47	85	15	65	32	1.00	40	Watson, 1-horse, 4-row.
21	Jordan.........	F. O. Chamberlin	4.2	7	235	8	175	6	60	2	......	40	Home-made, 1-horse, 4-row.
22	Riverhead......	D. H. Hudson...	30	6	228	49	170	13	58	36	.80	50–60	Hudson, 1-horse, 4-row (2 nozzles per row).
23	Atlanta........	T. S. Darling....	3	4	161	6	104	10	56	56	.92	40	Watson, 1-horse, 4-row.
24	Elba...........	C. W. Driggs....	4	7	214	40	158	—	56	40	1.05	40	2-horse, Aroostook sprayer, rigged for 4 rows.
25	Chateaugay.....	W. J. Barry....	7	5	401	48	347	11	54	37	.75	32	Iron Age, 1-horse, 4-row.
26	Glen Head......	T. Powell.......	10	7	300	—	246	—	54	—	1.00	60	Shangle, 1-horse, 6-row.

TABLE XVI.— SHOWING RESULTS OF VOLUNTEER EXPERIMENTS IN 1906.—(*Concluded.*)

Experiment.	LOCATION.	Name.	Area sprayed.	Times sprayed.	YIELD PER ACRE. Sprayed.		YIELD PER ACRE. Not sprayed.		Gain per acre due to spraying.		Cost per acre each spraying.	Price of potatoes.	Kind of sprayer.
			A.		Bu.	lbs.	Bu.	lbs.	Bu.	lbs.		Cts.	
27	Clay	C. N. Breman	2.5	4	196	29	144	47	51	42	......	50	Home-made, 1-horse, 4-row.
28	Peru	M. L. Roberts	5	3	143	29	92	18	51	11	......	45	Iron Age, 1-horse, 4-row.
29	Berkshire	G. W. Belden	2.5	5	215	47	167	53	47	54	......	40	Watson, 1-horse, 4-row.
30	Cutchogue	F. Tuthill	10	5	309	24	261	40	47	44	......	60	New Hudson, 1-horse, 4-row.
31	Phelps	D. E. Lyon	18	5	185	3	137	37	47	26	.55	40	1-horse, 4-row sprayer.
32	Hardys	L. H. Taylor	8.5	5	235	38	189	27	46	11	.53	35	1-horse, 4-row, pumped by hand.
33	Interlaken	Bradley Bros.	8	5	235	28	189	47	45	47	.95	40	Watson, 2-horse, 4-row.
34	West Rush	D. S. Norris	6	7	191	48	149	3	42	45	.48	40	1-horse, 4-row, home-made power sprayer; E. C. Brown pump.
35	Watermill	C. B. Foster	15	11	248	47	206	35	42	12	.88	50	Shangle, 2-horse, 5-row.
36	Avoca	C. Bellinger	9	5	135	29	94	12	41	17	......	40–45	Watson, 2-horse, 4-row.
37	Greenfield Center	E. D. Harris	.25	4	178	21	138	1	40	20	......	75	Hand sprayer
38	Danville	J. A. Miller	4	4	270	—	230	—	40	—	.56	45	Watson, 2-horse, 4-row.
39	Homer	H. H. Jones	3.5	4	175	—	135	—	40	—	.71	40	
40	Phelps	I. P. Rockefeller	9	6	275	42	237	36	38	6	1.00	40	E. C. Brown Co., 2-horse, 6-row.
41	Memphis	J. A. Klotz	8	3	228	48	193	36	35	12	.75	40	Aspinwall, 1-horse, 4-row.
42	Fulton	V. W. Shattuck	6.5	5	251	3	217	27	33	36	1.59	40	1-horse, 4-row.
43	Cutchogue	W. A. Fleet	12	5	241	44	208	35	33	9	.65	60	Hudson, 1-horse, 4-row.
44	Southampton	Fred Bennett	4.75	8	155	17	124	13	31	4	.78	55	Iron Age, 1-horse, 4-row (2 nozzles per row).
45	Macedon	L. F. Allen	7	4	186	13	155	11	31	2	1.00	40	E. C. Brown Co., 2-horse, 6-row.
46	Avoca	John Fox	5	4	100	55	69	54	31	1	1.07	40	Watson, 2-horse, 4-row.
47	Phelps	L. Salisbury	16	5	132	38	102	1	30	37	.90	40	Aroostook, 2-horse, 6-row (2 nozzles per row).
48	Denmark	H. E. Cook	3	3	448	—	420	—	28	—	1.66	40	Aroostook, 2-horse sprayer, rigged for 4 rows.
49	Coopers	W. L. McConnel	1.75	3	111	8	83	21	27	47	......	44	Knapsack.
50	Peru	J. Mannix	5	4	227	37	201	11	26	26	.60	40	5-gallon, compressed air.
51	Clifton Springs	P. H. Pettit	13	5	176	55	153	9	23	46	.60	40	E. C. Brown Co., 2-horse, 4-row.
52	Spencerport	F. E. Gott	13	4	200	21	178	14	22	7	.53	40	Aspinwall, 1-horse, 4-row.
53	Malone	T. J. Shields	10	5	154	—	132	—	22	—	.90	38	Aspinwall, 1-horse, 4-row.
54	Glenmore	C. H. Gubbins	1.5	3	189	—	170	—	18	54	......	40	Knapsack.

55	Syracuse.......	G. G. Hitchings..	18	7	100	49	82	29	18	20	.71	50	2-horse, 4-row Niagara Gas sprayer.
56	Batavia........	G. A. Prole.....	12	6	208	30	193	15	15	15	.72	42	Home-made, 2-horse, pumped by hand, 4 to 5 rows
57	Phelps.........	F. A. Salisbury..	16	4	146	6	132	11	13	55	.90	40	Aroostook, 2-horse, 6-row (2 nozzles per row).
58	Memphis.......	W. E. Ward....	8	3	188	41	175	15	13	26	1.00	40	Home-made, 1-horse, 4-row.
59	Norwood.......	W. D. Clark....	1	3	252	4	241	59	10	5	......	50	Rochester hand sprayer.
60	W. Henrietta...	Wm. Robert....	22	5	222	25	214	2	8	23	.51	35	E. C. Brown Co., 2-horse, 5-row.
61	Ellenburgh.....	Wm. Brennan...	6	5	259	20	259	20	0	0	......	35	Home-made, 1-horse, 4-row.[3]
62	W. Henrietta...	C. M. Lyday....	7.86	7	271	18	271	18	0	0	.54	42	Peppler's Perfection, 2-horse, 6-row.

REMARKS ON THE VOLUNTEER EXPERIMENTS IN 1906.

The yields given in Table XVI are all based upon actual weight or measurement and refer to marketable tubers except in Experiments 30 and 52 in which the potatoes were not sorted.

The expense of spraying as reported by the various experimenters includes, in all cases, labor and the expense of materials for making the bordeaux mixture. In some cases an allowance for wear of the sprayer is included, and sometimes, also, poison for "bugs." Because of this lack of uniformity in making up the expense accounts the amounts given in Table XVI in the column headed, "Cost per acre for each spraying," do not admit of close comparison.

Several of the experiments have interesting features which could not be shown in the table; hence they are presented here.

Experiment No. 1.— Mr. C. M. Dennis, who conducted this experiment, reports that the unsprayed rows died about three weeks earlier than the sprayed portions of the field. They were not injured by "bugs." There was a little loss from rot, amounting to 2.5 bu. per acre on the sprayed row and 6.3 bu. per acre on the unsprayed row. The gain due to spraying was determined by comparing the yield of an unsprayed row 396 feet long with that of a nearby sprayed row of the same length, the potatoes being carefully weighed in both cases. The sprayed row yielded 458 pounds, the unsprayed 247 pounds.

Experiment No. 2.— This experiment was conducted by T. E. Martin, West Rush. Mr. Martin is an ardent advocate of spraying. In 1906, he sprayed 18 acres 15 times going over the rows in both directions each time. Although the spraying cost about $12 per acre it was highly profitable. The following account of Mr. Martin's methods is an extract from a paper which he read before the Experimenters' League at Ithaca, N. Y., Feb. 22, 1906.

"In spraying, 331 55-gallon barrels of bordeaux mixture were applied to the crop, beginning July 2 and finishing September 10. About one ton of crystal sulphate of copper and 15 barrels of Ohio marblehead stone lime were used, keeping stock solutions of both in readiness. Ferrocyanide of potassium, in an oil can, is ever at hand to test the mixture if there is any doubt about the copper not being neutralized. Lime in excess is always safe, yet, apparently, does not lessen the 'burning,' or increase the efficiency of the bordeaux. The standard formula of bordeaux is followed: 6 lbs. copper sulphate, 6 lbs. lime to 50 gallons of water. Two pounds per acre of good paris green is added to the bordeaux, whenever the seasonable and persistent potato bugs arrive in destructive numbers. This will, under favorable climatic conditions, appease their insatiable appetite by complete annihilation. It costs no more in labor and material to destroy these beetles before the potato plant is partially or wholly defoliated, than after the damage is done. If potatoes are allowed to be ravaged by insect pests, they receive a shock which is seldom recovered from, also disease is courted and allured to these raw, enfeebled plants. 'Don't lock the stable door after the horse is stolen.'

"In order to do effective spraying, each application should be made in opposite directions; two such sprayings will be called a double application. July 20th the potato vines well covered the ground, and from this time on, at the beginning of each double application, all nozzles are directed to the left and down, at a 45 degree angle, twice over field, then into the centers of the rows; twice over, and then the nozzles are all directed to the right and twice over; going reverse ways each time. This plan requires six single or three double applications, and the spray is directed against the potato-plant, from *six different positions* and *angles*, and at the completion of the sixth spraying, every part of each plant will receive a *film* of *copper plating* from *top* to *bottom*. This spraying might be likened to the famous 'enveloping and flanking movements' of the Yankees of the East at Mukden. Twenty-three barrels of bordeaux made one double application. Thorough spraying cost us $12 per acre. One unsprayed row yielded 16 bu. of potatoes. Next adjoining sprayed row yielded 23½ bu. and yielding respectively 288 and 423 bushels per acre. By request of the Geneva Experiment Station, the spraying data was forwarded to Prof. F. C. Stewart, who computed the average gain due to spraying to be 127 bu. 29 lbs. per acre. Figuring this increase at 40c per bushel, a gain of $51.00 per acre would result. Deducting $12.00, the cost of spraying, a profit of $39.00 per acre would be realized as a net gain, and undoubtedly total on the whole crop a clear profit exceeding $600.00, due entirely to spraying; therefore, further argument is unnecessary. 'Facts are stubborn things.' And there are other valuable benefits derived from spraying, aside from the increase in crop.

"The sprayer used is a one-horse, two-wheeled, geared, home-made affair, on which is mounted a 3 x 5-inch Rumsey, double-acting force pump, air-chamber, 50 gal. spray barrel, revolving agitator, pressure gauge, relief valve and six bordeaux nozzles, for as many rows. Nozzles are ahead of drive wheels. The gear and relief valve are so adjusted that the pump develops and maintains a 60 lb. to 80 lb. pressure."

It will be observed that according to Mr. Martin's figures the gain from spraying was 135 bu. per acre instead of 127.5 as given in Table XVI. The rows were marked out with a 33-inch marker and the length being 924 ft. the number of rows required to make an acre would be 17.1, which is the number we have used in computing the yields. Mr. Martin states, however, that actual count shows that there were on the average 18 rows to the acre. He believes that this comes about from the fact that the field was on a side hill and that in planting from the lower toward the upper side the planter constantly slewed downhill a little so that the rows were brought closer together.

It is noteworthy that the total yield of marketable potatoes on 18 acres was 7510 bu., which is at the rate of 417 + bu. per acre. The variety was Sir Walter Raleigh.

Experiment No. 3.— Two men and one horse did the spraying of the entire 20 acres in one day each time. The unsprayed rows blighted three weeks earlier than the sprayed. The unsprayed rows were not injured by "bugs." There was no loss from rot.

Experiment No. 4.— This experiment was conducted by Pardy Brothers near Plattsburgh. A strip of six rows was left unsprayed. A few rows on one side of the unsprayed rows were sprayed six times, but the greater part of the field was sprayed only five times. A row sprayed six times yielded at the rate of 235 bu. 12 lbs. per acre, while one of the unsprayed rows yielded only 122 bu. 41 lbs., making the gain from spraying 112 bu. 31 lbs. per acre. A Station representative saw the unsprayed row dug and weighed, but the sprayed row had been dug before he arrived. However, he assisted in weighing the sprayed row. The sprayed and unsprayed rows had been treated alike in all respects except in the matter of spraying. The seed used in planting these rows consisted of cut pieces from large tubers.

One other row, planted with whole small potatoes and sprayed six times, yielded only 170 bu. 49 lbs. per acre. This row stood next to the sprayed row which yielded 235 bu. 12 lbs. per acre, and so far as known was treated like it in all respects except in the matter of seed. These two rows showed a difference in yield of 64 bu. 23 lbs. per acre in favor of the cut pieces from large tubers.

Another row sprayed only once yielded at the rate of 158 bu. 37 lbs. per acre, which is 35 bu. 57 lbs. more than the yield of the unsprayed row.

There was a severe attack of blight in this experiment, but no rot.

Experiment No. 5.— The yields given in Table XVI are the average of two tests. In one test, on the variety Green Mountain, the gain due to spraying was 85 bu. 15 lbs. per acre, while in the other test, which was on the variety Sir Walter Raleigh, it was 122 bu. 27 lbs. per acre. The average gain in the two tests was 103 bu. 51 lbs. per acre.

In both tests the unsprayed rows showed some blight August 15 and ten days later were all black; while the sprayed rows remained green until they were killed by frost on September 15. "Bugs" were in no way responsible for the large gain in the Sir Walter Raleigh test. Mr. Bernholz reports that "bugs" caused more damage to the sprayed rows than to the unsprayed ones.

Experiment No. 6.— This experiment was made by W. L. McDermott, Riverhead, Long Island. Two applications of poison were made before spraying with bordeaux was begun. The dates of spraying were July 13, 20, 28, August 8, 14 and 24. The test rows were in the variety Gold Coin. They were dug and weighed November 5 in the presence of a Station representative. The yields were as follows:

Two sprayed rows, 1,110 lbs. = 241 bu. 31 lbs. per acre.
Two unsprayed rows, 644.5 lbs. = 140 bu. 14 lbs. per acre.
Gain, 101 bu. 17 lbs. marketable tubers per acre.

Experiment No. 7.— The check consisted of two unsprayed rows through the center of the field. The dates of spraying were July 31, August 3 and 16.

Experiment No. 8.— There were three unsprayed rows, 419 feet long. These yielded 18 bushels, while three rows on both sides of the unsprayed strip yielded 28 bushels. On the unsprayed rows there were three bushels of rotten potatoes, but the sprayed portion of the field was free from rot and the potatoes kept well in storage. The cost of spraying materials was 40 cents per acre for each spraying.

Experiment No. 9.— The items of expense for materials to spray 5 acres 7 times and 8 acres 6 times were as follows:

495 lbs. copper sulphate	$35.47
16 sacks lime	3.65
Total	$39.12

The unsprayed rows died about three weeks earlier than the sprayed. The test rows were dug by hand and much care taken to secure accurate weights. There was no rot on either the sprayed or the unsprayed rows. The variety was Rural New Yorker No. 2.

Experiment No. 10.— The unsprayed rows were dead three weeks before the sprayed ones. Mr. Sterling writes as follows: "The spraying also lessened the work of digging by half as the rank foliage kept down the late grass and weeds. On the unsprayed rows the grass and weeds were very bad and made digging very difficult."

Experiment No. 11.— Concerning the blight on the unsprayed rows Mr. Kirkland writes: "Some blight was in evidence, but at no time was the attack virulent. Over the greater portion of the rows not much difference [between sprayed and unsprayed] was noticeable until after August 20; then the contrast was plainly discernible, but at no time was the contrast in appearance as sharply drawn as in 1905." There was no rot anywhere in the field.

The items of expense for spraying 5 acres 6 times were as follows:

300 lbs. copper sulphate @ 6½¢	$19.50
23 lbs. paris green @ 25¢	5.75
Freight on above	.28
Lime	1.10
51 hrs. labor for man @ 12½¢	6.38
51 hrs. labor for horse @ 10¢	5.10
Total	$38.11

Four rows were left unsprayed and the gain due to spraying was determined by comparing the yield of one of the middle unsprayed rows with the second sprayed row on one side.

Experiment No. 12.— The total expense of spraying 13 acres six times,— labor, chemicals and allowance for wear of sprayer,— was $68.02. The unsprayed rows died about three weeks before the rest of the field. Mr. Doolittle states that in his neighborhood blight affected some fields more than others and that some of his neighbors, judging by the greenness of their own fields, doubted that spraying had been profitable for him. However, the test rows show that it was highly profitable. The yields were as follows:

Sprayed row, 530 lbs. = 256 bu. 31 lbs. per acre.
Unsprayed row, 350 lbs. = 169 bu. 24 lbs. per acre.

There was no loss from rot even on the unsprayed rows.

Experiment No. 13.— The yields given in Table XVI are the average of two tests. In one test the yields were as follows:

Two sprayed rows, 1,368 lbs. = 293 bu. 6 lbs. per acre.
Two unsprayed rows, 895 lbs. = 191 bu. 45 lbs. per acre.
Gain, 101 bu. 21 lbs. marketable tubers per acre.

In the other test the yields were as follows:

Two sprayed rows, 703 lbs. = 246 bu. 24 lbs. per acre.
Two unsprayed rows, 515 lbs. = 180 bu. 30 lbs. per acre.
Gain, 65 bu. 54 lbs. marketable tubers per acre.

In both tests the sprayed rows outlived the unsprayed ones about two weeks.

The items of expense for spraying 16 acres 7 times were as follows:

712 lbs. copper sulphate	$49.84
712 lbs. lime	7.12
Labor	33.60
Total	$90.56

Mr. Sager considers that the expense of at least two sprayings should be charged to the "bugs."

A representative of the Station made a brief examination of this experiment August 30. We are of the opinion that the premature death of the unsprayed rows was due chiefly to late blight and flea beetles.

Experiment No. 14.—Altogether 32 acres were sprayed but the test rows were in a two-acre field at some distance from the other 30 acres. For spraying 32 acres 7 times 550 lbs. of copper sulphate and 5 bbls. of lime were required. The two-acre field in which the test was made contained 61 rows. The yield of 60 rows (58 sprayed and 2 unsprayed) was 22,340 lbs., which is at the rate of 189 bu. 6 lbs. per acre; while the yield of the middle unsprayed row was 208 lbs. or 105 bu. 44 lbs. per acre.

When we examined this experiment on July 19 the unsprayed rows were already so much affected with late blight that they were readily distinguishable from the sprayed rows throughout their whole length.

Experiment No. 15.— There were four unsprayed rows which were treated with poison in water at the same time that the sprayed rows received poison so that sprayed and unsprayed rows had an equal chance in this respect. When we saw the experiment on July 19 the unsprayed rows were nearly dead with late blight while the sprayed rows on both sides were in full foliage and but slightly affected. The contrast in appearance was very striking. A representative of the Station assisted in digging and weighing the test rows. The yields were as follows:

Two sprayed rows (second and third rows on the east), 1,636 lbs. or 236 bu. 35 lbs. per acre.

Middle two unsprayed rows, 1,045 lbs. or 144 bu. 44 lbs. per acre.

Experiment No. 17.— The high cost of spraying in this experiment was partly due to the high price paid for copper sulphate, viz., 12½ cents per pound. The unsprayed rows were quite badly affected with blight and the vines died before the potatoes were mature. There was but little rot. The unsprayed rows were kept free from "bugs" by hand picking.

Experiment No. 18.— There was scarcely any rot even on the unsprayed rows. The expense of spraying was as follows:

Spraying materials	$4.00
46½ hrs. labor @ 20¢	9.30
Total	$13.30

Experiment No. 19.— The yields given in Table XVI are the average of two tests. In each test there were three unsprayed rows. The yield of the middle unsprayed row was compared with that of the first sprayed row on one side. The yields in the two tests were as follows:

First test: Sprayed row, 270 lbs. = 182 bu. 45 lbs. per acre.
Unsprayed row, 166 lbs. = 112 bu. 21 lbs. per acre.
Gain, 70 bu. 24 lbs. marketable tubers per acre.

Second test: Sprayed row, 316 lbs. = 213 bu. 53 lbs. per acre.
Unsprayed row, 217 lbs. = 146 bu. 52 lbs. per acre.
Gain, 67 bu. 1 lb. marketable tubers per acre.

Experiment No. 20.— We made an examination of this experiment on August 8 and found late blight already well started on the four unsprayed rows and there was also a little on the sprayed rows. Mr. Brown states that the unsprayed rows were completely killed by blight about the middle of August. The sprayed rows became affected about as soon, but on these the disease made much slower progress so that the plants continued green until the second week in September.

Experiment No. 21.— The seven sprayings were made at intervals of one week. About 36 gallons of bordeaux per acre were used in each spraying. Mr. Chamberlain reports that the sprayed rows were quite green after the unsprayed rows were entirely dead from blight.

Experiment No. 22.— The yields given in Table XVI are the average of three tests in three different fields as follows:

Test No. 1.— Six sprayed rows, 1,330 lbs. = 208 bu. 35 lbs. per acre.
Six unsprayed rows, 930 lbs. = 145 bu. 51 lbs. per acre.
Gain, 62 bu. 44 lbs. marketable tubers per acre.

Test No. 2.— One sprayed row, 1,232 lbs. = 246 bu. 24 lbs. per acre.
One unsprayed row, 983 lbs. = 196 bu. 36 lbs. per acre.
Gain, 49 bu. 48 lbs. marketable tubers per acre.

Test No. 3.— Two sprayed rows, 505 lbs. = 231 bu. 27 lbs. per acre.
Two unsprayed rows, 367 lbs. = 168 bu. 12 lbs. per acre.
Gain, 63 bu. 15 lbs. marketable tubers per acre.

Mr. Hudson estimates that his total gain from spraying was 1,500 bushels. In view of the results of the three tests we consider his estimate a conservative one. Judging from an examination of this experiment made July 20 we are of the opinion that the increased yield on the sprayed rows was due to protection against the ravages of late blight and flea beetles, chiefly the former. Mr. Hudson states that the sprayed rows outlived the unsprayed rows as follows: In Test No. 1, three weeks; in Test No. 2, two weeks; and in Test No. 3, 19 days. There was no rot in any of the tests.

Experiment No. 23.— In this experiment there were three unsprayed rows and the increase in yield was determined by comparing the middle unsprayed row with the second sprayed row on each side.

The dates of spraying were July 16, 25, August 6 and 17. In the first two sprayings bordeaux of the 6-6-50 formula was used, but in the last two sprayings the strength was increased to 8-8-50. Mr. Darling reports that the unsprayed rows began to show blight the second week in August and by August 25 were completely dead. The unsprayed rows were kept thoroughly free from "bugs."

The items of expense for spraying three acres four times were as follows:

84 lbs. copper sulphate @ 7¢	$5.88
84 lbs. lime	.56
Arsenite of soda for "bugs"	.60
Labor	4.00
Total	$11.04

Experiment No. 24.— It is likely that a part of the gain in this experiment can not be properly credited to spraying. The unsprayed rows were somewhat more injured by "bugs" which may have been due to the less thorough use of poison on the unsprayed rows. Mr. Driggs states that the sprayed rows received poison with the bordeaux on July 11, but as all of the "bugs" were not killed a second application of bordeaux and poison was made July 23. The unsprayed rows were treated with poison but once (about July 15) which seemed sufficient since the "bugs" were all killed. However, about a month later the unsprayed rows were again quite severely attacked while the sprayed rows were free from "bugs."

Experiment No. 25.— When we saw this experiment August 18 the three unsprayed rows were not distinguishable from the adjacent sprayed rows. Later there was some contrast, but Mr. Barry states that there was very little blight and no rot.

Experiment No. 26.— Mr. Powell states that although there appeared to be very little blight and no injury from "bugs" the unsprayed rows died about two weeks earlier than the sprayed. There was no rot.

Experiment No. 28.— The unsprayed rows were killed by blight about three weeks earlier than the sprayed rows. This experiment was made in a field of potatoes planted about the middle of June. The first spraying was made August 13.

Experiment No. 29.— In this experiment the gain of nearly 48 bushels per acre should be credited to the last three sprayings since in the first two sprayings the entire field was sprayed. Mr. Belden had already made the first two sprayings before receiving our letter requesting him to leave some unsprayed rows. Nevertheless, the sprayed rows outlived the check rows between two and three weeks. The expense for spraying materials was $9.

Experiment No. 30.— Mr. Tuthill states that the yields reported for this experiment are for unsorted potatoes. If the potatoes had been sorted it is likely that the difference between the sprayed and unsprayed rows would have been somewhat greater because usually more small potatoes are found on the unsprayed rows.

The sprayed rows retained a large part of their foliage about two weeks after the unsprayed rows were dead. There was very little rot.

Experiment No. 31.— The yields given in Table XVI are the average of three tests as follows:

Test No. 1.— One sprayed row, 77 lbs. = 205 bu. 20 lbs. per acre.
One unsprayed row, 51 lbs. = 136 bu. per acre.
Gain, 69 bu. 20 lbs. per acre.
Test No. 2.— One sprayed row, 485 lbs. = 173 bu. 28 lbs. per acre.
One unsprayed row, 354 lbs. = 126 bu. 37 lbs. per acre.
Gain, 46 bu. 51 lbs. per acre.
Test No. 3.— One sprayed row, 445 lbs. = 176 bu. 22 lbs. per acre.
One unsprayed row, 379 lbs. = 150 bu. 13 lbs. per acre.
Gain, 26 bu. 9 lbs. per acre.

In the field containing Test No. 1 late blight started unusually early. From an examination of the conditions we incline to the opinion that this early outbreak was traceable to refuse from a nearby potato pit in which diseased tubers had been stored.

In Test No. 3 both the sprayed and unsprayed rows were killed by frost. Probably the gain would have been larger if frost had not come so early.

Experiment No. 32.— The test rows in this experiment were 80 rods long. The yields were as follows:

Two sprayed rows, 2,550 lbs. = 235 bu. 38 lbs. per acre.
Two unsprayed rows, 2,050 lbs. = 189 bu. 27 lbs. per acre.

The expense for copper sulphate and lime was $13.45 and the labor is estimated at three days for man and team, or $9, making a total of $22.45. The "bugs" were kept under control on the sprayed rows by using arsenite of soda solution (arsenic and sal soda boiled together) with the bordeaux in the first three sprayings, and on the unsprayed rows by two applications of paris green in water. The bordeaux (6-6-50 formula) was applied at the rate of about 50 gallons per acre in each spraying.

Judging from Mr. Taylor's report and from personal examination made August 31 we conclude that the smaller yield of the unsprayed rows was partly due to a mild attack of late blight and partly to a browning of the leaves resembling tip burn which seemed to have been partially prevented by spraying.

Experiment No. 33.— It is reported that there was not much blight in this field except at one end and here the unsprayed row died earlier than the sprayed ones. The unsprayed row was not injured by "bugs" and there was no rot among the tubers. The total yield of marketable potatoes on eight acres was 1,826 bushels or 228 + bushels per acre.

Experiment No. 34.— Thirty barrels of bordeaux mixture were used in spraying the six acres seven times. In the spring of 1906 Mr. Norris erected a "bordeaux platform" which proved a great convenience and saved considerable time. With this arrangement he could fill his sprayer and be off for the field again in ten minutes, while by the old method of pumping water and filling the sprayer by hand at least thirty minutes were required. We are under obligations to Mr. Norris for the description and illustration of his platform shown in Plate II.

The items of expense for spraying 6 acres 7 times were as follows:

205 lbs. copper sulphate @ 5¼¢	$10.76
5 bu. lime @ 25¢	1.25
33 hrs. labor for man @ 15¢	4.95
33 hrs. labor for horse @ 10¢	3.30
Total	$20.26

Mr. Norris states that the unsprayed rows showed blight about ten days earlier than the sprayed, but that there was not much blight at any time so that the contrast between sprayed and unsprayed rows was not great. There was no rot.

Experiment No. 35.— In this experiment there were four unsprayed rows. The gain due to spraying was determined by comparing the yield of four of the unsprayed rows with that of four sprayed rows nearby. The yields were as follows:

Four sprayed rows, 3,360 lbs. = 248 bu. 47 lbs. per acre.
Four unsprayed rows, 2,790 lbs. = 206 bu. 35 lbs. per acre.
Gain, 42 bu. 12 lbs. marketable tubers per acre.

We saw this experiment twice — July 18 and August 6. At the time of our first visit late blight was just beginning to appear here and there all along the unsprayed rows. There was also a

Plate II.— Bordeaux Platform of D. S. Norris, West Rush, N. Y.

The four barrels on the platform are for water only. They are connected, near the bottom, by a three-quarter-inch iron pipe. Water is pumped into the barrels by means of a windmill. In the bottom of the second barrel from the left is a discharge pipe fitted with a leather valve. By means of a lever-and-string device this valve may be opened and closed by a man standing on the ground. A stock solution of copper sulphate is kept in a barrel on the ground. A stock of lime paste is kept in another barrel, formerly on the ground, but since the photograph was taken it has been given a place on the platform and fitted with a discharge pipe so that the milk of lime may be drawn off into the spray barrel as required.

little early blight but no flea beetles. On August 6 we found the unsprayed rows dead and there was evidence that flea beetles had hastened their death. The sprayed rows still retained a part of their foliage. Mr. Foster states that the blight worked rapidly on the unsprayed rows during the latter half of July and that the sprayed portion of the field also became affected to some extent. However, at digging time only an occasional rotten tuber was found on the unsprayed rows and none whatever on the sprayed rows.

The items of expense for spraying 15 acres 11 times were as follows:

990 lbs. copper sulphate @ 6.3¢	$62.37
3 bbls. lime @ $2.25	6.75
85 lbs. paris green @ 26½¢	22.53
132 hrs. labor for man @ 20¢	26.40
66 hrs. labor for team @ 20¢	13.20
Wear on sprayer	15.00
Total	$146.25

Experiment No. 36.— This experiment included two fields with four unsprayed rows in each field. The yields given in Table XVI are the average of two tests as follows:

Test No. 1.— Four sprayed rows, 16 bu. = 108 bu. 12 lbs. per acre.
Four unsprayed rows, 10 bu. = 67 bu. 37 lbs. per acre.
Gain, 40 bu. 35 lbs. per acre.

Test No. 2.— Four sprayed rows, 18 bu. = 162 bu. 46 lbs. per acre.
Four unsprayed rows, 13 bu. = 120 bu. 46 lbs. per acre.
Gain, 42 bu. per acre.

In both tests there was considerable blight on the unsprayed rows but no rot among the tubers.

Experiment No. 40.— The sprayer used in this experiment was the same one used in Experiment No. 9. Three rows 544 feet long were left unsprayed.

Experiment No. 42.— The items of expense for spraying 6.5 acres 5 times were as follows:

375 lbs. copper sulphate @ 7¢	$26.25
Prepared lime	3.50
Labor	17.00
Wear on sprayer	5.00
Total	$51.75

Experiment No. 43.— The unsprayed rows were severely attacked by blight and died two weeks earlier than the sprayed rows. Mr. Fleet states that there was no rot in sprayed or unsprayed potatoes, notwithstanding the plants were killed by blight quickly and the soil very wet at the same time.

Experiment No. 44.— Mr. Bennett expresses the opinion that it is unsafe to leave unsprayed rows in a sprayed field because of the tendency of blight to spread from the unsprayed rows to the sprayed ones. This was plainly the case in his experiment. He left three unsprayed rows at one side of the field near his barn. These rows became affected with late blight quite early. When we saw them on July 18 they were already nearly dead from blight and several sprayed rows next to them were also severely attacked while the field in general was scarcely affected. It seems probable that fowls running among the plants assisted in spreading the spores of the blight fungus.

The items of expense for spraying 4.75 acres 8 times were as follows:

240 lbs. copper sulphate	$15.10
Lime	2.50
4 days' labor for man and horse	12.00
Total	$29.60

It is probable that the actual gain due to spraying was greater than is shown by the test rows.

Experiment No. 45.— Six rows were left unsprayed. The middle four unsprayed rows yielded 25 bushels marketable tubers while four sprayed rows adjacent yielded 30 bushels of marketable potatoes. Mr. Allen was suprised to find so much difference in yield since there had been no difference in the appearance of the foliage on sprayed and unsprayed rows. There seems to have been little or no blight in this experiment and there was no rot among the tubers.

The items of expense for spraying 7 acres 4 times were as follows:

216 lbs. copper sulphate @ 7½¢	$16.20
216 lbs. lime @ 20¢ per cwt.	.43
12 lbs. paris green @ 28¢	3.36
2 days' work, man and team	8.00
Total	$27.99

Experiment No. 47.— In this experiment there was a quite severe attack of late blight. We made two examinations during the season. On July 24 we found late blight just beginning to appear on the unsprayed rows. On September 7 there was a marked contrast between the sprayed and unsprayed rows — the former still retained most of their foliage while in some places the latter were almost bare.

Two nozzles per row were used in the last three sprayings, when the quantity of bordeaux applied was about 60 gallons per acre.

Experiment No. 48.—Although the field was sprayed three times the results obtained in this experiment should be credited to two sprayings, because no check rows were left until after the first spraying. Mr. Cook reports that there was only a trace of blight on the unsprayed rows and not much contrast in appearance between the sprayed and unsprayed rows. Neither was there any rot among the tubers and absolutely no damage from "bugs" anywhere in the field.

The expense account included the following items:

90 lbs. copper sulphate @ 7¢	$6.30
Lime	.40
1½ days' labor for man and team	5.25
Wear on sprayer	3.00
Total	$14.95

Experiment No. 50.— When we saw this experiment on August 20 there was already considerable contrast between the five unsprayed rows and the adjacent sprayed ones owing to the more severe attack of late blight and flea beetles on the unsprayed rows. Evidently Mr. Mannix did a fairly thorough job of spraying and it is surprising that the gain from spraying was so small.

The total expense of spraying, for labor and materials, was $12.

Experiment No. 51.— The sprayed rows held their foliage a week or ten days longer than the unsprayed ones.

Experiment No. 52.— The yields given in Table XVI are for unsorted potatoes. Mr. Gott reports that there was little if any blight in his experiment and that there was scarcely any difference in appearance of the foliage on the sprayed and unsprayed rows. Concerning the expense of the spraying Mr. Gott states that the materials cost $18 and that the labor amounted to

38 hours for one man and horse. Allowing 15 cents per hour for the man's time and 10 cents for that of the horse the expense for labor would be $9.50, which makes the total expense of spraying 13 acres 4 times $27.50.

Experiment No. 55.— It is plainly unfair to spraying to include this experiment because the check rows were sprayed three times before the experiment began. Consequently, the gain of 18 bu. 20 lbs. per acre should be credited to the last four sprayings only. The dates of spraying were, June 22, July 5, 19, August 4, 10, 17 and September 1. Mr. Hitchings informs us that there was no late blight or rot and very little contrast between the sprayed and unsprayed rows. The test rows were in a two-acre field of the variety Carman No. 3. The average yield for this field was 135 bushels per acre.

Experiment No. 56.— Mr. Prole, who conducted this experiment, states that there was an unusually small amount of blight even on the unsprayed rows. During the last two weeks of growth the sprayed rows made a slightly better appearance than the unsprayed. Part of the spraying was done with one nozzle per row spraying five rows at a time and part of it with two nozzles per row spraying four rows at a time.

Experiment No. 57.— The sprayer used was the same one used in Experiment No. 47. Mr. Salisbury states that there was very little late blight except at one end of the field, but that the plants died prematurely from some other cause. He thinks the yield would have been larger if the potatoes had been planted later. They were planted May 17-22.

Experiment No. 60.— Mr. Robert reports that there was scarcely any difference in appearance between sprayed and unsprayed rows in his experiment. There was very little if any blight, but both sprayed and unsprayed rows were somewhat affected with tip burn. The expense for materials and labor was $56.20. If we add to this an allowance for wear of the sprayer the expense of the spraying just about equals the value of the increased yield.

Experiment No. 61.—There was no blight in this experiment. In 1905 Mr. Brennan reported a gain of 209 bushels per acre due to spraying.

Experiment No. 62.— Mr. Lyday states that the conditions for a large yield of potatoes have not been so favorable for many years as they were in 1906. During July and August frequent rains followed by hot sultry weather led him to expect an attack of late blight, but for some reason it did not appear. In this experiment there was no blight at all. The dates of spraying were July 6, 12, 23, 31, August 7, 13 and 28.

SUMMARY OF VOLUNTEER EXPERIMENTS, 1904–1906.

The following table shows the results obtained in the volunteer experiments during the past three years — 1904 to 1906 inclusive:

TABLE XVII.— SHOWING RESULTS OF VOLUNTEER EXPERIMENTS, 1904–1906.

YEAR.	Number of experiments.	Total area sprayed.	Average gain per acre due to spraying.		Average market price per bushel of potatoes at digging time.
		A.	*Bu.*	*lbs.*	*Cts.*
1904	41	364	58	28	43.5
1905	50	407	59	32	57.0
1906	62	598	53	6	44.5

AN EXPERIMENT AT RIVERHEAD.

The following experiment does not belong to any one of our three classes of potato-spraying experiments and so must be considered separately. It was conducted by F. A. Sirrine on a field of potatoes belonging to H. H. Hallock, Riverhead, Long Island.

Forty-eight rows of potatoes covering an area of 2.07 acres, were divided into 12 plats of 4 rows each. Six plats were sprayed four times (June 25, July 10, 20 and 25) with a one-horse, four-row Hudson sprayer carrying two nozzles per row. The remaining six plats were left unsprayed for checks. The sprayed plats alternated with the unsprayed ones. The bordeaux mixture was applied at the rate of about 40 gallons per acre in each spraying. No poison was used with it. "Bugs" were kept well under control on sprayed and unsprayed plats alike. This part of the work was managed by the owner, Mr. Hallock. He applied paris green in dry form by means of a one-horse, four-row Leggett potato duster.

The potatoes made a large growth of vines. Late blight appeared the second week in July and by July 20 was well established on the unsprayed rows. There was also some on the sprayed rows. Ultimately, the sprayed rows as well as the unsprayed ones were considerably injured by late blight, but it was plain that the unsprayed rows suffered most. The alternation of the brown unsprayed strips with the green sprayed strips gave the experiment field a striped appearance. In the latter part of July flea beetles, also, became an important factor in the experiment.

At digging time the potatoes from the middle two rows of each plat were sorted into marketable tubers and culls and then weighed. The yields are shown in the following table:

Table VIII.—Showing Yields in the Experiment at Riverhead.

Plat.	Treatment.	Yield of two rows.		Yield per acre.			
		Marketable.	Culls.	Marketable.		Culls.	
		Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
1.	Check	810	79	156	36	15	16
2.	Sprayed	998	77	192	57	14	53
3.	Check	966	89	186	46	17	12
4.	Sprayed	1,141	48	220	35	9	17
5.	Check	1,036	62	200	17	11	59
6.	Sprayed	1,250	54	241	40	10	26
7.	Check	1,078	80	208	25	15	28
8.	Sprayed	1,230	60	237	48	11	38
9.	Check	1,102	84	213	3	16	14
10.	Sprayed	1,328	71	256	44	13	43
11.	Check	1,054	86	203	46	16	37
12.	Sprayed	1,278	64	247	5	12	22

Yield, 12 sprayed rows, 7,225 lbs. = 232 bu. 48 lbs. per acre.
Yield, 12 unsprayed rows, 6.046 lbs. = 194 bu. 49 lbs. per acre.
Gain, 38 bu. marketable tubers per acre.

There was no loss from rot. The greater yield of the sprayed plats was due to the prolongation of growth through spraying.

POTATO TROUBLES IN NEW YORK IN 1906.

Early blight, *Alternaria solani,* was more abundant in 1906 than at any other time since these experiments were commenced in 1902. In all parts of the State some fields suffered quite severely, but the majority were only slightly, if at all, affected. In the latter part of the season many fields, including the ten-year experiment at Geneva, were much affected with a trouble which, by some, was mistaken for early blight. The margins and tips of the leaves became brown and dry as in the disease known as tip-burn. Lacking opportunity for a study of this disease we are unable to say positively what may have been the nature of it. Probably it was a form of tip-burn although it appeared in some fields in which the plants surely were not suffering greatly from lack of water. Whatever the cause of the disease it was somewhat checked by spraying. In the ten-year experiment at Geneva and also in some of the farmers' business experiments there was appreciably less of this trouble on the sprayed rows than on the unsprayed ones.

Late blight, *Phytophthora infestans,* made an early appearance in many fields in all parts of the State. M. H. Sayre, Water Mill, Long Island, is positive that he saw late blight in his field on June 22. The first specimens actually seen by the writers were collected by Paul Roesel at Sagaponack, Long Island, July 11. On July 18 we visited Sagaponack, Bridgehampton and Southampton and saw several fields in which the late blight was already well established. In this region late blight usually appears earlier and is more destructive than in any other part of the State. Spraying is now well-nigh universal in this part of Long Island. In a field at Baiting Hollow, on the north side of Long Island, late blight had already caused considerable damage by July 15. Some fields at Riverhead began to show the disease about this time.

Outside of Long Island the first report of late blight came from Ontario County. F. A. Salisbury, Phelps, who certainly knows late blight, states positively that he saw the disease in his garden on July 12. On July 24 we personally examined Mr. Salisbury's garden and found late blight abundant; also in a neighboring field of late potatoes; but there was not yet any general outbreak of the disease in this part of the State. On July 30 we found late blight plentiful in a field of early potatoes at Montour Falls, Schuyler County. The first appearance of late blight in the ten-year experiment at Geneva was on August 4.

Over the greater part of the State the latter half of August was dry and hot and the late blight was severely checked. Although many fields were severely injured by late blight there was, on the whole, less damage than in any previous year during which these experiments have been conducted. Many fields were practically free from blight of all kinds. There was scarcely any loss from rot anywhere in the State, not even on Long Island where blight was severe and the ground wet at digging time.

The flea beetle, *Epitrix cucumeris,* as usual gave some trouble to potatoes on Long Island early in the season and considerably more in the latter part of July. In various other places throughout the State occasional fields were injured by flea beetles, but this trouble was by no means a general one. Taking the State as a whole, the loss due to flea beetles was perhaps about equal to that caused by early blight, while the loss from both these causes would not exceed that due to late blight.

Colorado potato beetles or "bugs," *Leptinotarsa decemlineata,* presented no unusual features. The damage caused by them varied greatly in different localities and even in different fields in the same locality. This pest is a universal one and treatment for it has become one of the regular operations of potato culture in New York.

MAKING EXPERIMENTS IN 1907.

During the season of 1907 the work on potato spraying will be carried forward along practically the same lines as in 1904, 1905 and 1906. The regular ten-year experiments at Geneva and Riverhead will be conducted again as usual; also, about fifteen farmers' business experiments in different parts of the State. In addition, the Station hopes to secure again, as in the past, reports of numerous volunteer experiments — the more the better. Potato growers throughout the State are earnestly requested to make spraying experiments in 1907 and report the results to the Station. Whatever the outcome of the experiments, whether for or against spraying, the reports are desired, provided, of course, the experiments have been properly conducted. Upon request, the Station will supply blanks for making such reports.

DIRECTIONS FOR SPRAYING.[11]

In general, commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of 10 to 14 days in order to keep the plants well covered with bordeaux throughout the season. During epidemics of blight it may be necessary to spray as often as once a week. Usually six applications will be required. The bordeaux should contain four pounds of copper sulphate to each 50 gallons in the first two sprayings and six pounds to 50 gallons in subsequent sprayings. When-

[11] Substantially the same as given in Bulletin 279, p. 228. The experiences of the past season do not warrant any material alteration in the recommendations there made.

ever bugs or flea beetles are plentiful add one to two pounds of paris green or two quarts of arsenite of soda stock solution to the quantity of bordeaux required to spray an acre.[12]

Thoroughness of application is to be desired at all times, but is especially important when flea beetles are numerous or the weather favorable to blight. Using the same quantity of bordeaux, frequent light applications are likely to be more effective than heavier applications made at long intervals; e. g., when a horse sprayer carrying but one nozzle per row is used, it is better to go over the plants once a week than to make a double spraying once in two weeks. A good plan is to use one nozzle per row in the early sprayings and two nozzles per row in the later ones.

Those who wish to get along with three sprayings should postpone the first one until there is danger of injury from bugs or flea beetles and then spray thoroughly with bordeaux and poison. The other two sprayings should likewise be thorough and applied at such times as to keep the foliage protected as much as possible during the remainder of the season. Very satisfactory results may be obtained from three thorough sprayings.

A single spraying is better than none and will usually be profitable, but more are better. Spraying may prove highly profitable even though the blight is only partially prevented. It is unsafe to postpone spraying until blight appears. Except, perhaps, on small areas, it does not pay to apply poison alone for bugs. When it is necessary to fight insects use bordeaux mixture and poison together.

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[12] For the preparation of bordeaux mixture and the arsenite of soda solution see Bulletin 243 of this Station.

DODDER IN ALFALFA SEED.*

F. C. STEWART AND G. T. FRENCH.

Dodder is a yellow, thread-like twining weed which is exceedingly troublesome in alfalfa fields. It appears in circular spots three to thirty feet or more in diameter. At the center of the spot the alfalfa is killed out while around the margin the ground is covered with a mat of yellow threads which twine closely about the stems of the alfalfa plants and slowly strangle them. The spots increase in size from year to year. Many fields have been completely ruined by dodder. It is not often injurious to other crops (except red clover), but once established in an alfalfa field it is very difficult to eradicate without killing the alfalfa.

In most cases dodder gets into the field through the use of impure alfalfa or clover seed. Hence, it is of the utmost importance that no dodder-infested seed be sown. Since much of the alfalfa seed on the market in New York State is more or less infested with dodder it is often difficult to obtain dodder-free seed. The statements of seed dealers should not be relied upon. Most of the alfalfa seed in this State is handled by hardware merchants who, themselves, do not know dodder seed. As these seeds are much smaller than those of alfalfa they may be easily overlooked. Good-looking seed, otherwise clean, may be badly infested with dodder. Even so small an amount as one dodder seed per pound makes alfalfa seed dangerous to sow until properly cleaned.

Farmers are advised to protect themselves against this weed, by sowing no alfalfa seed until it has been pronounced dodder-free by a seed expert or has been thoroughly sifted as directed below. The safest method is to have the seed both analyzed and sifted. This Station will make analyses of alfalfa seed free of charge. Samples should contain at least one ounce of seed, taken from the bottom of the bag. The packages should be addressed: Experiment Station, Geneva, N. Y.; and should be plainly marked with the name and address of the sender.

* A reprint of Circular No. 8, new series.

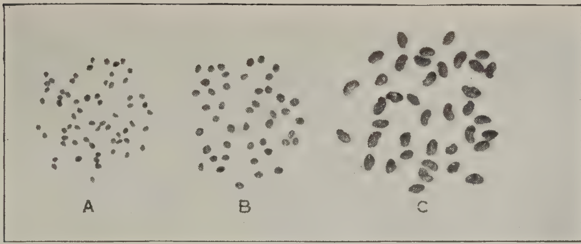
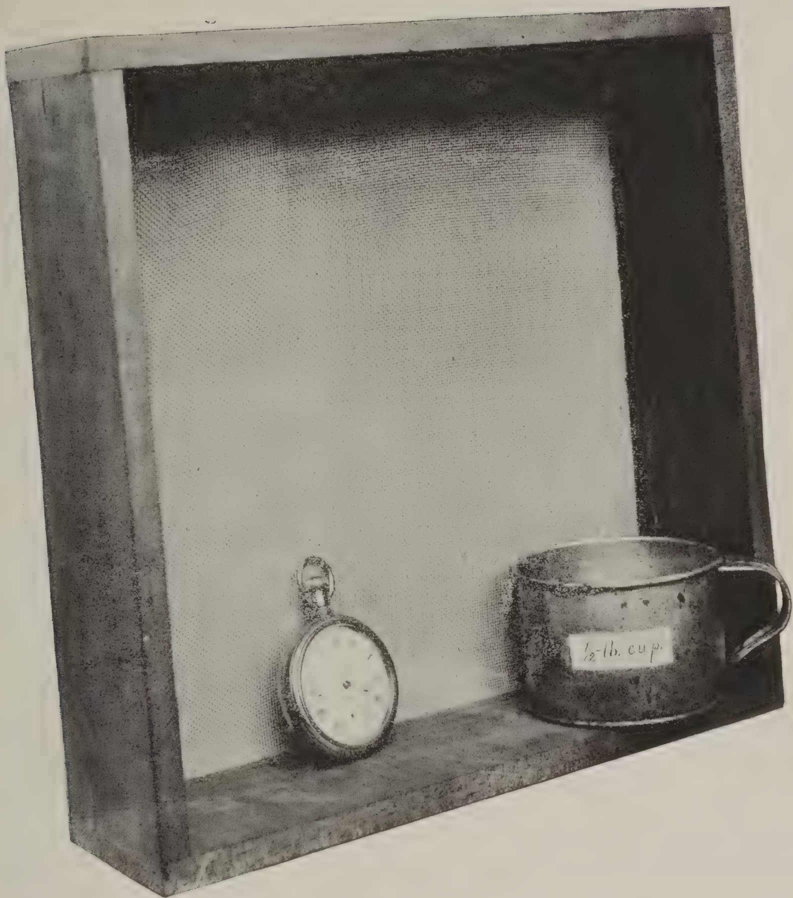


FIG. 2.— SEEDS OF DODDER AND ALFALFA:
a. SMALL-SEEDED DODDER; *b.* LARGE-SEEDED DODDER; *c.* ALFALFA.
(All Natural Size.)

FIG. 1.— ALFALFA PLANT INFESTED WITH DODDER.
(After F. E. Dawley.)
PLATE III.



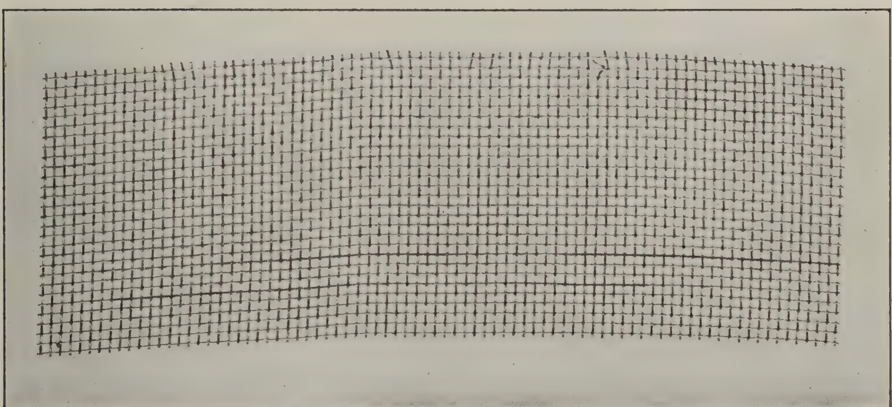


PLATE IV.— TOOLS REQUIRED FOR SIFTING ALFALFA SEED TO REMOVE DODDER SEED:

UPPER, HOME-MADE SIEVE 12 IN. SQUARE BY 3 IN. DEEP; LOWER, 20X20 MESH WIRE CLOTH MADE OF NO. 34 STEEL WIRE.

(Natural Size.)

At this time we wish to call particular attention to the desirability of hand-sifting alfalfa seed before sowing. Dodder seeds, being much smaller than those of alfalfa, are easily removed by sifting through a wire sieve having twenty meshes to the inch. Unfortunately, ready-made sieves of the proper kind are not readily obtainable at hardware stores, but a cheap, serviceable sieve for the purpose may be made by constructing a light wooden frame twelve inches square by three inches deep and tacking over the bottom of it 20 x 20 mesh steel-wire cloth made of No. 34 (W. & M. gauge) wire. Since few hardware dealers carry such wire cloth in stock the Station has found it necessary to have a quantity of it made to order. This has been placed in the hands of Dorchester & Rose, hardware merchants, Geneva, N. Y.; who will sell it (during 1907) at twenty cents per square foot, postpaid.

With such a sieve a man should be able to clean from three to seven bushels of seed per day. One-fourth to one-half pound of seed should be put into the sieve at a time and vigorously shaken during one-half minute. In order that the work may be uniformly thorough the operator should use a cup holding not over one-half pound thereby making it impossible to get too large a quantity at one time. A watch should be kept constantly in sight and no more than two batches of seed should be sifted in one minute.

If the seed is known to contain but little dodder, one sifting will do; but when there is much dodder and particularly if the dodder is of the large-seeded kind, two siftings, both made strictly in accordance with the above directions, are recommended.

Our experiments indicate that by the above method almost any alfalfa seed on the market in this State may be made practically free from dodder seed and safe to sow. Of course it is advisable to begin with seed as nearly free from dodder as can be conveniently obtained. Various other small weed seeds, broken seeds and dirt, as well as some of the smaller alfalfa seeds, also pass through the sieve. The quantity of siftings varies from one to five pounds per bushel according to the original cleanness of the seed and the thoroughness of sifting. It is believed that little if any real loss is sustained by the rejection of the siftings.

How many different species of dodder may be found in alfalfa seed we do not know; but from the practical standpoint of their removal by sifting they may be divided into two kinds; viz., small-seeded dodder and large-seeded dodder. Fortunately, the large-seeded kind is much the less common. Both kinds may be removed by sifting, but the large-seeded kind requires more care and a second sifting is recommended if it is abundant. The Station will furnish free samples of dodder seed upon request.

Since the farmer has no means of determining whether he is removing all of the dodder it is absolutely necessary for him to follow directions closely, and care should be taken to secure the right kind of sieve. Those purchasing sieves or wire cloth for making sieves should see to it that they are actually 20 x 20 mesh. This may be determined by placing a rule on the sieve and counting the number of spaces to the inch. Also, the size of the wire must be taken into account. The wire must not be coarse. No. 34 on the Washburn & Moen gauge is the proper size for steel and iron wire. If brass or copper wire cloth is used the wire should be No. 32 (English gauge). The Station will furnish small samples of the wire cloth free upon request.

The above directions for cleaning alfalfa seed do not apply to red clover seed. Owing to the smaller size of red clover seeds, dodder is not so easily separated from red clover as from alfalfa. For red clover, analysis is the chief safeguard.

REPORT

OF THE

Chemical Department.

L. L. VAN SLYKE, *Chemist.*
A. W. BOSWORTH, *Associate Chemist.*
E. L. BAKER, *Assistant Chemist.*
A. W. CLARK, *Assistant Chemist.*
A. R. ROSE, *Assistant Chemist.*
MORGAN P. SWEENEY, *Assistant Chemist.*
PERCY W. FLINT, *Assistant Chemist.*
JAMES T. CUSICK, *Assistant Chemist.*
OTTO MCCREARY, *Assistant Chemist.*

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REPORT OF CHEMICAL DEPARTMENT.

THE EFFECT OF TREATING MILK WITH CARBON DIOXIDE GAS UNDER PRESSURE.*

L. L. VAN SLYKE AND ALFRED W. BOSWORTH.

SUMMARY.

1. In making a study of the chemical changes in kumiss made from cows' milk, it was noticed that lactic acid forms in it much more slowly than in ordinary milk. This was found to be due to the action of carbon dioxide gas under pressure.

2. A series of experiments was undertaken in order to ascertain the effect of carbon dioxide under different pressures upon the development of lactic acid in milk.

3. The milk used was (1) fresh, separator skim-milk, (2) fresh whole milk, drawn and handled under good hygienic conditions, (3) fresh skim-milk pasteurized at 185° F. and (4) fresh whole milk pasteurized at 185° F.

4. The pressures of gas employed were 70, 150 and 175 pounds per square inch.

5. The most effective method of treating the milk was to charge it with carbon dioxide gas at the desired pressure in a tank such as is used in bottling establishments in preparing carbonated drinks and then to fill into bottles.

6. The carbonated milk was kept at temperatures varying from 35° to 70° F.

7. Pasteurized milk, carbonated, kept for five months with little increase of acidity. Fresh, whole milk, carbonated, kept, in one experiment, for about the same length of time.

8. Carbonated milk makes a pleasant beverage and may find practical use as a healthful drink. It may also be found useful for invalids and children.

*A reprint of Bulletin No. 292.

9. The effect of carbonating milk upon organisms other than lactic, under the conditions of our work, has not yet been studied.

INTRODUCTION.

In making a study of the chemical changes that take place in cows' milk when made into kumiss, we have observed that the product, if properly made and kept, remains for a much longer time without souring than in the case of ordinary milk kept under the same conditions. In the preparation of kumiss, conditions not present in normal milk are introduced; and the inquiry was naturally suggested as to what particular factor was responsible for the delay of formation of lactic acid in kumiss.

Our method of preparing kumiss, briefly outlined, is to add cane sugar (sucrose) and yeast to fresh milk, keep the mixture at about 100° F. until gas begins to form and then to bottle and keep at 35°–45° F. In the course of one or two days some alcohol is formed and enough carbon dioxide to cause considerable pressure. It is thus seen that, in the preparation of kumiss, the following factors are present, most of which do not exist in normal milk: (1) Sucrose, (2) yeast, (3) heat, (4) products of fermentation, especially (a) carbon dioxide and (b) alcohol.

In order to ascertain which of these factors might be the cause of the delay in the lactic fermentation in kumiss, we made a special experimental study of the different conditions involved.

INVESTIGATION.

FIRST EXPERIMENT: INFLUENCE OF DIFFERENT FACTORS IN RETARDING LACTIC FERMENTATION IN KUMISS.

In each of several bottles we placed about two liters of fresh, separator skim-milk and heated to 100° F. Four fresh yeast cakes (Fleischmann's) were rubbed up in 500 cc. of milk. The milk in the different bottles was treated in the manner indicated below.

1. Milk.
2. Milk + 20 grams of sucrose.
3. Milk + 100 cc. of yeast solution.
4. Milk + 100 cc. of yeast solution + 5 grams of sucrose.
4a. Milk + 100 cc. of yeast solution + 10 grams of sucrose.
4b. Milk + 100 cc. of yeast solution + 20 grams of sucrose.
4c. Milk + 100 cc. of yeast solution + 40 grams of sucrose.

We thus had (1) milk without any addition, (2) milk with sucrose alone added, (3) milk with yeast alone added and (4) milk with the same amount of yeast and varying amounts of sucrose added. These were all kept at 100° F. for about three hours, as in the operation of preparing kumiss; they were shaken occasionally. The milk was then transferred to half-liter pressure bottles fitted with tight stoppers (Plate V, figs. 1 and 2, and Plate VI, fig. 4) and these were kept at a temperature of 40°–45° F. during the continuation of the experiment.

The contents of these bottles were examined for acidity at the intervals indicated in Table I, one bottle being used for each examination. In making the determinations, we used 50 cc. of milk, boiling the sample in order to expel carbon dioxide before titrating with $\frac{n}{10}$ alkali. The results, expressed in percentages of lactic acid, are given in Table I.

TABLE I.— SHOWING AMOUNT OF ACID IN MILK AND KUMISS.

No. of experiment.	METHOD OF TREATING MILK.	Fresh.	1 day.	2 days.	3 days.	4 days.	5 days.	6 days.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Milk	0.17	0.27	*c*0.77	.....	.....	.....	.....
2	Milk + 20 grams sucrose	....	0.27	*c*0.67	.....	.....	.....	.....
3	Milk + yeast	....	0.26	*b*0.54	*c*0.88	.....	.....	.....
4	Milk + yeast + 5 grams sucrose	....	0.32	*b*0.50	*c*0.85	.....	.....	.....
4a	Milk + yeast + 10 grams sucrose	....	0.39	*b*0.35	*b*0.54	*c*0.77	*c*0.84	.....
4b	Milk + yeast + 20 grams sucrose	....	0.37	*a*0.27	*b*0.27	*b*0.52	*b*0.55	*c*0.86
4c	Milk + yeast + 40 grams sucrose	....	0.45	0.41	*b*0.27	*b*0.32	*b*0.37	*b*0.54

a Coagulated slightly on boiling but not sour.
b Coagulated quite completely on boiling but not tasting sour.
c Coagulated almost completely without heating and sour.

The results embodied in Table I are summarized in the following statements:

(1) The untreated sample of milk was sour in two days.

(2) The addition of sucrose alone to milk did not delay souring.

(3) The addition of yeast alone apparently delayed the formation of acid slightly.

(4) The addition of yeast and five grams of sucrose did not reduce the acidity much below that of milk to which yeast alone was added.

(5) The addition of larger amounts of sugar along with yeast delayed the souring of the milk to such an extent that coagulation did not occur for five or six days or longer.

(6) In the samples to which yeast and the larger amounts of sugar (20 to 40 grams) were added, the acidity appeared to be greater for one or two days than in the case of untreated milk. This was probably due to the action of carbon dioxide upon the calcium of the calcium casein of the milk, by which free casein was formed, and this on titration would neutralize more alkali and thus increase the apparent acidity of the milk. A part may be due to the action of carbon dioxide upon the phosphates of milk and a small part to such by-products of the alcoholic fermentation as have power to neutralize alkali.

(7) In general, this set of experiments appeared to indicate that the formation of acid and final souring of milk are delayed when milk contains yeast and sugar and these undergo alcoholic fermentation. The results could not decisively furnish information as to whether the active agent in delaying acid formation was the carbon dioxide or some other fermentation product. To settle this point other experiments were necessary.

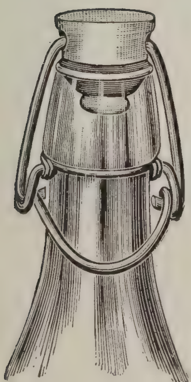
SECOND EXPERIMENT: EFFECT OF PASSING STREAM OF CARBON DIOXIDE GAS THROUGH MILK UPON KEEPING POWER.

We tried the effect of passing a stream of carbon dioxide gas through milk at pressures varying from that of the atmosphere to four or five pounds, but no effects on the keeping power of the milk were noticeable.

It occurred to us that only such amounts of carbon dioxide gas would be efficient as might be obtained under higher pressure. As a clue to this point, the pressure of carbon dioxide formed by kumiss several days old was measured and found to be 45 pounds to the square inch. We then decided to repeat our previous experiments and at the same time, for comparison, to treat milk under pressure with carbon dioxide alone.[1]

[1] It may be well to mention that after this work was finished our attention was called to a note by Mowry and Michel (*Compt. Rend.*, **115**: 959–960, 1892), in which they state as a result of some of their work that milk saturated with carbon dioxide would keep at a low temperature for eight days. They also state that the effect of the carbon dioxide is merely to check the growth of the bacteria. The bacteria are not killed.

1



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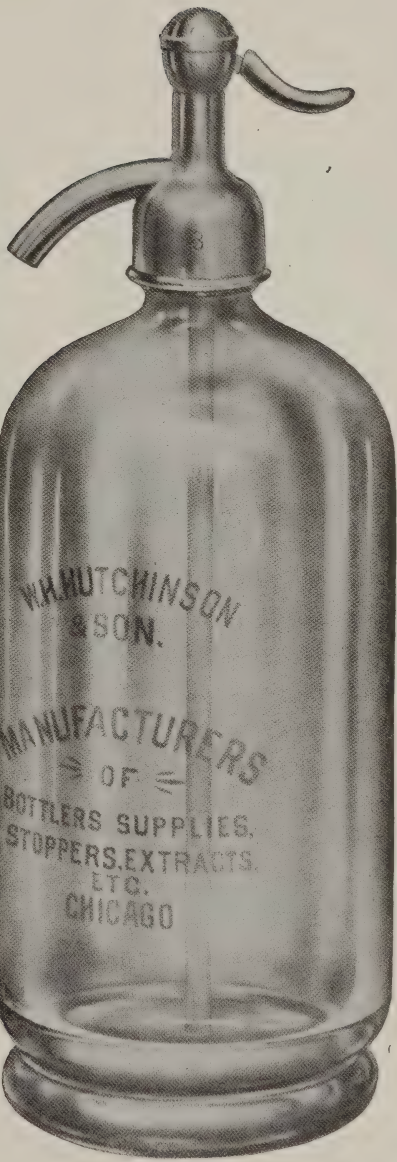

3

Plate V.— Bottles Used for Holding Kumiss and Carbonated Milk.

Plate VI.— Bottles Used for Holding Kumiss and Carbonated Milk.

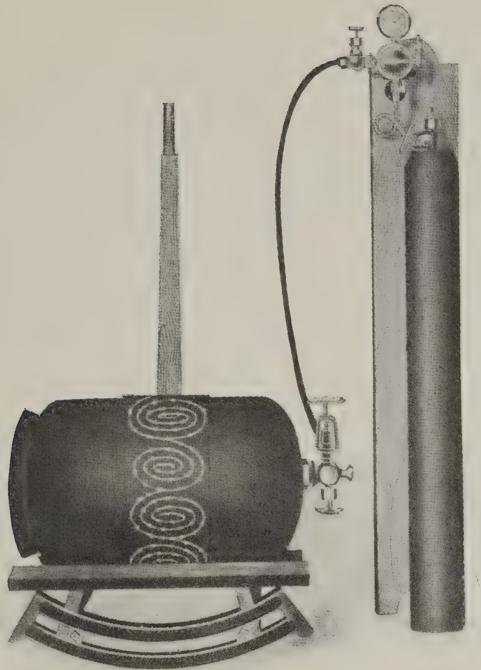

PLATE VII.

FIG. 6. APPARATUS USED FOR CARBONATING MILK. PRESSURE 150 TO 175 LBS. TO SQUARE INCH.

FIG. 7. DRAWING CARBONATED MILK FROM SIPHON BOTTLE.

THIRD EXPERIMENT: EFFECT OF TREATING MILK WITH CARBON DIOXIDE GAS UNDER PRESSURE OF SEVENTY POUNDS.

In this experiment, fresh skim-milk was charged with carbon dioxide gas under a pressure of 70 pounds to the square inch. In charging the milk, we made use of the apparatus of a local bottler of soda water. Pint bottles were used which were closed with patent tin and cork caps (Plate VI, fig. 5). The bottle-filling machine was set to deliver carbon dioxide gas under a pressure of 70 pounds. The bottles of skim-milk, half full, were placed in the machine and charged, after which they were shaken for a short time, and the caps removed to allow the carbon dioxide and air to escape. They were then charged again and, by repeated charging and opening three or four times, a comparatively pure atmosphere of carbon dioxide under a pressure of 70 pounds to the square inch was obtained. This method was found to be more troublesome and less effective than the method used later (p. 148).

In this set of experiments, the results of which are given below in Table II, the milk used in all the bottles was from one lot. The bottles of milk were kept at 40° to 45° F.

TABLE II.— SHOWING AMOUNT OF ACID IN MILK, KUMISS AND CARBONATED MILK.

AGE.	Milk untreated.	Milk heated to 103°F.	Milk and 20 grams sucrose.	Milk and yeast.	Milk, yeast and 5 grams sucrose.	Milk, yeast and 10 grams sucrose.	Milk, yeast and 20 grams sucrose.	Milk, yeast and 40 grams sucrose.	Milk and 70 lbs. carbon dioxide gas.
Days.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Fresh......	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1.........	0.22	0.36	0.21	0.25	0.30	0.30	*a*0.29	*a*0.32	0.25
2.........	0.23	*a*0.54	0.25	*c*0.90	*b*0.49	*a*0.43	*b*0.33	0.32	*a*0.29
3.........	*c*0.67	*c*0.83	*c*0.86	.....	*c*0.86	*b*0.45	0.36	*a*0.36	0.27
4.........	......	.....	.....	.....	.....	*c*0.84	0.55	*a*0.43	0.40
5.........	......	.....	.....	.....	.....	.....	*c*0.72	*a*0.65	*b*0.43
6.........	......	.....	.....	.....	.....	.....	.....	*a*0.58	*b*0.54
7.........	......	.....	.....	.....	.....	.....	.....	*a*0.54	*b*0.58
8.........	......	.....	.....	.....	.....	.....	.....	*a*0.65	*b*0.54
9.........	......	.....	.....	.....	.....	.....	.....	.....	*b*0.58
11.........	......	.....	.....	.....	.....	.....	.....	.....	*b*0.65
12.........	......	.....	.....	.....	.....	.....	.....	.....	*c*0.83

a Coagulated slightly on boiling but not sour.
b Coagulated almost completely on boiling but not tasting sour.
c Coagulated completely without heating; sour.

The results in Tables I and II show a general agreement, indicating that in the milk containing the largest amount of sugar with yeast and, therefore, the largest amount of carbon dioxide, the coagulation of the milk by souring was delayed beyond the eighth day, while in the milk containing only carbon dioxide under a pressure of 70 pounds to the square inch the souring was not complete until the eleventh day. From these results, it appears that the active agent in keeping the milk from souring is the carbon dioxide gas under pressure.

FOURTH EXPERIMENT: EFFECT OF TREATING PASTEURIZED MILK WITH CARBON DIOXIDE GAS UNDER PRESSURE.

Milk pasteurized at 185° F. (85° C.) before separation and about 24 hours old when bottled was put into bottles under a pressure of 70 pounds of carbon dioxide. Some untreated milk was kept for comparison. The bottles were kept at room temperature, about 70° F. (21° C.). The results of this work are given in Table III.

TABLE III.— SHOWING AMOUNT OF ACID IN PASTEURIZED MILK AFTER BEING CARBONATED.

AGE OF MILK AFTER BOTTLING.	Untreated milk.	Carbonated milk.
Days.	*Per ct.*	*Per ct.*
0	0.18	0.18
1	0.22	0.25
2	0.49	0.28
3	*a*0.72	0.30
4	....	0.26
5	....	0.31
6	....	0.42
7	....	0.59
8	....	0.59
9	....	*a*0.83

a Coagulated and sour.

The uncarbonated, pasteurized milk became sour in three days, while the carbonated portion kept nine days before souring, even at room temperature.

FIFTH EXPERIMENT: EFFECT OF TREATING FRESH MILK WITH CARBON DIOXIDE GAS UNDER PRESSURE.

We next treated some fresh, whole milk with carbon dioxide under a pressure of 70 pounds, keeping for comparison some untreated milk. These samples were kept at a temperature of 60°–70° F. The tabulated results follow:

Table IV.— Showing Amount of Acid in Fresh Milk After Being Carbonated.

Age of Milk after Bottling.	Untreated milk.	Carbonated milk.
Days.	*Per ct.*	*Per ct.*
0	0.22	0.22
1	0.22	0.24
2	0.23	0.41
3	0.23	0.32
4	*c*0.50	0.40
5	*d*1.04	*a*0.36
6	....	*b*0.47
7	....	*b*0.54
8	....	*b*0.66
9	....	*b*0.72
10	....	*b*0.76

a Slight coagulation on boiling.
b Casein mostly coagulated on boiling.
c Coagulation complete on boiling.
d Coagulated and sour.

These results agree with those previously obtained in showing that the formation of lactic acid is delayed by the presence of carbon dioxide under pressure. In this experiment, it is noticeable that the untreated milk remained in good condition for three days and then formed acid very rapidly.

SIXTH EXPERIMENT: EFFECT OF TREATING FRESH MILK, PASTEURIZED AND UNPASTEURIZED, WITH CARBON DIOXIDE UNDER PRESSURE.

We next bottled milk with carbon dioxide under a pressure of 70 pounds, using fresh, whole milk both unpasteurized and pasteurized at 185° F. The milk was kept at a temperature of 40°–45° F. The results are tabulated below.

Table V.— Showing Amount of Acid in Fresh, Whole Milk, Pasteurized and Unpasturized, Carbonated and Untreated.

Age of Milk after Bottling.	Whole milk, unpasteurized.	Whole milk, unpasteurized, carbonated.	Whole milk, pasteurized and carbonated.
Days.	*Per ct.*	*Per ct.*	*Per ct.*
0	0.25	0.25	0.25
1	....	....	0.29
3	....	....	0.23
4	*a*0.54	0.29	0.23
7	....	0.45	0.23
10	....	....	0.24
11	....	0.68	....
14	....	0.58	0.25
21	....	0.68	0.27
28	....	0.79	0.32
35	....	*a*0.83	0.28

a Coagulated and sour.

The whole milk, unpasteurized, coagulated in four days; the unpasteurized, carbonated milk, in 35 days; while the pasteurized, carbonated milk showed only about 0.3 per ct. of acid at the end of 35 days. We used the last bottle of the series for examination at this time and could not, therefore, tell how much longer the milk would have kept.

SEVENTH EXPERIMENT: EFFECT OF TREATING PASTEURIZED MILK WITH CARBON DIOXIDE UNDER HIGHER PRESSURE.

Fresh, whole milk, pasteurized at 185° F., was bottled and charged with carbon dioxide gas under a pressure of 150 pounds. In order to charge milk with the gas at this high pressure, a tank (Fig. 6) was used such as is commonly employed for charging soda-water fountains. The milk was placed in the tank, the carbon dioxide run in at the desired pressure and completely mixed with the milk by rocking the tank. The milk thus charged was run into siphon bottles (Fig. 3). This method was found more satisfactory in every way than the one used in previous experiments. The bottles of milk were kept at about 40° F. The results are given in Table VI.

TABLE VI.—SHOWING AMOUNT OF ACID IN PASTEURIZED, FRESH, WHOLE MILK CARBONATED UNDER PRESSURE OF 150 POUNDS.

Age of milk.	Per ct. of acidity.	Age of milk.	Per ct. of acidity.
Fresh	0.19	8 weeks	0.25
1 week	0.25	9 weeks	0.27
2 weeks	0.22	10 weeks	0.25
3 weeks	0.27	11 weeks	0.22
4 weeks	0.23	13 weeks	0.27
5 weeks	0.29	19 weeks	0.29
6 weeks	0.23	40 weeks	0.31
7 weeks	0.25		

The results show that fresh, whole milk, pasteurized and charged with carbon dioxide gas under a pressure of 150 pounds, formed practically no increase of acid in the course of about nine months. The milk was kept at a temperature varying from 40° to 60° F.

EIGHTH EXPERIMENT: EFFECT OF TREATING FRESH MILK WITH CARBON DIOXIDE UNDER PRESSURE OF 175 POUNDS.

The milk used was obtained under the best hygienic conditions, cooled to about 35° F. as soon as drawn and charged with carbon dioxide seven or eight hours later under a pressure of 175 pounds. The results are given below.

TABLE VII.— SHOWING AMOUNT OF ACID IN FRESH, WHOLE MILK, CARBONATED UNDER A PRESSURE OF 175 POUNDS.

Age of milk.	Per ct. of acidity.	Age of milk.	Per ct. of acidity.
Fresh	0.18	10 weeks	0.25
1 day	0.23	15 weeks	a0.37
1 week	0.24	15 weeks	b0.99

a In this bottle the casein had separated to some extent, but the milk was still sweet to taste.
b In this bottle the milk had coagulated and was sour.

NINTH EXPERIMENT: EFFECT OF TREATING FRESH MILK WITH CARBON DIOXIDE UNDER A PRESSURE OF 70 POUNDS.

The milk used in this experiment was obtained under the best hygienic conditions, cooled to about 35° as soon as drawn and charged with carbon dioxide gas seven or eight hours later under a pressure of 70 pounds. The results follow.

TABLE VIII.— SHOWING AMOUNT OF ACID IN FRESH, WHOLE MILK CARBONATED UNDER A PRESSURE OF 70 POUNDS.

Age of milk	Per ct. of acidity.	Age of milk.	Per ct. of acidity.
Fresh	0.22	4 weeks	0.24
5 days	0.23	5 months	a0.20

a At the end of five months the milk in some bottles had coagulated and soured, while in others there was no increase of acidity over the milk when first treated five months before.

GENERAL DISCUSSION OF RESULTS.

Thus far we have presented and discussed results relating solely to the effect of carbon dioxide gas in retarding the formation of lactic acid in milk. The fact that fresh milk can be made to keep in good condition for several weeks by treatment with carbon dioxide under a pressure of 70 pounds or more suggests important practical applications, provided other qualities than acidity are not affected unfavorably.

CARBONATED MILK AS A BEVERAGE.

Milk carbonated under a pressure of 70 pounds comes from the bottle as a foamy mass, more or less like kumiss that is two or three days old. It has a slightly acid, pleasant flavor, due to the carbon dioxide, and tastes somewhat more saline than ordinary milk. In the case of carbonated milk pasteurized at 185° F., there is, of course, something of a "cooked" taste. Though the cream separates in the bottle, it is thoroughly remixed by a little shaking as the milk comes from the bottle and there is no appearance of separate particles of cream. All who have had occasion to test the quality of carbonated milk as a beverage agree in regarding it as a pleasant drink. In the case of milk bottled under a pressure of 150 pounds of carbon dioxide, the milk delivered from the siphon is about the consistency of whipped cream (Plate VII, fig. 7), but, on standing a short time, it changes into a readily drinkable condition. From the experience we have had, it would seem that carbonated milk might easily be made a fairly popular beverage.

EFFECT OF CARBON DIOXIDE GAS ON ORGANISMS OTHER THAN LACTIC.

An important question in connection with the use of carbonated milk is the effect of carbon dioxide gas on organisms other than lactic. While lactic organisms may be retarded in development, might not disease germs present in milk develop and thus make unsterilized or unpasteurized carbonated milk a possible source of danger to health? We have done no work on this point up to the present time, and can only refer to the meager literature on this subject. It should be stated that in all of our work we did not detect any indications of bacterial action so far as could be judged by changes in the flavor of the milk. Foa[1] investigated the action of carbon dioxide gas under pressure of two to five atmospheres upon various organisms and states that it has a checking influence on the development of organisms, but does not act on enzymes and toxines. Thus, carbon dioxide under a pressure of four atmospheres checks alcoholic fermentation. Hoffman[2] treated fresh milk with carbon dioxide under a pressure of 50 atmospheres for some hours. Bacteria present in the milk were capable of growth afterward when the milk was relieved from pressure. This line of work needs thorough investigation and we hope to give attention to it in the near future.

POSSIBLE USES OF CARBONATED MILK.

There are several practical applications in which carbonated milk may find possible usefulness. On steamships, it would be easily possible to furnish sweet milk for several weeks from a supply of carbonated milk. Carbonated milk may be found very useful in hospitals. Experiments should be made with invalids in order to ascertain to what extent carbonated milk can be made to take the place of kumiss and similar drinks. It is also possible that carbonated milk might be found useful in feeding children in many

[1] *Chem. Centbl.*, **77**, II: 695. 1906.
[2] *Arch. Hyg.*, **57**: 379. 1906.

cases where ordinary cows' milk does not digest well. While we did not treat any cream with carbon dioxide under pressure, we believe that whipped cream could easily be prepared this way with a pressure of 150 pounds or less and could be used directly from a siphon bottle with convenience.

PRECAUTIONS IN PREPARATION OF CARBONATED MILK.

In the preparation of carbonated milk, several precautions are necessary, in order to meet with success. In the first place, the milk should be drawn so as to be as free as possible from dirt and promptly cooled below 45° F. It should be carbonated within a few hours. All the vessels with which the milk comes in contact, from milking to bottling, should be carefully sterilized before use. In case milk cannot be carbonated quite promptly after drawing, it should be thoroughly pasteurized before being charged and bottled.

II. SOME OF THE FIRST CHEMICAL CHANGES IN CHEDDAR CHEESE.*

III. THE ACIDITY OF THE WATER-EXTRACT OF CHEDDAR CHEESE.*

L. L. VAN SLYKE AND ALFRED W. BOSWORTH.

SUMMARY.

1. *Object.*— The work described in the first part of this bulletin was undertaken primarily for the purpose of learning what changes take place in the proteids of cheddar cheese during the time the cheese is in press, a period not previously studied here. The work was extended so as to include a study of the changes in the calcium and phosphoric acid compounds of cheese. The work on the acidity of the water-extract of cheddar cheese had for its purpose to learn what constituents of the water-extract cause it to neutralize alkali.

2. *Method of experiment.*— Five cheeses were made at different times under the usual conditions observed in making cheddar cheese. They were kept at 15.5° C. Determinations in cheese were made of the amounts of (1) total nitrogen, (2) nitrogen soluble at 55° C. in five per ct. solution of sodium chloride, (3) water-soluble nitrogen, (4) acidity of water-extract, (5) lactose, (6) total calcium and phosphoric acid compounds, (7) water-soluble calcium and phosphoric acid compounds, (8) calcium compounds in the salt-soluble portion, (9) calcium lactate, (10) total and water-soluble ash.

3. *Early changes in proteids of cheddar cheese.*—(1) The insoluble proteid of fresh cheese-curd (calcium paracasein) changes rapidly into a form soluble in 5 per ct. solution of sodium chloride at 55° C., until, in 9 or 10 hours after the cheese is put in press, the proteid, originally insoluble in the salt solution, becomes completely soluble in this solution. (2) Then the proteid soluble in salt solution changes into a form insoluble in salt solution, this

*A reprint from Technical Bulletin No. 4.

change taking place rapidly at first and then gradually. (3) Proteids in water-soluble form appear to increase only slightly, if at all, until after the salt-soluble proteid has partially changed into the form insoluble in salt solution.

4. *Changes in calcium and phosphoric acid compounds of cheddar cheese.*— The calcium and phosphoric acid compounds of cheese, insoluble at the start, become soluble, until about 80 per ct. of the calcium and all of the phosphates become soluble in water. This change is due to the formation of lactic acid and its action upon the phosphates of the cheese, resulting in the formation of monocalcium phosphate and calcium lactate. About 20 per ct. of all the calcium in the cheese is found in the salt-soluble portion, and the proteid in this solution shows an acidity about equal to that shown by calcium paracasein.

5. The acidity of the water-extract of normal cheddar cheese is largely due, not to the presence of free lactic acid, but to monocalcium phosphate.

II. SOME OF THE FIRST CHEMICAL CHANGES IN CHEDDAR CHEESE.

In previous studies of the ripening changes in cheddar cheese made at this Station[1] it was shown that the calcium paracasein of the freshly coagulated milk undergoes various changes, most prominent among which is the formation of a substance soluble at 50° to 55° C. in 5 per ct. solution of sodium chloride. Most of the work formerly done was confined to an examination of cheese after it was taken from the press, generally about 24 hours after the beginning of the operation of cheese-making or about 18 hours after putting in press. Little work was done in studying the intermediate period between putting the cheese in, and removing from, the press.

While working upon camembert cheese, it was noticed by one of the authors that marked changes occur in the cheese proteids during the first 24 hours from the time of commencing the operation of cheese-making. This fact naturally suggested that similar changes might occur in the early history of cheddar cheese during that period of time which had not been previously studied with care. It has been found that the changes taking place during this early period are of the same character and

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[1] N. Y. Agrl. Exp. Sta. Buls. 214 and 261.

due to the same causes in both camembert and cheddar cheese; the only essential difference is the extent of the changes, which go somewhat farther in camembert than in cheddar cheese. This is what would be expected from differences in the methods of manufacture, since camembert cheese is made without undergoing pressure to expel whey and it therefore contains more lactose, resulting in the formation of more lactic acid, which is the active agent in causing the first changes that appear in the cheese-making process.

Reviewing briefly the interpretation of the results secured in the work previously done[2] it was thought (1) that the calcium paracasein, formed from calcium casein of milk by the action of rennet enzym, was converted by the action of lactic acid into free paracasein with simultaneous formation of calcium lactate, that is, the calcium paracasein was decalcified; (2) that the free paracasein thus formed was soluble in warm 5 per ct. solution of sodium chloride; (3) that the proteids of cheese-curd and cheese fresh from the press were a mixture, in varying proportions, of calcium paracasein and free paracasein, a maximum of 78 per ct. of the total nitrogen of the cheese having been found in the form soluble in dilute salt solution; (4) that not all of the calcium paracasein was changed into free paracasein; (5) that the plastic and ductile properties of cheese-curd were due to the formation and presence of free paracasein; (6) that free paracasein appeared to be the body in which began to take place the various chemical changes grouped under the general term of cheese-ripening.

It now appears, as we shall show later, that a lack of knowledge as to the extent and character of changes occurring in cheese while in press led to an interpretation of results that must be very materially modified in order to harmonize with our recent work.

Another point of importance, not studied in previous work at this Station is the relation of some of the inorganic salts to the changes taking place in the early history of cheddar cheese. Somewhat extended and detailed studies of the calcium and phosphoric acid compounds have been made in some of our work and the results are presented in this bulletin. These results are intimately associated with the changes taking place in the chief proteid in the early history of cheese and appear to be essential to a correct understanding and interpretation of these changes.

[2] N. Y. Agrl. Exp. Sta. Bul. 261, pp. 36, 37.

ANALYTICAL DETERMINATIONS.

The following determinations were made, either wholly or in part, in each of the experiments described in this bulletin: (1) Total nitrogen in cheese, (2) water-soluble nitrogen, (3) nitrogen soluble in 5 per ct. solution of sodium chloride, (4) the amount of N-10 alkali neutralized by the water-extract from 100 grams of cheese, (5) the percentage of lactose in cheese, (6) the percentage of lime (CaO) and phosphoric acid (P_2O_5) compounds in cheese, (7) the percentage of water-soluble lime (CaO) and phosphoric acid (P_2O_5) compounds found in cheese, (8) the percentage of inorganic phosphorus in cheese in the form of phosphoric acid (P_2O_5) compounds, (9) the percentage of calcium (CaO) compounds in the salt-extract of cheese, (10) the percentage of lactic acid in the form of calcium lactate in cheese, and (11) the percentage of total and water-soluble ash in cheese.

The amount of nitrogen in the different forms was determined in the manner described in Bulletin 215 of this Station, except that, in case of water-soluble and salt-soluble nitrogen, the extraction was continued until 1,000 cc. of extract had been obtained. In all cases, the cheese was first extracted with water before treatment with salt solution. In those cases in which calcium was determined in the salt-extract, we used for extraction a solution of sodium chloride free from calcium salts.

The lactic acid in cheese, which is present in the form of calcim lactate, was determined by Palm's method,[3] which is, in brief, as follows: The cheese is acidified with sulphuric acid and then extracted with ether. The ether solution is evaporated to a syrupy consistency and then treated with water. This water solution is filtered, treated with lead acetate and then filtered from any precipitate that forms. More lead acetate is added to the filtrate and then alcoholic ammonia. The lead lactate is thus precipitated free from other substances. The precipitate is filtered and washed with alcohol. The amount of lactic acid is determined by loss on careful ignition. In place of lead acetate, one may use an excess of freshly precipitated lead hydroxide to precipitate the lactic acid, especially when the amount is small. From the precipitate thus obtained, one may separate pure lactic acid by treatment with hydrogen sulphide and subsequent extraction with ether. This method is not altogether satisfactory, but appears to be the most efficient one available.

[3] *Ztschr. Analyt. Chem.*, **26**, 33. 1887.

The amount of inorganic phosphorus in cheese is approximately found by calculation from the total nitrogen and total phosphorus, based on casein with a phosphorus content of 0.85 per ct. and a nitrogen content of 15.70 per ct. The amount of casein phosphorus thus found subtracted from the total amount of phosphorus in cheese gives the amount of phosphorus present as P_2O_5.

It will be noticed in the tabulated data presented that the analytical results do not always appear to be consistent. Such variations are generally due to variation in composition of the cheese in different portions, since it is well known that the mass of a cheddar cheese is quite far from being of uniform composition. Samples drawn from different parts of the same cheese generally show varying analytical results.

FIRST EXPERIMENT.

In some preliminary work carried on for the purpose of studying some of the changes that take place in the early history of cheddar cheese, two cheeses were made from separator skim-milk in the usual manner. One was made May 30, and the other June 12, 1906. These were kept at a temperature of 15.5° C., and this was the temperature at which we uniformly kept the cheeses in all our experiments described in this bulletin. The age of cheese in this and other experiments is dated, unless otherwise specified, from the time it was put in press, which was usually five or six hours after the actual operation of cheese-making began. The cheeses used in this and other experiments were made by Geo. A. Smith, Dairy Expert of the Station.

The results of this first experiment are given in Table I.

TABLE I.— CHANGES IN NITROGEN COMPOUNDS OF SKIM-MILK CHEESE DURING EARLY PERIOD.

NUMBER OF CHEESE.	Age of cheese when analyzed.	Total nitrogen in cheese.	Water-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Salt-soluble nitrogen expressed as percentage of total nitrogen in cheese.	N-10 alkali neutralized by water-extract from 100 grams of cheese.
	Hours	*Per ct.*	*Per ct.*	*Per ct.*	*Cc.*
1	When put in press	3.25	4.62	3.38	...
1	17	4.90	3.86	91.84	...
1	29	5.27	3.80	87.67	...
1	41	5.33	3.00	86.68	...
1	89	5.31	5.28	80.79	...
1	137	5.15	5.24	61.55	...
2	When whey was drawn.	2.85	7.72	3.86	36
2	When put in press	4.59	3.70	25.05	132
2	3	4.98	4.42	82.73	168
2	6	5.11	3.52	89.63	174
2	9	5.07	3.94	92.31	180
2	15	5.32	3.38	81.58	180
2	18	5.32	4.13	92.48	186
2	27	5.80	4.65	75.86	186
2	42	5.48	4.92	65.69	186
2	66	5.57	4.85	33.39	200

A study of Table I permits the following summary of results:

(1) The amount of nitrogen in the form of water-soluble compounds changes very slightly during the first few days after a cheese is made, consisting essentially of the milk albumin retained in the cheese. The decrease in percentage of water-soluble nitrogen in cheese noticed after being put in press is largely due to loss of albumin going out in whey. These statements agree with the results of previous work.

(2) The amount of nitrogen in the form of salt-soluble proteid increases very rapidly after the cheese is put in press and reaches a maximum in a comparatively short time, when, in the case of the two cheeses under consideration, it constitutes over 90 per ct. of the nitrogen in the cheese.

(3) After the salt-soluble nitrogen of the cheese reaches a maximum, it begins to decrease, but much more slowly than it had increased.

(4) Along with the increase of salt-soluble nitrogen there was an increase in the acidity of the water-extract of the cheese. We shall later discuss in detail what constituents of the water-extract of cheese are responsible for the apparent acidity of cheese.

SECOND EXPERIMENT.

It was desired to repeat the study made in the first experiment, using a cheese manufactured from normal milk instead of skim-milk, in order to ascertain whether the same results would be found in the case of whole-milk cheese. This cheese was made June 18, 1906. The study was extended to include the amount of lactose, calcium and phosphoric acid in the cheese, the observations and analyses being continued for a period of six months.

TABLE II.— CHANGES IN NITROGEN, CALCIUM AND PHOSPHORUS COMPOUNDS IN WHOLE MILK CHEESE.

Age of cheese when analyzed.	Water-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Salt-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Lactose in cheese.	N-10 alkali neutralized by water-extract from 100 grams of cheese.	Water-soluble Ca in cheese expressed as in CaO.	Water-soluble P^2O^5 in cheese.
	Per ct.	*Per ct..*	*Per ct.*	*Cc.*	*Per ct.*	*Per ct.*
When whey was drawn*—	6.11	8.02	1.10	36	0.17	0.15
When put to press†	4.68	14.33	1.70	100	....	0.54
3 hours	5.05	75.26	1.05	120	0.43	0.56
6 hours	5.48	71.54	0.68	120	0.48	0.61
9 hours	5.00	65.16	0.68	120	0.50	0.63
12 hours	5.45	70.65	0.68	136	0.54	0.57
15 hours	5.58	65.56	0.58	136	0.58	0.58
18 hours	6.58	64.81	0.58	136	....	0.61
2 days	7.73	61.17	0.58	152	0.65	0.67
4 days	9.11	45.31	0.50	160	0.64	0.64
1 week	11.02	44.62	0.10	164	0.65	0.72
2 weeks	18.60	46.51	0.07	190	0.66	0.74
2 months	28.68	45.89	0	....	0.75	0.78
4 months	34.39	40.87	0	230	0.82	0.82
5 months	31.53	34.24	0	212	0.76	0.71
6 months	43.22	21.61	0	180	....	....

* Gave strings one-eighth inch long on hot iron.
† Gave strings one inch long on hot iron.

The results in Table II are summarized as follows:

(1) The proportion of nitrogen in cheese that is present in water-soluble form remains quite uniform the first day and then slowly increases. As compared with the two skim-milk cheeses in the first experiment, the water-soluble nitrogen in this whole-milk cheese becomes somewhat greater in amount during the period for which a comparison can be made.

(2) The percentage of nitrogen in salt-soluble form increases rapidly. The maximum indicated by our results was not as high as in the case of the first experiment. After three hours a decrease appeared to begin and this continued during the six months of our study.

(3) The lactose in the cheese decreases in amount quite rapidly during the first 12 or 15 hours after the cheese is put in press and entirely disappears in about 2 weeks.

(4) The acidity increases, reaching its approximate maximum about the time the lactose disappears. The apparent increase of acidity later is due, in part, at least, to the presence of increased amounts of water-soluble proteids.

(5) The percentage of water-soluble calcium and phosphoric acid compounds increases quite rapidly during the first few hours after the cheese is put in press; the increase continues for some weeks but at a slower rate. As we shall show later, the water-soluble phosphoric acid is present mainly as mono-calcium phosphate, and the water-soluble calcium is present in combination mostly with phosphoric acid and with lactic acid.

The rapid increase of salt-soluble nitrogen to a maximum, followed by subsequent decrease, suggested the probability that the insoluble proteid of the fresh curd is completely converted into the salt-soluble form before the change into another form, insoluble in water and salt-solution, begins; but that the action is so rapid that it is difficult to get a sample at just the point when the nitrogen, originally insoluble, is entirely in the salt-soluble form. The probable truth of this suggestion appeared to be indicated by the fact that in one case when we were working on another point we were able to dissolve the insoluble cheese proteid completely in salt-solution.

From the suggestions afforded by the results obtained, it seemed desirable to make further study with the specific object of ascertaining: (1) Whether all the insoluble proteid of fresh cheese is changed into a salt-soluble form before it again becomes insoluble in salt-solution, and (2) what relation there might be between the formation of salt-soluble nitrogen and the formation of water-soluble calcium phosphate, and (3) whether the calcium of the calcium lactate that is formed comes wholly from the calcium of the insoluble phosphates or in part from the calcium of calcium paracasein.

THIRD EXPERIMENT.

For carrying out this study, another cheese was made July 9, 1906, from normal milk, the results of which are embodied in Tables III and IV. In order to obtain a sample of cheese when the nitrogen should be all in the form of the salt-soluble substance, it was necessary to take samples at more frequent intervals; and so samples were taken for 7½ hours at intervals of one hour and a half after the cheese was put in press.

TABLE III.— CHANGES IN NITROGEN COMPOUNDS AND IN ACIDITY IN WHOLE-MILK CHEESE.

Age of cheese when analyzed.	Total nitrogen in cheese.	Water-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Salt-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Lactose in cheese.	N-10 alkali neutralized by water-extract from 100 grams of cheese.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Cc.*
When whey was drawn	2.41	3.54	6.30	1.38	48
Just before salting	3.51	2.28	19.71	0.75	72
Just after salting	3.67	3.27	17.17	0.77	114
1½ hours	3.71	....	52.84	0.73	....
3 hours	3.82	3.15	65.62	0.68	116
4½ hours	3.77	3.45	70.03	0.44	112
6 hours	4.00	3.25	....	0.44	120
7½ hours	3.80	3.16	75.53	0.39	120
1 day	3.81	4.78	76.64	0.30	130
2 days	3.82	4.19	....	0.10	....
4 days	3.86	7.25	....	0.04	....
1 week	3.82	9.42	66.75	0.03	160
2 weeks	3.81	16.01	55.64	0	190
4 weeks	3.83	19.58	58.75	0	188
2 months	3.80	29.21	49.73	0	208
4 months	3.98	31.16	46.48	0	204
6 months	3.96	34.34	51.01	0	....

TABLE IV.— CHANGES IN CALCIUM AND PHOSPHORUS COMPOUNDS IN CHEESE.

Age of cheese when analyzed.	Calcium compounds in cheese expressed as CaO.	Water-soluble calcium compounds in cheese expressed as CaO.	Water-soluble CaO expressed as percentage of total CaO in cheese.	Total phosphorus in cheese expressed as P_2O_5.	Phosphorus in cheese in form of phosphate expressed at P_2O_5.	Water-soluble phosphate in cheese expressed as P_2O_5.	P_2O_5 in water-soluble form expressed as percentage of total phosphates in cheese.	Calcium lactate in cheese.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
When whey was drawn.	0.72	0.20	27.78	0.76	0.46	0.23	50.00	0.34
Just before salting	0.88	0.34	38.64	0.97	0.54	0.36	66.67	....
Just after salting	0.92	0.36	39.13	1.06	0.60	0.40	66.67	0.38
3 hours	0.90	0.52	57.78	1.14	0.67	0.46	68.66	0.68
4½ hours	0.94	0.48	51.07	1.16	0.69	0.45	65.22	0.68
6 hours	0.98	0.52	53.06	1.17	0.68	0.48	70.60	0.53
7½ hours	0.98	0.58	59.18	1.12	0.65	0.47	72.31	0.63
1 day	0.99	0.62	62.60	1.17	0.69	0.51	73.90	0.56
2 days	0.91	0.44	48.42	1.18	0.71	0.42	60.00	0.62
4 days	0.99	0.64	64.65	1.21	0.73	0.62	84.93	....
1 week	0.93	0.63	67.74	1.17	0.70	0.56	80.00	....
2 weeks	0.98	0.78	79.60	1.20	0.73	0.76	100.00	0.50
4 weeks	1.04	0.83	79.80	1.20	0.73	0.77	100.00	....
2 months	0.99	0.77	77.78	1.29	0.82	0.84	100.00	....
4 months	0.94	0.76	80.85	1.25	0.76	0.79	100.00	....
6 months	0.97	0.68	70.10	1.06	0.57	0.66	100.00	....

The results embodied in Tables III and IV are summarized as follows:

(1) The formation of water-soluble and salt-soluble nitrogen, together with the conversion of lactose into lactic acid, as shown in Table III, proceeds in general as in the preceding experiments. It will be noticed, however, that we failed to get a sample of cheese for analysis when the salt-soluble nitrogen was as high as in the preceding experiments. Apparently, between 7½ hours and 24 hours, very little change had taken place in the amount of salt-soluble nitrogen; but, according to results with other cheeses, there is reason to believe that, during this interval, the salt-soluble nitrogen increased until the nitrogen all became salt-soluble and then began to change into the succeeding form, which is insoluble in salt solution, and at the end of 24 hours had decreased nearly to the point at which the salt-soluble stood at the end of 7½ hours.

(2) The amount of calcium compounds found in the water-extract increases quite rapidly for a few hours and then more slowly, reaching a maximum in about 2 weeks, when about 80 per ct. of the calcium compounds in the cheese is found in the water-extract of the cheese. After this the amount of water-soluble calcium compounds appears to remain about constant. The water-soluble calcium appears to represent, in the main, two compounds, (1) mono-calcium phosphate and (2) calcium lactate. The results suggest that about 20 per ct. of the calcium in cheese is not given up to a water solution, either being held mechanically by the proteid or else existing in combination. It hardly seems probable that this calcium is there as insoluble calcium phosphates so long as enough lactic acid is formed to change it all into mono-calcium phosphate. It appears more likely that it is in combination with paracasein, as will be shown later.

(3) The amount of water-soluble P_2O_5 increases rapidly for the first few hours and then continues gradually to increase until finally all the inorganic phosphorus compounds appear in the water-extract. This indicates that enough lactic acid has been formed to convert the insoluble calcium phosphates entirely into mono-calcium phosphate with simultaneous production of calcium lactate.

(4) The amount of calcium lactate increases rapidly in the first few hours.

FOURTH EXPERIMENT.

Since we had failed to take a sample of cheese in the third experiment at the time when the nitrogen in the form of salt-soluble nitrogen was at or near its possible maximum, another experiment was made for this purpose, the results of which are embodied in Tables V and VI. The same determinations in cheese were made as before and, in addition, those of moisture, total ash and soluble ash. The cheese for this experiment was made November 15, 1906.

TABLE V.— CHANGES IN NITROGEN COMPOUNDS AND IN ACIDITY IN WHOLE-MILK CHEESE.

Age of cheese when analyzed.	Water in cheese.	Total nitrogen in cheese.	Water-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Salt-soluble nitrogen expressed as percentage of total nitrogen in cheese.	Lactose in cheese.	N-10 alkali neutralized by water-extract from 100 grams of cheese.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*C c.*
When curd was cut	77.70	1.28	14.84	3.13	4.00	144
When whey was drawn.........	65.34	2.00	6.00	4.50	2.72	72
When put in press.	40.00	3.45	3.77	30.15	1.52	88
2 hours..........	37.85	3.53	4.25	46.46	0.64	136
4½ hours.........	37.72	3.58	4.19	43.02	0.64	96
7 hours..........	38.16	3.55	4.79	40.00	0.68	96
9½ hours.........	38.89	3.55	6.48	96.06	0.72	128
12 hours.........	37.70	3.71	4.58	59.57	0.80	144
14½ hours........	37.87	3.61	6.37	65.62	0.80	128
17½ hours........	37.62	3.50	5.71	68.00	0.76	140
21½ hours........	37.68	3.45	6.09	85.22	0.80	....
2 days...........	37.45	3.79	4.75	68.87	0.36	140
4 days...........	35.20	3.75	5.87	46.94	0.32	132
1 week...........	35.88	3.63	8.26	43.80	0.22	140
2 weeks..........	34.01	3.74	10.16	37.43	trace	132
3 weeks..........	35.10	3.70	14.59	49.46	0	132
1 month..........	37.24	3.74	16.84	46.79	0	152
2 months.........	36.94	3.62	23.21	47.79	0	156
3 months.........	34.52	3.67	25.34	42.78	0	164
4 months.........	30.80	3.62	24.31	43.09	0	180

TABLE VI.— CHANGES IN CALCIUM AND PHOSPHORUS COMPOUNDS IN CHEESE.

Age of cheese when analyzed.	Calcium compounds in cheese expressed as CaO.	Water-soluble calcium compounds in cheese expressed as CaO.	Water-soluble CaO expressed as percentage of total CaO in cheese.	Total phosphorus in cheese expressed as P_2O_5.	Phosphorus in cheese in form of phosphate expressed as P_2O_5.	Water-soluble phosphate in cheese expressed as P_2O_5	P_2O_5 in water-soluble form expressed as percentage of total phosphates in cheese.	Ash in cheese.	Water-soluble ash in cheese.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
When curd was cut...	0.35	0.19	54.28	0.53	0.37	0.33	89.19	0.89	0.
When whey was drawn...........	0.56	0.25	44.64	0.73	0.48	0.46	95.83	1.29	0.52
When put in press....	1.00	0.55	55.00	1.06	0.63	0.51	80.95	3.51	1.64
2 hours.............	0.94	0.64	68.09	1.09	0.65	0.58	89.23	2.96	1.56
4½ hours............	0.94	0.72	76.60	1.13	0.69	0.59	85.51	2.84	1.52
7 hours.............	0.93	0.71	76.34	1.10	0.66	0.65	98.48	2.52	1.56
9½ hours............	0.93	0.67	72.04	1.11	0.67	0.69	100.00	2.88	1.72
12 hours............	0.93	0.69	74.19	1.15	0.69	0.69	100.00	2.80	1.32
14½ hours...........	0.94	0.72	76.60	1.11	0.66	0.67	100.00	2.72	1.70
17½ hours...........	0.94	0.69	73.40	1.10	0.67	0.66	100.00	2.60	1.72
21½ hours...........	*0.94	0.66	70.21	1.11	0.68	0.66	100.00	2.86	2.40
2 days..............	0.94	0.71	75.53	1.12	0.65	0.68	100.00	2.73	1.96
4 days..............	0.97	0.71	73.19	1.13	0.67	0.73	100.00	2.62	2.36
1 week..............	1.06	0.73	68.87	1.10	0.65	0.64	100.00	2.65	1.92
2 weeks.............	0.92	0.75	81.52	1.10	0.64	0.63	100.00	3.00	2.08
3 weeks.............	0.94	0.73	77.66	1.10	0.64	0.63	100.00	2.71	1.64
1 month.............	1.03	0.76	73.79	1.12	0.66	0.64	100 00	2.91	2.00
2 months............	†1.07	0.72	67.29	0.99	0.54	0.65	100.00	2.88	2.08
3 months............	1.14	0.78	68.42	1.05	0.59	0.74	100.00	2.98	2.16
4 months............	1.01	0.74	73.72	1.08	0.63	0.64	100.00	3.03	1.98

* CaO in salt-extract in two days equals 0.25 per ct. of cheese.
† CaO in salt-extract in two months equals 0.30 per ct. of cheese.

A study of the data in Tables V and VI suggests the following summary of results:

(1) The results agree with those previously obtained as regards the amount of water-soluble nitrogen in cheese during its early history.

(2) We were successful in getting a sample of cheese when the insoluble nitrogen had been nearly all converted into salt-soluble nitrogen. In 9½ hours after the cheese was put in press, we found that 96 per ct. of its total nitrogen was salt-soluble, or, stated another way, that all of the nitrogen originally insoluble had become salt-soluble. This dropped rapidly in the next few hours.

(3) The acidity of this cheese, when put in press, was somewhat less than that found in the other experiments. At the end of 9½ hours, it had reached about the same point as in most of the other cases. However, it did not later become as great as in the preceding experiments. It would appear as if the maximum amount of salt-soluble nitrogen is formed when the water-

extract from 100 grams of cheese neutralizes 120 to 130 c. c. of N-10 alkali.

(4) The lactose in this and the preceding experiments seems to disappear in one to two weeks. The rapidity of conversion of lactose into lactic acid depends upon temperature as one condition and this fact must be considered when we attempt to make comparison of results given by different experiments. Under the conditions of our work in this experiment, the temperature was lower while the cheese was in press than in the case of the other experiments.

(5) The amount of water-soluble calcium compounds increases at different rates in different experiments. Comparing this with the preceding, we notice that when cheese is put in press it contains .45 to .55 per ct. of CaO, which increases to .60 to .65 per ct. in 24 hours and in 2 weeks or more reaches about .75 per ct. About 80 per ct. of the total calcium in the cheese becomes ultimately converted into water-soluble calcium compounds. This appears to take place within 2 weeks, which is roughly coincident with the time at which the lactose in the cheese finally disappears.

(6) The water-soluble P_2O_5 increases quite rapidly for 9 or 10 hours after the cheese is put in press and then remains quite constant, the inorganic P_2O_5 all appearing in the water-extract. This complete change appears to take place in this experiment much more quickly than in the preceding one. In both cases, the maximum amount of water-soluble CaO is reached, when all the inorganic P_2O_5 appears in the water-extract.

(7) The results in determining total ash and water-soluble ash are inserted here for convenience of future reference. They do not now appear to give any information not furnished by the other data.

III. THE ACIDITY OF THE WATER-EXTRACT OF CHEDDAR CHEESE.

The acidity of cheddar cheese is often discussed as if it were due to the presence of free lactic acid in the cheese. This is illustrated by the fact that in the provisional official method[1] for determining acidity in cheese, the instructions are to express the result as lactic acid. However, we have been unable to isolate free lactic acid from normal cheddar cheese or to obtain

[1] U. S. Dept. Agr., Chem. Bul. 46, rev. ed., p. 56.

a test for it in any cheese examined by us. The behavior of indicators toward the water-extract of cheese is not such as free lactic acid would give.

In the discussion given in the preceding pages, it has been stated that the lactic acid formed during and after the cheese-making process combined with a portion of the calcium of the insoluble calcium phosphate present, forming mono-calcium phosphate and calcium lactate. The power of the water-extract of cheese to neutralize alkali appears to be largely due to the mono-calcium phosphate present and may, of course, be regarded as an indirect measure of the amount of lactic acid that has combined with calcium and remains in cheese. The different substances present in the water-extract of cheese that might be thought to influence appreciably the determination of acidity by titration with alkali are mono-calcium phosphate, calcium lactate and soluble proteid. While, as shown later, we know that all the calcium lactate of cheese appears in the water-extract, this salt is neutral and has no effect upon indicators. The amount of soluble proteid is for some time insufficient to account for any appreciable amount of acidity. Therefore, the only compound present in amounts that can account for any considerable part of the neutralizing property of the water-extract of cheddar cheese in its early history is mono-calcium phosphate. The behavior of the water-extract of cheese with indicators harmonizes with this statement. Thus, it is acid to phenolphthaleïn, neutral or very slightly alkaline to congo red, to cochineal and to litmus, and alkaline to methyl orange.

We have used the following modification of the official method for determining acidity in cheese and we believe that it gives more satisfactory results: Extract 25 grams of finely divided cheese with 200 c. c. of water at 50° C., decant the supernatant liquid on a filter of absorbent cotton and repeat the treatment with the residue until nearly a liter of extract is obtained. Make up to one liter and mix thoroughly. Of this solution take 100 c. c. for titration with N-20 solution of sodium hydroxide, using phenolphthaleïn as indicator. The result multiplied by 20 gives the number of cubic centimeters of N-10 alkali required to neutralize the water-extract from 100 grams of cheese, and this appears to be a desirable form in which to express the results of acidity determinations.

We have already referred to the fact that we made determinations showing that all the calcium lactate of cheese is removed by extraction with water. This was shown by determining the amount of lactate in cheese by the method given on p. 155, and also in the water-extract prepared as described above. For illustration, in the cheese itself we found in one case 0.58 per ct. of calcium lactate and in the water-extract, 0.587 per ct.

DISCUSSION OF RESULTS.

We will now bring together in comprehensive form the results of the experiments described in this bulletin and discuss them with the purpose of seeking an interpretation of them in their application to cheddar cheese. We will consider the results under the following headings: (1) Changes in the proteids of cheddar cheese, (2) the changes in calcium and phosphoric acid compounds.

CHANGES IN THE PROTEIDS OF CHEDDAR 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. In all of the analyses of cheese previously published[1] it is noticeable that there is always present in varying proportions each of these three different forms of proteid.

In order to show more clearly how this recent view of the series of changes in cheddar cheese differs from the former conception, we give the following statement of the views previously held: The succession of changes was believed to consist of (1) change from insoluble proteid (calcium paracasein) into (2) proteid soluble in salt solution, and this into (3) water-soluble proteids, under which conditions we were supposed to have—

(1st.) All insoluble proteid (calcium paracasein).

(2d.) Mixture of (a) insoluble proteid and (b) proteid soluble in salt solution.

(3d.) Mixture of (a) insoluble proteid, (b) proteid soluble in salt solution, and (c) water-soluble proteids.

It is thus seen that, according to the view formerly held, two points in the series of changes were entirely overlooked: (1) the *complete* conversion of the insoluble proteid (calcium paracasein) into salt-soluble proteid, and (2) the conversion of salt-soluble proteid into insoluble proteid. We formerly believed that the calcium paracasein of the fresh cheese-curd was at no time *completely* changed into salt-soluble or water-soluble forms, but that it persisted in some amount throughout the cheese-ripening process; whereas the insoluble proteid commonly found in cheddar cheese, now appears to be the product formed directly from the salt-soluble proteid.

The newer view is more complex in that it involves more changes, but is somewhat simpler in that the first step in the series of changes appears to be complete before the succeeding one takes place, that is, all the calcium paracasein appears to be changed into salt-soluble proteid before the succeeding insoluble proteid is formed.

The newer view also makes clear a point which was never satisfactorily explained under the former conception. While it was held that water-soluble proteid in cheese was formed directly from the salt-soluble proteid, the former increasing while

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[1] Buls. 214, 233, 234, 236 of this Station.

the latter diminished, the relation was extremely irregular and no explanation of this irregularity could be offered. The irregularity referred to can be readily seen by referring to the numerous analyses of cheese published in previous bulletins of this Station. The reason of this lack of uniform relation between salt-soluble and water-soluble proteid is now quite clear, if we understand that an intermediate insoluble proteid is formed, and that this precedes by some time the rapid formation of water-soluble proteids.

CHANGES IN CALCIUM AND PHOSPHORIC ACID COMPOUNDS OF CHEDDAR CHEESE.

Simultaneously with some of the changes occurring in the proteids, we have changes taking place in the inorganic constituents of the cheese, especially the calcium and phosphoric acid compounds. Tricalcium phosphate is the principal phosphate in fresh cheddar cheese-curd. There is probably some dicalcium phosphate and also small amounts of tri- and dimagnesium phosphates, but these details are immaterial at this time. The main fact is that the calcium and phosphoric acid compounds of cheese 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, mainly tri-calcium phosphate, and not from the calcium combined with paracasein as calcium paracasein.

Another point of interest in connection with the calcium of cheese 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 proteid 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 some unpublished work done by one of us 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. These details we are at work on and are encouraged to hope that satisfactory explanations may be found for these questions.

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?

It may be further mentioned that the salt-soluble extract of cheese is always acid to phenolphthaleïn and the degree of acidity is about equal to that shown by calcium paracasein.

CHEMICAL STUDIES OF CAMEMBERT CHEESE.*

ALFRED W. BOSWORTH.

SUMMARY.

1. Camembert cheese can be made in the laboratory which compares very closely to the cheeses found upon the American market, to the cheeses imported from Europe, and to those worked upon by other investigators.

2. The only function of the rennet in this type of cheese is to coagulate the milk.

3. The bacteria are responsible for the most important chemical changes which take place in the cheese during its early history.

4. The changes caused by the bacteria, directly or indirectly, are as follows:

(a) Lactic acid is produced from milk sugar.

(b) This acid as formed combines with some of the insoluble calcium which is present in a new cheese as phosphates and as calcium paracasein.

(c) The lactic acid in combining with some of the calcium of the insoluble phosphates produces calcium lactate and soluble phosphates. These soluble phosphates are acid salts and increase the acidity of the cheese.

(d) The production of lactic acid in some way, as yet not known, has an effect upon the calcium paracasein whereby it is completely changed into a form soluble in 5 per ct. salt solution.

(e) The further production of lactic acid changes this salt-soluble compound into a form insoluble in salt solution and water.

5. The acidity of camembert cheese is due, mainly, to two things: Paracasein and mono-calcium phosphate ($CaH_4P_2O_8$).

6. One of the characteristic differences in the making of cheddar cheese and camembert cheese seems to be the proper control of the production of the salt-soluble compound and of the subsequent change in this compound.

*A reprint of Tech. Bul. No. 5.

7. Molds are responsible for that part of the ripening of the cheese in which the compact insoluble curd is changed in texture and becomes a soft creamy mass almost entirely soluble in water. This is due to enzyms produced by the molds.

INTRODUCTION.

Early in the year 1904 some cheese investigations were started at the Storrs Agricultural Experiment Station, Storrs, Conn. This was coöperative work carried on by the Dairy Division of the U. S. Department of Agriculture and the Storrs Agricultural Experiment Station. The author accepted the position as chemist for this investigation and worked upon the problems connected with it until May, 1905, when he accepted a position at the New York Agricultural Experiment Station.

While at Storrs the proximity of Yale University permitted much time to be spent in the Laboratory of Physiological Chemistry of the Sheffield Scientific School, and the author wishes to acknowledge that his studies upon the salt-soluble form of casein found in cheeses are due to the influence of Dr. L. B. Mendel of that Laboratory.

The author also wishes to acknowledge the great help received through the opportunity to consult with Dr. L. L. Van Slyke, Chemist of this Station, and through his kindness in allowing the work to be carried on along with regular work of the laboratory.

While connected with the cheese work at Storrs the author became much interested in the problems connected with the making of camembert cheese. He was unable to make a complete study of the chemical problems involved during his short stay there. Soon after taking up his duties at Geneva, study of the problems was resumed as opportunity offered, with the hope of making some points more clear.

This paper is therefore published at this time because the author is unable to continue the work at present, and it seems best to present the studies so far made with the hope that some time in the future the work may be continued and developed.

It has been the aim to cover in this paper all the preliminary stages in such shape that a clear idea of the nature of the fundamental chemical changes may be obtained. Those interested in the work are referred to the following bulletins on the subject which have been published by the Dairy Division of the Bureau of Animal Industry of the U. S. Department of Agriculture:

Bulletin 71 treats the whole subject of camembert cheese in a preliminary way;

Bulletin 82 discusses the subject of molds used in making camembert cheese; and

Bulletin 98 gives detailed directions for making this type of cheese.

In these papers it is shown that in the making and ripening of camembert cheese there are three sets of active agents employed:

1. Bacteria are introduced into the milk to produce the proper acidity. These bacteria, or some of them, remain in the cheese and by the subsequent production of acid are responsible for other deep-seated changes.

2. Rennet is added to the milk to produce the coagulum or curd.

3. Certain kinds of molds are allowed to develop on the surface of the cheese. These molds produce proteolytic ferments which are responsible for the changes the curd undergoes after the bacterial action is complete.

Each of these agents produces a change in the cheese which is easy to follow and distinguish from the changes produced by the other agencies; for the changes occur at separate periods of the process.

After the rennet has set the curd, the bacterial activity is very marked and can be followed because the mold exerts no influence upon the cheese until after the curd is 12 to 14 days old. By that time the bacterial action is completed and the bacteria have been reduced to comparatively small numbers.

METHOD OF MAKING CAMEMBERT CHEESE.[1]

A brief outline of the process of making and ripening camembert cheese is as follows: The milk is first brought to the proper degree of acidity, and the curd is then produced by the action of rennet, enough rennet being added to form a solid curd which can be cut in about one and one-half to two hours.

The curd after being cut is allowed to stand in the whey a short time and is then ladled into forms and allowed to drain without pressure. After a few hours mold spores are sprinkled over the cheese. In about 24 hours the cheese has settled into a mass which

[1] For more complete details of the methods of making and ripening this type of cheese the reader is referred to Bulletin 98, of the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture, entitled "Directions for making the camembert type of cheese." By Theodore Issajeff.

will hold its own form. It is then rolled in salt, and carried to the ripening room, where it remains during the process of ripening, being turned occasionally to insure an even growth of mold on the surface. This ripening requires about four to five weeks to become complete, during which time the cheese is changed in texture and composition. The active agent, an enzym produced by the mold which grows upon the surface of the cheese, begins to produce proteolysis at or near the surface and works toward the center of the cheese until the entire curd has been acted upon, being transformed from a compact, insoluble curd to a soft, creamy mass which is very soluble in water. With this change a peculiar flavor develops, characteristic of this type of cheese.

METHODS OF ANALYSIS.

Van Slyke and Hart[2] have published methods for the separation of the groups of proteolytic compounds found in cheddar cheese. For comparative studies their methods serve very well and have been used for the work contained in this paper, with but slight modifications. As the cheese is cylindrical in form, being about 4 inches in diameter and one and one fourth inches high, a sample the whole thickness of the cheese was taken for analysis. In taking a sample therefore a wedge-shaped piece, weighing about 25 grams, with the apex at the vertical axis of the cheese, was taken. This was placed in a covered dish, weighed, and then rubbed up in a mortar with two successive portions of 200 cc. each of water. This was then heated in a water bath at 50° C. for half an hour, with occasional shaking, the supernatant liquid decanted onto a cotton filter and the extraction continued with 150 cc. portions of water until 1,000 cc. of solution was obtained.

To secure the salt extract, the residue from the water extract was treated with a 5 per ct. salt solution in the same manner as described for obtaining the water extract.

In determining peptones, tannic acid was always used. In this case 100 cc. of the water extract was placed in a 500 cc. flask, diluted to about 400 cc. and salt and tannic acid added according to the methods mentioned above, and allowed to stand over night. It was then made up to the 500 cc. mark filtered, and 100 cc. portions used for the determinations.

Phosphotungstic acid was tried but seemed to possess no particular advantage for the work.

[2] N. Y. Agrl. Expt. Sta. (Geneva) Bul. 215.

COMPARISON OF THE CHEESES STUDIED WITH THOSE FOUND ON THE MARKET.

The general nature of this type of cheese was ascertained by securing results of analysis by other workers and also by examining the cheeses as found upon the market.

The composition of camembert cheese as found by some investigators is given in the first section of the following table, which is taken from Richmond's Dairy Chemistry; while the composition of cheeses analyzed by the author is shown in the second section.

TABLE I.— GENERAL COMPOSITION OF CAMEMBERT CHEESE AS FOUND BY DIFFERENT INVESTIGATORS.

Authority.	Water.	Fat.	Proteids.	Ash.	Lactic acid.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Duclaux	45.24	30.31	19.75	4.70	....
Stutzer	50.90	27.30	18.66	3.14	....
Cameron & Aikman	51.30	21.50	19.00	4.70	....
Leffman & Beam	51.90	21.00	18.90	4.70	....
Pearmain & Moor	45.65	22.25	23.10	4.25	....
Muter	48.78	21.35	19.71	9.80	0.36
The author					
Cheese A*	46.36	30.19	20.32	2.97	....
Cheese B†	45.87	31.73	17.90	3.53	....

* A—Cheese 3 days old.
† B—Cheese when ready to eat.

The nature of the nitrogenous compounds present in ripe camembert cheese is shown in the following table.

TABLE II.— FORMS OF NITROGENOUS COMPOUNDS IN CAMEMBERT CHEESE.

Analyst, and source of cheese analyzed.	Total nitrogen in cheese.	Water-soluble nitrogen in cheese.	Percentage of total nitrogen in water-soluble form.	Percentage of water-soluble nitrogen precipitated by tannic acid.	Percentage of water-soluble nitrogen present as amids.	Percentage of water-soluble nitrogen present as ammonia.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Analysis by Stutzer	2.90	2.79	96.03	46.03	40.11	13.86
Analysis by author:						
Cheese made in America	3.39	3.11	91.74	66.24	22.51	11.25
Cheese made in Germany	......	......	......	60.37	32.67	7.12
Cheese made in France	3.13	2.79	94.89	49.83	29.97	20.20
Cheese made by author	2.52	2.25	89.29	35.11	44.89	20.00
Cheese made by author	......	......	......	52.07	33.14	14.79

Table I shows our cheeses to be normal in composition. The low water and high fat figures are due to the fact that we used whole milk which was rich in fat, and also to the fact that in Europe in some factories, it is said, the milk is first separated and then remixed in order to give a milk with a lower fat content.

It will be noticed that our figures agree very closely with those given by Duclaux.

Table II shows that there is no definite standard by which to be guided when we come to examine the amount of nitrogen in the different groups of nitrogen compounds. A wide variation is found among cheeses known to be true camembert cheeses and of good quality. This we should expect; for when we are considering a question where enzyms are concerned there are many factors which influence the activity and no two cheeses could be handled in such a manner as to give the same absolute results.

The main point in this connection is to secure a type of proteolysis similar in action to that in true camembert cheese. This has been done, as Table II shows. The details of controlling this to secure uniform results is another problem which is left to the practical cheese maker.

CHEMICAL CHANGES IN CHEESE.

RENNET.

The rennet when added to the milk causes the casein to coagulate. This precipitate, or curd, carries down with it most of the fat and some of the milk sugar, together with some of the inorganic salts. In this type of cheese this seems to be the only function of rennet.

BACTERIA.

In order to study the chemical changes due to bacterial action two sets of cheeses were made and examined and the results are given in Tables III, IV and V. The figures in Table IV are obtained from those in Table III and will be readily understood.

The first set of cheeses was made as follows: Milk from the previous evening's milking was heated to 86° F. and a small amount of starter added. Rennet was added in amount to curdle to the proper thickness in one and a half hours. The curd was then cut, allowed to stand in the whey one half hour, and then dipped into forms made for the purpose. The whey was allowed to drain away without pressure and caught in bottles containing chloroform to prevent further bacterial action.

The first sample was taken 5 minutes after all the curd had been dipped into the forms. The cheeses were examined at intervals of 2 or 2½ hours during the first 24 hours and determinations made as indicated in the tables.

Table III.— Changes in Cheese During its Early History.

Sample number.	Age of Curd.	Total solids in cheese.	Total nitrogen in cheese.	Water-soluble nitrogen in cheese.	Salt-soluble nitrogen in cheese.	Total ash in cheese.	Water-soluble ash in cheese.	Total P_2O_5 in cheese.	Organic P_2O_5 in cheese.	Inorganic P_2O_5 in cheese.	Water-soluble P_2O_5 in cheese.	Total CaO in cheese.	Water-soluble CaO in cheese.	Milk sugar in cheese.	Acidity of the water extract of 100g. cheese. as N-10.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cc.*
1	Fresh	21.59	0.74	0.20	0.05	0.93	0.56	0.35	0.09	0.26	....	0.33	0.14	4.10	28.0
2	2½ hours	26.46	1.27	0.14	0.05	1.04	0.46	0.50	0.16	0.34	0.25	0.41	0.16	5.00	24.0
3	5 hours	29.46	1.53	0.13	0.08	1.12	0.62	0.53	0.19	0.34	0.26	0.43	0.17	4.64	28.0
4	7½ hours	32.57	1.78	0.13	0.25	1.16	0.82	0.58	0.22	0.36	0.37	0.45	0.29	4.00	52.0
5	10 hours	38.15	2.01	0.16	1.10	1.23	0.94	0.64	0.25	0.39	0.37	0.45	0.37	3.44	60.0
6	12½ hours	40.17	2.11	0.18	0.61	1.18	0.93	0.65	0.26	0.39	0.39	0.43	0.41	2.56	88.0
7	14½ hours	42.22	2.16	0.10	0.40	1.23	1.03	0.65	0.27	0.38	0.38	0.47	0.45	2.08	100.0
8	16½ hours	41.51	2.28	0.10	0.26	1.14	0.86	0.59	0.28	0.31	0.31	0.42	0.41	2.12	100.0
9	18½ hours	42.02	2.13	0.17	0.32	1.20	....	0.65	0.26	0.38	0.38	0.45	....	1.60	56.0
10	20½ hours	44.42	2.48	0.12	0.38	1.19	1.05	......	....	....	0.35	0.44	0.44	1.64	80.0
11	22½ hours	41.71	2.28	0.12	0.28	1.19	0.93	......	....	....	0.39	0.45	0.45	1.56	80.0
12	2 days	42.70	2.28	0.13	0.10	1.18	0.91	0.69	0.28	0.41	0.39	0.45	0.45	1.28	120.0
13	5 days	63.37	3.05	0.17	0.20	1.13	0.70	0.73	0.38	0.35	0.30	0.33	0.33	0.76	84.0
14	13 days	......	....	....	....	......	....	......	....	....	....	......	....	0.66	72.0

TABLE IV.— CHANGES IN SOLUBILITY OF CHEESE COMPOUNDS DURING EARLY RIPENING.

Sample number.	Age of curd.	Total solids in cheese.	Percentage of total nitrogen in water-soluble form.	Percentage of total nitrogen in salt-soluble form.	Percentage of total ash soluble in water.	Percentage of inorganic P_2O_5 soluble in water.	Percentage of total CaO soluble in water.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
1	....	21.59	27.03	6.72	60.22	....	42.42
2	2½ hours.........	26.46	11.02	3.94	44.23	73.53	39.02
3	5 hours.........	29.46	8.43	5.23	55.36	76.47	39.53
4	7½ hours.........	32.57	7.30	16.04	70.70	102.80	64.44
5	10 hours.........	38.15	7.96	54.72	76.42	94.87	82.22
6	12½ hours.........	40.17	8.53	28.91	78.73	100.00	95.35
7	14½ hours.........	42.22	4.63	16.67	83.74	100.00	95.75
8	16½ hours.........	41.51	4.39	11.40	75.40	100.00	97.62
9	18½ hours.........	42.02	7.98	15.02	....	....	....
10	20½ hours.........	44.42	4.84	15.32	88.24	....	100.00
11	22½ hours.........	41.71	5.26	12.28	78.15	....	100.00
12	2 days..........	42.70	5.70	4.39	77.12	....	100.00
13	5 days..........	63.37	6.56	6.56	61.95	....	100.00

CHANGES IN THE MILK SUGAR.

The curd soon after being formed contained 4.10 per ct. sugar. After being placed in the forms and whey allowed to drain away the sugar content is found to be 5 per ct. From this time the amount of sugar present is found to decrease. During the first 24 hours *some* of the loss is due to drainage of whey.

CHANGES IN THE PHOSPHORUS.

With this change in the sugar is noticed an increase in the amount of water-soluble phosphorus. The lactic acid, as formed by bacterial action on the milk sugar, unites with part of the calcium of the insoluble phosphates, forming calcium lactate and soluble calcium phosphate ($CaH_4P_2O_8$).

ACIDITY.

Along with the decrease in sugar and increase in soluble phosphates is noticed an increase in the acidity of the water extract of the cheese. This acidity is not due directly to the lactic acid formed, for the lactic acid is not present as free acid but as calcium lactate. The acidity is due to phosphates formed by the partial decalcification of the insoluble phosphates by the lactic acid.

In studying the changes in the phosphorus it was noticed that the maximum acidity of the cheese was reached at the time when all the inorganic phosphorous became water-soluble. It was also noticed that the water extract of cheese is usually neutral or nearly neutral to litmus and quite strongly acid to phenolphthaleïn. If the acidity were due to lactic acid the reaction towards litmus would be as strong as towards phenolphthaleïn. This would be the case in a cheese less than 12 days old. Up to that time the amount of water-soluble proteids is quite small and constant and does not influence the acidity. The reaction of the cheese mass towards litmus is decidedly acid, due to the paracasein which reacts acid to litmus in the state in which it is found in cheese.

CHANGES IN THE CALCIUM.

Parallel with the other changes noted above, a change in the calcium is found. This is gradually rendered water-soluble but does not reach 100 per ct. of the total calcium until after all the phosphates have become soluble. This is due to the fact that the calcium is present in two combinations, with the phosphoric acid and paracasein. The calcium combined with the phosphoric acid is all rendered water-soluble before that combined with the paracasein.

The change in the calcium is directly connected with the changes in the proteids.

CHANGES IN THE PROTEIDS.

By an examination of Tables III and IV it will be seen that the solubility of the proteid in 5 per ct. salt solution undergoes rapid changes. After 10 hours the salt-soluble nitrogen amounts to 54.72 per ct. of the total nitrogen and then drops to 28.91 per ct. The question at once arose as to whether 54.72 per ct. was the maximum amount of salt-soluble nitrogen formed or whether it at some time reached 100 per ct. of the total nitrogen.

This salt-soluble nitrogen is formed by the decalcification (either partly or wholly) of the calcium paracasein by the lactic acid which is produced by the action of bacteria upon the milk sugar.

This change in the paracasein takes place quite rapidly and in order to study this point a special set of cheeses was made.

In making normal cheese the ripening of the milk allows the development of a great number of bacteria and the change in the milk sugar, with the development of acid, goes on very rapidly. It was hoped that, by making a set of cheeses without the addition of a starter and omitting the ripening process in the milk, and by taking samples at short intervals a set of figures could be obtained showing the decrease in the milk sugar, the development of acidity, and the changes which the paracasein undergoes.

A set of cheeses was made in this manner and the figures obtained are given in Table V.

TABLE V.— CHANGES IN THE SALT-SOLUBLE COMPOUND, THE LACTOSE AND THE ACIDITY IN CAMEMBERT CHEESE MADE WITHOUT STARTER.

TIME SAMPLE WAS TAKEN.	Age of curd.	Total nitrogen in cheese.	Salt-soluble nitrogen in cheese.	Percentage of total nitrogen in salt-soluble form.	Sugar in cheese.	Acidity of the water extract of 100g. cheese as N-10.	Acidity of 100cc. of whey as N-10.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Cc.*	*Cc.*
1 p. m. 1st day...	3 hours...	1.20	0.03	2.50	3.94	14.0	8.0
5 p. m. 1st day...	7 hours...	1.78	0.06	3.37	2.68	14.0	6.7
9 p. m. 1st day...	11 hours...	1.75	0.06	3.43	2.19	22.0	6.0
1 a. m. 2d day....	15 hours...	1.78	0.08	4.48	1.81	19.0	....
5 a. m. 2d day....	19 hours...	1.90	0.04	2.11	1.89	24.0	....
9 a. m. 2d day....	23 hours...	1.99	0.04	2.04	1.76	77.0	11.5
1 p. m. 2d day....	27 hours...	2.13	1.02	44.89	1.76	95.0	....
5 p. m. 2d day....	31 hours...	2.09	1.92	91.87	1.48	110.0	....
9 p. m. 2d day....	35 hours...	2.45	0.91	37.14	1.37	115.0	....
9 a. m. 3d day....	47 hours...	2.28	0.86	37.72	0.88	132.0	....
9 a. m. 4th day...	71 hours...	2.20	0.68	30.91	0.72	147.0	....
9 a. m. 5th day...	95 hours...	2.63	0.77	29.28	0.50	167.0	....
9 a. m. 6th day...	119 hours...	2.51	0.92	36.65	0.48	182.0	....
9 a. m. 7 th day...	143 hours...	2.93	0.27	9.22	0.47	152.0	....
9 a. m. 10th day..	....	......	......	......	trace	......	....

The rennet was added to the milk at 10.00 A. M. March 10, 1906.

In this case a sample was secured showing 91.87 per ct. of the total nitrogen in the salt-soluble form. This percentage rapidly decreased, going down as low as 4.39 per ct. of the total nitrogen. The question at once came up as to what causes this double change in the paracasein.

According to VanSlyke and Hart[3] the salt-soluble compound was thought to be base-free paracasein. Now if this is true we should expect all the calcium of the calcium paracasein to be split off from it and formed into calcium lactate which is soluble in water and would therefore be found in the water extract. That this is not the case will be seen by a glance at Table IV. There it is shown that all the phosphorus present in the cheese

[3] N. Y. Agrl. Expt. Sta. (Geneva) Bul. 261.

as phosphates becomes water-soluble very early in the ripening, so that any insoluble calcium which may be present could not be there as phosphates. The calcium as calcium lactate would be in the water extract so that the only way the calcium could be combined would be with the paracasein. As confirming this we have the fact as shown in Table IV that the whole of the calcium does not become water soluble until all the paracasein has been changed from the salt-soluble form to a form insoluble in both water and salt solution.

Work is being done by Dr. L. L. VanSlyke and the author to determine the nature of these changes in the cheese and what the changes in the paracasein are.

THE FUNCTION OF THE LACTIC ACID BACTERIA.

Previous work done by the author while connected with the U. S. Department of Agriculture shows that the rennet added to curdle the milk and the bacteria present in the cheese play practically no part in the ripening of the cheese after the first ten or twelve days; that is, up to the time when proteolysis begins. The actual ripening of the cheese from that point is due to the action of molds growing upon the surface of the cheese.

The real function of the bacteria may be placed under two headings.

1. To change the milk sugar into lactic acid thereby producing the changes in the paracasein noted in this paper.

2. By their growth in great numbers and their production of acid to inhibit nearly all other forms of bacterial life.

There seem to be good grounds for believing that the part the lactic organisms play in the ripening of nearly all types of cheese is the same, *i. e.*, to develop acid and thus bring about the changes in the paracasein. The extent of this change is quite different in the several types of cheese and may be one of the fundamentals which differentiate the types, their form of ripening and their flavor.

As an illustration, take the camembert and cheddar types. In the camembert type the paracasein all becomes soluble in salt solution and all this is further changed into an insoluble form. In cheddar cheese the paracasein is all changed into the salt-soluble form but not enough acid is produced (due to the method of making this type of cheese) to change this all into the insoluble form. We therefore find in this cheese that from 25 to 50 per ct. of the nitrogen is present in the salt-soluble form.[4]

MOLDS.

The molds present upon the surface of the cheese play a very important, if not the most important, part in the ripening of camembert cheese.

Spores are scattered upon the surface of the cheese when it is one or two days old; and these germinate and grow, producing a white velvety mass on the cheese which turns a dirty green about the tenth or twelfth day, due to the ripening of the spores. About this time the true ripening of the cheese begins, due to the liberation of a proteolytic ferment which penetrates slowly into the cheese, breaking the paracasein down into simpler forms of nitrogen compounds. It requires about four weeks for the entire mass to be acted upon.

The author has been able to secure a liquid which possesses strong proteolytic power by growing the kind of mold[5] used in making camembert cheese upon a modification of Raulin's fluid.[6] Proteolytic action was obtained in a range from 0.6 per ct. hydrochloric acid to 1.8 per ct. sodium carbonate, being strongest in weak sodium carbonate. No studies have yet been made to ascertain the nature of this ferment. The only fact of importance noted is that a strong proteolytic action is obtained by it in the presence of considerable acid phosphate ($CaH_4P_2O_8$) which condition exists in a cheese.

The nature of the changes produced by the enzym of the mold is shown in Table VI.

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[4] The changes which take place in cheddar cheese have been worked upon by Dr. L. L. VanSlyke and the author. It was found that the changes are the same as in camembert cheese but not so complete. For a full discussion of these changes, their cause, effects and relation to cheese ripening, the reader is referred to Technical Bul. 4 of this Station. (Page 152 of this Report.)

[5] *Penicillium camemberti* Thom.

[6] U. S. Dept. Agr., B. A. I. Bul. 82, p. 16.

TABLE VI.— CHANGES IN CAMEMBERT CHEESE DUE TO ENZYM ACTION.

AGE OF CHEESE—DAYS.	Total nitrogen in cheese.	Percentage of total nitrogen in water-soluble form.	Percentage of total nitrogen in form of para-nuclein, caseoses and peptones.	Percentage of total nitrogen in form of amids.	Percentage of total nitrogen in form of ammonia.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	2.73	11.72	3.30	8.42	0
3	2.73	15.02	7.33	7.69	0
5	2.81	16.02	8.54	7.48	0
6	2.73	19.78	9.89	9.89	0
7	2.81	18.51	8.90	9.61	0
8	2.92	18.15	9.59	8.56	0
10	2.81	25.98	12.46	13.52	0
11	2.92	25.68	4.79	20.89	0
12	2.90	23.79	5.52	18.27	0
14	2.92	56.51	40.07	16.44	0
18	2.90	60.69	43.79	16.55	0.35
19	2.65	60.00	43.02	16.23	0.75
20	2.90	63.79	47.24	14.48	2.07
21	2.65	67.55	47.17	18.11	2.27
28	2.61	80.08	54.41	17.62	8.05

A study of Table VI will show the following facts:

1. The water-soluble nitrogen does not increase appreciably until the cheese is ten days old.

2. The extent of the proteolysis is great, over 80 per ct. of the nitrogen being rendered water-soluble in 4 weeks.

3. Considerable ammonia is produced, but it does not appear until some days after proteolysis has started.

GENERAL SUMMARY.

The work presented in this paper, together with the other papers recently published,[7] demonstrates that the camembert type of cheese can be made in this country. The only difficulty is in understanding and controlling the complex changes which take place during the process of making this cheese. If the cheese is started correctly it will require little attention; and the chemical changes, when once started, work automatically.

Due consideration must be given to the fact that, whereas the chemical changes are the same in the early stages of the ripening as in the hard cheeses, they are, however, more extensive. Regard must be paid to this fact, and proper manipulation given the curd.

It seems to be an established fact that the only function of the rennet is to produce the coagulation of the milk. Any proteolysis produced by the rennet is very small in extent during

[7] Loc. cit.

the few weeks required to ripen this type of cheese and may safely be said to be of no importance in the process.

The bacteria also play no part in the proteolysis of the cheese. Their function is to change the lactose to lactic acid and thereby change the paracasein into a form desirable for the future action of the enzyms.

It is also an established fact that the acidity of cheese is not due to lactic acid[8] as commonly believed, but to mono-calcium-phosphate ($CaH_4P_2O_8$) which is formed by the action of the lactic acid, produced by bacterial action, upon the insoluble phosphates always found in fresh cheese curd.

The changes in the paracasein of the newly made cheese curd are more extensive than had hitherto been supposed, and the proof of another chemical change in the paracasein is established showing that the salt-soluble compound found by Van Slyke and Hart[9] undergoes another change which renders it insoluble again and that this insoluble product is the one attacked by the enzyms in the cheese and changed further into complex groups of water soluble forms.[10]

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[8] Paper by the author read at the meeting of the Assoc. Off. Agrl. Chemists, Nov., 1906. "The acidity of cheese and its determination."

[9] Loc. cit.

[10] For a more complete discussion of this point see Technical Bul. 4 of this Station.

IV. ANALYSES OF MISCELLANEOUS MATERIALS.*

L. L. VAN SLYKE.

SUMMARY.

This Bulletin includes the results of analysis of a great variety of materials which have come to the Station from time to time. Representative cases have been selected for publication. The materials included are (1) ashes, (2) dried blood, (3) nitrate of soda, (4) meat meal and tankage, (5) potash salts, (6) muck soils, (7) the fertilizer constituents of miscellaneous materials, (8) constituents of miscellaneous feeding stuffs, (9) molasses refuse, (10) commercial gruels, (11) poultry foods, (12) maple sugar, (13) home-made cider vinegar, (14) dried apples.

INTRODUCTION.

The Station has done gratuitously a large amount of work for individual farmers of New York State in the way of chemical analysis of materials connected with agriculture. As a result of this kind of work, large numbers of analyses of various kinds of materials have accumulated in our records during the twenty-five years of the Station's existence. It has seemed desirable to select from the data at hand such representative cases as would be of interest and to publish these for reference.

We have indicated in the tables such facts as would add interest to the results of analysis, so far as we are able to gain information regarding the samples.

I. ASHES.

In most cases a determination of potash only was called for, but in a few instances phosphoric acid also was estimated. We notice the following facts furnished by the tabulated results:

1. In the samples of wood ashes examined, the potash varies from about 1 to 10 per ct. About one-half of these samples were below 4 per ct. in potash, and only about one-third contained over

* A reprint of Bulletin No. 293.

5 per ct. of potash. Good wood ashes are supposed to, and should contain about 5 per ct. of potash.

2. The one sample of ashes known to be leached contained 0.69 per ct. of potash.

3. Canada ashes vary in potash from 3.56 to 6.62 per ct.

4. Coal ashes contain practically no potash.

5. Crematory ashes are made by burning city garbage and contain 1 to 2 per ct. of potash.

From the results obtained with samples of wood ashes, as given above, it would seem that this material should be purchased with extreme caution, and in no case without a definite guaranteed percentage of potash.

TABLE I.— ANALYSES OF ASHES.

No. of sample.		Potash.	Phosphoric acid.	No. of sample.		Potash.	Phosphoric acid.
	Ashes:	*Per ct.*			Ashes:	*Per ct.*	
336	....	0.83	......	88	Wood..........	5.18	....
345	....	3.41	......	107	"	5.54	....
431	....	0.23	......	108	"	3.94	....
849	....	1.60	......	319	"	6.08	....
857	....	0.43	......	326	"	3.69	....
25	Acid Factory....	1.44	......	327	"	3.68	....
317	" "	1.52	......	335	"	3.18	....
318	Canada..........	5.78	......	348	"	5.79	....
540	"	3.68	......	349	"	2.77	....
543	"	5.65	......	350	"	2.04	....
599	"	3.73	......	378	"	7.86	....
600	"	3.95	......	384	"	3.87	....
625	"	3.56	......	399	"	6.06	....
438	Canada hardwood.	6.62	......	407	"	6.87	1.63
814	Coal............	0.00	......	408	"	5.02	1.65
17	Crematory, from			433	"	6.14	....
	garbage........	2.15	3.91	434	"	2.89	....
813	Crematory, N. Y.			491	"	5.28	....
	city..........	1.02	......	496	"	6.94	....
24	Hardwood........	10.00	......	505	"	4.70	....
788	"	3.14	......	511	"	3.28	....
627	Leached.........	0.69	......	513	"	4.64	....
598	Michigan.........	4.61	......	515	"	4.70	....
19	Mixed coal and			527	"	4.80	....
	wood..........	0.38	0.47	528	"	3.15	....
623	Saw-mill.........	3.17	......	533	"	3.70	....
787	Soft-wood........	3.86	......	535	"	3.98	....
628	Unleached........	6.75	......	594	"	1.78	....
838	Waste-paper......	0.00	0.38	596	"	4.63	....
1	Wood............	5.12	......	616	"	5.36	....
2	"	2.53	......	725	" ..	1.17	0.96
3	"	3.21	......	730	"	3.47	....
9	"	3.31	......	749	"	4.00	....
32	"	2.96	......	754	"	1.57	....
34	"	4.48	......	774	"	3.41	....
35	"	6.71	1.60	776	"	1.10	....
42	"	6.13	......	791	"	3.45	....
47	"	3.18	......	839	"	2.68	....
50	"	5.22	......	840	"	4.31	....
81	"	8.67	..	841	"	1.67	....
85	"	4.97	......	822	" (lime-kiln).	5.32	....
87	"	2.72	......				

II. DRIED BLOOD.

The important commercial constituent of dried blood is nitrogen. In the samples examined, the blood varies from about 9 to 15 per ct. of nitrogen. One sample, containing only 8.32 per ct. of nitrogen, had been damaged by fire and had suffered loss of nitrogen. Dried blood of good commercial quality should contain not less than 10 per ct. of nitrogen.

Table II.— Analyses of Dried Blood.

Number of sample.		Nitrogen.	Number of sample.		Nitrogen.
		Per ct.			*Per ct.*
41		10.10	634		10.45
320		10.90	636		11.02
342		13.32	724		10.01
387		12.14	796		11.89
392		10.21	797		9.18
492		11.69	815		12.08
518		14.93	497	Bowker's	10.80
605		10.39	101	Swift's	13.64
608		12.37			

III. NITRATE OF SODA.

The important element in nitrate of soda for agriculture is nitrogen. This substance when chemically pure contains 16.47 per ct. of nitrogen, but the form used in agriculture contains some impurities. Nitrate of soda, when exposed to dampness, absorbs considerable moisture. The presence of impurities and moisture reduces the percentage of nitrogen. Nitrate of soda of good commercial quality should contain 15.5 to 16 per ct. of nitrogen. In the samples examined, the percentage of nitrogen varies from 15.33 to 16.20.

Table III.— Analyses of Nitrate of Soda.

Number of Sample.	Nitrogen.	Number of Sample.	Nitrogen.
	Per ct.		*Per ct.*
343	15.33	609	15.55
394	16.18	723	15.83
519	15.64	779	16.20
604	15.82		

IV. MEAT MEAL AND TANKAGE.

Meat meal contains nitrogen as its most important constituent in relation to fertilizers. Tankage is a mixture of refuse meat and bone in varying proportions. Tankage contains as its important fertilizing constituents nitrogen and phosphoric acid. The proportions of these constituents vary greatly according to the proportions of meat and of bone used in the mixture, and also according to the amount of moisture left in the materials, which is well illustrated by the figures given below.

TABLE IV.— ANALYSES OF MEAT MEAL AND TANKAGE.

Number of sample.		Nitrogen.	Phosphoric acid.	Number of sample.		Nitrogen.	Phosphoric acid.
		Per ct.	*Per ct.*			*Per ct.*	*Per ct.*
7.....	Meat meal....	6.52	......	709....	Tankage......	4.69	12.69
16.....	Tankage.....	4.54	20.92	753....	"	3.53	16.57
539.....	[1] "	1.44	2.03	798....	"	4.64	17.16
617.....	"	5.14	18.72	812....	"	4.70	14.19
639.....	"	3.56	23.12				

[1]Moisture 53.4 per ct.

V. COMMERCIAL POTASH SALTS.

The salts of potash most commonly used for fertilizing purposes are the muriate and sulphate. When chemically pure, the sulphate contains the equivalent of 54 per ct. of potash, and the muriate 63 per ct. The high grades of sulphate and muriate found in the market contain the equivalent of about 50 per ct. of actual potash. These salts absorb moisture readily, and samples usually contain considerable moisture when the percentage of potash falls below 50 per ct. Kainit is an impure form of sulphate, containing considerable amounts of salt and other impurities. Good kainit contains 11 or 12 per ct. of potash. In the samples examined, the potash varied from 11.79 to 14.05 per ct. The potash in the samples of muriate varied from about 48 to 58 per ct., while in case of the sulphate, there was only a little variation from 50 per ct.

TABLE V.— ANALYSES OF KAINIT, MURIATE AND SULPHATE OF POTASH.

Number of sample.		Potash.	Number of sample.		Potash.
		Per ct.			Per ct.
60	Kainit	14.05	712	Muriate	58.41
79	"	11.70	716	"	51.74
632	"	11.71	731	"	51.58
8	Muriate	49.96	765	"	53.62
39	"	50.54	770	"	47.68
55	"	52.84	771	"	52.06
340	"	53.13	772	"	49.46
495	"	50.10	393	Sulphate	49.38
520	"	47.96	514	"	50.96
611	"	52.28	606	"	49.48
705	"	56.88	722	"	50.78

VI. NITROGEN IN MUCK SOILS.

Muck soils consist largely of the products of decomposition of vegetable matter and, in comparison with ordinary soils, are usually very rich in nitrogen. This nitrogen, however, is not generally in a form readily available for use as plant-food, but may be made so in various ways, among which may be mentioned the application of lime in moderate amounts. The figures in the analyses given below represent the amount of nitrogen in the air-dried material. It is seen that the nitrogen varies from 0.47 to 1.96 per ct.

TABLE VI.— ANALYSES OF MUCK.

Number of sample.		Nitrogen.	Number of sample.		Nitrogen.	Number of sample.		Nitrogen.
		Per ct.			Per ct.			Per ct.
14	Muck	0.95	334	Muck	1.47	526	Muck	1.43
20	"	1.33	337	"	0.76	530	"	0.99
86	"	0.77	410	"	1.75	701	"	0.76
102	"	1.00	411	"	0.47	746	"	1.24
328	"	1.25	512	"	1.96	801	"	1.81

VII. PLANT FOOD CONSTITUENTS IN MISCELLANEOUS MATERIALS.

In the following table, we have given the results of analyses obtained from a considerable variety of materials.

TABLE VII.—ANALYSES OF MISCELLANEOUS MATERIALS.

No. of sample.	KIND OF MATERIAL.	Nitrogen.	Phosphoric acid.	Potash.
		Per ct.	*Per ct.*	*Per ct.*
1477	Apple pomace (air-dried, unsifted)	2.79	0.26	0.38
1478	" " (air-dried, sifted)	3.51	0.25	0.48
595	Barley (damaged by fire)	2.43	....	trace
755	Bat guano	0.74	13.12	....
783	Bat guano	0.42	10.38	1.20
756	Bone (burned)	....	19.01	....
631	Carbide refuse	0.03	0	0
763	Cattle manure (dried)	1.50	2.40	1.57
84	Garbage sludge	1.03	1.08	0.06
626	Hair waste (moisture 41.2 per ct.)	4.39	1.53	....
764	Hog manure (dried)	1.79	2.50	0.93
818	Ivory dust	4.95	12.93	....
104	Jadoo fiber	0.60	0.45	0.13
105	" liquid	0.10	trace	0.33
27	Linseed screenings	3.37	0.35	1.26
377	Malt dust	1.54	....	....
23	Sewage manure	0.32	0.34	0.11
406	Sheep manure	1.53	0.31	0.17
751	" "	3.22	1.72	2.84
752	" "	3.21	2.09	2.96
793	" "	2.18	1.46	1.80
794	" "	3.12	2.04	2.11
351	Soot	0.23	....	....
398	Sphagnum moss	0.86	....	....
641	Sphagnum moss	0.64	0.10	0.26
5	Street sweepings (N. Y. city)	0.29	0.38	0.31
6	" " " "	0.21	0.32	0.31
18	" " (Troy)	0.30	0.41	0.24
811	" " (Newburgh)	0.38	0.48	trace
89	Sugar-beet pulp, (moisture, 86.7 per ct.)	0.21	0.30	0.11
536	Tannery refuse	0.72	0	0.10
22	Tobacco waste	1.13	....	1.89
315	Vegetable ivory	0.74	....	0.45
852	Waste from casein manufacture	12.16	2.03	....
531	Waste from rendering wks. (moisture, 87.2 p. c.)	1.66	0.17	0.17
429	Waste from smokeless powder works	0.01	0	0
538	Wool waste	4.53	0.21	0.52
702	" "	7.32	....	....
817	" " (from rug mill)	2.62	....	2.82
819	" "	1.17	....	3.21

VIII. CONSTITUENTS OF FEEDING STUFFS.

A variety of materials used for feeding-stuffs has come to the Station for examination. As will be seen from the table following, the materials in many cases represent regular mill products, while others are mixtures. Some are familiar market products; others are not commonly known.

TABLE VIII.— ANALYSES OF MATERIALS USED AS FEEDING STUFFS.

No. of sample.		Protein (crude).	Fat (ether-extract).	Fiber.
		Per ct.	*Per ct.*	*Per ct.*
1624	Ashland stock food	11.5	2.9	....
1627	Blomo feed	16.7	1.4	....
1671	Bran and oats (oat hulls)	7.7	2.8	....
1606	Buckwheat bran	21.4	5.0	....
1635	" "	17.2	5.0	26.2
1826	" "	15.8	......	25.2
1728	" feed	19.2	3.6	7.5
1818	" "	12.7	3.6	....
1820	" "	31.9	8.6	....
1838	" "	12.6	......	25.7
1839	" "	13.6	......	26.3
1643	" middlings	17.2	5.4	....
1655	" "	17.8	5.0	20.7
1750	" "	17.8	5.2	23.7
1817	" "	33.3	......	....
1837	" "	24.2	......	11.8
1633	Calf meal (home made)	21.5	9.0	....
1634	" " " "	23.3	10.0	....
1667	Climax grains	32.1	13.3	....
1857	Clover food (seeds, stems, etc.)	23.2	7.4	16.2
1485	Cocoa pomace	6.7	58.6	6.4
1717	Corn flour (mixture of flour and plaster of Paris)	6.0	......	....
1819	Corn meal	9.3	4.9	....
1841	" "	9.6	4.2	1.7
1849	" "	9.1	......	2.6
1670	Corn protegran	29.4	9.3	....
1847	Crushed oats	11.4	6.5	12.1
1608	Empire calf food	22.4	6.2	....
1604	Dried molasses beet pulp	10.8	0.4	12.7
1547	"Force" feed	11.9	2.3	....
1821	"Gluten refuse"	15.5	43.0	....
1845	Ground flaxseed	24.6	35.1	....
1846	Ground oats	10.7	5.0	12.3
1856	Japanese millet (seed)	10.6	5.2	11.8
1715	Macaroni (gelatinized)	16.3	0.9	....
1716	Macaroni (Bartholds)	15.7	0.3	....
1652	Maizeline	9.4	8.1	7.1
1637	Molasses grains (Mueller)	19.7	2.4	....
1638	" " (Rankine)	23.8	4.1	....
1749	Pea meal	18.4	1.5	25.2
1740	Poonac (cocoanut residue)	21.4	10.6	12.3
1885	Protina dairy feed	20.0	4.2	20.2
1891	Raw linseed oil "foots"	7.7	88.3	....
1848	Rice middlings	7.6	4.8	26.2
1641	Ships	16.2	4.2	....
1545	Shredded wheat waste	10.8	2.1	....
1907	Spent hops	24.2	6.4	14.4
1860	Sterling oil meal (largely wild mustard)	29.3	10.3	....
1594	Sugar-beet pulp	7.4	0.9	....
1858	Viscid oil-meal, No. 1 (largely wild mustard)	29.6	10.3	....
1859	" " " No. 2 (" " ")	26.8	8.4	....
1491	Wheat bran	16.9	4.5	11.5
1532	" "	16.3	4.4	....
1597	" "	19.6	4.1	....
1601	" "	14.8	4.3	10.8
1602	" "	13.8	4.2	9.2
1603	" "	15.8	4.7	9.7
1605	" "	15.6	4.7	10.6
1706	" "	12.1	4.2	8.4
1730	" "	14.4	4.8	....
1823	" " (mixed with ground corn cobs)	10.6	......	....
1855	" " (" " " ")	12.1	......	....
1827	" " (mixed with ground corn and corn bran)	13.9	......	....
1533	Wheat middlings	14.8	3.7	....
1828	" " (with germs)	17.2	......	....
1904	" "	16.1	5.3	....

IX. MOLASSES REFUSE.

TABLE IX.— ANALYSES OF SAMPLES OF MOLASSES REFUSE.

Number of sample.		Water.	Sugar as invert sugar.
		Per ct.	*Per ct.*
1737	From beet sugar	28.2	42.3
1738	From Cuban cane	29.5	37.5
1739	"Black strap"	28.4	45.5

X. PROTEIN IN GRUELS USED FOR FEEDING.

There is in the market quite a variety of materials known as gruels, which have wide use in infant feeding. Below we give the protein content of some of these preparations.

TABLE X.— ANALYSES OF GRUELS.

Number of sample.		Water in material.	Protein in water-free material.
		Per ct.	*Per ct.*
1743	Patent barley	97.53	8.5
1742	Pearl barley	99.40	9.4
1745	Rolled oats	97.90	13.6
1746	Rolled oats, digested	88.76	13.5
1744	Wheat flour	97.28	13.2
1747	Wheat flour, digested	84.64	12.0
1748	Wheat toast	84.74	12.0

XI. POULTRY FOODS.

From time to time there appears in the market some widely advertised food for poultry, claiming remarkable virtues. Among such materials, one appeared several years ago under the attractive name of "red albumen." Several samples were obtained. Some samples were found to be essentially dried blood of good commercial quality, while others were found to be the grossest frauds, containing little or no albumen and a great deal of mineral matter, usually red oxide of iron. These analyses are given below.

TABLE XI.— ANALYSES OF POULTRY FOODS.

Number of sample.		Protein	Mineral matter.
	RED ALBUMEN:	*Per ct.*	*Per ct.*
421	Good quality	83.1	....
422	Good quality	82.4	....
424	Good quality	76.5	....
420	Fraudulent	0.13	Much.
423	Fraudulent	0.19	Much.
2008	Milk albumen	45.4	27.2

XII. MAPLE SUGAR.

TABLE XII.— ANALYSES OF MAPLE SUGAR.

	Moisture.	Sucrose.
	Per ct.	*Per ct.*
Maple sugar	....	86.4
Maple sugar	7.3	82.6
Maple sugar	8.1	78.6
Maple sugar	8.7	86.4
Maple sugar	3.3	87.2
Maple sugar	8.3	86.0
Maple sugar	7.2	87.4
Maple sugar	4.6	80.0

XIII. HOME-MADE CIDER VINEGAR.

The law of New York State requires cider vinegar to contain 4.5 per ct. of acetic acid and 2 per ct. of solids. Many samples of vinegar made from cider fail to reach these requirements. The trouble may be due to dilution of cider by water, to incomplete fermentation or to some injurious form of fermentation. A discussion of these points can be found in Bulletin No. 258.

TABLE XIII.— ANALYSES OF HOME-MADE CIDER VINEGARS.

Number of sample.		Acetic acid.	Solids.
		Per ct.	*Per ct.*
12	Four years old	4.78	2.04
27		3.95	....
29		3.59	....
48		2.60	....
52		2.78	....
53		3.44	....
64		4.00	....
65	One year old	1.48	....
66	Two years old	1.96	....
67		3.23	....
68		0.99	....
69		1.21	....
70		1.34	....
71		1.36	....
72		2.35	....
73		2.55	....
74		2.62	....
75		3.79	....
76		3.84	....
77		4.24	....
103		5.20	3.56
795		6.02	....
796		2.51	1.34
797		6.40	....
798		2.90	....
799		1.70	....

XIV. MOISTURE IN EVAPORATED APPLES.

A law has been in effect in New York State for about two years prohibiting the sale of evaporated apples containing more than 26 per ct. of moisture. Numerous samples have come to us for examination and we state below some of the results of our work.

TABLE XIV.— AMOUNT OF WATER IN DRIED APPLES.

Number of sample.	Commercial description.	Water.
		Per ct.
1663		26.3
1664		25.0
1665		26.3
1666		27.5
110	Fair to heavy	25.2
111	Heavy	27.8
112	Safe	23.0
113	Doubtful	24.5
114	Doubtful	24.5
115	Heavy	26.6
116	Doubtful	24.4
117	Safe	24.0
118	Safe	20.1
119	Safe	22.4
120	Heavy	25.9
121	Evaporated apple chops. Safe	26.9
122	Evaporated apple chops. Safe	20.0
123	Evaporated apple chops. Safe	23.2
124	Evaporated cores and skins. Safe	27.4
125	Evaporated cores and skins. Safe	20.8
126	Evaporated cores and skins. Safe	21.2
127	Evaporated cores and skins. Safe	22.5
128	Evaporated cores and skins. Fermented	25.7
129		23.5
130		25.9
131		24.0
132		27.5
133		25.5
134		23.0
135		19.8
136		35.7
137		36.3
138		37.0
139		23.7

REPORT

OF THE

Department of Entomology.

P. J. Parrott, *Entomologist.*

H. E. Hodgkiss, *Assistant Entomologist.*

W. J. Schoene, *Assistant Entomologist.*

TABLE OF CONTENTS.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

THE POPLAR AND WILLOW BORER.*

(*Cryptorhynchus lapathi* L.)

W. J. SCHOENE.

SUMMARY.

This bulletin deals with the poplar and willow borer, an imported beetle, which is causing extensive injuries to nursery stock and basket willows, and threatens ornamental poplars and willows.

This species has one brood a year. Egg-laying occurs during August and September, and from eighteen to twenty days are required for the eggs to hatch. The larval stage lasts till the following July when pupation occurs. The pupal period occupies about two weeks and the beetles commence to appear about July 15. From this date they may be found until the middle of October.

To avoid injuries by the beetle, new plantations of poplar and willow should not be planted near old blocks. In plantings subject to slight attacks, the borer may be controlled by cutting out and destroying in June the parts affected with the grubs. The numbers of the insect will be reduced by burning all branches and trees broken by the wind or otherwise injured and rendered unsalable.

Observations have been made of the feeding habits of the beetles which show that they do not discriminate between sprayed and unsprayed plants, and that beetles feeding upon sprayed plants succumb in three or four days. It is believed that nurserymen could avoid important injuries by this insect by spraying during July with bordeaux mixture containing an arsenical poison. Experiments are now being conducted to determine the value of this treatment.

* A reprint of Bulletin No. 286.

INTRODUCTION.

Attention has been called to the work of the poplar borer by complaints, from a number of nurserymen in western New York, of the extensive and continued injuries sustained in the growing of poplars and willows. In the year 1902 some blocks of poplars and willows near Rochester were so badly injured by this insect that some of the growers contemplated abandoning their culture. Since that time the annual loss in many nurseries has not been less than 10 per ct. of the trees and occasionally the entire planting has been ruined. In many localities the native willows along swamps, streams and canals are badly attacked, the trees often being so severely affected that many of them will ultimately die as a result of the injury. The same is true of certain species of willows planted for ornamental purposes. On account of the growing importance of this insect, an investigation was undertaken to determine its habits with special reference to discovering means for its control in nursery plantations.

HISTORICAL.

GENERAL.

The beetle was described by Linnaeus in 1763 in his "Systema Naturae," and mention is also made of this species in Turton's Linnaeus.[1] Kaltenbach[2] states that the adult feeds upon the dock, *Rumex hydrolapathum*. Later Prof. Schwägerichen[3] states that in the year 1844, the larvae appeared in the young alders in the Saxon Oberlausitz. In 1863, Westwood reported a serious outbreak of the larvae of this curculio among the cultivated willows in the County of Essex, England. Ratzberg in his "Waldverderbniss,"[4] under the heading "Erlanrüsselkafer" or alder snout beetle, gives a somewhat detailed account of the life history and habits of the insect, including reports from others who have observed its work. He states there is no record to show that the beetle has been seen sucking or chewing on the "dock Lapathum." Forstmeister v. Kamptz observed

[1] Vol. II, p. 231, 1806.

[2] Die Pflanzenfeinde aus der Klasse der Insekten.

[3] Wiegmann's *Archiv,* 11: 337.

[4] Bd. II, p. 247.

the work of the insect in 1863 on the black alder, which is very susceptible to the attacks of the beetle. In Brehm's "Thierleben"[1] Dr. E. L. Taschenberg mentions *Cryptorhynchus lapathi* as being the only European representative of a South American genus. Prof. F. M. Webster, in an article entitled "The Imported Willow and Poplar Curculio,"[2] states that there are now sixteen species of this genus inhabiting North America, north of Mexico, the majority of them being found in the south or southwestern states. Taschenberg makes the statement that the adult only becomes injurious through its feeding on the leaves. Dr. Bernard Altum[3] states that near Eberswalde upon the Leuenberger Weisen, an outbreak of *C. lapathi* was controlled by the cutting out of the affected stems. Dr. Altum also reports that in the district of Schonlanke (Bromberg) a plantation which had given eighty cords of wood per acre was ruined. A similar instance is reported from Weisbaden to the effect that about five acres of white alders were threatened with destruction. The Danish writer Dr. I. E. V. Boas, in 1883, in an article entitled "An attack of the snout-billed *Cryptorhynchus lapathi* upon willows" gives a short account of its habits and life history in Denmark, and also mentions the devastation of a plantation of willows, *Salix viminalis,* grown for the purpose of making hoops. In 1897 Dr. Freiherr von Tubeuf,[4] states, in effect, that, between Brenner-Post and Fenna, and also between eastern Arte and Brenner Bad, districts in Tyrol, Austria, the mountain alders presented a sickly appearance. Examination proved this was largely due to the work of *C. lapathi,* and that many of the trees were also attacked by a fungus *Valsa oxystoma* Rehm. The injuries by these two agencies are similar in external appearance.

HISTORY OF THE SPECIES IN THE UNITED STATES.

Attention was called to the appearance of *Cryptorhynchus lapathi* in this country by William Juelich in 1882, who found the insect in the northern part of New York City.[5] Five years later the willows near West Bergen, N. J., were discovered to be infested, and in 1891 Dr. J. B. Smith reported that in New Jersey willows were being killed by this insect. The beetle was found in injurious num-

[1] Bd. IX, p. 152, 1877.

[2] *Journ. Columbus Hort. Soc.,* **16**:146–155.

[3] Forstzoologie: Insekten, Abth. I.

[4] Two enemies of the Alpine alder, *Alnus viridis* D. C. *Forstl. Naturw. Ztschr.,* **1**:1892.

[5] *Entomologica Americana,* **3**:123.

bers at Melrose, Mass., in 1895 by Dr. C. H. Fernald. The presence of this insect in the willows about Boston and other towns in eastern Massachusetts had been known for many years. During the following year the beetle was found at Buffalo, N. Y., by Ottomar Reinecke; and in 1901 Mr. A. F. Burgess collected one specimen near the city of Ashtabula, Ohio. In 1903 the insect was found in two nurseries in the State of Wisconsin by Mr. Christian Bues, the State nursery inspector,[1] and in 1904 Prof. M. L. Washburn reported that he had received specimens of *C. lapathi* from North Dakota where it had been found upon poplars that had been imported into that state from a New York nursery.[2]

ECONOMIC IMPORTANCE.

THE BEETLE A NURSERY AND A SHADE TREE PEST.

The poplars, willows and alders, while not counted among our most valuable or most beautiful trees, serve useful purposes and are well worthy of preservation. They claim our attention not only for their quick growing qualities and economic value, but also for the native beauty possessed by many of the species. Indeed certain schemes of landscape decoration would be incomplete without some of the more attractive kinds. The native willows perform an important function as holders of the soil along the margins of lakes and streams; the poplars on account of their hardiness and rapid growth are invaluable as shade trees in newly settled suburbs; and in western New York the growing of the basket willow is an important industry.

In Europe this insect has been long recognized as an injurious pest upon alders and willows, and its work and life history have been a fruitful source of much discussion by German zoologists. The beetle is reported to be destructive in England, Germany, Austria and Denmark. There are many instances on record of injury to the basket willow and to the alders along the streams and in the forest, and more especially to the plantations of willows and alders cultivated for commercial purposes, which have often been destroyed.

From New Jersey, Dr. J. B. Smith reported that "*C. lapathi* was spreading and was doing serious injury to willows. Nearly all the clumps of willows near Newark and Arlington had been destroyed, and some fancy and garden trees had been killed." [3]

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[1] Wis. Agrl. Expt. Sta. Ann. Rpt., **21**:275. 1904.

[2] Ninth Annual Report of the State Entomologist of Minnesota, p. 115.

[3] *Can. Ent.*, **23**: 221.

Another interesting and somewhat similar account of injury by the insect was reported in 1899 by Mr. A. H. Kirkland from his observations of the behavior of this species in Massachusetts. In Winthrop, Revere, and other shore towns in the eastern part of the State, the land is somewhat marshy, and the Balm of Gilead poplar, being the indigenous tree that thrives best, is largely planted in the streets and yards for shade purposes. The branches are weakened by the boring of the larva and are broken down by the ice storms and winds. At present there is hardly a sound Balm of Gilead poplar in the localities mentioned. Mr. Kirkland also states that the work of this beetle caused similar injuries to the poplars in the larger nurseries of eastern Massachusetts, and that nurserymen were thinking of abandoning the growth of poplars and willows. Another observer states,[1] "So abundant is the pest and so extensive its ravages, that it is rarely possible to find a good healthy plant among the shrubby willows about Boston." Drs. C. H. and H. T. Fernald, entomologists of the Massachusetts Experiment Station, reported in 1893[2] that for several years *C. lapathi* has been present in great abundance. The injuries which it causes to willows, poplars and similar soft-wooded trees are frequently serious; and it is now almost impossible to raise these trees in some localities, thus greatly reducing their value for planting as holders of the soil in such places as sandy beaches.

The dissemination of this insect in the State of New York has been easy and rapid, because of the great number of lakes, canals, and small streams that are everywhere bordered with willows. The abundance of these trees aids in the propagation of the species and undoubtedly serves as a means of distribution. The insect spreads not only to the native willows along the waterways but also to the ornamental willows in the cities and to the cultivated poplars and willows in the nurseries. The insect has now become well established in many localities and the industry of growing poplars and willows is seriously threatened, as well as the usefulness and beauty of trees already mature.

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[1] J. G. Jack. *Gard. and Forest,* **10**: 394. 1897.

[2] Mass. (Hatch) Agrl. Expt. Sta. Rpt.. **16**: 108. 1903.

FOOD PLANTS.

The beetle attacks practically all of the poplars, willows and alders, for there are very few species that escape injury. Mr. J. G. Jack reports that the beetle has proved destructive to almost all species of willow and all the cultivated poplars grown in the Arnold Arboretum. It has been found boring in the stems of all native willows with the exception of a few mountain or very slender stemmed species which are too small to afford the borers sufficient sustenance. Of the foreign willows which make large trees, such species as the white willow, crack willow and laurel-leaved willow, are more or less attacked, though not so liable to injury as the Babylonian weeping willow. The beetle has been rarely found in small plants of two species of birch, the drawf birch, *Betula pumila,* and the red or river birch, *B. nigra.*

The plants in the following list are mentioned by German writers as being subject to the attacks of *C. lapathi* in Europe: Alpine alder, *Alnus viridis* D. C., white alder, *A. incana* Willd., black alder, *A. glutinosa* Willd., purple willow, *Salix purpurea* L., osier willow, *S. viminalis* L., *S. triandra,* Kilmarnock willow, *S. caprea* L., white poplar, *Populus alba* L., and *Rumex hydrolapathum* L.

The species mentioned as food plants in this country are: White willow, *S. alba* L., crack willow, *S. fragilis* L., weeping willow, *S. babylonica* Tourn., dwarf birch, *Betula pumila* L., red river birch, *B. nigra* L., Balm of Gilead, *Populus balsamifera* L. var. *candicans* Gray, Carolina poplar, *P. monilifera* Ait., and silver-leaf poplar, *P. alba* L. var. *bolleana.* The trees that have been observed to sustain injuries in this immediate locality are *P. monilifera* Ait., *S. lucida* Muhl., *S. caprea* L., *S. cordata* Muhl., *S. sericea* Marsh., *S. alba* L., and *S. amygdaloides* Anders.

These latter were kindly determined by Prof. W. W. Rowlee of Cornell University.

LIFE STAGES AND HABITS OF THE INSECT.

THE EGG STAGE.

Description of egg.— The egg is of a white color turning to a pale yellow when several days old. The shell is thin and fragile, the surface being smooth and slightly viscous. The shape is elongated oval, obtusely rounded at the ends, oftentimes determined by the shape of the cavity. The longer axis is 1.1 mm. and the shorter axis .8 mm. in length.

Parts of the plant selected for oviposition.— Oviposition occurs in the corky portions of the wood, near a bud or branch, or in the overgrowths caused by pruning. A cut or break in the bark is a favorite place. When the infestation is marked, eggs can be readily found in the callosities caused by injuries of this beetle in previous years.

The egg period.— The egg stage lasts eighteen to twenty days. This was determined as follows: A number of beetles were permitted to feed upon and to oviposit for one day in an uninfested cutting from the stem of a nursery poplar. This operation was repeated on succeeding days, fresh wood being used each time. The beetles were then excluded, the cuttings being kept in moist sand under cover to prevent reinfestation. After remaining for fifteen or more days, the entire bark was carefully examined, to ascertain the number and condition of the eggs deposited in the respective cuttings. The following is the result:

TABLE I.— TIME OF INCUBATION OF EGG OF *C. lapathi.*

Cutting No.	Date of oviposition.	Date of examination.	Interval between oviposition and examination.	Number of eggs.	Condition in which the eggs were found on examination of the bark.
	Sept.	*Oct.*	*Days.*		
1	13	4	21	6	Eggs hatched and larvae beginning to feed.
2	14	3	19	2	Eggs about ready to hatch.
3	15	4	19	1	Egg just hatched.
4	16	4	18	2	Eggs hatching.
5	18	9	21	2	Eggs hatched and larvae beginning to feed.
6	19	4	15	4	Eggs nearly ready to hatch.

DESCRIPTION OF THE LARVA AND ITS GROWTH.

Larva, Sept. 22, 1905.— When newly hatched, the larva is a soft fleshy grub destitute of feet and bearing a number of very fine hairs. It is 1.6 mm. long and .6 mm. thick at the broadest points, and .4 mm. at the caudal extremity. It is somewhat shining and of a pale yellow color, being whitish toward the caudal extremity. The head is light brown and the mouth-parts are dark brown, the tips of the mandibles and maxillae being black. The body is nearly cylindrical in form, tapering a little behind and swollen at the anterior extremity.

Larva, April 19, 1906.— At this time the larva has much the same appearance as the newly hatched form, except that it is larger, being 4.5 mm. in length. It is more cylindrical, the abdominal segments being slightly swollen. The latter have a pale brown color with a pinkish tint.

Larva, May 19.— The appearance of the larva is the same as the younger stages. Some of the individuals begin to show a slight variation in size. The length ranges from 5 mm. to 6 mm.

Larva, June 12.— The larvae show greater variation in size than was noted upon previous observations. Some members of the brood have apparently ceased to grow, while others have made a rapid growth. The larvae vary in length from 5 mm. to 11 mm., the average length being about 8.5 mm. The larger specimens have begun to bore in the heart wood and in most cases have made a channel about one-half inch long.

Larvae, June 21.— At this time the larvae shows still greater range in size, the length varying from 12.5 mm. in the larger specimens to 5 mm. in the smaller specimens. The largest larvae were ready to pupate.

HABITS OF THE LARVA.

Most of the eggs hatch between August 15 and October 1, and the larva upon hatching begins to bore into and feed upon the cambium tissue. During the winter the larva remains dormant, making very little growth until spring. There is no uniformity in the shape of the larval borings or channels during the first months of activity. The larva may remain in one place, making a flat irregular shaped chamber, or sometimes a zigzag channel, though more often the cambium layer is girdled, either partly or entirely, depending on the size of the tree. At first the channel of the young larva is small and has but one opening in the bark, but as the larva increases in size, the channel is gradually enlarged and frequently another opening is made.

The larva works in the cambium layer until within 3 or 4 weeks of the time to pupate. It then bores at an angle into the woody tissue until the heart of the branch is reached, when the direction is changed upward. It can usually be determined whether the larva is working in the cambium layer or the woody tissue by the character of the larval chewings and particles of excrement together with sap from the tree that appear as an exudation at the opening to the larval chamber. While the larva is in the cambium layer, the exudations are brown or black in color, being made up of very fine splinters. The exudations thrown out from the heart wood are clean, usually white, and larger both in length and thickness. In opening the channels, a few splinters or chips can always be found; but when the larva is ready to pupate, the channel is packed for the full length, with the exception of the pupal chamber at the upper end. After filling the channel with chips and making the pupal chamber, the larva turns itself head downward, in which position the pupa will be found.

DESCRIPTION OF THE PUPA.

The pupa is about one-fourth of an inch long, being somewhat stout and of a pale yellow color. The head, rostrum, and other parts of the body have a number of small tubercles, most of which bear curved brown hairs. The antennal case is nearly parallel with and slightly overlaps the femur of the foreleg. The wing cases are partly covered by the first two pairs of legs and in turn almost cover the third pair. The tip of the abdomen is provided with a pair of short strong inward-curving hooks.

THE LENGTH OF THE PUPAL STAGE.

In the vicinity of Geneva, most of the larvae pupate some time during July, as is shown by the following observations. In an examination of some twenty larval channels, made July 8, one adult, two pupae and fifteen larvae were found. In another examination of some larval channels on July 12, four adults, four purpae and ten larvae were found. While there were many adults in the larval channels up to the latter date, none had emerged. The appearance of the trees on July 30 seemed to indicate that practically all of the beetles had emerged. The pupal stage lasts from ten to sixteen days. In one instance, a larva ready to pupate was kept under observation. Pupation occurred during July 13 and the adult emerged July 27, the period being fourteen days.

A DESCRIPTION OF THE BEETLE.

The body of the beetle varies from one-third to three-eighths of an inch in length. The general color is a dull black, though the rear third of the wing covers, the basal half of the front thighs, and the ventral part of the prothorax, are covered with white scales. The other portions of the body are covered with black scales interspersed with a few white scales. A few jet black tufts of erect bristles or scales are found upon the wing covers and thorax. When the wing covers are magnified, each is plainly pitted in ten longitudinal rows, the thorax also being minutely, though irregularly, punctured. The under side of the abdomen and the legs are black, being marked here and there by white scales which are especially numerous on the femora, giving the latter a slightly banded appearance. The head and proboscis are black in color. There is a very marked groove in the sterna which lies between the first and extends to the middle of the second coxal cavities. If the beetle is not active, the proboscis is contracted into this groove. When handled the beetle frequently emits a squeaking noise, which is evidently made by rubbing the parts of the thorax together.

HABITS OF THE ADULT.

The adult belongs to the same family as the well known plum curculio and has somewhat similar habits. When moving about the beetle does not run, but walks with a slow, steady, lumbering motion. The beetle does not fly when disturbed but will drop to the ground with limbs and snout contracted, or if on the top side of a branch, will roll over on its side and to the ground. No beetles have been observed to puncture the leaves.

HABITS OF THE FEMALE DURING OVIPOSITION.

The female usually eats thirty to forty minutes in making a cavity to conceal the egg. She then reverses herself and stands still with ovipositor thrust deep in the opening for thirty seconds or a minute. The abdomen is then worked up and down as if the egg were being packed in. The whole operation requires two or three minutes. The position is again reversed and the female works the packing with snout and antenna for several minutes until apparently satisfied, when she moves off in search of another place in which to deposit an egg.

THE NUMBER OF EGGS OVIPOSITED BY ONE FEMALE.

Some observations were made in 1905 and 1906 to determine the number of eggs deposited by adult females. When the investigation of the life history of this insect was taken up, in the latter part of August, 1905, practically all the beetles of that year's brood had emerged from the larval channels. It was therefore too late to obtain beetles that summer to determine the capacity for egg laying, and know with certainty that no eggs had been deposited. However, some observations were made upon beetles that had been captured in a poplar plantation, and it is thought that since the beetles continue to emerge for several weeks after the first appearance of the adults, at least some of the beetles had not begun to oviposit.

The details of the observations are as follows: A pair of beetles while copulating were confined in a separate breeding cage, in which had been planted cuttings about an inch in diameter that had been made from the stem of a two or three year old nursery poplar to serve as food and for purposes of oviposition. After the beetles had fed upon and oviposited in the cuttings for several days, the punctures were dissected with the aid of a lens, the eggs not being counted until they were seen.

Observations were made on ten pairs of beetles lasting from Sept. 6 to Oct. 11. The examinations for the eggs in the bark were made at irregular intervals. The egg laying record of the insects is as follows:

TABLE II.— NUMBER OF EGGS DEPOSITED BY FEMALE, *C. lapathi.*

INSECTS.	Sept. 6	Sept. 7	Sept. 8	Sept. 9	Sept. 11.	Sept. 13.	Sept. 15.	Sept. 18.	Sept. 21.	Sept. 25.	Oct. 11.	Total.
A	.....	.....	2	3	5	4	.....	3	6	2	.....	25
B	.....	.....	2	1	.....	1	1	1	8	.....	.....	14
C	.....	1	.....	1	2	3	.....	8	5	.....	.....	20
D	.....	.....	1	.....	1	.....	1	.....	1	.....	.....	4
E	2	.....	1	2	7	4	2	7	.....	2	.....	27
F	.....	.....	1	2	6	.....	.....	6	5	3	.....	23
G	.....	1	.....	.....	.....	3	.....	2	4	.....	.....	10
H	.....	.....	.....	2	5	1	2	3	1	.....	.....	14
I	.....	.....	1	.....	4	1	.....	4	4	.....	2	15
J	.....	1	.....	1	.....	.....	5	.....	.....	.....	4	11

The average number of eggs deposited by the ten females is 16.3, and the greatest number deposited by one individual is 27.

An effort was made in 1906 to repeat these observations, upon beetles that had emerged in breeding cages. Many beetles were secured from the wood of some badly infested poplars and willows. A week or ten days after emerging some of the beetles began to copulate and a number of pairs were isolated. But for some unaccountable reason the beetles were short-lived and very few eggs were deposited.

FEEDING HABITS OF THE ADULT.

The adult is a voracious eater and obtains subsistence by puncturing the bark and feeding on the cambium layer. For the first week or ten days after emerging the beetle feeds extensively upon the tender bark of one year old branches, then copulation takes place, after which the beetles are more often found on the older parts of the tree. One observation seems to indicate that young bark is a prime necessity. A number of beetles developed in a breeding cage in which there was only the old wood from which they had emerged. The beetles did not eat the old bark and many appeared dead after three or four days, but revived when put on a diet of young twigs. This was probably the ripening period for oviposition, as during the first week or ten days after emerging no eggs are deposited. When the beetles are ovipositing they are more often found puncturing the bark of two to four year old wood, and if at this time they are given twigs and small branches of one year old wood exclusively for food, they will riddle the bark with punctures but will not oviposit in the bark. In several instances similar to this the eggs have been deposited on the floor or walls of the breeding cage. No eggs have been detected in the bark of one year old wood. This apparent distinction shown by the beetle between one year and two year bark is brought out strongly in one of the methods of growing poplars in the nursery, which is as follows: A cutting of one year wood is put in the ground. This is allowed to root and one bud to grow. After one year's growth the shoot and tap root are pruned and the stock replanted. At the end of another year it is called a one year old tree, though it may have six or eight inches of two year wood above ground. These one year trees are often infested but the point where the eggs are inserted will invariably be in the two year old wood. According to nurserymen, this pruning and replanting is done to give the tree a better root system.

DISTANCE THE BEETLES TRAVEL TO FIND NEW PASTURES.

In infested localities the beetles seem to be present everywhere upon willows and poplars, and it is evident that they occasionally migrate or are scattered by some means. However, none have ever been observed in the act of migration. The beetles have perfect wings but in the observations of two summers none have been seen flying. In a grove composed mostly of poplars and willows, some

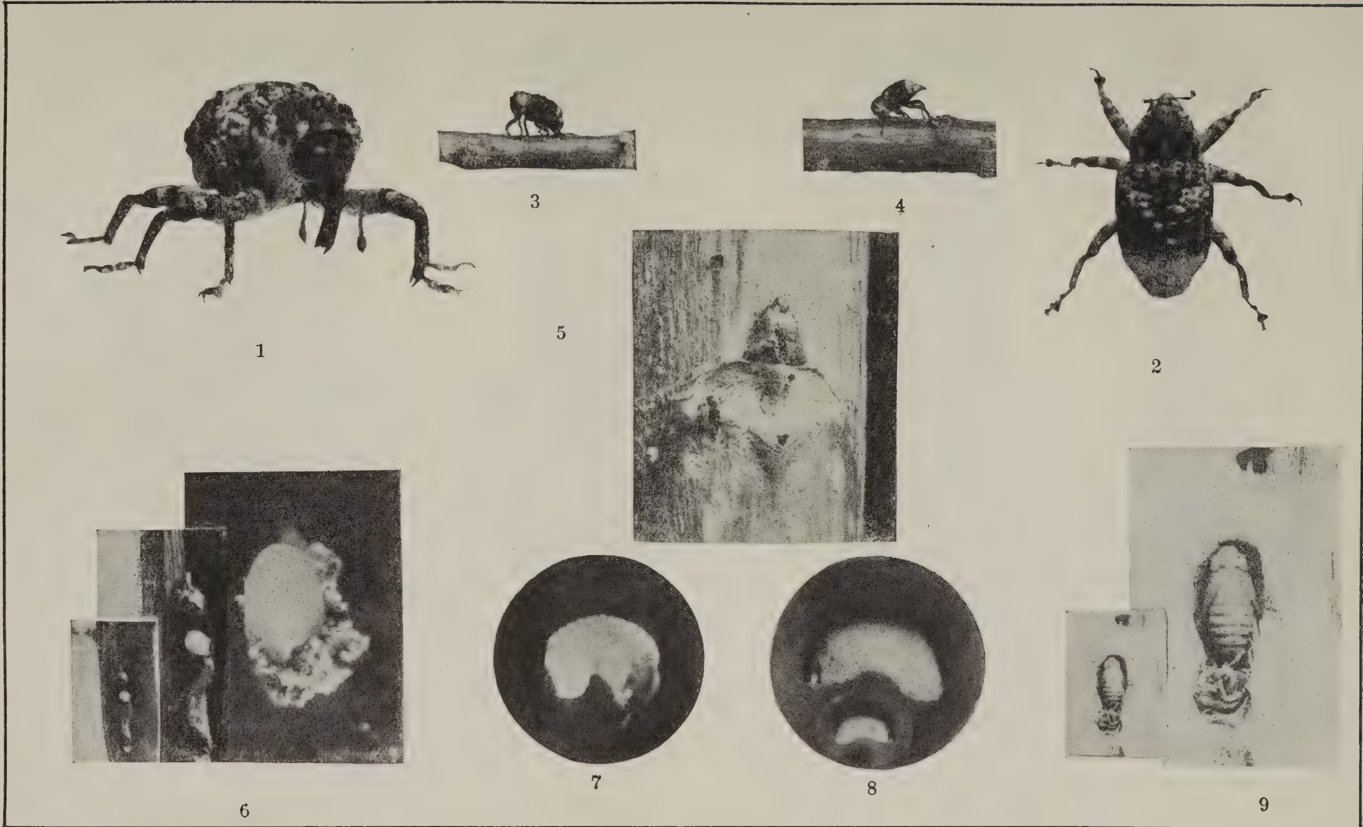
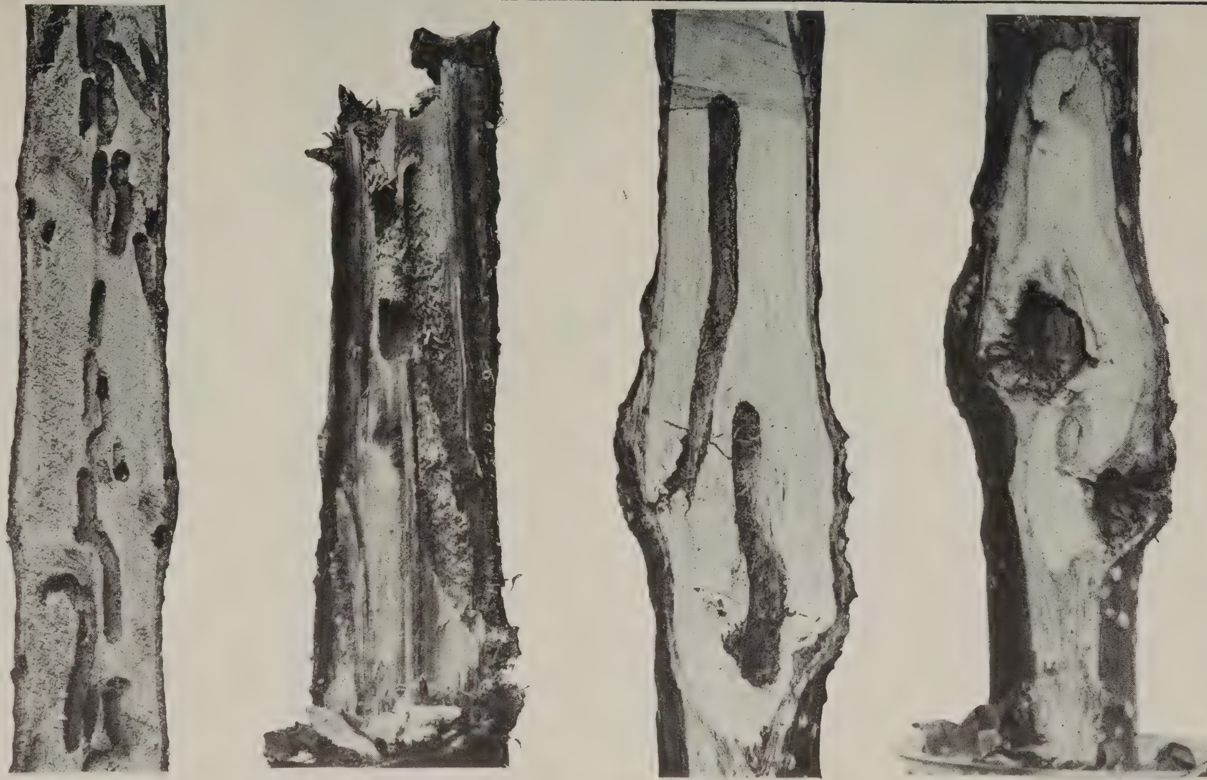


Plate VIII.— Life Stages of Poplar Weevil: Figs. 1 to 4, Adult, Enlarged and Life Size; Fig. 5, Punctures for Eggs; Fig. 6, Egg; Fig. 7, Newly Hatched Larva, Enlarged; Fig. 8, Mature Larva, Natural Size and Enlarged; Fig. 9, Pupa.

1 2 3 4

PLATE IX.—FIGS. 1 AND 2, BARK PUNCTURED BY ADULTS; FIG. 3, EXUDATIONS OF SPLINTERS AND EXCREMENT FROM LARVAL CHANNELS; FIG. 4, BARK REMOVED SHOWING GIRDLING BY LARVA.



1 2 3 4

PLATE X.— LONGITUDINAL SECTIONS SHOWING LARVAL CHANNELS OF POPLAR WEEVIL.

Plate XI.— Nursery Trees Showing Characteristic Injuries of the Poplar Weevil.

Plate XII.— Nursery Trees Injured by Poplar Weevil.

Plate XIII.— Native Willows Injured by Poplar Weevil.

of which were badly infested with this beetle, a lantern trap was placed on the nights of October 4th and 5th, 1905, and again for eleven nights during August, 1906. The catch of insects in each instance was large, both in variety and numbers, but included no *C. lapathi*. Some observations that are of interest in this connection were made in one of the nurseries belonging to Mr. H. E. Merrill of Geneva. There are four blocks of poplars in a line east and west, each about one hundred yards apart. The west and east blocks are the youngest, one being one year old, and the other, cuttings; and though frequently inspected no beetles were found on either. But the central blocks, one two years old and the other three years old, were each badly infested.

During the summer of 1906, in order to learn more of the migratory habits of the beetle, thirty-five specimens were caught in a nursery poplar block and marked so that they could be recognized. These marked beetles were then liberated at a distance of fifty yards from the block in which they were captured. At intervals of several days all the neighboring poplars were carefully examined, and more than four times the original number of beetles were captured, but none of the marked beetles were collected.

While these observations are not conclusive, yet it is believed from the behavior of the beetles that they do not naturally travel far and that they rarely migrate from an abundant food supply.

EXPERIMENTS WITH POISON SPRAYS FOR THE CONTROL OF THE PEST.

The adult is an external feeder and obtains subsistence by puncturing the bark.— The great number of punctures made in the bark by the adult while feeding at once suggested the possibility of using arsenical sprays as a means for the control of the pest in the nursery. In order to learn the effect of these sprays upon the beetles, a number of experiments ware made, as follows:

SPRAYING TESTS OF 1905.

Experiment No. 1.— On August 26, 1905, the branch of a poplar tree was sprayed with paris green at the rate of one pound to fifty gallons of water. Three pairs of beetles were then put on the branch, which was covered by means of strong mosquito netting. Four days later some of the beetles were apparently dead and the others were ailing. On September 1, six days later, all the beetles were dead. The bark showed no evidences of injury by the beetles.

Experiment No. 2.—On August 29, 1905, the tops of two poplars in a nursery row were headed in and then sprayed with arsenate of lead, using two pounds to fifty gallons of water. Eight pairs of beetles were then placed on each tree, being enclosed by means of large cheesecloth bags. On September 4, six days later, twenty of the thirty-two beetles were dead. The wood had been only slightly punctured.

Experiment No. 3.—On September 29, 1905, forty beetles were enclosed in a similar manner as in experiment 2 on two trees that had been sprayed twenty days previously with arsenate of lead, using two pounds to fifty gallons of water. The greater part of the spray had apparently washed off during the twenty days. On September 29, ten days later, some beetles were dead and all appeared ailing. On October 10, all but one of the forty beetles were dead.

As a check on the preceding experiments, twenty-six beetles, divided into five lots, were confined in bags on unsprayed trees to determine if the confinement itself affected the insects unfavorably. The results are as follows:

TABLE III.—EFFECTS OF CONFINEMENT OF BEETLES ON UNSPRAYED TREES.

Date beetles were confined in bags.	Number of beetles to each lot.	Number alive Sept. 23.	Number alive October 13.	
August 26	14	11	2	The bark in each instance was badly punctured
August 26	2	2	1	
August 25	4	4	1	
August 25	2	2	1	
August 25	4	3	1	

From the above table it will be seen that on September 23, twenty-nine days after the beetles were confined in bags, twenty-two of the twenty-six beetles were still living. On October 15, fifty days after the beetles were confined, six adults were still living. From these results it is believed that the use of bags to enclose beetles had no appreciable effect upon the health of the insect.

SPRAYING TESTS OF 1906.

On August 23, 1906, the following experiments were undertaken to corroborate the results of 1905 with the use of poisons for the control of the beetle.

A tree was selected that had been sprayed thirty-nine days previously (July 14) with bordeaux mixture, containing five pounds of arsenate of lead to fifty gallons of the spray. Most of the application had apparently washed off during the interval. The larger limbs of the tree were cut back and the tree was enclosed in a strong bag of mosquito netting in which twenty beetles were placed.

On the same day another tree was selected from a block of poplars which had been sprayed August 6 with arsenate of lead, using three pounds of the poison to fifty gallons of water. During the intervening seventeen days all but a trace of the poison had apparently washed off. This tree was bagged as the preceding one and twenty beetles were also confined.

A third tree was chosen from a block of poplars that had not been sprayed and was covered with mosquito netting to contain twenty beetles, to be used as a check. In three days the effect of the poison began to show upon the activities of the beetles, for the individuals on the sprayed trees appeared dormant. On September 5, thirteen days after being put on the trees, the contents of the bags were examined. All the beetles, forty in number, on the sprayed trees, were dead. Of the twenty specimens on the check tree, only four were dead. The remaining sixteen were apparently not affected by being enclosed in the bag of mosquito netting.

CONCLUSIONS OF THE EXPERIMENTS WITH POISON.

While the experiments with poison sprays were conducted according to laboratory methods and the number of beetles involved in the experiments was limited to about three hundred, the results are encouraging and indicate that thorough spraying with an arsenical poison of the 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.

THE EFFECT OF CONTACT SPRAYS UPON THE HIBERNATING LARVAE.

A number of experiments have been made to determine the effect of various washes, composed largely of lime, kerosene and arsenical poison in combination. These washes were applied during the winter to learn the effect upon the young larvae. In each case the application had no appreciable effect upon the larvae.

DOES POISON REPEL OR DESTROY THE BEETLES?

After the spraying and bagging experiments of 1905 were completed, it was evident that enclosing beetles in bags upon trees that had been sprayed with poison resulted in the death of the beetles. It was now desirable to ascertain whether the beetles died as a result of poison or of starvation. To determine this, on August 4th, 1906, forty-five beetles, divided into lots of fifteen individuals, were fed in three glass containers with an abundance of food. The first container held only sprayed twigs and branches, the second held both sprayed and unsprayed twigs, while the third held only unsprayed twigs. The beetles in container two fed upon both sprayed and unsprayed food with apparent relish, showing no discrimination between sprayed and unsprayed bark. On August 11, seven days afterward, of the beetles in containers one and two, only one beetle in each lot was alive, while in container three, holding only unsprayed food, thirteen beetles were alive.

NURSERY PRACTICES THAT FAVOR THE BEETLE.

In a study of the various methods of growing poplars and willows, a practice has now and then been observed that is favorable to the multiplication of the poplar beetle. It has been learned that in most cases the degree of infestation increases with the age of the poplar and willow blocks. Oftentimes a block of one year or two year trees that is practically free from infestation one year, will in the following season be so badly infested that from twenty-five to fifty per ct. of the trees will be unfit for sale. For this reason nurserymen should, as far as is practicable, dispose of the stock when it is not more than two or three years of age. When a tree becomes so badly injured by the beetles that it is unsalable, it should be taken out and burned, as the chances for its recovery are small, and such trees serve as breeding places for the beetle. The same practice should be pursued with infested native willows that are frequently allowed to grow in swampy places or along canals or streams adjacent to nurseries. Any brush or injured trees taken from the nursery blocks should be burned. On several occasions brush in nurseries has been found to contain adult beetles ready to emerge. A special instance was noted as follows: Several one year old trees were found in a nursery brush pile with the appearance of having been there a week or more. A number of these that had been broken off by the wind as a result of the girdling habit of the beetle, were put in a dry place and examined two weeks later. Of the larval channels that were examined, a number of the beetles had emerged, some were still in the channel ready to escape, and of thirty larvae present in the channels, all but three reached the adult stage.

DIRECTIONS FOR PREVENTION OF INJURY AND CONTROL OF BEETLES.

From observations that have been made, it is believed that planting young blocks of trees adjacent to old plantations facilitates the spread of the beetles, and their injurious work. Whenever practicable, young trees should not be grown near old infested blocks. When a few trees or a plantation is slightly infested, the insect can be effectually controlled by cutting out and burning the infested parts in June, before the beetles emerge. The presence of the larvae in the wood is indicated by the appearance of sawdust and excremental particles, and the exudation of sap at the external opening of the larval channel. Also much benefit will be derived by destroying by fire all branches and trees broken by the wind or otherwise injured, as they are likely to be infested. Plate IX, fig. 3.

Poplar and willow blocks grown in localities where the beetle is abundant should be sprayed during the last two weeks in July with bordeaux mixture, containing three pounds of lead arsenate to fifty gallons of the mixture. This is advised experimentally, as the tests in the nurseries to determine the value of this treatment are not as yet completed. The trees should be thoroughly sprayed so that all parts of the bark, including that of the small branches, are well coated with the poison.

The total cost of this treatment when applied to two year old nursery trees in our experiments, was approximately one-fourth of a cent per tree. The experiments indicate that if the treatment is properly applied it will control the poplar weevil. This spray also protects the tree from many other insect and fungus enemies.

If willows or poplars planted for windbreaks, or screens, or holders of the soil, should become so badly injured as to impair their beauty, it is advisable to dig out and burn the infested trees during the winter or spring, and to replant with some other kind of a tree. For this purpose, Mr. A. H. Kirkland of Massachusetts, recommends the silver maple, *Acer dasycarpum,* or its variety *weirii,* either of which is said to make a good growth in damp localities.

REPORT

OF THE

Horticultural Department.

U. P. Hedrick, *Horticulturist.*

N. O. Booth, *Assistant Horticulturist.*

Richard Wellington, *Assistant Horticulturist.*

Maxwell J. Dorsey, *Assistant Horticulturist.*

O. M. Taylor, *Foreman.*

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BORDEAUX INJURY ON A RHODE ISLAND *Greening* APPLE.

REPORT OF THE HORTICULTURAL DEPARTMENT.

I. BORDEAUX INJURY.*

U. P. HEDRICK.

SUMMARY.

1. Bordeaux injury is known under several names, as "spray injury," "bordeaux scald," "bordeaux burning," "spray russeting," "cork russeting," and "yellow leaf."

2. Accounts of bordeaux injury date back to the first use of bordeaux mixture upon the apple, and almost all subsequent workers in the field of experimentation have noted it.

3. Injury occurs in some degree wherever bordeaux mixture is used. Correspondence has brought out the fact that it is found in all apple-growing sections of North America, Europe, Australia, Tasmania and New Zealand.

4. Different species of plants are injured in different degrees by bordeaux mixture. The peach, apricot and Japanese plum are most susceptible to injury. The common plum, quince, pear and apple are injured in about equal degree. Varieties of the above fruits are susceptible to injury in greatly different degrees.

5. The amount of injury done to a given species or variety seems to depend: (1) Upon the specific susceptibility of the plant; (2) upon the solvent properties of cell sap on the copper hydroxid; (3) upon the permeability of the epidermis of the plant; (4) upon the weather conditions following spraying.

6. There are many anomalies of occurrence brought about, for most part, by weather conditions; as, damage in some seasons, not in others; in some localities and not in others; some report dry seasons as favoring injury, others wet; some trees of a variety

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are injured more than others; the injury is sometimes most severe on the fruit and sometimes on the foliage; the fruit alone of some varieties is immune and of others, the foliage; the injury may appear in a few days or may not show for several weeks after spraying; and a very weak mixture may cause greater injury than a stronger one used under similar conditions.

7. Injury on the fruit first appears as small, round, black or brown specks. Later, the injured specimens become rough and russeted because of a ruptured epidermis and layers of dead corky cells. Badly injured specimens are always more or less distorted through shrinkage of the injured portions, by teat-like malformations, or by rough, sunken scars.

8. Injured apples do not keep well. Their season in cold storage is not greatly shortened but when the fruit is exposed to the air the affected parts become mealy, decay sets in quickly, and the flesh becomes soft and flabby.

9. A microscopic examination of injured fruits shows that the waxy covering and the cuticle proper have been largely destroyed. Such of the epidermal cells as remain and those of the fruit flesh which are injured, have much thickened walls of a brown, corky appearance.

10. Affected leaves first show dead, brown spots of various shapes and sizes. Quickly following the appearance of these spots the leaf tissues turn yellow and the leaves fall. When the injury is slight the yellowing may not appear nor the leaves drop.

11. Bordeaux mixture has a particularly harmful effect on the apple blossom, killing the tissues of the floral organs.

12. Injuries from the arsenites, frost, fungi, work of blister mites, lens action of drops of water, and from lime, are somewhat similar to bordeaux injury and are often confused with it.

13. Some varieties of apples are injured much less than others by bordeaux mixture and there is a wide range in this variation. Immunity to bordeaux injury does not correspond with immunity to the apple scab fungus.

14. The chemistry of bordeaux mixture, though seemingly simple, is somewhat complex. The compounds formed vary greatly with the proportions of the ingredients used and the conditions under which the mixture is made. The mixture changes greatly under the influence of weather and especially of moisture in meteoric form.

15. Theories as to the toxic action of bordeaux mixture may be grouped into two classes: (1) The mixture is acted upon by

the moisture of the atmosphere and the toxic substances pass through the epidermis of the leaf with harmful effects. (2) Leaves and fruits secrete fluids which dissolve portions of the copper compound; this finds its way into the cellular tissue and death results to the cells reached.

16. A study of bordeaux injury in the State at large showed: That in 1905 about 70 per ct. of the orchards sprayed had been injured; that an excess of lime did not prevent the injury; that in some orchards spraying did more harm than good; that there had been similar losses in past years; that the use of power machinery seemed to increase the injury; that wet weather gave the favoring conditions for injury; and that some varieties are more susceptible to injury than others.

17. An experiment on the Station grounds to show the effects of bordeaux mixture on the fruit and foliage of the apple proved conclusively that this mixture causes the trouble known in New York as "spray injury."

18. In the above experiments injury appeared immediately after the first shower of rain following the spraying and continued to develop until the fruits of the Baldwin and *Greening* were half grown.

19. The toxic substance seemed to pass through the stomata and the basal cells of plant hairs into the cellular tissue of the fruit. Small black specks characterize the first stage of bordeaux russeting. Each of these was usually formed about a stoma.

20. As the fruits grow the epidermis is lacerated because the dead cells are unable to bear their share of the surface tension. It is these dead cells and the healing of the lacerations that cause the corky russeted surface of fruits.

21. Bordeaux injury on fruit comes from early spraying, after the blossoms have dropped, and it is not probable that much damage is done after the hairs have been shed and the stomata changed into lenticels.

22. No conclusion could be reached as to how the toxic ingredient finds its way into the cellular tissue of the leaves. Since the dead spots are nearly always under heavy bordeaux mixture stains, it may be that the dissolved salts enter osmotically into the cells of the leaf surface.

23. An experiment to show whether wet or dry weather gave favoring conditions for bordeaux injury confirmed the opinions of fruit-growers that wet weather gives the favoring atmospheric condition for this trouble.

24. Bordeaux mixture containing an excess of lime, in the experiments on the Station grounds, did not prevent nor greatly lessen bordeaux injury, again corroborating the experience of fruit growers.

25. In a wet season there may be some slight advantage in the use of an excess of lime in that it may delay the fungicidal action of the copper salts, an advantage in controlling the scab fungus in such a season.

26. Disadvantages of an excess of lime are that a mixture containing it is more difficult to apply well and that the fungicidal action of the mixture may be weakened in a dry season.

27. An experiment to show the effects of bordeaux mixtures made with varying quantities of copper sulphate and lime, showed that, the more copper sulphate, the greater the injury.

28. The experiment noted in 27 showed that in general the stronger the solution, as to copper sulphate, the better the control of the scab fungus. But the differences between the 4-4-50 solution and the 3-3-50 one in controlling the fungus were so insignificant that it is believed that the weaker one can be used and to advantage as it would cause less bordeaux injury.

29. There are no means of entirely preventing the toxic action of the copper salts in spraying fruits with bordeaux mixture. The problem is to spray so as to control fungi and yet injure the host plant as little as possible.

30. Practical suggestions for spraying are: 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.

31. Some varieties of apples may be sprayed without much fear of injury. Others must be sprayed with great care. Distinguish between the varieties in spraying operations.

32. 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.

33. 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.

INTRODUCTION.

It has long been known that under some conditions bordeaux mixture injures the fruit and foliage of the apple. Such injury is becoming more common and is increasing in severity in New York. A circular letter sent in the fall of 1905, to 116 leading apple growers of the State, brought 108 replies from men who had used bordeaux mixture, 98 of whom had used it that season. Of the 98, practically all had had some experience with the bordeaux injury in the past, and 69, or about 70 per ct. of them, had severely injured their fruit and foliage in 1905. Ten men reported that spraying had done more damage than the apple scab for which it was used. Accounts of similar losses to the apple crop in this State date back to 1894, when Beach[1] first reported upon it.

Attempts on the part of the fruit-grower to control the injury by adding lime, decreasing the amount of copper sulphate, and by varying the time of spraying, having failed to bring forth methods of control, this Station began investigations in the spring of 1906 to determine: (1) The cause of bordeaux injury; (2) conditions favoring the injury; (3) means of preventing such injury. This bulletin is a report of the investigations, with a discussion of the whole matter of bordeaux injury.

There is danger that a careless reader of the discussion that follows may think that the writer is advocating giving up bordeaux mixture as a spray for apples. There should be no such thought. This mixture is still by far the best fungicide for the apple. It was premised when the experiments herein described were begun, and it is still held after their completion, that, in spite of the injury, *the apple-grower must continue* to spray with bordeaux mixture.

It should be noted that the trouble which we have called "bordeaux injury" is known under several names in this State and in the country at large. The most common of these is "spray injury"— an indefinite term since several spraying compounds may cause injuries; other names are "bordeaux scald," "bordeaux burning," "spray russeting" and "cork russeting" as applied to injury on fruit, and "leaf spot" and "yellow leaf" when the foliage is the part injured. It is hoped that "bordeaux injury" may come into common use in designating this trouble.

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[1] Beach (9). The number in ( ) refers to the bibliography.

ACCOUNTS OF BORDEAUX INJURY.

Early experimenters with bordeaux mixture in this country reported injury from its use upon the apple, and almost all subsequent workers in the field of experimentation have noted it, though no one seems to have given it careful attention in America. It is not necessary, and I shall not attempt, to give all of the references to bordeaux injury to be found in spraying literature; the following from American authorities are those which seem of special interest from one standpoint or another:

In 1889 Weed[2] states that experiments have shown that, "it is not safe to use bordeaux mixture against apple scab since it injures the apples." Jones[3] found in 1892 that strong bordeaux mixture, "in some cases injured the leaves of the trees (apple) seriously." Green[4] in 1893, says, speaking of bordeaux mixture, "it sometimes causes a russet appearance of the fruit if applied too late." By far the fullest description of bordeaux injury until 1894, was given by Beach.[5] He describes the injury on apples and pears, discusses causes of it and gives lists of apples and pears susceptible to the injury. In 1894 Lodeman[6] also discusses bordeaux injury on apples and pears and gives an account of the microscopic appearance of injured and healthy portions of a Baldwin apple. Jones[7] again records spray injury. The following year Lodeman writes upon the subject at some length in several publications and recommends an excess of lime as a means of lessening the injury. Under the head of "Spotting and Dropping of Apple Leaves Caused by Spraying," Stewart and Eustace[8] give the fullest account of bordeaux injury on foliage up to the time of their writing in 1902. Von Schrenk[9] in writing of spraying for the bitter-rot of apples in 1903 says, "the early spraying resulted in a severe rusting of the fruit during one year." Scott[10] in 1906 gives an account of the injurious effects of spraying with bordeaux mixture to control bitter-rot. He recommends the use of less copper sulphate and more lime.

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[2] Weed (62, p. 188).
[3] Jones (30, p. 32).
[4] Green (26, p. 10).
[5] Beach (9, pp. 20–33).
[6] Lodeman (35).
[7] Jones (31).
[8] Stewart and Eustace (58).
[9] Von Schrenk (62).
[10] Scott (52).

A complete bibliography would require many references to European literature and especially to the works of several Germans who seemingly noted and described bordeaux injury long before and much more fully than experimenters in this country. References are given as this discussion proceeds to such foreign literature on the subject as has been available to the writer.

OCCURRENCE OF BORDEAUX INJURY.

GEOGRAPHICAL OCCURRENCE.

So far as the writer can learn, injury occurs in some degree wherever bordeaux mixture is used upon the apple. It is lessened, but not entirely prevented, by climatic conditions. Correspondence has brought out the fact that it is found in all apple-growing sections of North America, Europe, Australia, Tasmania and New Zealand. The following letters, published in considerable numbers, are but a few of those received reporting the injury.* The letters chosen for publication are those which bring out some special phase of the subject; as, geographical occurrence, severity of the injury, descriptive peculiarities, and in short all statements that will in any way illuminate the subject.

The following are from New York apple growers:

"Nearly one-half the foliage of my ten-acre Baldwin orchard dropped through spray injury the past season. I had the same trouble last year. Formula used was 5 pounds of lime, 5 pounds of copper sulphate, 2 pounds of arsenate of lead and 50 gallons of water. Spraying has done more harm than good for me the past season. Warm, cloudy weather and frequent rains favored the production of the injury."—W. D. AUCHTER, Barnard.

The above orchard is controlled by this Station and was sprayed under its direction.

"This season I have lost about one-half the foliage on a ten-year-old apple orchard. Have suffered in the same way two or three times before, but never so much as this year. I used 18 pounds of copper sulphate, about 12 pounds of lime and 2 pounds of green arsenoid to 150 gallons of water. I used the ferrocyanide test for the bordeaux. Spraying has done more harm than good to my apples the past season. The varieties injured were Winesap and Yellow Newtown."—E. W. BARNS, Middlehope.

"I have had spray injury the past season. I think my crop was lessened about 100 barrels because of the injury. There was no apparent injury to the foliage or fruit till the heavy rains began. The formula used was 10 pounds of copper sulphate to 135 gallons of water, with lime enough to

* See acknowledgments, p. 281.

satisfy the ferrocyanide test. One pound of paris green was added to the above mixture. Continuous heavy rains just after spraying seemed to give favoring conditions for the injury. The *Greening* suffered most, after which came the Fameuse. All the green colored fruit, except Fall Pippin, seemed to be susceptible to the injury, however."—W. A. BASSETT, Interlaken.

Note the influence of the rains.

"Have had some spray injury this season. Last year I had a great deal. My leaves were badly spotted and over half of them fell. I sprayed four times with 6 pounds of copper sulphate and lime to satisfy the ferrocyanide test. This year I have used 4 pounds to 50 gallons of water with the test and an excess of lime to which was added paris green. Rain after spraying, if it comes in an hour or two, does more damage than if dry a week. With me, Baldwin is most susceptible to damage. We have had some of this trouble for the past eight years. With the reduced amount of copper sulphate this year we have had just as good results in controlling the scab and one-half less injury to the leaves."— F. M. BRADLEY, Barker.

"This year, 1905, nearly every tree that we sprayed was injured both in foliage and fruit. The injury can be seen at a great distance, the trees having a brown, russeted, stunted appearance with but little new growth. In making the bordeaux we used 5 pounds of copper sulphate and 5 or 6 pounds of lime to 50 gallons of water, to which was added 8 ounces of paris green. The present wet season seems to be very favorable to the injury. In our orchard Twenty Ounce, Red Astrachan, Fallawater and Baldwin were all badly injured, especially on the lower branches. We sprayed but twice; once before the blossoms opened, and once just after the petals fell. The weather at both sprayings was very favorable to spraying. The mixture dried thoroughly on the trees each time."— DOBSON BROS., Charlotte.

In this case the serious injury reported was done by a spraying just after the blossoms fell, a significant fact.

"The past season some varieties of apples were nearly all thinned off the trees and I lost nearly all of the first leaves in my orchard. Three-year-old trees suffered badly. My fruit has suffered some from spray injury in past years. This year's crop was damaged more than spraying did good. I use 4 pounds of copper sulphate, 6 pounds of lime, 2 pounds of arsenate of lead to 50 gallons of water. A heavy fall of rain followed by bright sunshine seemed to me to give conditions most favorable for spray injury. King, Rhode Island *Greening* and Twenty Ounce are most susceptible to injury in my orchard."— GRANT HITCHINGS, South Onondaga.

Note the severe injury in Mr. Hitchings' orchard in spite of a considerable excess of lime.

"We have had more russeting of fruit the past season than usual and at the same time a good deal of spotting of the foliage. In past years we have always lost more or less foliage and have always had some russeted fruit through spray injury. The formula used is, 12 pounds of copper sulphate with lime enough to correct the acid in accordance with the ferrocyanide test and three-fourths of a pound of paris green to 150 gallons of water. We can see very clearly that the spotting of the leaf and the russeting of the fruit were due to our spraying. We have never been able to spray in such a manner as to do no injury in some places and yet get on enough of the spray mixture to protect the fruit and foliage;— especially in wet seasons, which seem to favor such injury."— C. M. HOOKER AND SONS, Rochester.

" We have had serious spray injury in one orchard of Newtown Pippins. In this orchard I lost fully half the foliage. I use 6 pounds of copper sulphate and 6 pounds of new process lime to 50 gallons of water, the ingredients mixed in fully diluted solutions. To the above I add from one-third to one-half pound of paris green. In answer to your question as to whether spraying has done more harm than good the past season, emphatically, yes. I have used the same material and the same formula for fifteen years and I have never had any injury before. The season with us has been the driest in my recollection. The Newtown Pippins suffered most but all varieties have been injured. I could not believe that spraying caused the trouble at first but five or six trees on a very steep hillside that were not sprayed did not show the injury."— HENRY D. LEWIS, Annandale.

This is the most serious case of injury reported as having occurred in a dry season.

" Rhode Island *Greenings* and some other varieties were badly russeted the past season (1905). I used 7 pounds of copper sulphate and from 12 to 14 pounds of lime and one-half pound of paris green for 100 gallons of water. During the past four years I have had considerable spray injury. In 1902 all of my fruit was russeted and some of it was cracked open. I believe that many hundreds of barrels were destroyed by the spray injury. The mixture contained 10 pounds of copper to 100 gallons of water and the ferrocyanide test was used. In 1903 I took more care in making and applying the bordeaux but still had much damage. In 1904 I further reduced the amount of copper sulphate and yet had considerable injury. In 1905 I greatly increased the amount of lime and was very cautious in making applications but the injury continued though it was not as serious as before. During these four years I have used a power sprayer. Previously I used a hand pump and without serious injury during the ten preceding years. I believe the copper sulphate causes the injury. I am inclined to think also that spraying under high pressure, which causes a very fine spray, and thereby gives a larger amount of material which adheres on the fruit, is also a cause of the difficulty. I have never observed similar injury in unsprayed orchards and I have driven many miles in looking this matter up. I am convinced that such injury is to be found only in sprayed orchards. The varieties most susceptible to spray injury, according to my experience, are Rhode Island *Greening,* McIntosh, Boiken and Twenty Ounce."— W. T. MANN, Barker.

This letter deserves especial attention as it gives a series of experiences all of which throw light on bordeaux injury.

"Last season our apple foliage was spotted and burned and much of it dropped. The fruit was russeted, malformed and reduced in size. In 1904 we sprayed with the same formula with excellent results to the fruit and with but slight injury to foliage. We used 6 pounds of copper sulphate to 50 gallons of water and lime sufficient to satisfy the ferrocyanide test. For an arsenite, 55 ounces of acetate of lead and 20 ounces of arsenite of soda to 50 gallons of the bordeaux. Since we have used a power sprayer and have given the foliage a thorough drenching from above and below, we have had more spray injury than when we used a hand pump and only sprayed from above. Moisture and excessive heat closely following spraying seemed to give favoring conditions for the injury. Some years we have had excellent results without apparent injury, while in other seasons our spraying has either injured the fruit or foliage, or both, and without any apparent reason."— C. E. & E. H. MUNT, Leroy.

It is to be noted that several growers, as above, state that bordeaux injury has come with the advent of power sprayers and thorough spraying whereby more of the spraying mixture is used.

"My fruit was not injured to any great extent the past season but some trees showed considerable injury to the foliage. I have had more or less trouble with this injury ever since we have followed the practice of spraying thoroughly. We used 4 pounds of copper sulphate and double that quantity of lime to 50 gallons of water with white arsenic and sal soda. Do not know which ingredient does the harm but think that spraying during wet time gives conditions under which the injury is liable to occur."— W. E. PALMER, Brockport.

According to Mr. Palmer, more than doubling the amount of lime necessary does not prevent the injury.

"The past season my apples were badly russeted and from 15 to 25 per ct. of foliage dropped. On some trees 50 per ct. of the foliage dropped. In 1903 my fruit was badly russeted but there was no injury to the foliage. In 1904 the foliage was most susceptible to the injury, although the fruit was injured some. I suffered most damage in 1905. I use 8 pounds of copper sulphate and twice as much lime as the ferrocyanide test requires, to 100 gallons of water. To bordeaux so prepared, I add two-thirds of a pound of arsenite of soda. I think the injury is due to the copper sulphate. In our orchards where the trees have been sprayed most thoroughly, the injury has been greatest. I have thought that the injury was due to weather conditions but the varying conditions of the past three years have upset my theories in this regard. King has suffered most after which, in order named, come Baldwin and *Greening*. Another year we shall use a smaller amount of copper sulphate."— F. A. SALISBURY, Phelps.

Attention is called to the great excess of lime used by Mr. Salisbury in spite of which the injury occurs.

"My fruit was badly russeted the past season but was not seriously injured as to size or shape. The foliage was badly injured and much of it turned yellow and dropped during the summer. In past seasons I have had some yellow leaves and some foliage drop but no trouble in comparison with that of 1905. I use 5 pounds of copper sulphate to 50 gallons of water with lime much in excess as determined by the ferrocyanide test. In part of the orchard I have used green arsenoid and in part, paris green. It seems to me that spraying followed by a heavy rain greatly increases the injury. The varieties most susceptible are *Greening,* Hubbardston, Twenty Ounce and Baldwin."— C. K. SCOON, Geneva.

"Nearly every leaf on my trees the past season was burned. The trouble showed as small, brown dead spots, some of which were as large as a kernel of wheat, others larger. There were from 5 to 20 of these dead spots on many leaves. I have had similar trouble in the past but at no time has it been nearly so serious as in 1905. For a 250-gallon tank of water I use 17 pounds of copper sulphate and 25 pounds of lime. To this I add about 1½ pounds of white arsenic cut with concentrated lye. In my opinion this injury is greatest when one sprays most thoroughly and especially if at short range and with steam power. There is more russeting on Twenty Ounce than on any other variety in my orchard. There was considerable injury on *Greenings.* When I began to spray seven or eight years ago, I used 25 pounds of copper sulphate to 30 pounds of lime and 1½ pounds paris green to 250 gallons of water. I now use but 17 pounds of the copper sulphate, having lessened the amount from year to year. *I still use a considerable excess of lime.* I have had the spray injury perhaps one-half of the years but at no time as bad as the season of 1905."— ISAAC W. STEBBINS, Albion.

"In the season just passed, the foliage of our apples was badly spotted and burned and a good many leaves dropped. The fruit was russeted some and a very few were malformed and the size of some was reduced. I have had similar trouble before in wet seasons but never so serious as in 1905. I have never had any such injury in a dry season. I use 10 pounds of copper sulphate, 40 pounds of lime and 8 pounds of arsenate of lead to 200 gallons of water. In part of the orchard I used the arsenite of soda. The trees were spotted about the same as in the part in which I used arsenate of lead. I believe the trouble comes from the copper sulphate. I sprayed immediately after the blossoms fell, in damp, wet weather. The foliage scarcely dried day and night for a week. Some neighbors who waited a week later when the wet weather had passed did not have the spray injury even though they used a stronger bordeaux than did I. Wet, damp, cloudy weather gives favoring conditions for the injury. Three years ago an excess of lime seemed to prevent the injury but it did not this year. Baldwin foliage was hurt most. Twenty Ounce fruit showed most russeting. Northern Spys were not injured on leaf or fruit."— DELOS TENNY, Hilton.

Mr. Tenny's experience clearly shows that weak bordeaux mixture will injure fruit and foliage under unfavorable conditions.

"Nearly all trees sprayed with bordeaux in 1905 were injured so that they dropped many leaves. Much of the fruit was russeted and one-sided. Spraying has done more harm than good in 1905. I have had such injury for four years, and though I have lessened the amount of copper sulphate in the bordeaux, it still continues. I use 5-5-50 formula with an arsenite. The more thoroughly I spray, the more injury I have. The tops of the trees that are hard to reach are the least injured. I have thought that wet weather favored the injury, but I have had the trouble for four years, wet or dry. Wet weather makes the injury show more quickly. Rhode Island *Greening* suffers most. Then Baldwin, Jonathan, and Ben Davis, while the Russets suffer but little."— FLOYD Q. WHITE, Yorktown.

"About 50 of my trees were injured to the extent that more than half the foliage dropped. In the remainder of the orchard the injury was not so great. For the past five years I have had some such injury on the foliage. It seems to be on the increase. I used 5 pounds of sulphate, 3 pints of a white arsenic solution, composed of 10 pounds of white arsenic, 40 pounds of sal soda and 10 gallons of water, to 50 gallons of water. In some instances spraying has done more harm than good the past season. I am inclined to lay the injury to atmospheric conditions, of which wet weather favors spray injury most. Baldwin is most susceptible to the injury. I have four trees which were not sprayed this year and all had first-class foliage."— T. B. WILSON, Halls Corners.

Reports from other states than New York are conflicting as to the possibility of properly made bordeaux mixture injuring fruit or foliage. In seeking information on the subject from the horticulturists of all of the apple-growing states in the Union, I found that a majority of them doubted the possibility of serious harmful effects from the use of this spray. In all parts of the United States, however, experiences were related so nearly identical to those of fruit-growers in New York, that the fact of bordeaux injury wherever bordeaux mixture is used in this country, is established. The following letters from apple-growing regions of America furnish evidence to substantiate the above statement.

"There has been considerable of the so-called spray injury on apples in this section the past season. There were all degrees of the damage seen from a slight russeting to a warty russeted pointed side growth of the apples. These malformations and the russeting were confined almost exclusively to Ben Davis. There was a little of the russeting seen on Coffelt, Winesap, Gano, Shockley and Northern Spy. Arkansas showed some traces of the russeting."— ERNEST WALKER, Horticulturist, Arkansas Station, Fayetteville, Ark.

"There have been some complaints made of spray injury in different parts of Canada, especially in the Maritime provinces, and in the Annapolis

Valley in particular. There have also been complaints along the lake region of Ontario. Sometimes the injury has been very great, reducing the value of the fruit considerably. I have come to the conclusion that the injury is largely due to climatic conditions and that a liquid of any kind on fruit under certain conditions will cause injury, for this russeting occurs on trees which have not been sprayed at all. In the Annapolis Valley and in the lake districts the air is moister, and in moist seasons, especially, I believe that the skin of the apples is more tender than it is where the atmosphere is drier; then, when a spray, or even heavy dew, rests on the fruit during bright sunshine and very hot weather, scalding and russeting follow. The bordeaux mixture and arsenites used generally by fruit growers are: Four pounds bluestone, 4 pounds lime, 40 gallons (Imperial) water, with 4 to 6 ounces of paris green. I do not mean it to be inferred that no injury is done by improperly prepared spray mixtures, but what I do believe is that considerable injury can be done even when mixtures are well made."— W. T. Macoun, Horticulturist, Central Experimental Farm, Ottawa, Can.

"I have just received a report for the season from our field horticulturist at Grand Junction, Mr. Whipple, and in it I find the following item on the subject of bordeaux injury to apples: 'It is found that a bordeaux mixture of 2 pounds of copper sulphate, 4 pounds lime, and 50 gallons water will russet Ben Davis and Gano apples though not to any serious extent, if used on any other than a clear day, and even then russeting may occur on the shaded portions of large trees.'"— W. Paddock, Horticulturist and Botanist, Colorado Station, Fort Collins, Colo.

"I may say we noted some injury from bordeaux spray but not enough to attract much attention. We did, however, reduce the copper sulphate from four to three pounds. We shall not use more than the latter amount the coming season. Have used only paris green as insecticide with the bordeaux."— A. G. Gulley, Horticulturist, Storrs Station, Storrs, Conn.

"This past season I had an experimental spraying for apple scab and codling moth, to test to my satisfaction which is the best insecticide to put in the bordeaux. I used with this Taft's and Kedzie's formulas, paris green, home-made arsenate of lead, and Swift's arsenate of lead. All injury to apples was about the same with all sprays, showing it was not the insecticide. I am convinced it was the bordeaux (and it makes no difference how well it is made) applied the second time to trees just as they were dropping their petals. I am convinced, but need a second year to be absolutely *sure* of it, that it was due to *unpleasant weather* when we put on this spray. It was fearfully windy, accompanied by light rains, and very cold for that time of year. Several men in our neighborhood suffered equally, all apples being distorted, but Jonathans the worst. Another fruit-raiser, Mr. Veatch, did not spray at this time, but about ten days later, and he had *almost no injury,* using same spray as did I, bordeaux and Swift's. Some think it is poor lime, but I do not, for our local lime, with hot water, slakes beautifully, and Mr. Veatch had no injury from the same lime. Mr. Veatch thinks it due to *frost,* but this cannot be, as my check trees, next to those sprayed, showed no injury. I am going at this again next year; using only insecticide at this time with most trees, spray some at just this time with bordeaux and insecticide to serve as checks. I have a bulletin now in press on spraying for scab and moth, and speak of injury. We used 4-4 bordeaux, or eight pounds of each, lime and bluestone, to 100-gallon tank."— L. F. HENDERSON, Entomologist and Plant Pathologist, Idaho Station, Moscow, Idaho.

"In reply to your inquiry of November 16th concerning spray injury in Iowa following the use of the bordeaux mixture will say that I have observed some of this injury to apples in this state but have never known it to be so serious. We have received no complaints from Iowa fruit growers as to injury of this kind. Possibly this may be due in part to the fact that the practice of spraying is not as general here as it is among New York orchardists, but I have the impression that both foliage and fruit of orchard trees are less liable to spray injury in Iowa than they are in New York."— S. A. BEACH, Horticulturist, Iowa Station, Ames, Iowa.

"During the past season there was much of the so-called 'spray injury' in our orchards at Manchester. This was particularly noticeable upon the Baldwins. As to the formula which works this injury, I may say that both the 5-5-50 formula and a 3-5-50 formula resulted in a decided russeting of the fruit. Since in making this mixture, we used prepared or hydrated lime, it has occurred to me that possibly the amount of lime used was insufficient; although it seems to me that with 5 pounds of lime to 3 pounds of copper sulphate such a condition would hardly exist. The usual formula employed in this State is the one which the Station has recommended for several years; this is the 5-5-50 for the bordeaux, adding about 1 pound to 2 pounds arsenate of lead to the 50 gallons of water."—W. W. MUNSON, Pomologist, Maine Station, Orono, Maine.

"The 'spray injury' of the apple has been quite common during the past year. Certain varieties of apples, notably the Jonathan, Ben Davis, Baldwin and Grimes, have been injured quite seriously. I have seen the injury in the orchards of some of our best orchardists. The fruit in our College orchard was more or less affected. There can be no doubt but that the spray was properly made and applied in the right manner, nevertheless, the injury occurred. The formula used in these cases is, 4 pounds bluestone, 6 pounds lime, ½ pound paris green. I do not think the injury is caused entirely by the spray. I have seen it where no spraying was done. But spraying may aggravate it."— S. W. FLETCHER, Associate Horticulturist, Michigan Station, Agricultural College, Mich.

"I think it safe to say that injury has occurred in every orchard in South Missouri (I am unacquainted with conditions in North Missouri) in which bordeaux mixture has been used, regardless of whether it be the successful or unsuccessful orchardist. As a rule the injury has not been serious since 1901. I am of the opinion that the strength of the mixture has little to do with injury to apples. It appears to be more a question of climatic or rather weather conditions, rainy weather following the applications being almost certain to produce some injury, especially to foliage. In some seasons, however, which are comparatively dry, the injury is apparently as bad as in wet seasons. The 4-4-50 or the 5-5-50 formulas are the ones mostly in use. It is difficult to say which has preference. We are inclined now to recommend the 5-5-50. From an experimental standpoint I can give you nothing, as what occurs one year is contradicted the next. Our experiments have been with different strengths of mixtures and thus far we have noticed but little if any difference."— F. W. FAUROT, Assistant in Plant Diseases, Missouri State Fruit Experiment Station, Mountain Grove, Mo.

"There was some injury in most of the orchards visited by me in Nebraska this year. The injury was by no means as serious, however, this year as the year before. During the past year the Nebraska Experiment Station, in co-operation with United States Department of Agriculture, made demonstrations in six orchards in southeastern Nebraska. In some of these the fruit was russeted very slightly, and in several of them the leaves were burned. In case of the Missouri Pippin apple in one or two of the orchards the leaves were injured so much that many of them fell by mid-summer. In no case was the injury permanent, and in most cases the foliage of the sprayed trees was decidedly better in the late summer and fall than was the case with the unsprayed trees.

"I began an experiment on a very small scale to test the effect of different strengths of bordeaux on the russeting of the fruit, using the Jonathan apple for the test. The trees sprayed with 4-4-50 bordeaux showed great injury, many of the fruits being deformed and most of them being russeted. The 4-6-50 bordeaux gave some injury, as did also 3-4-50 bordeaux, but the injury was by no means as serious as in the case of the 4-4-50 mixture. A tree sprayed with 3-6-50 bordeaux showed some injury, though the crop as a whole was almost free from the russet. The peculiar thing about this is, that even with this 3-6-50 mixture a few apples were injured almost as seriously as any of the fruits sprayed with 4-4-50. This, together with some observations made in orchards, leads me to believe that the quantity of spraying material applied at any one time may have something to do with the injury. While I am not certain of this, yet my observations would indicate that where a tree or any part of a tree receives an overdose of bordeaux the apples are apt to be injured."— R. A. EMERSON, Horticulturist, Nebraska Station, Lincoln, Neb.

"There was very little spraying in the orchards of New Hampshire. In our own work this season we sprayed at four widely scattered points in southern New Hampshire and russeted over 95 per ct. of the fruit in every instance where we used the home-made bordeaux mixture, 5-5-50 formula. This was made of fresh stone lime and was carefully tested with the ferrocyanide test and also with a knife blade. As I have previously written you, where we used proprietary bordeaux mixtures in the same orchards we russeted the fruit hardly at all. In most of these cases we used arsenate of lead, but in some paris green and green arsenoid. We are confident that the arsenites have nothing to do with the russeting. I feel quite certain that the trouble is largely due to the cold, wet weather in the spring at the time of spraying. I am inclined to the opinion that in a normal season the same bordeaux mixture would not russet the fruit. I am not able to give any opinion as to how to prevent this injury except to use weaker bordeaux or to use a bordeaux prepared in a different way so that the copper hydrate will be a more stable compound. It appears to me that the proprietary bordeaux may not russet the fruit on this account."— E. D. SANDERSON, Entomologist, New Hampshire Station, Durham, N. H.

"In regard to the bordeaux injury we have some seasons a good deal of it. It is to be found in all sprayed orchards, those of the best of our growers as well as the poorer ones. It is shown in the case of the leaves by a browning of parts of the tissues and still more by the fall of the leaves, either partly brown or yellow. Of course we have similar falling of leaves in unsprayed orchards, but there is no doubt that in certain seasons this is aggravated by spraying. On the fruit the effect is shown in a russeting of the skin. This is particularly noticeable on tender-skinned sorts like the Gravenstein, but to a greater or less extent on all others. The surface will not be uniformly russeted, but it will run in irregular lines and streaks over the surface.

"The formula almost universally used here is 4 pounds of copper sulphate, 4 pounds of lime, 40 gallons of water and 4 to 6 ounces of paris green.

"Russeting of the fruit and damage to the leaves seem more likely to occur where we have a long spell of damp weather without heavy rains, that is, showers, fog, drizzle."— F. C. SEARS, Horticulturist, Agricultural College, Truro, Nova Scotia.

"In reply to your letter regarding spray injury to the apple, I will say that we commonly find more or less of a russet appearance on our apples, due to the spray materials used. This seldom does sufficient harm to injure the apples for market, although in some cases it makes them somewhat unsightly, and very rarely the side which is considerably injured by this russeting fails to develop as fast as the other side of the apple. I think that none of our orchardists is able to avoid this injury altogether, although there is but little complaint concerning it.

"We have experienced another trouble in the yellowing and premature falling of the leaves. This has been worse in wet than in dry seasons, but it has seldom done any appreciable harm. In a few cases it has undoubtedly prevented the development of the apples. The formula which we use for bordeaux mixture is 4 pounds of copper sulphate, 4 pounds of lime. In this we commonly use arsenite of soda. Sometimes we use the arsenate of lead, and often growers use a combination. There are a few who use arsenate of lead alone after the second or third spraying."— W. J. GREEN, Horticulturist, Ohio Station, Wooster, Ohio.

"In regard to the spray injury of apples I have to say that quite a little complaint has reached me this season. The 6-4 formula of bordeaux and paris green have been the materials used when the russeting of the apples was observed and the only explanation given is the cloudy or damp weather following the application."— G. C. BUTZ, Horticulturist, Pennsylvania Station, State College, Pa.

"In general, scorching from bordeaux is very general in the humid coast country. Very frequently it causes as much harm as the scab would have done on unsprayed trees. I have been consulting with Professor Henderson of Idaho, and he states that in the wooded regions of his State scab is prevalent and he has continuously met with this russeting where bordeaux has been used alone or in connection with insecticides. He agrees with me that arsenate of lead with bordeaux has given no greater a percentage of russeting than bordeaux used with paris green or alone. In our spraying in an experiment at Spokane a block of trees was treated with bordeaux of half strength, at the second spraying. This block of trees gave very little increase in scab, but a marked decrease in the amount of russet."— A. L. MELANDER, Entomologist, Washington Station, Pullman, Wash.

The following letters show that bordeaux injury is found in Europe as well as in America.

"In the experiments made in the Station De Pathologie Végétale we have often scorched the leaves of apples and pears spraying with bordeaux mixture. This burning is produced if the mixture is either acid or alkaline, even if the proportion of copper sulphate is small. In preventing this burning we avoid spraying in a wet time and use a mixture containing no more than 1 per ct. of copper sulphate, neutralized *exactly* by the milk of lime diluted considerably. The neutralization of the mixture appears to us to be the condition indispensable to avoid burning the foliage of apples and pears with bordeaux mixture."— DR. GEORGES DELACROIX, Station De Pathologie Végétale, Paris, France.

"When bordeaux mixture is used on fruit trees in Germany the fruits are sometimes injured and less frequently the foliage as well. The most important literature I have seen on this subject is found in the 1903 report of the 'Direktor der Kaiserlichen Biologischen Anstalt für Land-und Forstwirtschaft.' It is stated in this publication that one can sometimes diminish the injury by doubling the quantity of lime ordinarily used. However, bordeaux injury is not entirely avoided by this excess of lime. The cuticle of fruit and leaf is much stronger or weaker according to the weather and for this, and for still other reasons, the resisting ability of the organs varies greatly from year to year, causing a similar variation in the amount and degree of bordeaux injury."— R. ADERHOLD, Dahlem b. Berlin, Germany.

"I have noticed at this institution, at the orchards of the Royal Pomological Institute, and on the trees at the Hungarian State Orchard, the same kind of injury from the use of bordeaux mixture that you describe as having in America.

"The injury occurs for the most part in damp, warm weather without sunshine, when the tissues of the leaves, and especially the cuticle, are very tender and the scorching properties of the copper-lime mixture can act best.

"A small portion of the apple orchard here at the Royal Institute was not treated at the usual time, but at my suggestion it was sprayed with bordeaux mixture eight days after the leaves were fully exposed to the sunshine. There was no injury on the trees so sprayed.

"I have observed similar injuries, with properly prepared bordeaux mixture, on bush beans, grapes, potatoes and peaches when the foliage had not been properly hardened.

"I recommend, in practice, the spraying of a few test plants if it is feared that the leaves are tender; if after two days no injury can be seen the whole plantation can be sprayed.

"It is believed here that the tender-skinned fruits, like the White Winter Calville, must usually suffer from applications of bordeaux mixture.

"I have no knowledge of injury to the foliage of the pear from bordeaux mixture."— DR. EWERT, Proskau bei Oppeln, Germany.

OCCURRENCE ON OTHER FRUITS.

Different species of plants are injured in different degrees by bordeaux mixture. The peach and the Japanese plum are so easily injured that it is seldom profitable to spray them with this compound; a strength of the spray which will control fungi will usually injure the foliage of the trees. Bain's[11] splendid work in laboratory and field shows not only that there are injurious effects from the use of copper compounds on the foliage of the peach, but the manner in which such injury is produced. In spraying practice it is found that the apricot and the Japanese plum behave much as does the peach when sprayed with bordeaux mixture and that the Domestica plum, while not so easily injured, yet not infrequently shows harmful effects on both fruit and foliage. Duggar[12] was one of the first to call attention to the injury of the apricot and plums. The quince and pear suffer in about the same degree as the apple. According to Sturgis[13] bordeaux mixture injured peaches, Japanese plums and apricots, while apples, pears, quinces and European plums were uninjured at the Connecticut Agricultural Experiment Station in 1899. Beach[14] has given a fairly full account of bordeaux injury on the pear, including a description of the trouble and a list of pears injured by spraying.

Since Beach's writing at this Station the list of pears given by him as showing susceptibility to injury has been revised and is here given:

Injured badly.—Angouleme, Anjou, Ansault, Clairgeau, Congress, Doctor Reeder, Easter Beurre, Flemish Beauty, Frederic Clapp, Jones, Lawrence, Tyson and White Doyenne.

Injured but little.— Bartlett, Bosc, Boussock, Garber, Kieffer, Le Conte, Seckel, Sheldon and Winter Nelis.

A number of writers have noted with greater or less detail bordeaux injury of the grape, and Dr. Franz Muth[15] of Oppenheim, Germany, has described such injury in full. In reading his treatise on the subject one is struck with the similarity of the injury to that of the peach as recorded by Bain,[16] and of the apple as set forth here. The conditions favoring the production of the injury of the three widely separated fruits are much the same.

The writer has not concerned himself with the reason for the varying susceptibility of different plants, that phase of the subject

[11] Bain (4).
[12] Duggar (18).
[13] Sturgis (59).
[14] Beach (9, pp. 24-29).
[15] Muth (46).
[16] Bain (4).

belonging to the plant physiologist rather than to the horticulturist. Clark[17] has studied this phase of the subject and has drawn the following conclusion:

"The amount of injury done to a given species will depend on the following considerations, provided always that carefully prepared bordeaux mixture has been used:

"1. The *specific susceptibility* of the protoplasm of the plant to poisoning by copper.

"2. The *solvent properties* of the cell sap on copper hydroxid.

"3. The *permeability of the epidermis or cuticle* to these cell contents when the conditions are favorable for their exosmosis, and for the entrance of the copper after its solution is affected.

"4. Weather conditions following spraying, particularly conditions as regards moisture (dew, etc.), providing the conditions for the exosmosis of some of the contents of the cells of the leaf."

ANOMALIES OF OCCURRENCE.

In the study of bordeaux injury in field and laboratory, many anomalies are found, and in no phase greater than in its local occurrence. The expression is often heard from men who have lost heavily from the injury, "I have sprayed just as in past seasons when I have had no injury." The damage is severe in some seasons, and in others scarcely occurs at all; it is to be found in some localities in a certain season and not in others; in some orchards and not in others though the treatments have been much the same; some report dry seasons most favorable for the injury, others, wet; even in an orchard seemingly uniformly sprayed in all respects, parts of the trees may be injured and not all; there is a great difference in individual trees, some seeming to be far more susceptible to injury than others; in some seasons the injury is most severe on the fruit and in others on the foliage. A variety with immune fruit may have foliage very susceptible to injury. Sometimes the injury is not to be found until several weeks after spraying, while in other cases it may be detected within a few days. Strangest of all, not infrequently very weak bordeaux mixture causes greater injury than a much stronger one used under similar conditions, though usually the stronger the mixture, the greater the injury. Some cases of injury result from the first spraying after blossoms drop and others from a second or third spraying.

[17] Clark (13).

These seeming anomalies are often very suggestive and when grouped and correlated have given important clews for further work. Most of them can be explained, though not all. They are brought about, for most part, as we shall see later, by weather conditions; though the manner of spraying, the kind of nozzle used, and the quantity of the mixture applied, have important bearings upon the occurrence of the injury. Since fertility of soil, cultivation, age of trees, and all conditions which favor the rapid development of foliage make leaves larger and more succulent, these conditions probably make the foliage more tender and susceptible to the injury. At any rate the most thrifty, best kept orchards in which foliage is abundant and healthy, seem most susceptible to bordeaux injury.

DESCRIPTION OF BORDEAUX INJURY.

In describing the injury the writer has confined himself, for most part, to gross characters,—has described the injury as it appears to the fruit-grower. Examinations of portions of diseased leaves and fruits were made under the microscope at different times; but the descriptions of the microscopic characters which are given are not as full as we should like to have them.

THE INJURED FRUIT.

Some of the common names of the injury, as "spray russeting" and "cork russeting," indicate in a very general way the nature of the injury of the fruit. Injured specimens always become more or less rough and russeted and the layers of damaged cells thick and corky. The roughness and russeting vary much in degree with individual fruits. These characters give the fruit the appearance of having been attacked by a fungus and the injury is often taken to be the work of some parasite. The appearance of brightly colored fruit is much marred, not only because of the russet blotches, but the colored portions of the apple are less brilliant. This russeting usually comes as an after effect.

The injury first appears as small, round, black or brown spots or specks resembling fly-specks, usually less than a millimeter in diameter. Unlike apple-scab the spots are regular in shape, smaller and not sunken. The spots are clustered about the basal or the apical half of the fruits depending upon whether the injury comes from a spraying before or after the calyx end of the apples turns downward, as the spraying material adheres in greatest quantity to the upper half of the fruit and does most damage there. A microscopic examination shows that these black points usually start at the basal cells of the hairs which cover the young fruits — or at the stomata which are interspersed between the hairs. It is possible that the comparatively large cells from which the hairs seem to arise permit, through some peculiarity of structure, the entrance of the toxic substance of the bordeaux mixture to a greater extent than do other cells. The stomata give an almost unobstructed entrance to such dissolved substances.

Badly injured specimens are always more or less distorted in shape. Usually the distortions are of the nature of a shrinkage of the injured portion of the fruit; but not infrequently they are unsightly, teat-like malformations as shown in Plate XVII; in half-grown fruits, gaping cracks, reaching into the flesh, often appear (Plate XVI), which, as the fruits come to full size, grow over leaving a rough sunken scar. There is no evidence of fungi in these cracks. The russeting mentioned in the previous paragraph seldom injures the appearance of fruits except for fancy trade, but when accompanied with the distortions, malformations or cracking, the fruit is ruined for commercial purposes.

KEEPING QUALITIES OF INJURED FRUIT.

In the winter of 1905, F. C. Stewart, Botanist of this Station, called attention to the fact that spray-injured apples in his cellar were not keeping well. Upon investigation it was found that injured stored fruit, whether in cellar or in cold storage, did not keep as well as uninjured fruits in the same packages. A marked difference can be noted in an individual fruit, one side of which is injured. The part of an apple showing russeting from bordeaux mixture gives up its moisture more rapidly than the uninjured portion and becomes soft and flabby. In a comparatively dry room, as a store-room or a living-room, the moisture is given off very quickly and the flesh in extreme cases turns brown as if bruised or exposed to the air. Or, affected parts often become mealy. Decay sets in quickly. With late-keeping apples, as Baldwin and Rhode Island *Greening*, this effect upon the keeping qualities of the fruit is an important phase of bordeaux injury, as no matter how slight the injury, the keeping quality is affected to some degree.

The season of injured apples kept in cold storage is not greatly shortened and the other effects noted are not pronounced. An investigation of the keeping qualities of injured fruit in cold storage by correspondence with a number of the leading apple storage men of the State brought out the fact that they had but little to fear from storing russeted fruit. But a similar investigation among retailers showed that such fruit was not wanted because it kept poorly when exposed to the air or in a dry atmosphere.

The following brief description of the microscopic characters of the russeted epidermis of an apple enables one to see why shriveling and decay set in more quickly with injured than with sound apples.

MICROSCOPIC CHARACTERS OF BORDEAUX INJURY ON FRUIT.

A study of the structure of the skin of the apple shows that this heavy outer covering is composed of comparatively large cells whose outer walls are thick, strong and cutinized.[18] Over these outer cutinized membranes is the cuticle proper. Outside of this cuticle we have still further, with many varieties, a coating of a bluish white, waxy substance, the bloom. On still other varieties, or with all of the russet apples, there is here and there, or covering the whole surface of the fruit, a yellow-brown or gray-brown rough, corky condition of the outer part of the epidermis. The number of layers of cells in the epidermis of an apple seems to vary from two to five or more. The cells of the fruit flesh, directly underneath the epidermis, are small, flattened by tangential stretching, and have comparatively thick walls. Toward the center of the fruit the cells increase in size and their walls become thinner and soon they become large, true, flesh cells with nearly equal diameters.

A comparison of the epidermis of a bordeaux-injured apple with that of a healthy one shows that the waxy covering, the cuticle proper, and many of the cells of the epidermal layers have been destroyed. (Plate XX.) Such epidermal cells as remain, and those of the fruit flesh which are injured, have much thickened walls, of a brown, corky appearance. The more severe the injury, the thicker this corky condition. In some cases it is very superficial, involving, as nearly as can be ascertained, but one or two cell layers; in other cases, four, six, eight and sometimes ten layers of cells are destroyed. No attempt was made to ascertain whether the cell injuries are of a physiological or of a mechanical nature, this field of investigation belonging more properly to others; but

[18] Tschokke (61).

it is reasonable to assume that some of the changes in the cellular structure are due to healing processes since it is known that irritations of many kinds, as rubbing against a branch, heal similarly in many tree fruits. It seems certain, as will be shown later on, that the toxic substance in the bordeaux mixture combines with the cell contents and is stored up in the dead cells, and that the poisoning or corrosion, as the case may be, does not spread from cell to cell; only the cells in which the toxic compound enters are affected.

The amount of injury varies greatly with: (1) The structure of the skin (there is great variation in the skins of apples of different varieties). (2) The condition of the skin as to the age of fruit and the succulency or tenderness from weather conditions. (3) It is not improbable that the chemical constituents of the cell juices may hinder the toxic action of the bordeaux mixture in some varieties, thus in part accounting for comparative immunity.

This brief study of the skin of the apple under normal and the diseased conditions indicates why we should expect injured fruits to keep poorly. The skin is the protective organ. When wholly or partially destroyed, as in bordeaux injury, the doors are open for the escape of moisture through evaporation and for the entrance of the germs of decay.

RORDEAUX INJURY OF THE FOLIAGE.

On the foliage bordeaux injury very greatly resembles the leaf spot supposed to be caused by any one of several fungi. The affected leaves first show dead, brown spots; the majority of these spots are circular or roundish with a diameter of two or three millimeters, but they may be of various shapes and sizes; many are of irregular outline and so large as to appear to have been caused by the coalescing of smaller spots. The line of demarcation between the dead tissue of the spots and the living green of the leaf is well marked so that the spots are very conspicuous. Quickly following the appearance of the brown spots the remaining tissues begin to turn yellow and this usually continues until the living tissue is of a yellowish color when the leaves fall, the petioles breaking from the stem as in natural falling. When the injury is slight the yellowing may not appear, in which case the leaves do not drop. In general, the injury on the leaves of all varieties, so far as I have been able to observe, is of the same character.

Sprayed and unsprayed trees in orchards suffering from bordeaux injury present a marked contrast. One can note the difference as far as green can be distinguished from yellow. A visit to such an orchard convinces one that spraying with bordeaux causes the injury and shows the amount of damage that can be done by spraying. The trees not infrequently are so damaged as to appear to have been scorched. Slight degrees of injury can be best seen by standing under a sprayed tree and looking through the foliage toward the light.

The falling of the foliage varies much in an orchard in accordance with the variety and even with individuals of a variety. It may take place within two weeks from the time of spraying or it may continue for as many months. The number of leaves that fall varies, of course, with the degree of injury; it ranges from a slight sprinkling on the ground to defoliation. A fair average in the bordeaux-injured apple trees of western New York for the season of 1905 is from one-third to one-half. Craig[19] reports that in an experiment carried on by him in this State in 1906, he found 2,500 leaves upon a square yard beneath an apple tree sprayed with bordeaux mixture made with four pounds of copper sulphate, forty gallons of water, and lime to satisfy the ferrocyanide test.

BORDEAUX INJURY OF BLOSSOMS.

It is not necessary to spray the apple while in bloom and such spraying is seldom practiced in New York. A discussion of bordeaux injury of blossoms has, therefore, but little practical significance; but since blossoms are modified foliar organs, it may throw some light on the injury of leaves to know how the bordeaux mixture affects the blossoms. Beach and Bailey[20] conducted extensive experiments in 1900 on spraying in bloom and their conclusions in regard to the injury of blossoms are as follows:

"In some cases the spray mixture had a corrosive effect and killed the tissues of the stamens and pistils. In other cases pistils with particles of the spray mixture on the stigmatic surfaces awaited fertilization for several days, apparently unharmed and perfectly healthy, but eventually withered and died. A number of blossoms were observed which showed particles of spray

[19] Craig (15, p. 3).
[20] Beach and Bailey (10, p. 443).

mixture on the stigmatic surfaces but none of these set fruit. It appears, therefore, that in these cases the spray mixture inhibited the process of fertilization and thus eventually caused the death of the entire blossom.

"Blossoms which had been open several days before they were sprayed seem to have reached a stage where the treatment did not check the progress of fertilization, and the fruit set as abundantly as it did from corresponding blossoms which were not sprayed."

From theoretical considerations one would expect that the blossoms of fruits would suffer greater injury than foliage; for the floral organs lack the protective cuticle of leaves, and the cellular tissue is more delicate in structure than the tissues of leaves. It is probable, too, that the secretions from the nectaries and the stigmas would have a solvent action on the copper salts. The structure of the flower is such that moisture is retained longer than by leaves and its action on the copper compound would be to bring more or less of the latter into solution.

INJURIES SIMILAR TO BORDEAUX INJURY.

It is hard to convince fruit growers, and some experimenters as well, of the fact of bordeaux injury. Their argument is that such injuries occur in unsprayed orchards. It is true that there are similar injuries caused by other agents, some of which are often confused with the trouble under discussion. It is necessary to distinguish between these various injuries.

INJURY FROM THE ARSENITES.

When used in too great quantity, improperly prepared, or under very favorable conditions, the arsenites may injure foliage as does bordeaux mixture. In fact, bordeaux injury is often ascribed to an arsenite, the two compounds being usually combined in spraying the apple in New York. There are but few apple growers in this State who have suffered from bordeaux injury that have not satisfied themselves by the simple experiment of spraying without the one or the other as to which of the compounds injures fruit and leaves. In our experiments we have hardly considered the possibility of injury from the arsenite, and the check trees sprayed with arsenate of lead without injury shows that there was no necessity for such consideration.

Injury from an arsenite may or may not differ from that caused by bordeaux mixture. In my own experience injury from the former, usually arsenite of lime, has followed almost immediately, within a day or two, and consisted of a blackening of the parts damaged, the injured portions consisting of large blotches or a whole leaf and if only a part of the leaf was affected the remaining portion withered. My attention has only been called to extreme cases and these Woodworth and Colby[21] designate as the *acute* poisoning of arsenic and describe a *chronic* poisoning which more nearly resembles bordeaux injury. The following is their description of the two forms:

"While paris green is entirely insoluble in pure water, it appears that as ordinarily used a certain amount of it does find its way into solution and thus enters the plant; and if very much goes in, the death of the part of the plant thus poisoned ensues. The most critical period seems to be the time during which the spray remains wet upon the leaf, and each subsequent wetting of the leaf from any cause, such as fog or dew, continues the danger. It has been demonstrated repeatedly that dry paris green can be placed upon a leaf in any quantity, and so long as the leaf remains dry no evil results will follow. After an application in the wet way, almost immediately, within twenty-four hours, a blackening of the leaf, or of parts of the leaf may occur, or the leaf may entirely escape at that time, but later, after a dew or fog, show the signs of the action of the poison; or again, there may be no blackening of the leaf observed at any time, but the leaf may become prematurely yellow and drop off within two or three weeks from the time the application was made; showing that the poison which entered the plant, though not enough to kill it at once, deranged its functions to such an extent as to cause this premature dropping. These two forms of poisoning we have designated as the *acute* and the *chronic* poisoning of arsenic."

After having investigated every supposed case of injury from an arsenite of which I could hear in 1906, and after much correspondence with those who have had injury in previous years which they ascribed to an arsenite, I am quite convinced that there is but little injury from this source to apple foliage in New York. Practically all of the growers in this State use lime to prevent arsenical injury, and with success.

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[21] Woodworth and Colby (64, p. 11).

FROST INJURY.

Frost causes a very similar russeting of the fruit; and injury from the two causes is often confused. Usually it is not difficult to distinguish between them, however. Frost russeting on fruit nearly always appears in bands or zones of greater or less width running around the fruit midway between base and apex. Whenever russeted fruits in any considerable number show this banded appearance it is safe to attribute the injury to frost. In most cases, too, the corky, russeted layer is not so thick and is smoother, there being far less of the tissue injured. Frost injury is not commonly found on many fruits in an orchard and is usually confined to certain trees in a low, frosty situation, or the limbs of a tree most exposed to frost action. Frost injury on the fruit is almost always associated with some injury from the same source on the foliage and this is radically different from bordeaux injury of the foliage.

Stewart and Eustace[22] of this Station, describe frost injury on the foliage as follows:

" On the upper surface the leaves were variously wrinkled and puckered, but the under surface was fairly even and normal in appearance except for certain areas on which the color was gray-green. On some trees the leaves were badly distorted with the margins drawn downward and together as if they were unable to unfold properly. Usually the wrinkles were most abundant along the mid-rib of the leaf and the elevated portions were of a somewhat lighter green than the other parts of the leaf. By cutting across the leaf with scissors it was found that where the wrinkles occur the lower epidermis is separated from the green, pulpy tissue (mesophyll), thus forming a large interior cavity or blister. The distance between the green tissue and the loosened epidermis was frequently as much as four millimeters (one-sixth of an inch), and the blisters thus formed were of all sizes up to those having an area of 100 square millimeters or even more. In many cases the separated epidermis became ruptured as if slit with a knife, leaving the cells of the mesophyll exposed. Sometimes the tender cells thus exposed died, causing the formation of an irregular, dead, brown spot, visible on both surfaces of the leaf. However, in the majority of cases the exposed cells remained green throughout the season."

[22] Stewart and Eustace (58, p. 218).

A passing glance will enable one to distinguish between the two kinds of injury on fruit or foliage and they need never be confused if an examination be made of even their gross characters.

INJURIES FROM FUNGI.

Not infrequently the scab fungus of the apple and pear (*Venturia inæqualis* (Cke.) Aderh.) causes russeting and malformation similar to that described as coming from bordeaux injury. Such russeting occurs very often on pears and even on the apple, when the scab spots are seemingly being thrown off by the healthy growth of the apple; one sometimes needs to make a critical examination to determine whether a russeted blotch is due to injury or to a fungus. F. C. Stewart, Botanist of this Station, tells me that there is an undetermined fungus which causes the russeting of the Kieffer pear in this locality and that its work, under some conditions, might easily be mistaken for bordeaux injury.

Reference has already been made to the resemblance between bordeaux injury on leaves and the supposed work of certain fungi, as by species of *Phyllosticta*. Stewart and Eustace[23] found in the summer of 1902, that the spots caused by bordeaux injury were free from the pycnidia of *Phyllosticta* in early summer, July 10, but that later, August 28, the majority of the spots were inhabited by a species of *Phyllosticta*. These writers raise the question as to whether much of the so-called leaf-spot of the apple attributed to species of the above fungus may not be primarily due to bordeaux injury, the fungus being a saprophyte rather than a parasite. They say:

"So far as known to the writers, the parasitism of the apple Phyllosticta has not been previously questioned. In the past the presence of the *Phyllosticta* pycnidia on circular, dead brown spots on apple leaves has been considered conclusive evidence that the spots were caused by the *Phyllosticta*, and the disease has been promptly diagnosed as leaf-spot. In the future the problem of determining the cause of such spots on apple leaves will be a more difficult one. It is our opinion that at least a large part of the so-called apple leaf-spot is due to spray injury and weather conditions and is not of fungus origin."

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[23] Stewart and Eustace (58, p. 232).

BLISTER MITE INJURY.

In Bulletin No. 283 of this Station, P. J. Parrott, Station Entomologist, speaks of the confusion of mite injury with bordeaux injury and clearly indicates the distinction between the two:

"Injuries by the mite and by spraying mixtures often appear upon the same leaf and have been much confused. The two are quite distinct and may be easily distinguished. Injuries due to treatment by the bordeaux-arsenical mixtures appear as dead brown spots of various sizes and shapes, and are irregularly distributed over the leaf surface. Frequently these spots are roundish or circular with a diameter of one-twelfth to one-eighth of an inch, while others are irregular in outline and much larger. Although the line of demarcation between the dead and living tissue is sharp, these spots are to the touch flat, often depressed, and are not in this manner distinguishable from the general surface of the leaf as are the mite-blisters. Spray-injured spots show the venation of the leaf which is seldom apparent in the mite galls, and the dead areas also lack the small hole leading to the interior, which is always present in the corky spots produced by mites."

INJURY FROM THE LENS ACTION OF DROPS OF WATER AND BRIGHT SUNSHINE.

Beyond question the lens action of drops of water on leaves in bright sunshine may injure them. The drops of water act as lenses and concentrate the sun's rays so as to burn the tissues beneath. Schander[24] says that Von den Planitz places the responsibility of the cork-like russeting of the fruit on this agency. He also says that injurious action may be observed at times on the leaves when sprayed in too strong sunlight. Duggar[25] gives an account of a case in which bright sunshine following rain caused the appearance of "shot-holes" in peach leaves. Such lens action of drops of water in sunshine is not uncommon in greenhouses and serious damage often results in this way. In an orchard, such injury might follow a burst of sunshine either after spraying or after a shower.

An attempt was made to investigate lens action as a possible cause of fruit-russeting and leaf-dropping in connection with the work of this experiment, but the results were not such as to lead

[24] Schander (53, p. 578).

[25] Duggar (18, p. 388).

me to believe that much damage is done in this way. Under some conditions lens action might aggravate bordeaux injury, and under some, possibly, it might do damage worthy of note, but the latter I regard as doubtful.

INJURY FROM LIME.

Many apple growers who have used an excess of lime attribute the russeting of the fruit, and some say the spotting and dropping of leaves, to the lime. I cannot find anything to substantiate this belief in the work of this season, where many trees sprayed with bordeaux mixture containing an excess of lime came under my observation, the excess ranging from the same amounts of copper sulphate and lime to four times as much lime. A Rhode Island *Greening* tree sprayed twice with sixteen pounds of lime to forty gallons of water, with an interval of ten days between the applications, showed no injury. Neither can I find any record of injury to the apple through the use of slaked lime.

I have seen injury on the young leaves and shoots of a pear tree dusted with unslaked lime for the pear slug, but it had no resemblance to the spotting and yellowing of leaves through bordeaux injury. In this case the unslaked lime caused the leaves and shoots to wither and dry up, and the leaves which were badly burned by the lime dropped almost immediately. It is barely possible that lime improperly slaked, or of poor quality, may injure the tender tissues of small apples or of young leaves, but it is doubtful if such injury is ever sufficient for consideration.

IMMUNITY OF VARIETIES.

Some varieties of apples are injured much less than others by bordeaux mixture and there is a wide range in this variation in immunity. Such variations are inherent in the variety and do not depend on season or other conditions of environment. Fruit and foliage do not always show the same degree of immunity; that is a variety may be susceptible to the injury on the fruit and comparatively immune in the foliage, or the reverse. In 1894 Beach[26] published from this Station a classified list of apples of which the fruit is injured by spraying. In the twelve years that have followed, it has been possible to revise and add to this list, especially favorable opportunities occurring in 1905 and 1906; the following is the revised list:

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[26] Beach (9, p. 31).

APPLES CLASSIFIED AS TO IMMUNITY TO BORDEAUX INJURY.

1. *No injury or very slight.*— Alexander,* Akin, Bietigheimer, Bloomfield, Baxter, Canada Baldwin, Doctor, Doctor Walker, Deacon Jones, Domine, Early Harvest, Esopus *Spitzenburg,* Fall Pippin, Fall Wine, Fishkill, Florence, Gano, Golden Russet, Judson, Keswick, Northern Spy, Oliver, Perry, Pomme Grise, Ralls, Red Canada, Richard Early Winter, Rome, Roxbury, Rutledge, Smokehouse, Stump, Swaar, Titovaka,* Tompkins King, Yellow Bellflower.

2. *Slight injury.*— Buckingham, Chenango, Clayton, Elgin Pippin, Fallawater, Fameuse, Fanny, Gideon, Grimes, Haas, Holland Winter, Hubbardston, Jewett, Karabovka,* Lady, Lady Sweet, Landsberg, Louise, McIntosh, McMahon, Maiden Blush, Monroe Sweet, Munson, Oldenburg,* Ontario, Pawaukee, Primate, Prince Albert, Pumpkin Sweet, Red Astrachan,* Reinette Pippin, Saint Lawrence, Shannon, Standard, Stark, Sutton, Tetofsky,* Tolman *Sweet,* Tufts, Wallace Howard, Washington Strawberry, Western Beauty, Williams, Wolf River, York Imperial. Crabapples.— Excelsior, Montreal Beauty.

3. *Badly injured.*—Autumn Streaked,* Barry, Belborodooskoe,* Ben Davis, Borsdorf,* Boskoop, Canada Reinette, Constantine,* Cooper Market, Czar Thorn,* Ewalt, Flory, Golden Sweet, Gravenstein, Hurlbut, Jefferis, Jersey Sweet, Kalkidon,* Lankford, Late Dutchess,* Longfield,* Milden, Milwaukee, Monmouth, Mother, Nero, Newman, Northwestern *Greening,* Ostrakoff,* Paragon, Parry White, Peck *Pleasant,* Peter, Rambo, Red June, Scott, Smith Cider, Sops of Wine, Switzer,* Wagener Improved, Walbridge, Washington Royal, Wealthy, White Pippin, Windsor, Winesap, Workaroe,* Yellow Newtown, Yellow Transparent.* Crabapples.— Chicago, Coral, Hyslop, Martha, Paul Imperial, September, Transcendent, Whitney.

4. *Very badly injured.*— Baldwin, Collamer, Jonathan, Mann, Red Transparent,* Repka,* Rhode Island *Greening,* Romna,* Saint Peter,* Twenty Ounce, Vineuse Rouge,* Winter Banana, Wagener, Yellow Calville.*

This classification shows, as did the one prepared by Beach in 1894, that crabapples and the Russian varieties are usually more susceptible to bordeaux injury than other varieties. The fact is better shown in the following table:

Table I.— Classification of Apples as to Immunity to Bordeaux Injury.

Class.	Injury.	Crabapples.		Russian apples.		Other apples.	
		No.	*Per ct.*	*No.*	*Per ct.*	*No.*	*Per ct.*
1.....	No injury or very slight.	......	......	2	8.3	34	28.3
2.....	Slight injury..........	2	20	4	16.7	41	34.2
3.....	Badly injured.........	8	80	12	50.0	37	30.8
4.....	Very badly injured.....	......	......	6	25.0	8	6.7

Attention should be called to the fact that while Russian apples as a class are susceptible to bordeaux injury, yet some of the most

* Russian varieties.

valuable of them are immune. Thus Alexander, Oldenburg, Red Astrachan, Tetofsky and Titovaka are classed with the sorts which show no injury or very slight injury.

Immunity to bordeaux injury does not correspond with the immunity to the apple scab fungus; many examples may be noted, some of which follow: Early Harvest, Esopus *Spitzenburg*, Fall Pippin, Northern Spy and Red Canada are all very susceptible to the scab fungus in the Station orchards, but none of them were injured by bordeaux mixture, or if so, but very slightly. So, too, we find in the list of sorts slightly injured by bordeaux mixture the following very susceptible to scab: Chenango, Fameuse, Louise, McIntosh and Primate. Coming to the sorts that are badly injured by the spray we find Ben Davis, Gravenstein, Mother, Northwestern *Greening*, Wealthy, Yellow Newtown and Yellow Transparent not subject to scab. Of those very badly injured by bordeaux mixture, Jonathan and Wagener are not subject to attacks of the scab fungus.

A few sorts are subject to the injury and to the scab in like degree as follows: Alexander, Gano, Rome, Roxbury, Swaar and Tompkins King are nearly immune to the scab and the injury. So, too, Grimes, Hubbardston, Oldenburg, Red Astrachan, Sutton and Tolman *Sweet* are but slightly injured by bordeaux mixture and are free from scab in most seasons. Red June, Rhode Island *Greening* and Twenty Ounce are the most conspicuous examples of sorts very susceptible to both bordeaux injury and the apple scab.

The comparative immunity of varieties to both the bordeaux injury and to the scab should be considered in selecting varieties for planting. From the data it appears for the most part that varieties immune to the one are susceptible to the other; though it should be said that our data regarding immunity to scab are not as reliable nor extensive as those pertaining to bordeaux injury, and hence the conclusion that varieties do not show like immunity to the two troubles is not as well established as we should like it to be.

THE CHEMICAL AND PHYSICAL COMPOSITION OF BORDEAUX MIXTURE.

A clear understanding of the injurious action of bordeaux mixture on plants cannot be had without some knowledge of the chemical and physical composition of the compound. Fortunately this ground has been well covered by Chester,[27] Fairchild,[28] Lodeman[29] and Swingle[30] in this country, and by many workers in Europe, references to whose work are found in the bibliography at the close of this bulletin. Further efforts at study of the chemistry of bordeaux mixture seemed needless. The following presentation of the nature of bordeaux mixture is taken from the work of the above men. It is hardly necessary to say that this phase of the subject is not treated exhaustively; rather, the intention is to make the discussion as brief and concise as possible and yet give the main facts.

Bordeaux mixture is made by stirring together a solution of copper sulphate and the milk of lime, the latter being obtained by adding water to freshly slaked lime. Copper sulphate is acid and as such, in any considerable quantity, injures the tissues of plants, and the milk of lime is added in sufficient quantities to combine with *all* of the copper sulphate so that the mixture gives an alkaline reaction. It does not require as much lime by weight to secure this alkaline reaction as there is copper sulphate in the mixture, but in practice at least, equal parts of lime and the copper sulphate are used, and a considerably greater excess of lime is very commonly used. To secure a proper chemical and physical combination, chemists recommend that the solution of copper sulphate and the milk of lime be greatly diluted before they are combined and that both diluted portions be cold.

The name bordeaux mixture is not confined to any exact formula containing the above ingredients, but is given to any mixture of copper sulphate, lime and water used for spraying purposes. The name comes from Bordeaux, France, where the mixture first came in use. The year 1882 is given as the time of the discovery of the fungicidal properties of the bordeaux mixture. Several men claim the honor of having discovered the fungicidal value of the copper compounds, but A. Millardet[31] was the first to plan tests and publish results which showed their value in commercial work. Its introduction in the United States dates from 1886, when a circular was issued from the United States Department of Agriculture calling attention to its merits in controlling diseases of grapes.

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[27] Chester (11). [28] Fairchild (20).
[29] Lodeman (37). [30] Swingle (60).
[31] Millardet (40).

Twenty years of experimentation with copper compounds have given us none equal to bordeaux mixture. The value of copper as a fungicide was known long before the discovery of this mixture, but no compound of copper was known before, nor has been discovered since, which is so cheap, easily prepared, convenient to apply, adhesive to plants, safe to use, and withal so efficient a fungicide as bordeaux mixture.

When properly made, and fresh, bordeaux mixture is light blue, robin-egg, or sky-blue, in color. If there be an insufficiency of lime, the mixture is greenish-blue; the greater the excess of lime, the lighter the color. When exposed to the air for some time it becomes a dirty blue-green. Unexposed to the action of the air, bordeaux mixture can be held indefinitely without apparent change in chemical composition. As a liquid it is thick, but not viscid, though it lacks mobility.

When the ingredients of bordeaux mixture are combined a heavy precipitate forms at once. The character of this precipitate depends upon the formula used; upon the diluteness of the solutions; the character of the lime; the temperature of the solution; and somewhat upon other minor factors as the kind of water, exposure to air, and the quantity of the mixture being made. But the physical characters are, in a general way, the same in all mixtures prepared under normal conditions. Roughly speaking the precipitate is a gelatinous mass. Examined under the microscope it is found to be somewhat granular and crystalline as well as gelatinous. A most important physical character of well-made bordeaux mixture is that it is very adhesive. When well dried on sprayed foliage, wind does not affect it and only long-continued washing with rain removes it. This adhesive property of bordeaux mixture is one of its chief points of merit. Sometimes soap, sugar or molasses is added to increase this adhesive quality, but these are of doubtful value.

The chemistry of bordeaux mixture, though seemingly simple, is somewhat complex. The compounds formed vary greatly, as we have seen, with the proportions of the ingredients used and with the conditions under which the mixture is made. Since there is so much variance in the chemical composition, and since chemists who have studied it do not wholly agree, it is of little value to go into the details of the various changes thought to take place in combining copper sulphate and lime solutions. Only such parts of its chemistry as are well agreed upon need be mentioned here.

When a solution of copper sulphate and the milk of lime are combined the resulting mixture is a saturated solution of calcium sulphate and calcium hydroxide holding in suspension in solid form copper hydroxide and calcium sulphate. While the semi-solid mass of the precipitate is gelatinous in character, it contains, as before stated, some granules and some crystals. The particles of solid matter are crystals of calcium sulphate, and after standing a short time crystals of copper hydroxide. Interspersed in the gelatinous mass are generally to be seen small, dark blue, irregular, spherical bodies. According to Schander[32] these are small grains of uncombined calcium hydroxide which have been covered by fine particles of copper hydroxide. Schander holds that these bodies greatly diminish the action of the bordeaux mixture on the spores of fungi and lessen the adhesive power. The particles can be avoided in part, the same writer asserts, by a slow and complete slaking of the lime or by slaking the lime and pouring it through a fine sieve.

One important character of bordeaux mixture is agreed upon by all chemists; namely, that all but a trace of the copper is in the form of an insoluble precipitate. The clear liquid above this precipitate, which always forms when the mixture stands, has no value as a fungicide, the precipitate containing all of the fungicidal properties. The precipitate must therefore be kept in uniform suspension by agitation when spraying.

When bordeaux mixture is exposed to the air marked changes at once take place. The excess of lime is changed by the carbonic acid in the air into carbonate of lime, forming as a crust on the surface of the superimposed liquid. When the lime has been transformed into calcium carbonate, the copper hydroxide is changed by the action of the air into copper carbonate.

This change is greatly hastened by rain, dew or even a moist atmosphere if the mixture has been applied to foliage. When this change takes place in a considerable quantity of the mixture, the dirty, blue-green color hitherto mentioned is assumed. At the same time the precipitate becomes much more granular in character.

The greater the excess of lime, the slower the above changes take place; the greater the exposure to the air, the quicker the changes occur. Clark,[33] Bain,[34] Schander,[35] Swingle,[36] and others state that substances secreted by the cells of the plant sprayed or

[32] Schander (53, p. 519).

[33] Clark (13, p. 43). [34] Bain (4, p. 93). [35] Schander (53, p. 578). [36] Swingle (60, p. 21).

by the germinating spores of fungi bring about changes, the most important of which is the bringing into solution of small amounts of copper. Since the mixture is brought into a fine state of division in spraying, the above changes take place very rapidly on foliage where atmospheric agencies have easy access to the small particles. In this condition the copper is especially easily acted upon by the carbonic acid in the air and more or less of it is dissolved.

THE TOXIC ACTION OF BORDEAUX MIXTURE.

The toxicology of bordeaux mixture in relation to both fungi and host has been studied by many investigators, chief of which are Rumm,[37] Fairchild,[38] Zucker,[39] Swingle,[40] Aderhold,[41] Miani,[42] Clark,[43] Bain,[44] and Schander.[45] Space does not permit a discussion of the theories set forth by these investigators and I am able to present here but a brief summary of their conclusions. The results of investigation in this field may be roughly grouped into two classes.

I. Small quantities of copper are dissolved by rain, dew, or a moist atmosphere and pass through the epidermis of leaf or fruit to the interior with harmful effects.

Bain[46] seems to have been the first worker to present evidence in support of the above theory from direct experimentation though other writers had suspected the part played by meteoric moisture. Bain states his conclusions drawn from carefully conducted experiments on peach foliage as follows:

"1. Bordeaux mixture and pure basic copper produce no injury to peach foliage if no liquid water accompanies them.

"2. In a saturated atmosphere, where water is not deposited on the leaves, there results no injury from bordeaux mixture, and but little from pure copper hydroxide; this injury is also probably less than in a dry atmosphere under like conditions, even if water be present.

"3. When protected from direct sunlight even the presence of water does not call forth this injury to peach foliage; but whether its immunity under these conditions is due to less light, less heat, or absence of strong air currents, or to the combined action of all these circumstances does not appear from these investigations.

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[37] Rumm (48, 49, 50, 51). [38] Fairchild (20, p. 26). [39] Zucker (66) [40] Swingle (60, p. 21,33). [41] Aderhold (1). [42] Miani (39).
[43] Clark (13). [44] Bain (4). [45] Schander (53).
[46] Bain (4, p. 51).

"4. While no direct experiments were made to test this matter, it is still very probable that all the above-mentioned conditions hold true likewise of the foliage of the apple and the grape.

"5. Applied to practical orchard conditions, these results mean that rain in the daytime and, probably, the dew first falling in the evening are pre-eminently the determining factors in the injury of copper fungicides to foliage, the mere presence of dew or rain-water on the leaves in the dark influencing this action to only a very slight extent. The outermost leaves on a sprayed tree being most exposed to dew, rain and sunshine are the first to suffer injury, those on the interior following in regular order the falling of the more exposed leaves toward the ends of the branches."

II. Leaves and fruit secrete fluids which dissolve small amounts of copper hydroxide after which the dissolved copper salt finds its way into the cellular tissue and death results to the cells reached by the copper solution.

Of these secretions Schander[47] says:

"1. The plant secretes acids, and dissolves therewith small amounts of copper hydroxide, after which the dissolved copper salt works through the walls into the leaf cells and kills them. I found this mode of toxic action in Fuchsia and Oenothera.

"2. The fluids secreted by the leaves react as alkalis as in *Phaseolus multiflorus*. I believe that the toxic action of bordeaux upon Phaseolus leaves must be ascribed to this condition, although I was unable to establish soluble copper salts in a secreted fluid in which I put a drop of equally alkaline reacting bordeaux mixture. These plants, however, secrete a very small amount of liquid, so that I could obtain this only drop by drop for my experiments. Alkalis, indeed, only act as solvents of copper hydroxide when they are in excess."

In 1891 Galloway[48] conducted an experiment on the pear in which he found that injury came from the use of air-slaked lime instead of fresh lime. He lets the inference stand that all such injury comes from the use of air-slaked lime. Fairchild[49] agrees with Galloway, as shown by the following: "Numerous cases have been recorded of serious injury to the foliage from its use. Weed, Göthe, Chester and Galloway have shown its occasional injurious

[47] Schander (53, p. 579).
[48] Galloway (23, p. 40).
[49] Fairchild (20, p. 26).

nature. But as pointed out by Galloway and Göthe, and corroborated by a knowledge of the chemical composition of the mixture, this injury is owing to the use of air-slaked lime in its preparation. It is probable that the use of air-slaked lime not only causes injury from leaving a small amount of copper sulphate in solution, but from the formation of the basic sulphate of copper, which in itself is injurious."

In the light of more recent investigations, and of experiences in practice, it is very doubtful if either of the above workers would now lay much stress upon air slaked lime as a cause of the injury from bordeaux mixture.

In a letter dated January 23, 1907, Bain kindly sends me the following as to the relation of lime and weather to injury from bordeaux mixture: "You will recall that I found lime to be the sole constituent of the bordeaux mixture which retards its injurious action. Since that time I have found that liquid water in contact with hydrate of lime is necessary for its conversion into the carbonate. In fact, I have bordeaux sprinkled on glass plates in my laboratory which have been in a dry atmosphere for about six years, and the lime still exists in the form of the hydrate. It is a well-known fact that the hydrate of lime is very much more soluble in meteoric water than the carbonate. I found that one night's exposure to a good dew is sufficient to convert the hydrate into the carbonate. A rain falling within a short time upon the leaves sprayed with the bordeaux mixture will find the lime in its soluble hydrate condition and will wash off a greater percentage of the lime present. Following rains or dews will thus cause much greater injury than would have occurred if a few dews had followed the spraying before the occurrence of the rain. It is probable that this fact will influence but slightly the practical control of injury to foliage, though it explains in many instances the injury, which I have hitherto been unable to comprehend."

INVESTIGATION IN REGARD TO BORDEAUX INJURY AT THE NEW YORK AGRICULTURAL EXPERIMENT STATION.

It was the unusual severity of bordeaux injury in 1905 that caused this Station to begin a study of the trouble. There was a greater loss of fruit and more damage done to apple foliage in New York in 1905 than in any preceding year in the history of spraying. True, there had been other years in which the losses were great, as in 1894 and in 1904, but in these seasons the injury occurred in localities, while in 1905 it extended over the entire apple-growing territory of the State. Many apple growers maintained that they did more harm than good by spraying with bordeaux mixture in 1905. Some growers declared their intention of giving up the use of this fungicide in future spraying operations; a few having suffered severe losses in preceding years had given it up. The extracts from letters written by apple growers of the State, published in the first pages of this bulletin, give an idea of the damage done in 1905. The conditions seemed to warrant a careful investigation of bordeaux injury. The campaign was begun with a preliminary survey of the field in the fall of 1905.

A PRELIMINARY SURVEY.

To get an idea of the amount and the nature of the damage done in spraying apples in 1905, a circular letter was sent to 116 apple growers in the State; 108 replies were received. The following is a synopsis of the information so obtained:

1. *The amount of bordeaux injury in 1905.*— Of the 108 men who replied, 98 had used bordeaux mixture in 1905. Of these, 69, or 70 per ct., had had spray injury. Their injury varied in degree from "badly spotted foliage" to a loss "of one-half the foliage in a ten-acre Baldwin orchard;" one man reports that his "apples were nearly all thinned off the trees" and that he had "lost nearly all of the first leaves in his orchard." Another reports that his crop was lessened by 100 barrels. The letters on pages 224 to 228 give further accounts of the losses suffered.

2. *Spraying materials and formulas.*— Of the 69 men who reported "spraying injury," 55 used an excess of lime in making the bordeaux mixture used. Of these, three used a 4-8-50 formula; one a 3-10-50; one a 5-12-50; and two a 5-15-50 formula. In these cases of more than double and more than triple the amount of lime than of copper sulphate, the injury varied from a slight amount to a heavy dropping of foliage and badly russeted fruit. These seven cases would not vary in degree of injury in any particular from any other seven that might be chosen from the 69 injured orchards; the great excess of lime seemed to make little difference in regard to injury. Of the 48 remaining cases in which an excess of lime was used, eighteen used a 4-6-50 formula; twelve, 5-5-50; seven, 3-6-50; and eleven, 4-4-50.

In the orchards where there was no injury the formulas used were as varied as those in which spraying was harmful. The proportion of 4-4-50 formulas was high in the cases where there was no injury, but without doubt this is a coincidence. From the statements made in these reports one cannot conclude that either the amount of copper sulphate — in no case was there less than 3 pounds to 50 gallons of water — or the amount of lime, materially influences the amount of bordeaux injury. One point is made very clear, *an excess of lime does not prevent injury.*

There were 95 answers in regard to arsenites. In 42 cases of these paris green was used; 37, arsenite of soda; 8, arsenate of lead; 7, green arsenoid; 1, disparene. Most of the men answering were satisfied from observation or experience that the injuries in their orchards were not due to the arsenite used.

3. *Did spraying do more harm than good in 1905?*— Ten of the 69 men who had suffered losses from bordeaux injury reported that spraying had done more harm than good for them in 1905; all will continue spraying, however. In nearly all of the replies to this question, only the fruit was considered for the current year. It is certain that in orchards where the foliage was badly injured early in the season, succeeding fruit crops have suffered.

4. *Experience with bordeaux injury in previous years.*— There were comparatively few direct answers as to injury in previous years, but the tone of the most of the reports indicated that those who suffered losses in 1905 had had similar losses in past seasons. The letters published in the previous pages give some information on the point and are fairly representative in this regard of all the letters received.

5. *The cause of the injury.*— In 41 of the 69 cases of injury, the copper sulphate was mentioned as the cause, or the probable cause; in 9 cases the arsenite was considered the harmful ingredient; in 5 others, too much lime; in the remaining cases, those replying confessed to having no opinion as to what caused the injury or gave an indefinite answer; several ascribed the injury to one or another phase of the weather. When definite answers were given, the information in many cases was based on experiments with the several spraying substances.

6. *Does the manner of spraying have anything to do with "spray injury?"*— The answers to this question can hardly be classified because of their great diversity. There were 67 answers and with a somewhat liberal interpretation we may consider 24 of them negative and 43 affirmative. The trend of the affirmative answers

was, that with the increasing use of power machinery more of the spraying mixtures were used, and more injury resulted; and that the more thorough the spraying in all respects, the greater the amount of injury.

7. *Similar injury in unsprayed orchards.*— Thirty-nine correspondents had seen this injury only in sprayed orchards; 29 had seen such injury in unsprayed orchards. It should be said that frost injury as described by Stewart and Eustace[50] of this Station, is to be found nearly every season in New York apple orchards and on the fruit, at least, is easily mistaken for bordeaux injury; so, too, is the work of the apple blister-mite on the leaves.

8. *Favoring conditions for "spray injury."*— Fruit growers are almost of one mind as to the weather conditions favoring bordeaux injury. Under one head or another, as wet, muggy, cloudy and wet, wet and hot, wet and cold, 57 answered, wet weather. The six other answers received indicated dry weather either under that head or under that of sunshiny weather. It is unfortunate that the question of dew or no dew in these dry weather cases cannot be settled.

9. *What varieties are most susceptible to spray injury?*— Rhode Island *Greening*, 31; Baldwin, 28; Twenty Ounce, 12; Ben Davis, 6; Tompkins King, 6; Jonathan, 5; Snow, 5; Boiken, 3; Lady Sweet, 2; Northern Spy, 2; Hubbardston, 2; Esopus *Spitzenburg*, 2; Newtown Pippin, 2. The following were indicated but once: Fall Pippin, Peck *Pleasant*, Cranberry Pippin, Red Astrachan, Fallawater, Sweet Winesap, Tolman *Sweet*, Swaar, McIntosh, Wagener, Bismarck, Maiden Blush.

The three sorts first named are the most widely grown varieties and the number of times they are specified in the above list is not an indication of their susceptibility in comparison with the other apples in the list. In the main, this list agrees with the one prepared from the Station orchards given on page 247.

THE EXPERIMENTS.

OUTLINE.

The data from the survey suggested four experiments:

1. Effects of bordeaux mixture on the fruit and foliage of the apple.

2. Effects of bordeaux mixture on apple trees sprayed during wet weather.

[50] Stewart and Eustace (58).

3. Effects of bordeaux mixture containing an excess of lime:
   (a) As to injury,
   (b) As to control of the scab fungus.

4. Effects of bordeaux mixtures made with varying quantities and varying proportions of copper sulphate and lime:
   (a) As to injury,
   (b) As to control of the scab fungus.

An apple orchard on the Station grounds was available for the experiments and 27 Rhode Island *Greening* and 18 Baldwin trees were selected for the work. The trees are 55 years old, normal and healthy in growth, and were selected from a considerably greater number of the same varieties in the orchard to give uniform plants for the experiment. The varieties named were selected because both are susceptible to injury from spraying and because they are the sorts most commonly grown in New York.

The usual treatment for apple scab in this State consists of three applications of bordeaux mixture; the first before leaf buds open; the second, just after blossoms fall; third, ten days to two weeks later. The first application is omitted when an orchard has been treated with lime and sulphur for San José scale. The Station orchard had had this lime and sulphur treatment and it was necessary to give but the two last mentioned applications to comply with the custom of apple growers.

The 45 trees were divided into nine plats, each containing three Rhode Island *Greenings* and two Baldwin trees. Each plat was sprayed with bordeaux mixture as follows:

Plat (1)	1 lb.	copper sulphate	—1 lb. lime	—50 gals. water.
Plat (2)	2 lbs.	" "	—2 lbs. "	—" " "
Plat (3)	3 "	" "	—3 " "	—" " "
Plat (4)	4 "	" "	—4 " "	—" " "
Plat (5)		Check.		
Plat (6)	1 lb.	" "	—2 lbs. "	—" " "
Plat (7)	2 lbs.	" "	—4 " "	—" " "
Plat (8)	3 "	" "	—6 " "	—" " "
Plat (9)	4 "	" "	—8 " "	—" " "

Arsenate of lead was used at the rate of three pounds to fifty gallons of water on all the plats. The time and the conditions under which the plats were sprayed will be given in the discussion of the several experiments.

MAKING AND APPLYING THE BORDEAUX MIXTURE.

Many of my correspondents state positively that no injury results from "properly made bordeaux mixture." Bulletins and horticultural press urge the necessity of using the "properly made" mixture, though scarcely any two men make the spray in the same manner. After years of teaching students how to make bordeaux mixture "properly," and after having talked much about the supposed virtues of bordeaux mixture made in such and such a way, I am convinced that much of such talk is worse than useless. It has made this spray a bugbear to the average farmer when in reality it is simply putting a solution of copper sulphate and the milk of lime together. I can find no data to show that the *manner of putting the ingredients together makes the slightest difference in controlling fungi or in preventing injury*. The manner of putting the ingredients together does make a great difference in the physical composition of the mixture, and it is quite worth while to strive for a mixture of good physical composition. But the idea that failing to have a certain color, or condition of suspension, means any loss of fungicidal properties, or that power to cause injury is thus brought about, is erroneous. There is little basis for the claim so often made that "properly made bordeaux mixtures" do not injure fruit or foliage.

Due care was exercised in making all of the mixtures used in these experiments. The writer personally weighed, measured, and combined all ingredients used. The method of making was that recommended in Bulletin 243 of this Station, in common use throughout the State. The copper sulphate was dissolved and diluted to one-half of the 50 gallons of water. The lime was slaked and diluted with the remaining half of the water. The two diluted ingredients were then poured together in the spray tank. Lastly the arsenate of lead was added. The mixture was thoroughly agitated during its application.

The spraying was done with a gasoline power outfit equipped with Vermorel nozzles. The pressure was kept high, giving a fine mist. The trees were sprayed from every direction, the effort being to do the work thoroughly and yet not drench the trees so that the spray ran from them. It was assumed that injury might be caused by over-spraying and great care was taken not to spray too heavily. The workmen in the orchard were supervised by one or another of the assistants in the Horticultural Department.

EXPERIMENT I.— EFFECTS OF BORDEAUX MIXTURE ON THE FRUIT AND FOLIAGE OF THE APPLE.

The results of this experiment are conclusive. Bordeaux mixture causes the trouble commonly known in New York as "spray injury." All of the 40 trees sprayed with the different strengths of bordeaux mixture showed more or less injury to fruit and foliage. None of the five check trees showed more than a trace of such injury. A trace was found on two check trees, but the bordeaux mixture was found there also, having been blown or thrown into the check plats in spraying nearby trees. The following table gives the results:

TABLE II.— EFFECTS OF BORDEAUX MIXTURE ON THE APPLE.

Plat No.	Strength of Mixture.	Fruit.									
		Injured.		Uninjured.		Injured.	Scabby.		Without scab.		Scabby.
	C.S. Lime Water	*Lbs.*	*oz.*	*Lbs.*	*oz.*	*Per ct.*	*Lbs.*	*oz.*	*Lbs.*	*oz.*	*Per ct.*
1.....	1 —1 —50	182	12	2343	2	6.1 *(4.1)	78	2	2447	12	3.0
2.....	2 —2 —50	111	0	2099	3	5.0	53	6	2156	13	2.4
3.....	3 —3 —50	209	5	2445	12	7.8	47	2	2607	15	1.7
4.....	4 —4 —50	301	13	1530	9	16.4	28	7	1803	15	1.5
5.....	Check	Trace		2509	3	......	272	9	2269	12	10.7
6.....	1 —2 —50	47	13	2351	5	1.9	137	4	2261	14	5.7
7.....	2 —4 —50	107	12	2485	6	4.1	178	10	2414	8	6.8
8.....	3 —6 —50	311	0	2617	9	10.6	45	13	2882	12	1.5
9.....	4 —8 —50	179	12	1487	2	10.7 *(13.3)	37	2	1629	11	2.2

* The percentage of injured fruit in Plat 1 is abnormally high because one of the five trees in the plat had 22 per ct. of its fruit injured. If we discard the crop of this tree and take an average from the remaining four trees in the plat we have instead of 6.1 per ct. 4.1 per ct. So, too, the percentage of injured fruit in Plat 9 is abnormally low because one of the trees had but 3.1 per ct. of injured fruit, far below that of the other four trees in the plat, the average percentage of the latter being 13.3.

The crop was picked and sorted between September 24 and October 13. The weights given in the table include both picked fruit and windfalls. In sorting for bordeaux injury, apples having a sufficient amount of russeting to detract from the general appearance of the fruit, were considered injured; all others were considered without injury. Many specimens showing traces of injury, under the above specification, fell in with the uninjured fruits. In sorting for scab, apples with well defined scab spots were designated as "scabby." The crop was not a large one, averaging only 10¾ bushels to the tree for the 45 trees; it was, however, well distributed, each tree in the experiment having its share of fruit.

Time of appearance of bordeaux injury.— Four trees in each of the eight treated plats were sprayed May 31, the fifth tree in each plat being left until it could be sprayed before or during a rain. Rain fell on June 5, and the unsprayed trees in the plats, a Rhode Island *Greening* in each case, received their application. Daily examinations of fruit and foliage were made; and until the rain on June 5, no trace of injury was to be found. The morning of June 5 was clear, bright and hot, but in the middle of the forenoon a light thunder storm came up and spraying was begun on the unsprayed trees in the plats, and was continued during the intervals between showers until finished at three in the afternoon. The weather continued showery until the morning of June 6, the amount of precipitation for the 24 hours being .74 inch. On the afternoon of the sixth, it was found that all of the 40 trees sprayed with bordeaux mixture, either on the last day of May or the fifth of June, showed injury.

Rate of development.— The rate at which any disease, physiological or pathological, of a living organism develops must depend upon environment, and with plants, upon temperature and moisture in particular. The weather following the first appearance of the injury was warm and moist. From day to day the injury, which appeared at first as faint black or brownish specks, became more conspicuous. On the ninth of June a severe hailstorm did such damage to fruit and foliage that the bordeaux injury was partly obscured. On the thirteenth, the observer, Mr. Eustace, noted, "At this date it is easy to see that the injury is much more pronounced on the plats that have received the largest amounts of copper sulphate. It is apparent, too, that the injury at this time is more severe on the Rhode Island *Greenings* than on the Baldwins and that it is most severe on the trees sprayed during rain." On June 12, the second application of bordeaux mixture was made, leaving as before a tree in each plat to be sprayed during a rain. On the afternoon of the fifteenth and the morning of the sixteenth, the fifth trees in the plats were sprayed between heavy showers.

A week of rain* followed the second spraying and the injury increased apace from day to day. Notes taken from time to time showed that the injury continued to increase on the fruit until about July 30, when it apparently reached the maximum except as the increased size of the fruit made it more visible.

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* See data on page 270.

At this time the degree of injury, as noted by the eye, stood about as at the close of the experiment.

In the daily observations it was noted from the start to the finish of the experiment that the injury was greater on the trees sprayed during rain than on those sprayed during dry weather; with both applications of the copper compound considerable injury appeared *immediately* on the trees sprayed in rain; on those not so sprayed, only traces of injury were found until rain had fallen. The inevitable conclusion to be drawn from observation, quite aside from the results to be given later, is, that *wet weather favors the production of the injury.*

The injury on fruit was more noticeable in July than at any other time. After July the fruit seemed to outgrow and throw off much of the russeting. This was the case in our experimental plats, but much more so in other orchards that came under my observation. On the fifteenth of June the writer was called to Albion, New York, to visit a number of orchards in which it was supposed some new fungus was destroying the fruit; — the trouble turned out to be the bordeaux injury. About twenty orchards were visited, some of them showing the worst cases of bordeaux injury I have ever seen. Many fruits were covered with russet; some had gaping cracks; much of the fruit was malformed; and the foliage of all was badly injured. A later visit on the twentieth of July showed that the fruit was in much better condition than at the first visit. There was less russeting; many of the cracks had healed over and the malformations were less pronounced. Reports from the damaged orchards at harvest time were to the effect that the injury was even less apparent than at the last visit; and that comparatively little of the fruit was wholly unmarketable, the loss being in the lessened yield through reduced size.

Unfortunately there was comparatively little injury to foliage in our experiment plats; an unexplainable condition, for in the State at large there was much injury to foliage. For this reason the results given have to do chiefly with injury to the fruit.

Manner of development of bordeaux injury on fruit.— From its appearance until the crop was harvested, studies were made of the injury as it developed. A brief summary of these studies is made here.

Examined with the naked eye, the surface of a young apple, for from four to six weeks after blossoms drop, is found to be covered with a felt of fine hairs. Examined under the microscope, one sees upon the epidermis of the young apple many stomata. In time the hairs and most of the stomata are lost, the former dropping off leaving a distinctive scar, while the latter split through surface expansion and give rise to a corky formation agreeing with the structure, and, I take it, the function of the lenticels. The hairs are thin walled and consist of a single cell. The walls of the neighboring epidermal cells, even at an early age, are thicker and stronger and as the fruits develop this difference becomes more marked. So far as the Baldwin and Rhode Island *Greening* are concerned the stomata are not to be found in any considerable numbers after the fruits are half grown, though a few are present almost up to harvesting time. In the young fruits these stomata are very evenly distributed over the surface of the apple.

These plant hairs and stomata are the parts of the epidermis which seemingly permit the entrance of the toxic ingredient of bordeaux mixture. In its first stages bordeaux injury appears as tiny black or brown specks. Under the microscope these specks are found to consist of a circle of dead cells usually surrounding a stoma, but sometimes one of the thin celled hairs. It may be assumed that the copper salts are dissolved by moisture or other atmospheric agencies and enter the cells through the stomata, and possibly the hairs, and destroy them. Whether the young apples secrete through the hairs, or otherwise, a liquid which would dissolve the copper salts in small quantities, is not known; it is possible, and it seems very probable, that there is such a secretion, in which case injury might arise independently of atmospheric agencies.

Schander[51] holds, after investigations of his own and a consideration of the work of others, some of whom are not in accord with his views, that plants do secrete liquids which dissolve the copper salts. Clark,[52] as we have seen, page 235, gives the solvent properties of cell sap on copper hydroxid as a factor in bordeaux injury. He says further:[53] "When the dew is on the leaf we have two solutions — the dew drop without, and the cell sap within — separated by a more or less permeable membrane. These conditions must result in the exosmosis of at least some of

[51] Schander (53, p. 279).
[52] Clark (13, p. 44).
[53] Clark (13, p. 43).

the contents of the cell sap, which coming in contact with the copper hydroxid adhering to the leaf surface causes more or less of it to pass into solution." Bain[54] concludes as the result of an experiment that the secretions from peach leaves do not increase the toxic action of copper salts. He says: "Both cane and grape sugar increase the action of the copper slightly, while gum arabic and the gum secreted by peach leaves are without influence on this injury."

[55]Pons[56] found that although acid and neutral salts of copper are strongly insoluble in fats and fatty matters, the hydrate and basic salts are rather easily soluble. He believes the fatty matters of the cuticle of plants are comparable with animal fats and not with wax, and consequently that they would be likely to exercise a solvent action on copper salts.

It should be said that we found in our work that the hairs of both the fruit and the leaf of the apple secrete a considerable quantity of some substance, whether "fatty matter" or "wax" was not ascertained.

Whether the dissolved salts pass readily from cell to cell, and so cause the large blotches of russet, I do not know, but I think that they do not do so; for, I am told by Dr. Van Slyke, Chemist of this Station, that dissolved copper salts upon coming in contact with the proteids in the protoplasm of the cell would form an insoluble compound which would be stored up in the dead cells. If this be the case the copper poisoning does not spread from cell to cell. But, rather, the injured tissue lies, for most part, directly under the blotches of bordeaux mixture.

Fruit injury seems to occur as follows: The part of an apple injured by copper poisoning is in the first stage thickly sprinkled with dead points — a circle of dead cells surrounding a stoma or a hair; in the enlargement of the surface which follows the growth of the young fruits the dead cells are unable to bear their share of the surface tension; the result is that the epidermal cells are torn, the lacerations being of greater or less length and depth according to the fruit, the number of dead cells, rapidity of growth of the apple and possibly other factors. *It is the dead cells, and the healing of these lacerations, the cicatrization of wounds, that causes the corky, russeted layer on fruits which we call bordeaux injury.*

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[54] Bain (4, p. 54).
[55] Quoted from Swingle (53, p. 21).
[56] Pons (47).

Green[57] believes that the russeting on the fruit comes with late spraying. He cautions against using bordeaux mixture more than twice after blooming, since, "when applied too late in the season it sometimes causes a russet appearance of the apple." But from the study of the matter at this Station it does not seem probable that bordeaux injury occurs on apples after the hairs have been shed, the stomata changed into lenticels, and the waxy coating formed. This period of immunity begins with Baldwins and Rhode Island *Greenings* in from four to six weeks after blossoms drop. It may be assumed that the time for these changes must vary greatly with the season and possibly with the variety. Unfortunately these early weeks cover the period when we must spray for the scab fungus — the immunity which apparently comes with age is too late in the season to take advantage of in spraying operations.

Development of bordeaux injury on leaves.— Unfortunately for these experiments there was so little bordeaux injury of the foliage in our experimental plats that it is not possible to give as clear a statement of its development on the foliage as one would like. It is certain, too, that such observations as were made would, for most part, be modified more or less by varying weather conditions and on other varieties than the two in these experiments.

The injury develops less quickly on foliage than on fruits. It first shows as dead brown spots of various shapes and sizes though usually of irregular outline. These spots begin to appear as did the injury on the fruit, immediately after the first rain following the application of the bordeaux mixture, but in comparison with the injury on the fruit the development of the characteristic spots was slow and two weeks intervened between the first indication of the injury and the full formation of the dead brown spots; it was almost two weeks later before the leaves took on the yellow color, accompanied with falling, this being at its height July 6, too late for the injured leaves to be replaced by new ones.

In a few cases the dead spots fell out, but in no great number of leaves did this occur. There was none of the "shot-hole" effect which Bain[58] describes on peaches, and Muth[59] on grapes. The separation of dead from living tissues in the leaves of

[57] Green (26, 9:13).

[58] Bain (4, pp. 69-73). [59] Muth (46, p. 2).

apples, as in the case of members of the genus Prunus, probably does not take place and in the few cases where the "shot-holes" in apple foliage are to be found in bordeaux injury, the lifeless tissue has been blown out or removed by some other mechanical means as by rain or a later spraying.

The injury is greatest on young leaves and develops more quickly on young than on mature leaves. Thus, leaves at the end of shoots almost always show more injury than those at the base of shoots. It is reasonable to assume that this is because the young leaves are not so well protected by thickened cell walls as the older ones.

There were always to be found among the defoliation from injury some yellow leaves which did not show the dead, brown spots. I am wholly unable to say whether these turned yellow and dropped from bordeaux injury or otherwise. I could not, it should be said, establish a definite proof that there was copper in either the dead brown spots of leaves showing these spots or in the yellow leaves, though the tests with iodide of potassium may have lacked proper management.

From examination made I can form no conclusion as to how the dissolved copper salt enters the cells of the leaves. Schander[60] found on leaves of *Phaseolus vulgaris* that the injury always started from the base cells of the plant hairs. Bain[61] found with apple, grape and peach leaves that the injury is greatest along the veins because "the cuticle is more permeable there;" and according to the same author "it occurs at definite points under and around spots of copper hydrate because the cuticle happens to be more permeable at these points." All of my observations seemed to point to but one conclusion; namely, that the dissolved copper salts pass osmotically into the cells of the leaf surface, and of the upper surface chiefly, though occasionally of the lower surface. This seems to me to be the case because the *brown spots are nearly always under the bordeaux stains.* Muth[62] reached practically the same conclusion in his work with the grape. I could see nothing to lead me to think that the copper solution entered through breathing pores or leaf hairs, as in the fruits, though I must confess that the examinations of leaves were not satisfactory. The

[60] Schander (53, p. 580).
[61] Bain (4, p. 98).
[62] Muth (46, p. 7).

injuries were too far advanced before my examinations were made.

It is true that plant hairs, and especially those along the midrib and its branches, are often destroyed by the bordeaux mixture, causing very small dead specks in the leaf, but I could not find that the large spots formed about these. It may be that a sufficient amount of the copper poison enters the leaves through leaf hairs and stomata to cause the "yellow-leaf" so often found unaccompanied with the spotting. The dead spots form chiefly on the midrib and the main veins of the leaves because liquids collect in the depressions in which these parts lie.

EXPERIMENT II.— EFFECTS OF BORDEAUX MIXTURE ON APPLE TREES SPRAYED DURING WET WEATHER.

Detailed results of this experiment are shown in Tables III and IV. Plats in Table III contain one Rhode Island *Greening* tree; plats in Table IV, two trees of the same variety.

TABLE III.— BORDEAUX INJURY TO FRUIT SPRAYED DURING RAIN.

STRENGTH OF MIXTURE.			FRUIT.				
			Injured.		Uninjured.		Injured.
C. S.	*Lime*	*Water*	*Lbs.*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1	—1	—50	88	4	312	12	22.
2	—2	—50	30	12	401	14	7.1
3	—3	—50	92	5	533	8	14.7
4	—4	—50	133	11	298	14	30.9
	Check		....		647	6	0.
1	—2	—50	12	14	405	4	3.1
2	—4	—50	63	6	603	10	9.5
3	—6	—50	117	4	625	12	15.8
4	—8	—50	93	6	302	14	23.6

TABLE IV.— BORDEAUX INJURY TO FRUIT SPRAYED DURING DRY WEATHER.

STRENGTH OF MIXTURE.			FRUIT.				
			Injured.		Uninjured.		Injured.
C. S.	*Lime*	*Water*	*Lbs.*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1	—1	—50	83	10	1148	6	6.8
2	—2	—50	62	10	770	3	7.5
3	—3	—50	89	14	915	2	8.9
4	—4	—50	135	12	692	3	16.4
	Check		....		1161	4	0.
1	—2	—50	28	9	1060	15	2.6
2	—4	—50	37	8	1063	10	3.4
3	—6	—50	129	4	899	3	12.6
4	—8	—50	36	11	774	14	4.5

The abnormally large percentage of injured fruit on the 1-1-50 tree sprayed during rain is wholly unexplainable — one of the anomalies of bordeaux injury. So, too, the very low percentage of injured fruit on the 4-8-50 trees sprayed during dry weather is unexplainable. In the latter case the low percentage comes from the fact that the fruit on one of the two trees in the plat showed almost no injury.

The figures in these two tables show that in all except one of the 16 sprayed plats, the injury was greatest on the trees sprayed during rain, and in the exception the difference is but 0.4 per ct. If we average the percentages of injured fruits in the two tables, the figures are, 15.3 per ct. for the trees sprayed during rain, and 7.6 per ct. for those sprayed during dry weather, or a little more than twice as great injury in the former as in the latter.

The results of the experiment emphatically confirm the opinions of the fruit growers who have suffered from bordeaux injury that wet weather gives the favoring atmospheric conditions for this trouble. In the survey of the injury for 1905, 57 men out of 69 who had had experience with the injury that year, gave wet weather as the favoring condition. The results agree with the opinion of all the horticulturists of experiment stations of other states who had knowledge of bordeaux injury.[63] They agree, too, with those of various experimenters in studying similar injury from bordeaux mixture on other plants; thus Bain[64] in his work with peaches; Muth[65] with grapes; Schander[66] with beans and peaches; Sorauer[67] with potatoes; Mueller[68] with peaches; have all found in their experimental work that meteoric moisture gives a favoring condition for bordeaux injury.

The first experimenters with bordeaux mixture frequently make note of the deleterious effect of falling rain on the adhesive properties of the mixture. Much attention was given in the early days of spraying to securing a mixture that would stick and not disintegrate and wash away; molasses, soap, sugar and other substances were added to increase its adhesive power. Rain, without question, dissolves and washes out to some extent the fungicidal ingredients of the bordeaux mixture. The conclusion was long ago reached, however, that this effect is comparatively insignificant and the washing effect of rain on bordeaux mixture is now but little considered. The influence

[63] See letters, pp. 228–232.

[64] Bain (4). [65] Muth (46). [66] Schander (53). [67] Sorauer (54). [68] Mueller (45).

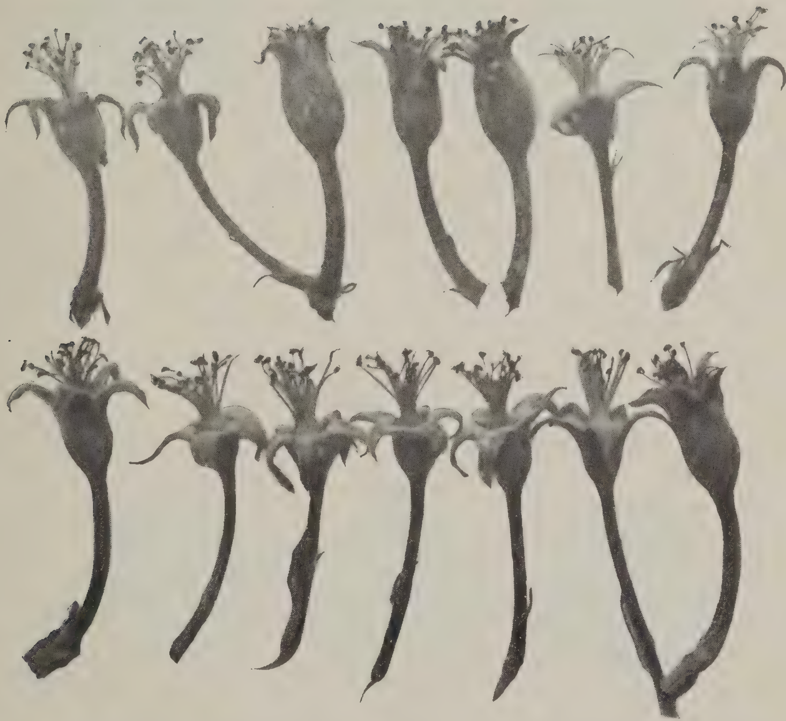


Plate XIV.— Size of Fruit When First Sprayed on May 31; Upper Row, Baldwins; Lower Row, Greenings.

PLATE XV.— SIZE OF FRUIT AND RUSSETING AND MALFORMATION FROM BORDEAUX INJURY ON JUNE 18, SHORTLY AFTER THE LAST SPRAYING: UPPER ROW, BALDWINS; LOWER ROW, GREENINGS.

PLATE XVI.— SEVERE BORDEAUX INJURY OF HALF-GROWN BALDWIN APPLES.

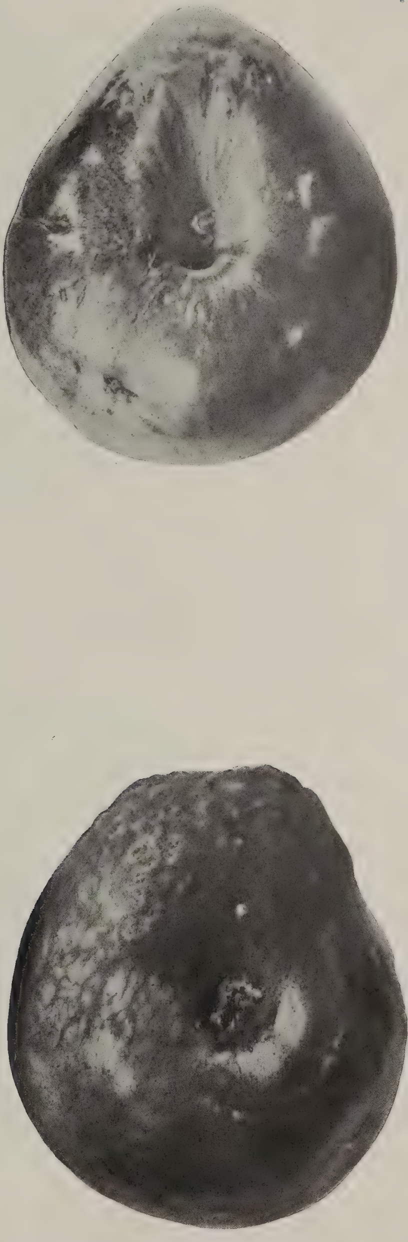
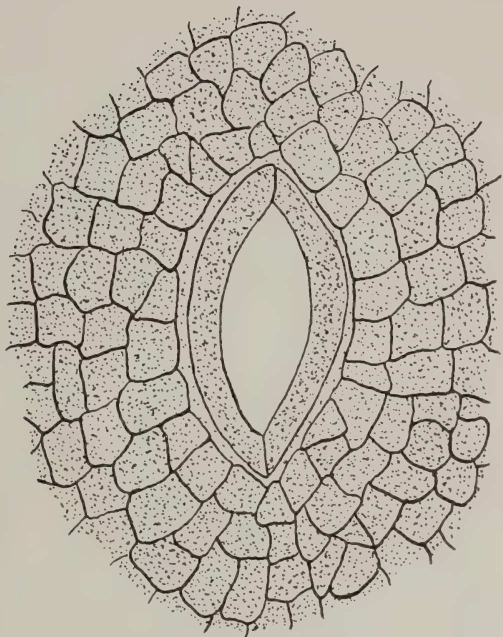


PLATE XVII.— TEAT-LIKE MALFORMATIONS ON BEN DAVIS APPLE CAUSED BY BORDEAUX MIXTURE.

Plate XVIII.— Character of Dead Spots on the "Yellow Leaf" of the Apple Caused by Bordeaux Mixture.



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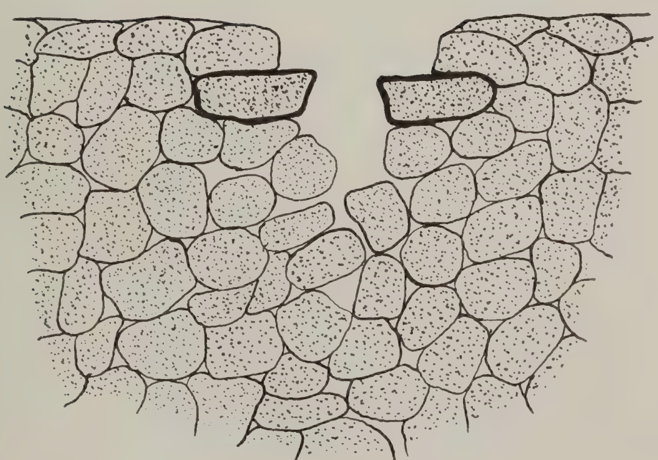

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PLATE XIX.— STRUCTURE OF STOMA ON YOUNG GREENING APPLE: 1, SURFACE VIEW; 2, CROSS SECTION.
Drawing by N. W. Coil, Cornell University.

Plate XX.— Section Through Bordeaux-Injured Portion of a Baldwin Apple, Showing Ruptured Epidermis and Dead Corky Cells.

Drawing by N. W. Coil, Cornell University.

which has to do with bordeaux injury is of quite a different nature. Moisture is necessary, whether meteoric, secreted by the host plant, or from whatever source, for the germination of the spores of fungi. It is always an accompaniment of bordeaux mixture in the destruction of germinating spores. It is the presence of this moisture with bordeaux mixture, in greater or less quantities, that becomes a prime factor in bordeaux injury.

Attention has already been called to the anomalies of bordeaux injury. The influence exerted by moisture explains many of them. The fact of injury or no injury is for most part dependent upon rain or dews; the degree of injury is likewise so dependent; this factor controls the length of time after spraying at which injury appears, whether one or several weeks. Different sets of conditions are brought about if the moisture comes as a dew, a fog, a mist, a shower, or as a torrent. If the rain be accompanied by wind, parts otherwise protected may be injured. Sunlight makes a difference in degree of injury largely because of its influence on external moisture and leaf secretions. It is probable that temperature exerts a similar influence.

There is still another influence of wet weather that demands attention; namely, its effect upon the parts of the host plant injured by bordeaux mixture.

It is reasonable to suppose that leaves and fruit have less resistant power against the action of copper poisons when wet weather prevails than during dry weather; for it is a matter of common botanical knowledge that green plant organs are more succulent, their epidermis thinner, and more tender in wet weather than in dry. Kohl[69] found "the cuticle to be much thinner when the plant is grown in a moist atmosphere;" Lothelier[70] that it may entirely disappear when grown in a saturated atmosphere. Bain[71] shows remarkable differences in the cuticle of the apple and peach leaves in accordance with weather. His conclusions are: "The cuticle of the apple leaf, and especially that of the peach leaf, shows in common with other plants considerable variations in thickness, dependent on the medium in which the leaves are developed; exposure to a dry atmosphere, to strong air currents, in short, to all the atmos-

[69] Kohl (33).
[70] Lothelier (38).
[71] Bain (4, p. 67).

pheric conditions that have a tendency to increase transpiration, results in an increased thickness of cuticle."

In the spring of 1905, preceding the unusually severe bordeaux injury of that year, the weather was such that foliage was tender and succulent. The shoots came out under abnormal conditions; the weather was warm, foggy and wet. The new growths were what the fruit grower calls "sappy." It can well be assumed that the protective cuticle was poorly formed and the parts under it spongy and weak. The power to resist entrance of solutions must be low in foliage such as was produced under these conditions, and the injury of this year well illustrates the relations of weather to succulency of foliage and consequent injury.

Table V is a record of the moisture and temperature and meteorological conditions attending the experiments under discussion.

TABLE V.— DAILY MAXIMUM AND MINIMUM TEMPERATURES AND PRECIPITATION AT EXPERIMENT STATION, GENEVA, FOR JUNE, JULY AND AUGUST, 1906.

DAY OF MONTH.	JUNE.			JULY.			AUGUST.		
	Temperature.		Precipitation.	Temperature.		Precipitation.	Temperature.		Precipitation.
	Max.	Min.		Max.	Min.		Max.	Min.	
	Deg. F.	*Deg. F.*	*Ins.*	*Deg. F.*	*Deg. F.*	*Ins.*	*Deg. F.*	*Deg. F.*	*Ins.*
1	82	52	......	79.5	55	......	85	54	.06
2	73.5	53	......	81	63	Trace	82.5	58.5	.55
3	89.5	59	......	79	60	.61	80	66	.96
4	83	50	......	76	62	.05	88	66.5	......
5	83	63	.74	74	55	......	93	66	......
6	81	63	......	78	52	......	88	70	.05
7	83.5	58	.05	82.5	59.5	......	83	67	.12
8	92	67	......	83	61	......	84.5	66	......
9	91.5	62	Trace	82	65	.07	87	60	.26
10	80	57	.61	81.5	65	.17	86	65	.14
11	70	45	......	78.5	55	......	84.5	67	.40
12	67	37	......	82.5	53	......	82	61.5	......
13	72	39	......	86.5	60	......	76	48	......
14	81	45	......	87	62	......	80	56	......
15	86	60	.25	87	65	......	77.5	54	......
16	82	61	.29	85	64	.61	81	47	......
17	70.5	53	.45	79	66	.11	88	60	Trace
18	79	58	.22	80	59	......	85	67	.05
19	74	62	.02	83.5	54	......	86	70	.62
20	79	59	......	89	62	.04	87	66	.17
21	81	64	.49	87	68	Trace	87	66	......
22	76	58	.37	89	64	.26	92	68	......
23	72.5	56	......	89	68	.20	91	68.5	.02
24	74	51	Trace	77	54	......	79	60	......
25	77	56	......	79	50	......	79	64	......
26	78	51	......	81	55	......	84	65	.08
27	83	57.5	......	83	60	.06	84	64	.20
28	89	63	1.46	81	62	Trace	78	55	......
29	87	65.5	.12	86	63	.06	82	51	......
30	83	70	.24	83	67	.13	80	63	......
31	......	......	......	88	61	......	77	57	......

EXPERIMENT III.— EFFECTS OF BORDEAUX MIXTURE CONTAINING AN EXCESS OF LIME.

(a) *As to injury.*— In this experiment four plats were sprayed with one part of copper sulphate to one of lime, a slight excess of the latter, since an equal weight of lime is not needed to neutralize the copper sulphate; and four plats were sprayed with one part of copper sulphate and two parts of lime, more than double the quantity of lime needed. There were five trees in each of the sprayed plats and the same number in the control plat. Table VI gives the detailed results.

TABLE VI.— EFFECTS OF BORDEAUX MIXTURE CONTAINING AN EXCESS OF LIME.

PLAT NO.	Strength of mixture.			FRUIT.				
				Injured.		Uninjured.		Injured.
	C. S.	Lime	Water	Lbs.	ozs.	Lbs.	ozs.	Per ct.
1	1	—1	—50	182	12	2343	2	6.1
2	2	—2	—50	111	0	2099	3	5.0
3	3	—3	—50	209	5	2445	12	7.8
4	4	—4	—50	301	13	1530	9	16.4
5		Check		Trace		2509	3	....
6	1	—2	—50	47	13	2351	5	1.9
7	2	—4	—50	107	12	2485	6	4.1
8	3	—6	—50	311	0	2617	9	10.6
9	4	—8	—50	179	12	1487	2	10.7

The figures in this table show plainly that an excess of lime not only does not prevent bordeaux injury, but does not materially lessen it. The slight differences in favor of the excess of lime are not out of the range of fortuitous variation as the figures stand. I have called attention to the fact that in Plat 1 a Rhode Island *Greening* tree gave an abnormally large percentage, 22 per ct., and that in Plat 9 a Rhode Island *Greening* tree gave an abnormally low percentage, 2.5 per ct. If we eliminate these trees, two out of the 45 in the experiment, the percentages in the results read for Plats Nos. 1, 2, 3 and 4: 4., 5., 7.8 and 16.4 per ct.; and for Plats Nos. 6, 7, 8, and 9: 1.9, 4.1, 10.6 and 17.2 per ct. With this reading, which it seems to me is more nearly correct than that given in the table, the excess of lime does not even decrease the amount of injury.

These results are corroborated everywhere in practice. In the letters[72] published in the preceding pages of this bulletin attention has been called to a number of cases in which double,

[72] See letters, pp. 223–228.

treble and four times as much lime as is necessary was used and yet there was much bordeaux injury. In the survey of bordeaux injury in 1905, 55 out of the 69 men who reported injury used a considerable excess of lime. The experience of horticulturists of experiment stations, as recorded in this bulletin,[73] indicates that all over the United States an excess of lime does not prevent injury nor retard the toxic action of the copper salts to any great degree.

It is difficult to understand how the value of an excess of lime in bordeaux mixture has come to be so greatly overestimated. Almost without exception experimenters and writers recommend it as a means of preventing bordeaux injury. Even so recent and careful an experimenter as Bain[74] has fallen into the error. He says: "At the same time, before the sixth day after application, the pure basic copper has already begun to cause injury to the apple leaf, not because copper is entering at a more rapid rate than into the grape leaf, but because a far smaller dose of copper proves fatal to the apple leaf. Here likewise after the lapse of a certain time, the leaf tissues die. This injury may be retarded or prevented by the use of lime, just as in the grape leaf." Several similar statements may be found elsewhere in his work; in one of these[75] he makes the following positive assertion of the value of lime in preventing injury. "It is especially to be remembered that lime prevents entirely the partial injury occurring to foliage in a moist atmosphere." Schander, also an experimenter and a recent writer, seems to be of two minds in regard to the effects of an excess of lime. He says:[76] "All of these injuries have this in common, that they occur with different intensity according to the amount of lime in the bordeaux. For this reason Bain properly recommends an excess of lime as suitable for counteracting the toxic action of bordeaux." But in the same paragraph continues, "Mueller, however, who conducted experiments along this line with four times the quantity of lime, found that, despite it, toxic action occurred on peaches. My researches with potted peaches and beans which were sprayed on August 1, 1902, with differently combined 1 per ct. bordeaux mixture (I, equally alkaline reaction; II, one part $CuSO_4$ + one

[73] See letters, pp. 128–132.

[74] Bain (4, p. 97).

[75] Bain (4, p. 54).

[76] Schander (53, p. 582).

part $Ca(OH)_2$; III, one part $CuSO_4 +$ two parts of $Ca(OH)_2$, gave exactly the same results." Sturgis found that two parts of lime to one of copper sulphate in a very weak solution did not prevent injury. According to him:[77] "Bordeaux mixture of the 2–4–50 formula can not be unconditionally recommended for use upon peach trees. Although somewhat less injurious to the foliage and decidedly less so to the fruit of certain varieties, than the stronger mixtures, it nevertheless causes in some cases a marked deterioration both in the quantity and the quality of the fruit."

Scott[78] in a comparatively recent bulletin recommends an excess of lime: "When russeting is feared it might be advisable to use less bluestone and a greater quantity of lime in the preparation of bordeaux mixture for application to the very young fruit. The mixture used in spraying stone fruits (3 pounds of bluestone and 9 pounds of lime to 50 gallons of water) is suggested."

I am not to be understood as claiming that there may not be some slight advantages in the use of an excess of lime; in a wet season an excess of lime may make the mixture more adhesive; it probably delays the fungicidal action of the copper salts, an advantage in controlling scab in a wet season; and it may possibly have a greater influence in preventing injury on the leaves of apples than on the fruit, my experiment having been only with the fruit. However, I am extremely doubtful if it has any *practical* value in preventing injury on the foliage of apples.

There are disadvantages in the use of an excess of lime worth considering. A gritty lime wears out spraying machinery. A mixture containing more than four or five pounds to 50 gallons is harder to apply uniformly, and makes pumping harder; and large particles of lime offer a resisting surface to drops of rain so that more of the mixture is washed from trees. This is an important point, for a fungicide is of value in proportion to its adhesive power and it is certain that this power is greatly reduced by an excess of lime.

It is to be hoped that the foregoing investigation, with the experiments of Mueller and Schander, the experience of apple growers in this State, and of horticulturists in other States, will stamp out the error into which spraying practice has fallen re-

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[77] Sturgis (59, p. 227).

[78] Scott (52, p. 27).

garding the value of an excess of lime in preventing injury from bordeaux mixture.

(b) *As to the control of the scab fungus.*— Does an excess of lime hinder the action of bordeaux mixture as a fungicide? Several writers have suspected that lime in a greater quantity than enough to satisfy the immediate chemical changes which take place will suspend the fungicidal properties of bordeaux mixture. Among these are Lodeman[79] who states that there is such a suspension though he draws the conclusion from theoretical considerations and not from experimental work. Clark[80] holds that while the solution of copper is possible in the presence of an excess of lime it is apparently detrimental to the solvent action of copper. According to Schander:[81] "A too great excess of lime affects a great dilution of copper hydroxide in the mixture. In this way the fungicidal action of the mixture is weakened." Still others might be quoted but their conclusions would fall in for most part with one or other of those given above.

The season's experiments with bordeaux injury throw some light on this question. I must hasten to say, however, that these experiments were not planned, primarily, to control scab; and that as there was comparatively little of the scab fungus in 1906, the results as here set forth are to be looked upon as suggestive rather than conclusive.

In order to make a fair comparison of the results attending the use of a moderate amount of lime (one part each of lime and of copper sulphate), and a considerable excess (one part of copper sulphate and two of lime), each of the nine plats must be divided into three parts, for there are two varieties and the plats were divided as to time of spraying. The tables show varieties and times of spraying as follows: Table VII, Rhode Island *Greening* trees, one tree in each plot, sprayed during rain June 5 and June 12; Table VIII, Baldwin trees, two trees in each plat, sprayed during dry weather May 31 and June 12; Table IX, Rhode Island *Greening* trees, two trees in each plat, sprayed during dry weather May 31 and June 12.

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[79] Lodeman (37, p. 128).
[80] Clark (13, p. 43).
[81] Schander (53, p. 583).

TABLE VII.— EXCESS OF LIME IN CONTROL OF SCAB FUNGUS ON GREENINGS DURING RAIN.

PLAT No.	Strength of mixture.			FRUIT.				
				Scabby.		Without scab		Scabby.
	C. S.	*Lime*	*Water*	*Lbs*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1	1	—1	—50	22	8	378	8	5.6
2	2	—2	—50	17	—	415	10	3.9
3	3	—3	—50	9	—	616	13	1.4
4	4	—4	—50	1	10	430	15	0.4
5		Check.		66	8	606	10	9.9
6	1	—2	—50	11	10	406	8	2.8
7	2	—4	—50	3	12	663	4	0.6
8	3	—6	—50	2	12	740	4	0.4
9	4	—8	—50	—	10	395	10	0.2

TABLE VIII.— EXCESS OF LIME IN CONTROL OF SCAB FUNGUS ON BALDWINS IN DRY WEATHER.

PLAT No.	Strength of mixture.			FRUIT.				
				Scabby.		Without scab		Scabby.
	C. S.	*Lime*	*Water*	*Lbs.*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1	1	—1	—50	9	4	883	10	1.0
2	2	—2	—50	7	8	937	4	0.8
3	3	—3	—50	9	14	1014	6	1.0
4	4	—4	—50	4	—	567	14	0.7
5		Check.		21	—	679	9	3.0
6	1	—2	—50	10	2	881	6	1.1
7	2	—4	—50	9	—	816	—	1.1
8	3	—6	—50	17	7	1139	11	1.5
9	4	—8	—50	11	8	447	8	2.5

TABLE IX.— EXCESS OF LIME IN CONTROL OF SCAB FUNGUS ON GREENINGS IN DRY WEATHER.

PLAT No.	Strength of mixture.			FRUIT.				
				Scabby.		Without scab		Scabby.
	C. S.	*Lime*	*Water*	*Lbs.*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1	1	—1	—50	46	6	1185	10	3.8
2	2	—2	—50	28	14	803	15	3.5
3	3	—3	—50	28	4	976	12	2.8
4	4	—4	—50	22	13	805	2	2.8
5		Check.		185	1	983	9	15.8
6	1	—2	—50	115	8	974	—	10.6
7	2	—4	—50	165	14	935	4	15.1
8	3	—6	—50	25	10	1092	13	2.5
9	4	—8	—50	35	—	776	9	4.3

A study of Table VII shows that in each plat two parts of lime to one of copper sulphate gives a materially smaller percentage of scabby fruit than where one part of lime was used to one part of copper sulphate. This result at least greatly strengthens the supposition, on theoretical grounds, that an excess of lime may be of value in wet weather in preventing too rapid dissolving of the copper sulphate.

Tables VIII and IX show that in dry weather the double quantity of lime hinders the fungicidal action of the bordeaux mixture. The Baldwins in the eight plats, Table VIII, do not show marked differences, but the fact that in the comparison of two parts lime with one part, in each case, the percentage of scab is less in the plats in which but one part is used is very significant. With the Rhode Island *Greenings*, Table IX, the differences are quite marked in favor of the one part lime to one part of copper sulphate mixture in dry weather.

The experiment is a very strong confirmation of the statements of Lodeman, Clark, Schander and others, as noted above, that in dry weather an excess of lime is detrimental to the fungicidal properties of bordeaux mixture.

EXPERIMENT IV.— EFFECTS OF BORDEAUX MIXTURE MADE WITH VARYING QUANTITIES AND VARYING PROPORTIONS OF COPPER SULPHATE AND LIME.

(a) *As to injury.*—The plats must be again subdivided to give fair comparisons. Taking the Rhode Island *Greening* tree in each plat sprayed during a rain, Table IX, page 275, the figures show that, with one exception, in the plats where equal quantities of copper sulphate and lime were used, the greater amount of copper sulphate the greater the injury. The exception is the unexplainable, abnormal 22 per ct. in the 1-1-50 plat. In the plats in the series where one part of copper sulphate and two of lime were used, the amount of injury increases markedly with the increase in the quantity of copper sulphate. Despite the capriciousness of bordeaux injury in rainy weather, the data given show, with the exception of the 22 per ct., that doubling the quantity of copper sulphate practically doubles the amount of bordeaux injury.

Taking the remaining four trees in the eight plats, two Baldwins and two Rhode Island *Greenings*, sprayed during dry weather, Table X, the experiment shows again that the more copper sulphate, the more injury. In each of the two series in this experiment, divided in accordance with the proportion of lime used, there is an increase in injury, though not as uniform as in the case of the trees sprayed in rain, with the increase of the copper salt.

TABLE X.— EFFECTS OF BORDEAUX MIXTURES MADE WITH VARYING PROPORTIONS OF COPPER SULPHATE AND LIME.

PLAT No.	Strength of mixtures.			FRUIT.									
				Injured.		Un-injured.		Injured.	Scabby.		Without scab.		Scabby.
	C. S.	*Lime*	*Water*	*Lbs.*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*	*Lbs*	*ozs.*	*Lbs.*	*ozs.*	*Per ct.*
1.....	1	—1	—50	94	8	2030	6	4.4	55	10	2069	4	2.6
2.....	2	—2	—50	80	4	1697	5	4.5	36	6	1741	3	2.0
3.....	3	—3	—50	117	—	1912	4	5.7	38	2	1991	2	1.3
4.....	4	—4	—50	168	2	1231	1	12.0	26	13	1373	—	1.9
5.....		Check.		—	—	1861	13	—	206	11	1663	2	11.0
6.....	1	—2	—50	34	15	1946	1	1.7	125	10	1855	6	6.3
7.....	2	—4	—50	44	6	1881	12	2.3	174	14	1751	4	9.0
8.....	3	—6	—50	193	12	1991	13	8.8	43	1	2142	8	1.9
9.....	4	—8	—50	86	5	1184	2	6.7	46	8	1224	1	3.6

These results are in accord with what should be expected theoretically, and they certainly are in accord with the experience of apple growers throughout the State. Bain[82] states the reason for the difference in effect between strong and weak bordeaux mixtures very clearly as follows:

"In this connection attention may be called to the difference in action between so-called 'strong' and 'weak' bordeaux mixtures. One frequently sees in horticultural literature the mixture thus referred to, as if the copper were all in solution. The only difference between a one per ct. and a two per ct. bordeaux mixture properly made, so far as their fungicidal action is concerned, is that *the latter contains twice as much solid copper hydrate as the former.* From this consideration alone it is clear that a somewhat larger percentage of the leaf surface will be in actual contact with copper particles when a certain amount of the stronger mixture is applied to a similar leaf surface, than when an equivalent amount of the weaker mixture is applied to the same surface. Moreover, it is plain that the larger surface of the copper hydrate exposed to the solvent action of the water standing on the leaf in the case of the strong bordeaux, will produce a saturated solution of the copper in less time than would occur in a weaker mixture. This latter condition would come into play, probably, more during alternating showers and sunshine." In the same paragraph he says: "But from actual experiment the writer has found very little difference between the effects of half and full strength bordeaux mixtures, and for the reasons here stated it may be

[82] Bain (4, p. 95).

assumed that the difference in percentages of copper used in bordeaux mixture has, except within wide limits, very little to do with the action of the contained copper on the foliage." I feel sure that this statement does not hold with apples and I should have to see definite data before I could believe that it is true with other fruits, though in practice I have seen instances in which injury was greater with weak than with strong bordeaux mixture in the same orchard. I take all such instances to be exceptions, however.

(b) *As to the control of the scab fungus.*— Tables II and X show that the percentages of scabby fruit on the check trees in all of the plats are low. In the average season, on the varieties in question, the percentages would run from four to six times as high. The results in this season's investigation do not, therefore, represent the average year. The experiments were not planned, primarily, to show the value of different strengths of bordeaux mixture in controlling the scab fungus; and no special study of this problem was made in the field. Therefore, the results to be given under the head of this topic are only interesting and suggestive.

Table VII shows that with one Rhode Island *Greening* tree in each plat sprayed during rain, the percentages of scabby fruit decreased quite uniformly with the increase in the amount of copper sulphate in the mixture. Table VIII with two Baldwin trees in each plat, sprayed during dry weather, shows varying data in respect to strength of bordeaux mixture in controlling the scab fungus. The differences shown are so slight that they are not out of the range of fortuitous variation. With the two Rhode Island *Greening* trees in the several plats, sprayed as were the Baldwins, there are somewhat marked differences between the least amount of copper sulphate and the greatest amount of the fungicide used, but the differences in the trees taken serially prove little or nothing; thus the 3-3-50 plat and the 4-4-50 plat give the same percentages, 2.8 per ct. of scabby fruit; while the 2-4-50 plat gives 4.5 per ct. more of scabby fruit than the 1-2-50 plat and the 4-8-50 gives 1.8 per ct. more infected fruit than the 3-6-50 plat.

The general trend of the results favors the stronger solutions in the control of the scab fungus; yet I believe, from observations made in a number of orchards sprayed with the weaker solution than the 4-4-50 now commonly used in this State, that we shall find it practicable to decrease the amounts of copper sulphate and lime to at least 3-3-50 in spraying for apple scab. The difference between these strengths shown in the three tables given are so slight as to be insignificant. The proof is positive, that the greater the amount of copper sulphate, the more the bordeaux injury; if, then, there be but little difference in the amount of scab on trees sprayed with 4-4-50 and 3-3-50, and if this should be in favor of the former strength, the less amount of injury from the weaker solution may offset the increase in the percentage of scabby fruit. This Station has used the 3-3-50 formula in the home orchards and in a ten-acre Baldwin orchard near South Greece, with apparently as good results as when much stronger mixtures were used.

APPLICATION OF RESULTS.

We have no means of entirely preventing the toxic action of the copper salts in spraying fruits with bordeaux mixture. It is possible, and probable, that we shall discover some fungicide that will kill the germinating spores of fungi and not injure the plant. Until such a discovery be made, the problem is *to spray so as to control fungi and yet injure the host plant as little as possible.* While the investigations at this Station have by no means solved this complicated problem, they do afford a basis on which to make several practical suggestions to fruit growers.

Immunity to bordeaux injury.—A number of the apples most widely known in New York, as set forth on page 247 of this bulletin, are not injured, or but slightly, by bordeaux mixture. These may be sprayed without much fear of injury. On the other hand the sorts named as being susceptible to injury must be sprayed with great care. *Growers will find it worth while to distinguish between varieties in their spraying operations.*

Immunity to scab fungus.—A number of commonly cultivated apples are nearly immune to attacks of the scab fungus. A partial list of these is: Alexander, Ben Davis, Gano, Hubbardston, Oldenburg, Red Astrachan, Rome, Roxbury, Sutton, Tompkins King, Tolman *Sweet*, Wealthy, Yellow Newtown, Yellow Transparent. All of these, and others possibly, need *comparatively light applications of bordeaux mixture in the average season.*

Less copper sulphate.—The results of the experiment with different quantities of copper sulphate in bordeaux mixture are not conclusive enough to lead me to state positively that the fruit grower can use less of the copper sulphate than in the 4-4-50 formula now in common use. But the investigation indicates that the differences between the 3-3-50 and the 4-4-50 formulas, as regards apple scab, are so small that the one is practically as efficient as the other as a fungicide, while it is certain that the weaker solution will produce less bordeaux injury. I recommend, therefore, a thorough trial of the 3-3-50 formula.

Excess of lime.— Investigations in the orchards of the State, information from other apple regions, and the season's experiments prove conclusively that *an excess of lime will not prevent bordeaux injury nor greatly lessen it.* Therefore, a formula containing no greater excess of lime than one part to one part of copper sulphate is advised.

Moderation in spraying.— Moderation in the quantity of bordeaux mixture applied is recommended. The experience of fruit growers is that, the more liquid they apply, the greater the injury. From theory, such a result can be assumed. Power sprayers, now to be found in nearly every commercial apple orchard, are partly accountable for the great increase in bordeaux injury. *Spray to cover the foliage and fruit with a thin film and yet not have the trees drip heavily.*

The modern nozzle, which breaks the stream into a fine spray, thus bringing the particles of copper salts in contact with a greater percentage of the leaf surface and exposing them to a greater degree to the solvent action of moisture, is a factor in bordeaux injury. But the fine spray for these same reasons increases the fungicidal value of bordeaux mixture and it is not therefore acvisable to discontinue the use of nozzles which produce such a spray.

Weather and spraying.— In the past it has been the custom to spray, rain or shine. These investigations show plainly that spraying in rainy, foggy, damp weather favors the production of bordeaux injury. So far as possible the bordeaux mixture should be used only in dry weather. A slightly greater excess of lime may be used in wet weather than in dry weather. Since May is wet and June is comparatively dry, the time of spraying, whether early or late, may modify practice as to the use of lime. I doubt if the danger is great to fruit or foliage of the apple from bordeaux mixture in this State after July.

In conclusion.— Bordeaux mixture is still the best fungicide. Spray injury is a serious matter, but apple scab is worse. *No fruit grower can afford to give up the use of bordeaux mixture in fighting apple scab.* It is to be feared that because of the very small amount of the apple scab fungus during the past few years, and because of spray injury, some who have previously used the copper compound will not use it in the future. Such a course will be a mistake for there are sure to be years with apple scab and corresponding losses in unsprayed orchards.

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Beckwith, D. S., Albion.
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Dunning, D. M, Auburn.
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Forster, W. B., Stanley.
Gott, Fred E., Spencerport.
Gregory, Hiram, Lockport.
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Hart, Wm. H., Poughkeepsie.
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Huested, Percy, Blauvelt.
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Kayner, Geo. L., Gasport.
King, T. H., Trumansburg.
Lamont, E. W., Cobleskill.
Lewis, Henry D., Annandale.
McKay, W. L., Geneva.
McNair, H. R., Dansville.
MacPherson, Roy P., Leroy.
Mann, W. T., Barker.
Moffat & Son, S. L., Washingtonville.
Moody & Sons, E., Lockport.
Morey, J. B., Dansville.
Morgan, B. Frank, Albion.
Munt, G. E. & E. H., Leroy.
Niles, T. F., Chatham.
Northrup, W. I., Brockport.
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Outwater, Wm. H., Olcott.
Palmer, W. E., Brockport.
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Pease, Ira, Oswego.
Peck, H. J., Rochester.
Peck, C. M., Fayetteville.
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Powell, Geo. T., Ghent.
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Rogers, W. P., Williamson.
Rose, J. F., South Byron.
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Salisbury, J. L., Phelps.
Scoon, C. K., Geneva.
Shaw, C. W., Mountainville.
Stebbins, Isaac W., Albion.
Tanner, Leslie, Medina.
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Thomson, J. A., Rochester.
Tyron, D. D., Pulaski.
Udell, Foster, Brockport.
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Van Alstyne, Edward, Kinderhook.
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Wadhams, S. W., Clarkson.
Ward, G. E., Ravena.
Way, W. S., Brockport.
Webster, D. W., Kent.
Wells, J. Q., Shortsville.
Wells & Son, Samuel J., Fayetteville.
White, Floyd Q., Yorktown.
White, John H., Brockport.
White, Henry L., Brockport.
Wiley, H. S., Cayuga.
Wilson, T. B., Halls Corners.
Wood, Albert, Carlton Sta.
Yeomans, E. L., Walworth.

Experimenters in Other States.

Bain, S. M., Botanist, Tennessee Station.
Beach, S. A., Horticulturist, Iowa Station.
Blair, J. C., Horticulturist, Illinois Station.
Butz, G. C., Horticulturist, Pennsylvania Station.
Card, F. W., Horticulturist, Rhode Island Station.
Close, C. P., Horticulturist, Delaware Station.
Cordley, A. B., Entomologist, Oregon Station.
Dickens, Albert, Horticulturist, Kansas Station.
Emerson, R. A., Horticulturist, Nebraska Station.
Faurot, F. W., Assistant in Plant Diseases, Missouri State Fruit Station.
Fletcher, S. W., Associate Horticulturist, Michigan Station.
Garman, H., Entomologist and Botanist, Kentucky Station.
Green, W. J., Horticulturist, Ohio Station.
Green, Samuel B., Horticulturist, Minnesota Station.
Gulley, A. G., Horticulturist, Storrs Station.
Henderson, L. F., Entomologist and Plant Pathologist, Idaho Station.
Hutt, H. L., Horticulturist, Ontario Agricultural College.
Judson, L. B., Horticulturist, Idaho Station.

Keffer, C. A., Horticulturist, Tennessee Station.
Macoun, W. T., Horticulturist, Experimental Farm, Ottawa, Can.
Melander, A. L., Assistant Entomologist, Washington Station.
Munson, W. M., Pomologist, Maine Station.
Northrop, R. S., Horticulturist, Utah Station.
Paddock, W., Horticulturist and Botanist, Colorado Station.
Price, H. L., Horticulturist, Virginia Station.
Sanderson, E. D., Entomologist, New Hampshire Station.
Sandsten, E. P., Horticulturist, Wisconsin Station.
Sears, F. C., Horticulturist, Agricultural College, Truro, Nova Scotia.
Stuart, Wm., Horticulturist, Vermont Station.
Thornber, W. S., Horticulturist, Washington Station.
Troop, J., Horticulturist and Entomologist, Indiana Station.
Walker, Ernest, Horticulturist, Arkansas Station.
Waugh, F. A., Horticulturist, Massachusetts Hatch Station.
Whitten, J. C., Horticulturist, Missouri Station.
Woodworth, C. W., Entomologist, California Station.

Experimenters in Foreign Countries.

Aderhold, Rudolf, Dahlem b. Berlin, Germany.
Delacroix, Dr. Georges, Station de Pathologie Vegetale, Paris, France.
Ewert, Dr., Proskau bei Oppeln, Germany.
Muth, Dr. Franz, Oppenheim, a. Rh., Germany.
Prillieux, Ed., Prof de botan. et pathologie végét. a l' Institute National Agronomique, 14 Rue Cambacérès, Paris, France.
Salmon, E. S., South-Eastern Agricultural College, Wye, Kent, England.
v. Tubeuf, Prof. Dr. Karl Freiherr, Universität München, Amalienstr., München, Germany.

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RINGING HERBACEOUS PLANTS.*

U. P. HEDRICK, O. M. TAYLOR AND RICHARD WELLINGTON.

SUMMARY.

1. The objects of ringing are: To cause unproductive plants to set fruit; to increase the size of the fruit and thereby the productiveness of the plant; and to hasten the maturity of the fruit.

2. Many woody plants, especially the apple and grape in America, have been advantageously ringed. But the operation does not seem to have been used on herbaceous plants though theoretically it can be practiced as well on exogenous herbaceous plants as on woody plants.

3. This Bulletin is a report of experiments in ringing two herbaceous plants, the tomato and the chrysanthemum, chosen because their product and the manner of growth of the plants should show most advantageously the effects of ringing.

4. In ringing, a wound is made through the cortex and the bast of a plant. Usually a band of bark of greater or less width is removed. Plants are ringed during the period of growth when the bark peels most readily from the wood.

5. The theory upon which ringing is founded is: That unassimilated food passes from the roots of the plant to the leaves mainly through the outer layer of the woody cylinder. The assimilated food is distributed through vessels in the cortex of the inner bark. When plants are ringed the flow upward continues but that downward is checked and the top of the plant is thus supplied with an extra amount of food at the expense of the parts below the ring.

6. Ringing is unnatural and while it may favor some of the organs of a plant must be harmful to the plant as an individual.

7. There are other means of securing the ends attained by ringing, as the bending or the twisting of shoots, which should be less harmful to the plant than ringing.

8. Tomatoes were ringed in the winter of 1905–'06; the variety was Lorillard; the soil a good greenhouse loam; plants were

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trained to single stems. The members of one group of plants were ringed as soon as the second cluster of fruits had set; those of a second group, when the fourth cluster had set. Plants in a third group were unringed.

9. Ringing consisted of removing a five-eighths inch strip of bark, cutting through to the woody tissue.

10. The heights of the stems were not affected; but irregular, bunchy swellings of greater or less size were to be found above all of the rings. There was a tendency toward the thickening of the whole stem above the wounds. These swellings were probably caused by stored food.

11. Ringing had no effect on the time of maturity of the fruit.

12. The average number of fruits per plant was reduced 18 per ct. by the first ringing and 10 per ct. by the second ringing. The average loss in weight per plant due to the first ringing was 16 per ct.; to the second ringing, 12 per ct. In the first ringing there was a gain of six one-hundreths of an ounce in the average fruit; in the second ringing, a loss of five one-hundreths of an ounce.

13. There were no differences to be noted in regard to either the color or the flavor of the fruits from the ringed plants.

14. The foliage of the ringed plants was more or less abnormal, taking on a curved, pendant position with elevated cushiony areas and having very succulent tissue. There was a slight yellowing in the foliage of ringed plants showing an unhealthy condition.

15. The roots of ringed plants were less well developed, fewer in number, and smaller in size. The root system seemingly suffered from starvation.

16. Several varieties of chrysanthemums were ringed in the autumn of 1906; the plants were trained to single stems; the grouping and the manner of ringing were as with tomatoes.

17. The first group was ringed just as the buds appeared; the second group when buds were one-third grown, the interval between ringing being about two weeks.

18. The foliage began to show injury about one month after ringing. The upper leaves of many plants had a slight yellowish tinge and portions of some of them turned reddish purple. This trouble gradually increased until the end of the experiment when the foliage of some plants was ruined.

19. As with the tomatoes, the stems were more or less swollen; considerably so just above the ring and somewhat throughout the entire upper part. Ringing decreased the height of the plant.

20. The first ringing hindered the opening of the buds in all the varieties except one; the second ringing slightly hastened the maturity of all except one.

21. The size of the blossoms of all the varieties was reduced and the earlier the ringing the greater the injury.

22. The effect of the ringing on the roots of the plants was to decrease their number and lessen their vigor. Ringed plants produced almost no suckers. The first ringing harmed the roots most.

23. It is very doubtful if ringing can be made beneficial to herbaceous plants. The loss to the plant is great and there seems to be little or no compensating gain.

24. The deleterious effects of ringing on herbaceous plants are so marked that the query arises as to whether woody plants do not suffer in similar degree and the operation possibly cause a greater loss to the plant than is gained in the product.

INTRODUCTION.

The ringing of woody plants is a well known horticultural practice. Its objects are: To cause unproductive plants to set fruit; to increase the size of the fruits and thereby the productiveness of the plant; and to hasten the maturity of the fruit. In European countries particularly, all of the tree fruits are subjected to the process, but in America only the apple and the grape are advantageously ringed. Among others in this country Booth[1] and Goodman[2] have described the ringing of apple trees while Paddock[3] has published a bulletin from this Station on ringing grape vines.

Strange to say, ringing seems to have been applied almost exclusively to woody plants, though theoretically it can as well be practiced on many exogenous herbaceous ones. In practice, so far as known, herbaceous plants are never ringed and there seem to have been but few experiments to determine the effects of such an operation, though opportunity has not offered to review carefully foreign literature that might contain accounts of experiments in ringing. The only accounts of ringing herbaceous plants that have been found are by Sablon,[4] Daniel[5] and Hedrick.[6]

If ringing would bring herbaceous plants into fruiting, increase the productiveness, and hasten the maturity of the product, as with grapes and apples, the operation would be of especial value in growing some greenhouse plants, since the qualities mentioned are essential to success in growing commercial crops under glass. It would commend itself, too, because the devitalization which eventually follows the ringing of plants would be of little consequence with most of those grown in the greenhouse, since they are grown for but one or two seasons and then discarded.

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[1] Booth, N. O. *Rural N. Y.*, 59:621. 1900.

[2] Goodman, L. A. N. Y. State Fruit Growers' Association, An. Rpt., 5:59. 1906.

[3] Paddock, W. N. Y. Sta. Bul. 151. 1898.

[4] Sablon, Leclerc du. *Compt. Rend. Acad. Sci.* (Paris), 140:1553–1555. 1905.

[5] Daniel, L. *Compt. Rend. Acad. Sci. Paris*, 131:1253–55. 1900.

[6] Hedrick, U. P. *Amer. Florist*, 17:729–730. 1901.

This Bulletin is a report of experiments with two plants, the tomato and the chrysanthemum, to ascertain what the effects of ringing may be on herbaceous plants. Daniel has reported, in the reference given above,[5] marked increase in the size of the fruits of the egg-plant and tomato; and work done in 1901 under the direction of one of the authors, as noted above,[6] seemed to show an increase in the size of the flower of the chrysanthemum and a slight acceleration in time of blooming. The effects indicated in these reports gave some promise of a favorable outcome of the experiments in the way of positive results at this Station. Such has not been the case, but the results are nevertheless of interest though negative. They show, more plainly than could similar experiments on woody plants, the effects of ringing on plant organs and on the growth of the plant; and thus become of interest to the fruit-grower as well as to the gardener and florist.

RINGING.

The term "ringing" is one given to the making of a wound through the cortex and bast of a plant. It may consist of a simple cut made with a knife, or a band of bark of greater or less width may be removed. In horticultural practice the operation is performed during that period of growth when the bark peels most readily from the wood — the period of greatest cambial activity. This term is to be preferred to "girdling" since the latter is used to designate a wound which extends into the wood of a plant for the purpose of killing it. The French phrase for the operation, "décortication annulaire" (annular decortication), is more exact than either ringing or girdling.

The theory upon which ringing is founded is a simple one. Crude, unassimilated sap passes from the roots of a plant to the leaves mainly through the outer layer of the woody cylinder. In the leaves this raw material is acted upon by various agents and is distributed to the several organs of the plant through vessels in the cortex, or the inner bark. When plants are ringed the upward flow of sap continues nearly as before the operation, but the newly-made food compounds can not pass below the injury, accumulate above it, and are supposed to supply the top of the plant with an extra amount of food at the expense of the

[5] Daniel, L. *Compt. Rend. Acad. Sci. Paris,* 131:1253–55. 1900.
[6] Hedrick, U. P. *Amer. Florist,* 17:729–730. 1901.

parts below the ring. When the bark is removed the outer layers of wood dry out very quickly and because of this the upward flow of sap is also checked somewhat through evaporation from the exposed woody cylinder.

Ringing is unnatural and while it may favor some organs of a plant must be harmful to the plant as an individual. It could be of value with herbaceous plants in the ways that have been enumerated only as an exceptional treatment to secure some particular end and in cases where the plant or branch could be sacrificed for the current season's product.

The experiments recorded here have had to do with ringing only. There are other means of securing the ends attained in ringing woody plants and they are worth trying with herbaceous plants, especially as most of them are less harmful to the plant than ringing. Thus the bending of shoots causes uneven distribution of the elaborated plant food whereby some parts of the plant are favored; so, too, twisting, whereby the bark is loosened from the wood, causes a diminution of the upward flow of raw material and supplies the buds above the twist with more than their natural amount; notching and peeling the stems are similar operations used on woody plants but not adapted to most herbaceous plants.

RINGING TOMATOES.

A test of the value of ringing tomatoes was made in the Station greenhouses during the winter of 1905–'06. The experiment was in the hands of O. M. Taylor, Foreman in Horticulture, who gave every detail of the experiment close attention. The experiment was carried through under the most favorable circumstances, the plants being extra fine and all conditions normal.

The plants.—The variety grown was the Lorillard, one of the best forcing sorts. The seeds were sown in small boxes August 1. The young plants were pricked out into two-inch pots August 16, and were shifted into four-inch pots September 1. The plants were benched September 16. A selection for the experiment was made from several hundred plants, using only those of uniform size and vigor. Two rows were set in each bench with the rows two and a half feet apart. The plants were two feet apart in the row, with spaces alternating.

Soil.— The soil used consisted of a mixture of three parts rotted sod, one part sand, and one part compost. This mixture con-

a *b* *c*

PLATE XXI.— TOMATO STEMS: *a*, RINGED WHEN SECOND CLUSTER OF FRUIT HAD SET; *b*, RINGED WHEN FOURTH CLUSTER OF FRUIT HAD SET; *c*, NOT RINGED.

Plate XXII.— The Tomato Plants a Few Weeks Before the First Ringing.

Plate XXIII.— The Tomato Plants Toward the Close of the Experiment.

a *b* *c*

PLATE XXIV.—EFFECT OF RINGING ON CHRYSANTHEMUM ROOTS: *a*, FIRST RINGING; *b*, SECOND RINGING; *c*, NOT RINGED.

tained an abundant supply of plant food during the earlier period of the growth of the plants. After several clusters of fruit had set and the soil had become well filled with roots, a thin coating of well rotted stable compost was given.

Temperature.— A temperature suitable for tomatoes was maintained throughout the experiment. The night temperature averaged 60°–65° F.; the day temperature ranged from 15°–25° higher, depending on outside conditions.

Training the plants.—All plants were trained to single stems which were tied to vertical wires as growth developed. Laterals were removed as occasion required. Toward the end of the experiment the lower leaves of all plants were removed as fast as they developed the yellowish tinge which indicates that they are reaching maturity.

Ringing.— The plants were divided into three groups. The members of the first group, Numbers 1, 4, 7, etc., were ringed as soon as the second cluster of fruit had set. Those of the second group, Numbers 2, 5, 8, 11, etc., were ringed when the blossoms of the fourth cluster of fruit had set. Plants in the third group, Numbers 3, 6, 9, etc., were unringed and were the controls.

The first group was ringed on October 18. At this time nearly all blossoms in the second cluster had set and the first blossoms of the third cluster were opening. The second group was ringed on October 31. At this date the fourth cluster had set fruit and several blossoms of the fifth cluster were open.

The plants were ringed directly below the leaf which developed under the first fruit cluster. A five-eighths inch circular strip of the outer layer of tissue was removed, cutting through to the hard woody tissue. In making the cut a curved two-bladed knife was used, so that the width of material removed would be the same in every case. As the stems of tomatoes are irregular in outline, the knives cut slightly deeper at the ridges than at other places. The cut surfaces were examined from time to time during the experiment and all callus which formed in the effort to heal and bridge over the wound was removed. The wounds dried very quickly after the removal of the bark and callus began to form almost at once. In no case could any immediate ill effects to the plant from the ringing be discovered. The appearance of the ringed stems at the close of the experiment is shown in Plate XXI. The stems of all plants were more or less enlarged directly above the point of ringing.

Effect on the stems.—At the time of the first ringing, on October 18, all plants were measured as to height. The average height of group 1 was 35.54 inches, group 2 was 34.65 inches, and group 3 was 33.71 inches. These measurements showed that the plants were very uniform in height at the beginning of the experiment. At the close of the experiment, on January 12, the heights of the plants were again taken but it could not be discovered that the differences in the heights in the three groups had changed in the least.

As can be seen in the accompanying illustration, Plate XXI, there was a most marked effect upon the stem and especially on the part just above the ring. Irregular, bunchy swellings, of greater or less size, were to be found above all of the rings. There was some tendency toward a general thickening of the whole stem above the wound and with some plants a decided inclination toward fasciation. It is to be supposed that the swelling came from stored food, though most unfortunately no analyses were made of the stored material.

Effect on the maturity of the fruit.—Record was kept of the date of opening of the first blossom of each plant. The average date of coming into bloom was very uniform for the three groups, being September 29 for Groups 1 and 2 and September 30 for Group 3. The first fruit picked in any quantity was on November 10, at which time a small and nearly uniform yield was obtained from all of the groups. During the progress of the experiment, the ripe fruits were picked twice each week, counted and weighed. The average dates of the first pickings were for first ringing, November 18; second ringing, the 16th; and for the check plants, the 18th. Thus it is seen that the ringing had no apparent effect on the time of maturity of the fruit. The general character of the plants at early and late stages is shown in Plates XXII and XXIII.

Yields.—The data in regard to number and weight of fruits for the first half of the experiment are given in the first section of Table I which includes the yield up to December 14 inclusive.

TABLE I.—EFFECT OF RINGING ON YIELD OF RIPE TOMATOES.

EARLY YIELD, NOVEMBER 10–DECEMBER 14.

	Total number plants.	Total number fruits.	Total weight of fruits.	Average number fruits per plant.	Average weight of fruits per plant.	Average weight of individual fruits.
			Ozs.		Ozs.	Ozs.
1st ringing	45	460	1769.8	10.2	39.3	....
2nd ringing	46	509	1920.	11.1	41.7	....
Check	46	484	1823.25	10.5	39.6	....
TOTAL YIELD, NOVEMBER 10–JANUARY 12.						
1st ringing	45	876	2833.	19.5	63.	3.23
2nd ringing	46	978	3054.2	21.3	66.4	3.12
Check	46	1093	3464.5	23.8	75.3	3.17

An examination of this part of the table shows that there was practically no difference between the plants of the first ringing and the check in the average number of fruits per plant or weight of the fruit. The second ringing appears to have increased the average number of ripe fruits slightly with a corresponding increase in weight. These differences are not large enough to be beyond the range of fortuitous variation and yet since all conditions were so uniform in the experiment they may be taken as an expression of actual gain for the second ringing.

The results for the entire experiment are given in the second half of Table I. This gives the record of ripe fruit to January 12 at which time the experiment was discontinued, as the bulk of the crop had then been ripened. The results do not include the unripe fruits on the plants on January 12.

These figures show that the average number of fruits per plant was reduced 18 per ct. by the first ringing and 10 per ct. by the second ringing. The average loss in weight per plant due to the first ringing was 16 per ct., and the loss due to the second ringing was 12 per ct. There was but little variation between the average weight per fruit in the different groups, the difference in the case of the first ringing being a gain of only six one-hundredths of an ounce, and in the second ringing a loss of five one-hundredths of an ounce. These differences are not worth considering.

Effect on color and flavor of fruit.— With the tree fruits and the grape, ringing usually changes the color and the flavor of the product. The color in most cases is heightened and the quality is not so good. Because of differences in these respects, horticultural societies often refuse to award premiums to fruits which have been modified in this way. In this experiment with the tomato, however, there was no difference to be noted in regard to either color or flavor. Daniel[7] reports that the product of ringed tomatoes and egg-plants in his experiments lacked flavor and that the deterioration was very marked. He says that the "flavor was insipid and less savory" than with fruits on unringed plants.

Effect on foliage.— The foliage of the ringed plants was more or less abnormal but not nearly so much so as with the chrysanthemum. The foliage of forced tomatoes not infrequently takes on a peculiar curved pendent position with elevated cushiony areas, more succulent than on normal plants. This abnormal condition results from derangement of the cell tissue because of the disturbance of the physiological processes. When exaggerated, this condition becomes a disease, the œdema of the tomato, named and described by Atkinson.[8] The plants of the ringed tomatoes seemed to suffer from a mild case of œdema. According to Atkinson œdema is brought about[9] "by an excess of water which stretches the cell walls, making them very thin and the cells very large." It would seem from theoretical considerations, and from the behavior of the plants as well, that ringing, in checking the flow of plastic material downward, causes an excessive quantity to be stored in the leaves and in this way brings on the swelling and the distortion of certain parts known as œdema. There were slight differences in color to be noted in the foliage of ringed and unringed plants, probably due to the breaking down of the stretched cell walls, causing the death of the cells and consequent injury to the adjacent parts followed by the yellowish tinge indicating diseased or dead tissues.

Effect on the roots.— The theory of ringing, to promote fruitfulness by keeping the prepared plant food in the top of the plant, acknowledges that the top is fed at the expense of the roots. Should the wound of the ring never heal over, the roots must starve and die unless there should be foliage below the ring to support them. The roots of the ringed tomatoes in this experiment showed the effects of this starvation. As with the chrysanthemum roots illustrated in Plate XXIV they were less in number and of smaller size.

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[7] Daniel, L. *Compt. Rend. Acad. Sci. (Paris)*, 131: 1253–55. 1900.
[8] Atkinson, Geo. F. N. Y. Cornell Sta. Bul. 53. 1893.
[9] Idem, p. 107.

RINGING CHRYSANTHEMUMS.

To test the effect of ringing chrysanthemums, the following varieties were ringed in the fall of 1906: Ivory, Major Bonnaffon, Nagoya, White Bonnaffon and William Duckham. In most respects the experiment was a duplicate of the one with tomatoes. The experiment was in charge of Richard Wellington, Assistant Horticulturist.

Propagation.— The rooted cuttings of these varieties were potted in four-inch pots on May 7 and on June 18 one hundred plants of each of the above varieties were selected and benched in the greenhouse. The rows were 12 inches apart and the plants were set with intervals of 9 inches in the row.

Soil.— The soil used in the benches consisted of seven parts of rotted sod, five parts of well rotted stable manure, and two parts of sand, the whole thoroughly mixed. The chrysanthemum is a gross feeder and for a further supply of plant food an inch of well rotted stable compost was applied just as the buds began to form.

Pruning and training.— The plants were pruned to produce one terminal bud each. During the experiment the suckers and side shoots were kept in check by pinching. As the plants became topheavy they were tied to a wire trellis. It was thought that by training to a terminal bud, thus concentrating the whole energy of the plant in one blossom, whatever effect there might be from the ringing would be better shown.

Grouping.— The plants were divided into three groups. The plants in the first group, which consisted of every third one in the row, commencing with the first plant, were ringed September 17; those in the second group, which consisted of every third plant in the row commencing with the second plant, were ringed October 5; and those in the third group, which consisted of every third plant in the row commencing with the third plant, were left as checks.

Ringing.— When the first plants were ringed the buds had just appeared and the bark was in a very succulent condition, peeling readily from the stems. At the time of the second ringing the buds had increased considerably in size and the bark had become less succulent, especially on the Ivory and William Duckham varieties; the bark peeled far less easily than with the first group.

A penknife was used in removing the bark from the stems. Two horizontal cuts, five-eighths of an inch apart, were made, encircling the stem about 5 inches above the ground. The ring was split by a vertical cut and the bark was easily peeled from the woody cylinder. The process was concluded by scraping the bared portion with the edge of the knife to remove all of the cambium tissue. The wounds dried almost immediately and the plants suffered no appreciable ill effects from the ringing.

Effect on foliage.— On October 19, the foliage of the first ringed plants of the varieties Ivory, Major Bonnaffon, White Bonnaffon and William Duckham had begun to show ill effects from the ringing. The upper leaves of many of these plants had a slight yellowish tinge and portions of a few leaves of the same plants, exposed to the direct sunlight, had turned reddish purple. This coloring was undoubtedly due to a physiological disorder, since no fungi nor bacteria were present.

At the end of the following week all the plants in Group 1 and a few Ivory and William Duckham plants in Group 2 showed the effects of the ringing. The yellow and reddish purple colors were, however, more pronounced on the group first ringed than on the second ringed plants. By the first of November all the ringed plants in Group 2 showed similar changes in color. This trouble increased gradually. As with the tomatoes, the leaves were curved and pendent, with the elevated cushiony areas and succulent tissue indicating a severe disturbance of the physiological processes. By the end of the experiment, several of the ringed plants were so badly affected that they were worthless.

Effect on the stems.—As the plants of the three groups of the same variety varied in height, measurements were taken two days before the cutting commenced. These measurements are given in Table II. The plants in Group 1 averaged 2.4 inches less and the plants in Group 2 ½ inch less than the check plants.

As with the tomatoes, the stems were more or less swollen, sometimes greatly so just above the ring. So, too, the swelling throughout the entire upper part of the stem was noticeable and there was also the same tendency to fasciation as with the tomatoes. The swellings were most marked on Group 1. See Plate XXIV.

The stems of one of the varieties, Nagoya, showed numerous small, wartlike outgrowths scattered over almost the entire length. These protuberances were much more numerous and more highly developed on the ringed than on the unringed plants, and specially so on the swollen parts just above the rings. These outgrowths were light brown in color; stuck out sharply from the stems; and were composed of parenchymatous tissue with a trace of woody tissue in the central portion. From the fact that when damp moss was tied about the stems the outgrowth developed into true roots, there can be no doubt but that they are rudimentary, ærial rootlets. The point of special interest is that the formation of these rudimentary organs was greatly favored by the ringing.

TABLE II.— EFFECT OF RINGING ON HEIGHT OF CHRYSANTHEMUM PLANTS.

VARIETY.	EARLY RINGING.		LATE RINGING.		NOT RINGED.	
	Number of plants ringed.	Average height.	Number of plants ringed.	Average height.	Number of plants ringed.	Average height.
		Ft.		Ft.		Ft.
Ivory	34	2.86	34	2.88	32	2.96
Major Bonnaffon	34	3.64	34	3.77	32	3.78
Nagoya	32	4.68	32	4.76	31	4.88
White Bonnaffon	34	2.80	34	3.18	32	3.19
William Duckham	34	3.58	34	3.75	32	3.76
Average height	....	3.51	....	3.67	....	3.71

Effect on maturity of blossoms.—A record was taken each week, commencing October 20 and ending November 13, of the date when the buds began to open, when half opened, and when fully opened. These results are given in Table III. A few White Bonnaffons and several Nagoya buds had not matured at the later date. From the above data the following conclusions can be drawn: The first ringing hindered the opening of the buds in all varieties except the Major Bonnaffon; the second ringing seemed to very slightly hasten the maturity of all the varieties with the exception of Nagoya.

TABLE III.— EFFECT OF RINGING ON MATURITY OF CHRYSANTHEMUM BLOSSOMS.

VARIETIES.	Dates.	EARLY RINGING. FLOWERS—			LATE RINGING. FLOWERS—			NOT RINGED. FLOWERS—		
		Opening.	Half opened.	Opened.	Opening.	Half opened.	Opened.	Opening.	Half opened.	Opened.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Ivory	Oct. 20	11.8	....	....	85.3	2.9	....	87.5	....	....
	Oct. 26	94.1	26.5	....	100.	88.3	....	100	90.6	....
	Nov. 2	97.1	94.1	....	....	100	29.4	....	100	9.4
	Nov. 9	100	100	100	....	....	100	....	....	100
Major Bonnaffon	Oct. 20	76.5	....	....	85.3	2.9	....	81.3	....	....
	Oct. 26	97.1	17.6	....	100	85.3	....	100	71.9	....
	Nov. 2	100	94.1	....	....	100	5.9	....	96.9	3.1
	Nov. 9	....	100	100	....	....	100	....	100	100
Nagoya	Oct. 26	6.9	....	....	65.6	....	....	74.2	....	....
	Nov. 2	58.6	3.4	....	93.7	3.1	....	96.8	12.9	....
	Nov. 9	96.6	41.4	6.9	96.9	90.6	40.6	100	96.8	48.4
	Nov. 13	100	82.8	17.2	100	96.9	87.5	....	96.8	90.3
White Bonnaffon	Oct. 20	....	....	....	14.7	....	....	28.1	....	....
	Oct. 26	61.8	....	....	97.1	14.7	....	93.8	15.6	....
	Nov. 2	88.2	51.5	....	97.1	85.3	....	93.8	90.6	....
	Nov. 9	100	90.9	78.8	100	97.1	97.1	100	93.8	93.8
	Nov. 13	....	100	90.9	....	97.1	97.1	....	93.8	93.8
William Duckham	Oct. 20	....	....	....	11.8	....	....	12.5	....	....
	Oct. 26	35.3	....	....	91.2	8.8	....	100	3.1	....
	Nov. 2	97.1	32.4	....	100	91.2	5.9	....	93.8	3.1
	Nov. 9	100	100	97	....	100	100	....	100	100
	Nov. 13	....	....	100	....	....	....	....	....	....

Effect on size of blossoms.— The diameters of all the blossoms that matured were taken and these are given in Table IV. The blossoms in Group 1 averaged .48 inch less, and the blossoms in Group 2 averaged .11 inch less than those in Group 3. These results, as in the case of the measurements of the height of the plants, indicate a direct injury to the plant through ringing and that the earlier the ringing the greater the injury.

TABLE IV.— EFFECT OF RINGING ON SIZE OF CHRYSANTHEMUM BLOSSOMS.

VARIETIES.	EARLY RINGING.		LATE RINGING.		NOT RINGED.	
	Number of mature blossoms.	Average diameter.	Number of mature blossoms.	Average diameter.	Number of mature blossoms.	Average diameter.
		Ins.		*Ins.*		*Ins.*
Ivory	34	3.6	34	3.84	32	3.84
Major Bonnaffon	34	4.39	34	5.12	32	5.07
Nagoya	5	4.45	28	4.51	28	4.70
White Bonnaffon	30	4.00	33	4.43	30	4.66
William Duckham	33	4.39	34	4.81	32	4.99
Average diameter	....	4.17	....	4.54	....	4.65

Effect on roots.— The effect of the ringing was very conspicuous on the roots of the plants, as is shown in Plate XXIV. The roots of the plants of Group 1 were weak and few in number; the roots of the plants of Group 2 were more abundant and slightly stronger; while the roots of the plants in Group 3 were very numerous and strong. The difference was still further marked by the sprouts which had been produced by the plant for future growth. The roots of the plants in Group 1 had but 1.7 per ct. as many sprouts as Group 3, while the roots of the plants in Group 2 had but 17 per ct. as many sprouts as Group 3.

CONCLUSION.

The outcome of the experiments in ringing tomatoes and chrysanthemums is not promising for the ringing of herbaceous plants. It is true that these experiments cover but two species of plants, but both are species which, because of their vigor, the nature of their product, their manner of growth, and other qualities should show most advantageously the effects of ringing. It is true also that the time, manner, and place of ringing might be varied with these and other species and give somewhat different results. But the deleterious effects of the treatment were so marked on several plant organs, and especially the root system, that it is extremely doubtful whether varying the method of ringing, on these species at least, could have given widely different results.

It is shown by most of the experiments in ringing woody plants that there is considerable loss in the economy of several plant organs; there is, however, with the apple and grape among woody plants some compensating gain in other organs, chiefly the fruit. Why is there not such a compensating gain in herbaceous plants? This is a question for the plant physiologist. Meanwhile it does not seem that in practice the fruit grower is finding the ringing of plants, except in rare cases, a valuable orchard or vineyard operation. The gains scarcely offset the losses. The investigation here recorded shows that the loss in the root and leaf systems in particular of herbaceous plants is most severe. Is it not more than likely that there is a similar loss to these organs in woody plants, thereby accounting for their decrease in vigor?

THE EFFECT OF WOOD ASHES AND ACID PHOSPHATE ON THE YIELD AND COLOR OF APPLES.[1]

U. P. HEDRICK.

SUMMARY.

1. Because of the condition of growth of the plant, manner of development of the product, and nature of both plant and product, the apple is difficult to deal with experimentally in the matter of fertilization.

2. The apple growers in New York should give attention to the fertility of their soils; for the orchards are growing old; the soil of some orchards was not originally fertile; and double-cropping has exhausted the fertility of many orchards.

3. This experiment has to do with potash, phosphoric acid and lime as found in wood ashes and acid phosphate. It was begun in 1893 and completed in 1904.

4. The seat of the experiment is a 55-year-old orchard on the Station grounds. The location is a sloping upland with a medium heavy clay soil. The orchard had been in grass for several years before the experiment.

5. Throughout the experiment the orchard was given clean cultivation until about August 1 and was then seeded to a cover crop of oats, barley or clover.

6. The trees were 43 years old when the experiment was started. There were 94 trees in the test representing the following varieties: Baldwin, Fall Pippin, Rhode Island *Greening*, Roxbury and Northern Spy. The orchard was divided into eight plats, four treated and four untreated.

7. Wood ashes were applied to the treated plats at the rate of 100 pounds per tree or 4,800 pounds per acre. During the last seven years of the experiment acid phosphate was applied at the rate of 8½ pounds per tree or 408 pounds per acre. Calculations made from analyses of the fertilizers show that,

[1] A reprint of Bulletin No. 289.

on the average, 169 pounds per acre of actual potash were applied each year; 72 pounds of phosphoric acid from the ashes and 57 pounds from the acid phosphate; and lime at the rate of 32 pounds per tree, 1,536 pounds per acre. The amounts are in excess of the usual recommendations of these fertilizers for apples.

8. The effects of the fertilizer were measured by two standards, yield of fruit and color of fruit.

9. The annual average increases per tree on the treated plats for the several varieties were, in bushels, as follows: Fall Pippin, 1.05; Roxbury, 2.65; Rhode Island *Greening,*— 0.34; Northern Spy, 2.55; Baldwin, 0.28.

10. From a financial standpoint the results are practically negative. The estimated increase in value of the crop on the treated plats for a hypothetical five acres is $99.00. The estimated value of the fertilizers for the above area is $74.50, leaving a gain of but $24.50, which does not more than pay for handling the fertilizers.

11. An interesting fact is that both treated and untreated plats increased markedly in yield from 1893 to 1904. The probable explanation is, that prior to 1893 the orchard was in sod, but during the experiment was kept under cultivation and grew more productive under the treatment.

12. The results as to color of fruit lack uniformity and were not decided enough in a sufficient number of the twelve seasons to enable us to state that the fertilizers applied improved the color of the apples. The influence on color was most marked in the seasons when the climatic conditions were unfavorable to the development of the fruit.

13. This experiment shows that 57 years of orchard cropping has not reduced the soil of the Station orchard to the condition where it needs a "complete" fertilizer. The fact that plowing under leguminous crops gives beneficial effects in the orchard shows that the soil is having a *one-sided* wear. It needs nitrogen and humus rather than potash and phosphoric acid.

14. The results of this experiment should not lead the fruit grower to conclude that his soil does not need the nutrients supplied. They suggest, however, since the soil of the Station orchard is an average piece of soil for western New York, that there may be many other orchards in the State that do not need these fertilizers.

15. The fertilizers applied may not have been thrown away. Phosphoric acid, potash and lime will remain in the soil for a time at least.

16. The practical application of the results obtained by this experiment is that fruit growers should not apply manures in quantity until good evidence has been obtained as to what food elements, if any, are wanted in the soil.

17. As long as trees are making good wood growth and producing average crops of well colored fruits, it may be taken as granted that they need no additional food from fertilizers. If the contrary be true the fruit grower should put in operation tests with fertilizers to ascertain what plant foods his soil needs.

THE PROBLEM OF ORCHARD FERTILIZATION.

Feeding the apple tree is a complex problem. There is a series of phenomena in the growth of all orchard trees very difficult to deal with in fertilization. Among these are: The perennial nature of the plants; the several seasons of growth before a crop is borne; the continuous cropping without chance for rotation; the facts that tree growth must proceed with fruit development, and that a whole season is required for the development of the fruit; the uneven production in different varieties and on different trees; and the necessity of the storage of plant food in bud and branch. These form a set of conditions so different from those encountered in growing general farm crops that the practices in fertilizing cereals and herbaceous plants do not apply to orchard trees.

Because of the nature of the plant and of its products, as set forth above, it is exceedingly difficult to measure the value of fertilizers in an apple orchard, and this complicates the problem of their use still more. Thus, who can give the relative values, as measures of the worth of manurial treatment, of size of tree, number and area of leaves, the fruit and its qualities, and such abstract characters as hardiness, productiveness, longevity and early bearing? Again, the effects of added or modified plant food cannot be seen in an orchard in one season, as with farm crops, but several seasons are required to gauge their influence with satisfactory accuracy.

The apple growers of New York should be especially interested in maintaining and increasing the fertility of their soils. The orchards are growing old; many, if not most of them, are past their prime and the trees are beginning to show the decay of old age. However trees and herbaceous plants may differ in use of food, they agree in this; — each succeeding crop harvested from either finds the soils somewhat poorer. Again, much of the soil upon which apples have been planted did not originally possess high fertility; and such orchards are now in need of plant food. Then, too, some orchards have been double-cropped until the plant food in the soil is exhausted. Quite as detrimental to the soil as double-cropping is the lack of tillage. Jethro Tull announced in 1733 that "tillage is a means of increasing the pasture of a plant," and since that time we have come to know that it is the chief of all means of maintaining soil fertility. Orchards can be grown profitably without tillage only in the most fertile soils; unfortunately, however, the operation is neglected in many New York orchards, the soils of which are not fertile.

It is scarcely necessary to point out that fruit growers have little definite knowledge of the manurial requirements of any of the tree fruits. In fact, it is only within the past few years that there has been any thought that orchards needed fertilizers, the assumption having been that trees could take care of themselves in this, as well as in many other respects. The literature of the subject is scant, fragmentary, and for most part unreliable. There are records of but very few long-continued experiments with fertilizers for the apple. The apple grower cannot carry on fertilizer experiments of much value to others than himself and it is a difficult task for the experiment station.

The investigation discussed in the following pages throws light only on the use of potash and phosphoric acid as found in certain fertilizers and as they affect but two qualities of the apple — yield and color of fruit; but the experiment has been carried on with care and exactness for twelve years, and since these are two of the chief mineral constituents of the food of the apple, and the fertilizers in which they were used are common ones, and the tree qualities important ones, the work, though not comprehensive, should be valuable, and especially so, in view of the meagerness of our knowledge as to the effects of these foods on the apple.

THE EXPERIMENT.

The trial of wood ashes as a fertilizer for apples was begun by Professor S. A. Beach in the Station orchard in 1893 and was carried on by him to its completion at the close of the season of 1904; a preliminary report of the experiment was published in Bulletin No. 140 from this Station in 1897. The remaining data were turned over to the writer, as Professor Beach's successor, and this report is based on the one published in Bulletin No. 140 and on the subsequent data. The experiment was planned to determine the effects of wood ashes on the scab fungus of the apple as well as the value of the ashes as a fertilizer, but when it was found, after liberal applications of the ashes for five years, that the immunity of the apples to the fungus was in no degree increased, this phase of the experiment was dropped.

Beginning with the season of 1898 the test of wood ashes was supplemented by one with acid phosphate, and the two experiments were carried on jointly until the close of the season of 1904. Since wood ashes contain considerable quantities of phosphoric acid and lime, the original experiment was really one with potash, phosphoric acid and lime as found in wood ashes.

Location and character of soil.— The seat of the experiment is a mature apple orchard, 55 years old at the close of the experiment, on the Station grounds. The location is a piece of upland sloping to the south and running into the bottom land of a small creek. The soil is a heavy clay loam from twelve to eighteen inches deep, resting on a still heavier, compact clay sub-soil; this in turn is superimposed on shale to be found at a depth of from four to six feet near the creek, to from fifteen to twenty in parts of the orchard. An analysis of essentially the same soil taken in an adjoining field shows the following constituents:

TABLE I.— COMPOSITION OF SOIL OF STATION ORCHARD.*

	Top-soil.	Sub-soil.
	Per ct.	*Per ct.*
Moisture	1.23	1.04
Organic matter	4.09	2.78
Insoluble	81.83	80.09
Soluble silica	.30	.23
Iron and alumina	9.34	10.95
Lime	.62	.96
Magnesia	.85	1.26
Soda	.33	.36
Sulphuric acid	none	none
Potash	.89	1.23
Phosphoric acid	.093	.097
Ammonia	.255	.181
Nitrogen	.210	.149
Chlorine, carbonic acid, undetermined, etc	.43	.13

These analyses show that the sub-soil differs from the top-soil in having " less insoluble matter, more iron and alumina, lime, potash and soda, less organic matter by twenty-five per ct., less phosphoric acid, and thirty per ct. less nitrogen." Both top and sub-soil, it can be seen, have a large percentage of potash and of lime.

The soil is not an ideal one for apples, probably not better than the average western New York clay soil for this fruit. The trees make a good growth and fruit sets in abundance, but with most varieties, all in this experiment, the size of the product is small; the fruit does not take on high color; and in many seasons does not properly mature. Though well drained, the soil is yet wet and heavy, probably because of the fine state of division of the soil particles. The tillage given the orchard and the cover crops planted in it have greatly improved the character of the soil, though rain quickly renders it unworkable. The root-run, because of the quality and depth of the soil, is too limited for the best results in growing apples.

An inspection shows that there are no considerable variations of soil in the orchard, the chief one being a tendency, as the ground approaches the bottom land of the creek, to less depth in top-soil and to a coarser texture. The difference is not so great, however, that the value of the field for experimental purposes is impaired to any great degree. In general, the soil is such that the trees behave essentially as in the great majority of the orchards in the region in which the Station is located.

* Wheeler, W. P., N. Y. Sta. An. Rpt., **8**:55. 1889.

Before the experiment was begun, in 1893, the orchard had been in grass for several years. During the winter of 1892–3, it was given a liberal application of barnyard manure, which was plowed under the following spring. Throughout the experiment the orchard has been given clean cultivation until about August 1st, and then seeded to a cover crop of oats, barley or clover.

The trees.— The experimental plats contain 241 bearing trees, 142 of which are in full bearing. Of these, however, there are a few varieties which are not well enough represented in treated and untreated plats to permit them to be used in the experiment. Excluding these odd varieties there remain 94 trees, 47 in each division of the experiment. The varieties represented are: Baldwin, Fall Pippin, Rhode Island *Greening*, Roxbury and Northern Spy. The numbers of treated and untreated trees of each of these varieties are:

	Treated.	Untreated.
Baldwin	9	6
Fall Pippin	7	6
Rhode Island *Greening*	12	18
Roxbury	4	4
Northern Spy	15	13

The orchard was divided into eight plats, numbered from 1 to 8. The accompanying diagram of the orchard, page 311, shows the positions of the plats and of the trees in each. The shaded portions of the diagram indicate the plats which were treated with ashes. The trees in the experiment are indicated by number in the explanation, and by shading in the diagram.

The trees selected were planted in 1850 and were, therefore, 43 years old when the experiment was begun. The orchard as a whole does not form a uniform block, but the trees selected, as numbered above, were fairly uniform and in the main were well adapted for the investigation.

THE FERTILIZERS.

Wood ashes were applied to the four treated plats at the rate of 100 pounds per tree annually, with the exception of two years, 1901 and 1902, when the applications were omitted. As there are 48 trees per acre, 4,800 pounds were applied per acre. The ashes were thoroughly mixed, weighed separately for each tree, and applied broadcast to a line midway between adjacent rows. Applications were made in the spring and were well worked into the ground. No other fertilizer was applied to any part of the orchard during the first five years of the experiment; cover crops were plowed under as follows:

1893—Oats and peas
1894—Crop not stated
1895—Crop not stated
1896—Sweet clover
1897—Mammoth clover
1898—Crimson clover
1899—Crimson clover
1900—Rye
1901—Oats
1902—Barley
1903—Crimson clover
1904—Mammoth clover

Explanation of Diagram.

Baldwin, treated, Nos. 10, 101, 102, 108, 109, 125, 126, 127, 128.

Baldwin, untreated, Nos. 81, 111, 133, 136, 137, 207.

Fall Pippin, treated, Nos. 31, 33, 34, 35, 37, 38, 39.

Fall Pippin, untreated, Nos. 1, 4, 5, 6, 8, 9.

R. I. *Greening,* treated, Nos. 50, 51, 52, 54, 55, 56, 58, 70, 105, 107, 129, 146.

R. I. *Greening,* untreated, Nos. 24, 25, 26, 27, 28, 29, 42, 43, 46, 48, 62, 69, 82, 83, 162, 165, 184, 185.

Roxbury, treated, Nos. 143, 145, 147, 149.

Roxbury, untreated, Nos. 150, 153, 161, 175.

Northern Spy, treated, Nos. 74, 75, 76, 77, 202, 205, 210, 212, 213, 215, 221, 223, 224, 225, 245.

Northern Spy, untreated, Nos. 116, 206, 208, 227, 228, 229, 230, 233, 234, 249, 250, 251, 253.

Acid phosphate was added to the treated plats during the last seven years of the experiment in quantities stated hereafter.

Analyses were made of each application to determine the percentage of potash and with the following results:

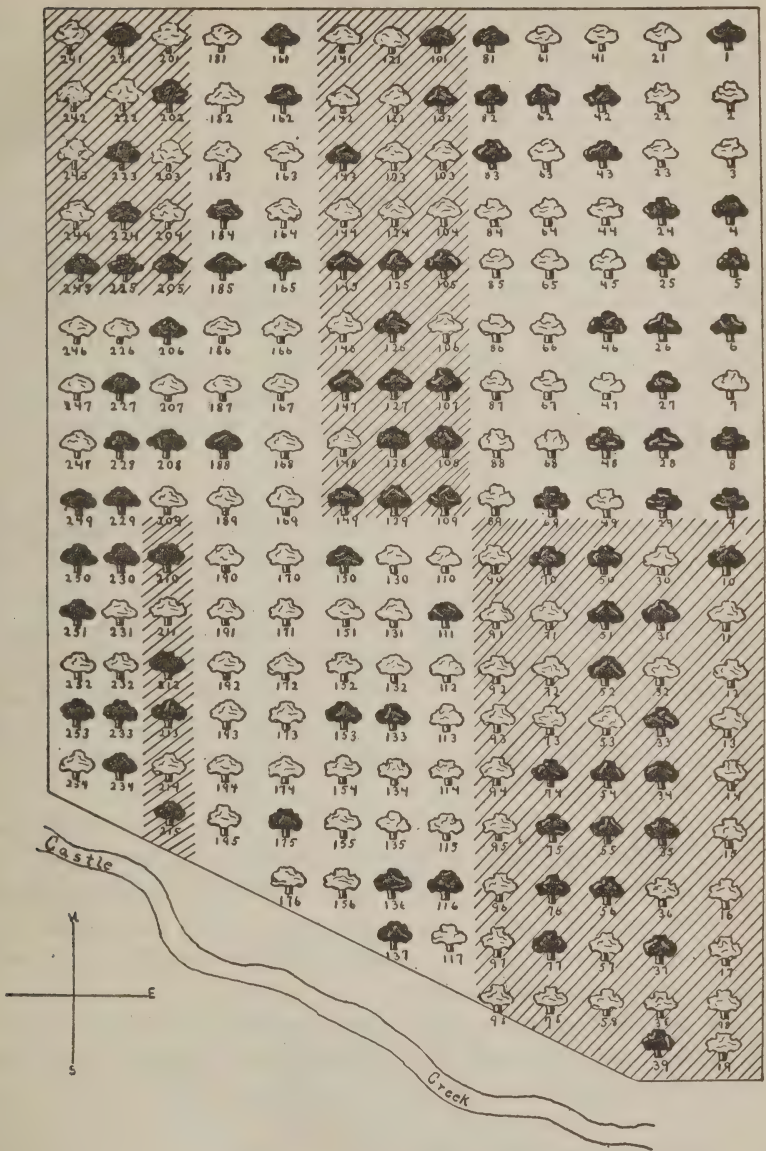
Castle
Creek
N
E
S

TABLE II.— PERCENTAGE OF POTASH IN ASHES APPLIED.

Year	Per ct.	Year	Per ct.
First	4.13	Seventh	3.24
Second	3.89	Eighth	4.39
Third	5.71	Ninth	....
Fourth	5.71	Tenth	....
Fifth	1.38	Eleventh	5.06
Sixth	4.01	Twelfth	4.79

Since 100 pounds of ashes were applied to each tree annually these figures show the number of pounds of actual potash per tree each season. Thus, 42.31 pounds were applied per tree during the twelve years; 2,031 pounds per acre; an average of 169 pounds per acre for the twelve years. The amount of potash applied was much greater than is generally used in orchard practice, from 50 to 100 pounds per acre for apples being the common allowance.

Unfortunately the amounts of phosphoric acid and lime in the ashes used were not determined. But since the amount of phosphoric acid found in ashes varies from 1 to 2 per ct., 1½ per ct. being a fair average, we can assume that 1½ pounds of phosphoric acid were applied per tree each year, or 72 pounds per acre. The average analysis of commercial wood ashes shows them to contain 32 per ct. of lime, so that there was probably added about 32 pounds of lime per tree annually, or 1,536 pounds per acre. These amounts are in excess of those commonly thought to be necessary per acre for apples, and therefore this experiment has to do with phosphoric acid and lime as well as the potash in the wood ashes. It is true that phosphoric acid in ashes becomes available slowly. But its effects should be seen in twelve years, especially since the conditions, cultivation and the plowing under of cover crops, were favorable for its becoming available.

It is held by some that the apple does best on a slightly acid soil and it may be claimed that in this experiment lime has hindered the action of the other ingredients. However, I can find no data to show that an alkaline condition of the soil brought about by lime hinders any specific function of potash or phosphoric acid in growing apple trees; nor that the lime accompaniment could in any way nullify or obscure the action of these nutrients as to the yield or color of apples. In this connection it is worth noting that some of the best apple regions in the United States have limestone soils. Many fruit growers use lime in moderate quantities as a fertilizer for apples. From these considerations it may be assumed that lime in the quantities added did not have a deleterious effect on the yield or color of the apple in this experiment; on the contrary, it might be suspected that the lime was in part responsible for such beneficial effects as were noted.

While no tests to determine the acidity of the soil were made, it may be inferred, since all leguminous cover crops grew readily in the untreated plats, that the soil of the orchard is not strongly acid, for the clovers, in particular, do not thrive in an acid soil.

Acid phosphate was applied to the treated plats at the rate of 8½ pounds per tree during the last seven years of the experiment. With 48 trees per acre, there were, therefore, 408 pounds of the acid phosphate applied to each acre. The fertilizer was guaranteed to contain 14 per ct. of phosphoric acid (analysis proved it to contain approximately that much) and the amount of available phosphoric acid per tree each season was 1.19 pounds, or 8.33 pounds per tree in the seven years. This is equivalent to 399.84 pounds per acre, an average of 57 pounds per acre annually. The amount of phosphoric acid recommended for apples ranges from 30 to 60 pounds per acre. Adding to the above amount the phosphoric acid to be found in the wood ashes, approximately 72 pounds per acre, the total quantity is about 129 pounds per acre,— an abundance and to spare.

The phosphoric acid was applied as were the ashes — scattered broadcast in the spring over an area slightly greater than that covered by the branches of the trees; a disk harrow was used to work the fertilizer rather deeply into the soil.

THE RESULTS.

There are several standards of measurement as to the merit of any treatment to which a fruit tree is subjected; as, growth of wood; leaf-size and total leaf-area; the several qualities of fruit, as size, color, texture of flesh and keeping quality; and such tree characters as hardiness, productiveness, bearing habit and longevity. That is, the health and vigor of the tree and the value of the product are proportional to these qualities and characters and especially as to the degree of agreement between them. A wholly reliable method of testing any treatment of a fruit tree should take all of the above features into consideration and a method of measurement lacking any considerable number of them, generally speaking, is faulty. Data can be given in this investigation only as regards fruit, and at first thought there may be objections to conclusions drawn from such data. But since yield and quality of fruit constitute the ultimate criterion of the value of any orchard treatment; and since tree characters are not so important with old trees as in this experiment; and since the data regarding fruit are unusually full and detailed, the lack of information regarding tree characters does not seriously lessen the value of the experiment.

It is true that a crop is an uncertain standard of measurement; for with the apple there is a tendency to biennial bearing; the accidental variations in the crop are large; there are marked individual differences in the trees as to yield; and the varieties differ greatly in bearing capacity. These uncertainties have been largely overcome in this investigation by taking an average for twelve years and by including five varieties in the experiment.

In harvesting the crops the yields of the trees were recorded separately in pounds and ounces for the firsts, seconds, culls, and total weights. This enables us to study the crops from the standpoints of weight of product and of average size, there being three grades as to size. Attention is called to these two quite different standards of measurement. Size of individual fruits is one of the best criterions of the vigor of a tree if there be the average number of fruits. Large, succulent fruits indicate, as a rule, rapid and vigorous growth. The number of fruits, however, is probably a more accurate index of the food used by a tree, and therefore of the exhaustion of the soil and of the need of fertilizers; for it seems fairly well established that a small and possibly poorly developed fruit contains practically as much dry matter, which represents plant food, as a large fruit. In other words, fruits seem to increase in size chiefly by the enlargement of cells, the contents being largely water, rather than by the multiplication of cells, a process seemingly requiring more solids.

YIELD OF FRUIT.

The yield of fruit is shown in Table III. The average yield per tree is given for each variety for the twelve years and the annual average per tree for the whole period. Fortunately the period during which the experiment was carried on was one of extreme fruitfulness for the apple in western New York and some fruit was harvested in each of the twelve years, excepting in 1903, giving a high average of productiveness for the orchard during the period.

TABLE III—AVERAGE YIELD OF APPLES PER TREE, WITH AND WITHOUT APPLICATIONS OF POTASH AND PHOSPHORIC ACID.

YEAR.	Baldwin.		Fall Pippin.		Roxbury.		R. I. *Greening.*		Northern Spy.	
	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1893.......	a few fruits	none	0.08	2.01	1.57	0.50	2.58	2.72	5.98	0.14
1894.......	2.57	2.94	0.74	0.58	6.44	2.80	5.41	4.11	8.64	5.85
1895.......	6.88	9.81	5.43	3.94	6.89	7.52	8.31	5.55	6.47	6.35
1896.......	25.26	24.10	20.64	19.77	30.56	21.37	19.14	23.78	19.87	13.40
1897.......	3.29	2.69	1.41	1.52	12.47	11.24	2.06	1.09	8.68	6.93
1898.......	8.22	8.02	2.96	2.70	9.98	4.66	6.94	7.92	4.12	1.40
1899.......	2.86	5.06	6.36	2.40	8.48	7.12	1.98	0.44	4.46	2.72
1900.......	17.82	15.62	13.96	10.38	15.20	10.38	12.94	16.30	10.62	7.28
1901.......	1.38	1.60	2.60	1.16	2.02	2.90	1.34	0.04	1.80	0.48
1902.......	16.08	13.78	11.94	10.62	19.90	17.22	15.68	18.80	11.56	10.48
1903.......	......	......	......	......	......	......	......	......	......	......
1904.......	20.74	18.48	20.64	19.12	20.52	16.46	24.18	23.96	12.66	9.16
Annual av. per tree..	8.78	8.50	7.23	6.18	11.16	8.51	8.38	8.72	7.90	5.35

In order to make comparisons of the annual averages per tree the figures given by Beach in Bulletin No. 140 for the first five years of the experiment are published as Table IV.

TABLE IV.—ANNUAL AVERAGE YIELD OF APPLES PER TREE FOR FIVE YEARS, WITH AND WITHOUT APPLICATIONS OF POTASH AND PHOSPHORIC ACID.

YEARS.	Baldwin.		Fall Pippin.		Roxbury.		R. I. *Greening.*		Northern Spy.	
	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1893–1897..	7.66	7.91	5.66	5.56	11.59	8.69	7.50	7.4[illegible]	9.93	6.53

The annual averages showed, at the end of the first five years, an increased average yield per tree for Fall Pippin, Roxbury, Rhode Island *Greening* and Northern Spy and a decrease for the Baldwin. The differences are shown in Table V.

TABLE V.— INCREASED YIELDS ON APPLE PLATS TREATED WITH POTASH AND PHOSPHORIC ACID, CALCULATED AT THE END OF FIVE YEARS.

NAME.	Annual average increase per tree.	Rate per acre.
	Bu.	*Bu.*
Fall Pippin	0.10	4.8
Roxbury	2.90	139.2
R. I. *Greening*	0.05	2.4
Northern Spy	3.40	163.2
Baldwin	—0.28	—13.4

The results at the end of the twelve-year period are quite different, having changed the negative result for the Baldwin, as shown in Table V, to a positive one; and the positive result of the Rhode Island *Greening* to a negative one. Differences in yields for the twelve years are shown in Table VI.

TABLE VI.— INCREASED YIELD ON APPLE PLATS TREATED WITH POTASH AND PHOSPHORIC ACID, CALCULATED AT THE END OF TWELVE YEARS.

NAME.	Annual average increase per tree.	Rate per acre.
	Bu.	*Bu.*
Fall Pippin	1.05	50.4
Roxbury	2.65	127.2
R. I. *Greening*	—0.34	—16.3
Northern Spy	2.55	122.4
Baldwin	0.28	13.4

A very interesting fact is brought out in Table VII, namely, that both the treated and the untreated plats increased markedly in yield from 1893 to 1904 and that the productiveness of the orchard was for the treated plats 1.13 times, and the untreated plats 1.17 times as great in the second six-year period of the experiment as in the first six-year period, notwithstanding the facts that in 1903 in the second period not an apple was borne; that the 1896 crop, which came in the first period, was one of the most remarkable crops in quantity of fruit ever known in western New York. There can be but one explanation: *Prior to* 1893 *the orchard was in sod, but during the continuance of this experiment it has been kept under cultivation and seemingly grew much more productive under the treatment.*

TABLE VII.— SUM OF THE AVERAGE YIELDS OF APPLES WITH AND WITHOUT APPLICATIONS OF POTASH AND PHOSPHORIC ACID.

	1893.	1894.	1895.	1896.	1897.	1898.
Treated, bushels	10.21	23.80	33.98	115.77	28.59	32.22
Untreated, bushels	5.37	16.28	33.17	102.42	23.47	24.70

TABLE VII.—(Continued).

	1899.	1900.	1901.	1902.	1903.	1904.
Treated, bushels	24.14	70.54	9.14	75.16	......	98.74
Untreated, bushels	17.74	59.96	6.18	70.90	......	87.18

A study of the yields shown in these tables gives only uncertainty as to the effect produced by the fertilizers. If we regard the varieties separately, there are but two of the five varieties, Roxbury and Northern Spy, in which the effect has been sufficiently great to be looked upon as outside the range of variation; when we consider the varieties collectively the average annual gain per tree, 1.24 bu., is not great enough to be of practical importance. It must be noted, too, that the results obtained at the end of the five-year period, and those of the twelve-year period, are reversed with two of the five varieties and very materially changed with the other three.

Let us calculate the financial gain from the use of the fertilizers. Taking the sum of the gains and losses for the five varieties, for a hypothetical five acres, and we have in round numbers an annual gain of 99 barrels, including firsts, seconds and culls. At $1 per barrel, a fair average for twelve years for the three grades, we have $99 greater income from the treated five acres than from the untreated. With potash and phosphoric acid at five cents per pound each, the value of the fertilizer applied is $74.50 and we have a gain of but $24.50, not counting the work of handling, applying and working in the fertilizers to five acres of orchard, which practically offsets the gain. So that in practice, if not strictly in fact, the results from the fertilizers as to yields have been negative.

COLOR OF FRUIT.

It is commonly thought that out of the baker's dozen of elements made use of by plants, potash is the one which gives color to fruits. The statement is not infrequently made, too, that phosphoric acid has a decidedly beneficial effect on the color of fruit. This phase of the present experiment is therefore approached with some interest. In the Station orchard apples do not color well and if the addition of these fertilizers would heighten color their use might be desirable, even though there was no great gain in yield. On sandy soils, apples as a rule take on their brightest colors, while on clay they run to duller hues. Because of their influence on color, potash and phosphoric acid are thought to be especially valuable on clay soils. The clay soil of the Station orchard was, therefore, a very favorable one upon which to try these substances to influence color.

The records for the twelve years for the varieties in question run as follows:

1893. Slight improvement was noted in the color of all the varieties on the treated sections. Even the Roxbury was smoother and more highly colored on the treated than on the untreated section.

1894. Fall Pippins were smoother and fairer on the treated plats. Baldwins showed but little difference and that in favor of the untreated trees. Rhode Island *Greenings* had a riper appearance, more yellow and a tinge of red on treated plats. No difference discernible with Northern Spy and Roxbury. The results for this year were not at all uniform.

1895. Effects were not more noticeable for this season than in the previous one, Rhode Island *Greenings* and Northern Spys showing best color in untreated plats and Baldwins and Roxburys highest colored in treated plats; no difference noted between the plats of Fall Pippins.

1896. Colors developed as well on untreated plats as on treated.

1897. Crop comparatively small and poorly colored on both treated and untreated plats without noticeable difference.

1898. Effects not at all uniform, the product of the trees in the same plats differing as much as the products from different plats.

1899. Slight improvement in color of Baldwins and Northern Spys, the red sorts, no difference in Rhode Island *Greening,* Fall Pippin and Roxbury, the green varieties.

1900. No differences could be noted.

1901. Small crop of undersized fruit all poorly colored and no difference in favor of either set of plats.

1902. All of the treated plats showed more brilliant colors, though the differences could scarcely be noted in the green varieties.

1903. No crop.

1904. Differences slight and variable and not to be counted in favor of either treated or untreated trees.

Taken as a whole, the results are disappointing. They lack uniformity and were not decided enough in a sufficient number of the twelve seasons to enable us to state that the addition of the substances applied heightened the color of apples under the conditions of this experiment. The effects varied not only from season to season, but varieties varied greatly in some seasons, and in others the same variety would color differently in plats receiving the same treatment. When we consider the number of factors which are known to influence color in fruit we cannot assume with any degree of certainty that the results set forth above show that the addition of these fertilizers changed the color of the fruit in this experiment in any season; thus, exposure to light; the intensity of the light; amount of foliage on the tree; the healthfulness of the foliage; the amount of stored food in the plant; soil heat; the texture of the soil; all of these, besides potash and phosphoric acid, have an influence. The relations of these factors are so intricate that it is almost impossible to separate them in an experiment like this, and especially as the differences were so slight.

A comparison of the color data with meteorological data for the twelve-year period shows that the treatment seemed to have an influence in coloring fruit only in those years when the apple did not develop well, as in 1893 and 1902; and that in other seasons, as in 1896, 1900, 1904, when climatic conditions were favorable to the development of fruit and foliage, the coloring was as nearly perfect on the untreated as on the treated plats.

APPLICATION OF RESULTS.

The returns obtained in this twelve-year experiment are negative from a practical standpoint. This experiment shows that it is not profitable to apply potash, phosphoric acid, or lime to the soil of the Station orchard. Fifty-seven years of orchard cropping has not reduced this soil to the condition where it needs a "complete" fertilizer, yet the leguminous cover crops plowed under in the orchard have usually produced beneficial effects the same or the next season. This seems to show that the orchard is having a one-sided wear. It needs nitrogen, or humus, or the physical condition to be obtained by plowing under organic matter. It would be an assumption to say whether it is the food, or the condition of the soil brought about by the organic matter, or both, that has proved beneficial when cover crops were plowed under.

"Potash for fruits" has been the cry for so long that many fruit growers are misled as to its use. It is true that the "out-go" of potash from the soil is relatively great, as shown by analyses, and if the soil lacks this ingredient, trees are not fruitful. But it is becoming more and more apparent that in many orchard soils potash is more abundant, or more available, or is less needed by the trees, than was formerly thought. Orchard practice, as well as the present experiment, has demonstrated that the plea for potash in orchards may not always be founded on a real need.

It must not be concluded, because the effects from the fertilizers applied were scarcely apparent in the Station orchard, that they would be ineffectual in all orchards, or necessarily for all time in this orchard. Plants require food, and the fact that certain nutrients added to this soil gave no results must mean that this particular soil contained an abundance of the elements added when the experiment was begun. Since, however, the soil of the Station orchard is an average piece of land for western New York — no better, no worse — there must be many other orchards in the State that do not need these fertilizers. In view of the fact that fertilizers are now very generally used in growing apples, it may be that considerable sums of money are wasted in buying and applying fertilizers which are not needed.

The fertilizers that have been misapplied to orchards have not been absolutely thrown away. The phosphoric acid put in the soil will remain stored up for a period of years; the potash will remain for a few years at least; and the lime is of more or less permanent value in the soil. Meanwhile it is possible that all of these compounds will have a beneficial effect on the cover crops grown in the orchard. Still, it is not profitable to buy fertilizers and store them in the soil in this way.

Since the ordinary farm and garden crops on the Station grounds, on soils quite similar to that upon which this experiment was carried on, show more or less marked beneficial effects from the use of potash and phosphoric acid fertilizers, it may be assumed that, during the fifty-seven years this orchard has been growing, general farming has been more exhaustive of the elements added in this experiment than have the apple trees. There are many facts that lead us to assume that the apple does not quickly exhaust a soil, but to the contrary wears a soil but little. This experiment suggests that such may be the case, but of course does not prove it; for the question is a complicated one, involving many factors not here considered.

The practical application of the information obtained by this experiment is, that the apple grower should not apply manures in quantity until he has obtained some evidence as to what food elements, if any, are needed in his soil. Good evidence in this direction is furnished by the trees themselves. So long as trees are growing well, adding a fair amount of new wood each year, and producing good crops of well-colored fruit, it may be taken for granted that they need no additional food from fertilizers. Should the growth and behavior of the trees be otherwise, it may be suspected that they need more, or other foods, and experiments should be set on foot to determine what and how much.

PLAN FOR FERTILIZER EXPERIMENT.

The following is a brief plan whereby a man may determine, in some measure at least, what fertilizers his orchard needs. The plan is adapted from a fertilizer experiment which has now been running for ten years in a young apple orchard on the Station grounds.

The trees selected for this experiment should be of the same variety and age and should stand in a soil as uniform in texture and fertility as the orchard affords. Unless one has positive proof that the trees do not need any one or more of the three elements we commonly supply in fertilizers, he should make use of all of them on his experimental plats. There should be a sufficient number of trees in each plat to offset individuality in the trees. Five trees for each plat is probably the least number that can be used with any degree of accuracy. There should be six or seven plats. For the average orchard in western New York, the following fertilizers might be tried:—

On Plat 1, use stable manure to supply nitrogen. Manure sufficient to supply 50 pounds of nitrogen to the acre per year would be a fair amount. On the average, according to analyses for our experiments, this would take about 7½ tons of well-rotted stable manure per acre. In an orchard where the trees stand 40 feet apart, this amount means about 400 pounds per tree.

On Plat 2, use a phosphate fertilizer in sufficient amount to supply 50 pounds of phosphoric acid per acre per year. A good recommendation is, 360 pounds of 14 per ct. guaranteed acid phosphate per acre, or 13 pounds of the fertilizer per tree.

On Plat 3, apply muriate of potash, guaranteed 48 per ct. to 52 per ct. actual potash. Apply 100 pounds of the potash per acre, which would require, of 50 per ct. actual potash, 200 pounds of the muriate of potash per acre, or 8 pounds per tree.

On Plat 4, combine the acid phosphate and the muriate of potash in the amounts prescribed for Plats 2 and 3.

On Plat 5, use a "complete" fertilizer, consisting of nitrogen as applied in Plat 1, and of phosphoric acid and potash as applied in Plat 3. Or, for the stable manure, substitute dried blood and nitrate of soda. The former may be had with a guaranteed analysis of from 9 per ct. to 12 per ct.; the latter contains from 15 per ct. to 16 per ct. of nitrogen. The following amounts of these two substances should be applied: 350 pounds of dried blood per acre, or 12.84 pounds per tree; and 100 pounds of nitrate of soda per acre, or 3.67 pounds per tree.

Plat 6 should be a check. It is desirable to have two control plats, though, as the number of plats is increased, the work of the experiment is greatly increased.

If thought desirable to test the influence of lime, duplicate Plat 5 with the addition of 25 pounds of good stone lime per tree, which is to be applied unslaked.

Some care should be exercised in applying the fertilizers. The best time, all things considered, is spring, as soon as the ground can be worked. It might be well to apply the fertilizers containing nitrogen at a later time. The fertilizers should be weighed as accurately as possible. Spread broadcast about the tree over an area slightly greater than that covered by the branches of the tree. In cultivated orchards the commercial fertilizer should be harrowed in and the manure plowed under.

If the results are to be at all conclusive, such an experiment should run several years. It is not impossible in the average orchard to accurately weigh or measure the crop at harvest time to determine the relative value of the different treatments. It is not sufficient in packing to keep count of the number of barrels of marketable fruit from each plat; culls and windfalls should be accounted for.

It will be urged that this plat experimentation will be entirely out of the question for the busy fruit grower. The objection is not well founded. The plats can be laid out, the materials weighed, and all plans made for such experimentation in the winter, so that the actual work in the spring need not be great.

Such a simple experiment as has been outlined here may give results of financial value; at the same time it is true investigation and should stimulate the spirit of investigation to the great good of the fruit grower himself. If such investigations were developed among fruit growers as a body, in all phases of their work, the industry would soon be revolutionized.

CONCLUSION.

The most important lessons taught by the experiment here recorded are: That an orchard soil may not need potash, phosphoric acid, nor lime, even though the soil may have been cropped a half century; that in a soil which produces apples of poor color potash and phosphoric acid may not improve the color; and that the apple does not seem to be as exhaustive of soil fertility as farm crops. The experiment suggests, as well, that to assume without definite knowledge that a tree needs this or that plant food often leads to the waste of fertilizing material; and that in the matter of fertilizing an orchard a fruit grower should experiment for himself, since an orchard's need of fertilizer can be determined only by the behavior of the trees when supplied with the several plant foods.

INSPECTION WORK.

REPORT OF ANALYSES OF SAMPLES OF FERTILIZERS COLLECTED BY THE COMMISSIONER OF AGRICULTURE DURING 1906 and 1907.*

(The analyses reported in these Bulletins cease to have value long before they could be reprinted in this Report; and are, therefore, omitted.— W. H. JORDAN, *Director.*)

INSPECTION OF FEEDING STUFFS.†

(See note above. Some comments on results of feeding stuffs inspection will be found in the Director's report (pages 22–25 of this volume).—W. H. JORDAN, *Director.*)

* Printed as Bulletins Nos. 285 and 294.
† Printed as Bulletin No. 291.

APPENDIX.

I. Periodicals Received by the Station.

II. Meteorological Records.

Appendix.

PERIODICALS RECEIVED BY THE STATION.

Acclimitation	Complimentary
Agricultural Epitomist	Complimentary
Agricultural Experiments	Complimentary
Agricultural Gazette of New South Wales	Complimentary
Agricultural Journal and Mining Records (Natal)	Complimentary
Agricultural Journal of the Cape of Good Hope	Complimentary
Agricultural Ledger	Complimentary
Agricultural News	Complimentary
Allegan Gazette	Complimentary
American Agriculturist	Subscription
American Chemical Journal	Subscription
American Chemical Society, Journal	Subscription
American Cultivator	Complimentary
American Entomological Society, Transactions	Subscription
American Fancier	Subscription
American Fertilizer	Subscription
American Florist	Subscription
American Grange Bulletin	Complimentary
American Grocer	Complimentary
American Hay, Flour and Feed Journal	Complimentary
American Home Magazine	Complimentary
American Journal of Physiology	Subscription
American Miller	Complimentary
American Naturalist	Subscription
American Philosophical Society, Proceedings	Complimentary
American Poultry Advocate	Complimentary
American Poultry Journal	Complimentary
American Poultryman	Subscription
American Stock Keeper	Complimentary
Analyst	Subscription
Annales de l'Institute Pasteur	Subscription
Annales de la Societe Entomologique de Belgique	Complimentary
Annals and Magazine of Natural History	Subscription
Annals of Botany	Subscription
Archiv der gesammte Physiologie (Pflueger)	Subscription
Archiv fuer Hygiene	Subscription
Association Belge des Chimistes, Bulletin	Complimentary
Australian Garden and Field	Complimentary
Beet Sugar Gazette	Complimentary
Beitrage zur Chemischen Physiologie und Pathologie	Subscription

Berichte der deutschen botanischen Gesellschaft	Subscription
Berichte der deutschen chemischen Gesellschaft	Subscription
Better Fruit	Complimentary
Biochemisches Centralblatt	Subscription
Biological Bulletin	Subscription
Biologisches Centralblatt	Subscription
Biophysikalisches Centralblatt	Subscription
Blooded Stock	Complimentary
Boletim da Agricultura	Complimentary
Boletin de la Sociedad Nacional de Agricultura	Complimentary
Boston Society of Natural History, Proceedings	Subscription
Botanical Gazette	Subscription
Botanisches Zeitung	Subscription
Botanisches Centralblatt	Subscription
Botaniste, Le	Subscription
Buffalo Society of Natural Sciences, Bulletin	Complimentary
Bulletin of the Department of Agriculture, Jamaica	Complimentary
Caledonia Era	Complimentary
California Cultivator	Complimentary
California Fruit Grower	Subscription
Canadian Entomologist	Subscription
Canadian Horticulturist	Complimentary
Canadian Magazine	Complimentary
Cellule, La.	Subscription
Centralblatt fuer Agrikultur-Chemie	Subscription
Centralblatt fuer Bakteriologie, etc.	Subscription
Chemical Abstracts	Subscription
Chemical News	Subscription
Chemical Society, Journal	Subscription
Chemiker Zeitung	Subscription
Chemisches Centralblatt	Subscription
Chicago Daily Drovers' Journal	Complimentary
Chicago Dairy Produce	Complimentary
Cincinnati Society of Natural History, Journal	Complimentary
Cold Storage and Ice Trades Review	Complimentary
Colman's Rural World	Complimentary
Colonial Dairy Produce Report	Complimentary
Columbus Horticultural Society, Journal	Complimentary
Commercial Poultry	Complimentary
Country Gentleman	Subscription
Country Life in America	Subscription
Country World	Complimentary
Criador Paulista	Complimentary
Dairy and Creamery	Complimentary
Dairy and Produce Review	Complimentary
Down Town Topics	Complimentary
Elgin Dairy Report	Complimentary
Elisha Mitchell Scientific Society, Journal	Complimentary
Engineer	Subscription
Engineers' Review	Subscription

Engineering Review	Subscription
Entomological News	Subscription
Entomological Society of Washington, Proceedings	Subscription
Entomologische Zeitschrift	Subscription
Entomologist	Subscription
Entomologists' Record	Subscription
Fanciers' Review	Complimentary
Fancy Fruit	Complimentary
Farm and Fireside	Complimentary
Farm and Live Stock Journal	Complimentary
Farm and Stock	Complimentary
Farm Journal	Complimentary
Farm Life	Complimentary
Farm News	Complimentary
Farm Poultry Semi-Monthly	Complimentary
Farm, Stock and Home	Complimentary
Farm Stock Success	Complimentary
Farmers' Advocate	Complimentary
Farmers' Call	Complimentary
Farmers' Guide	Complimentary
Farmers' Progress	Complimentary
Farmers' Sentinel	Complimentary
Farmers' Tribune	Complimentary
Farmers' Visitor	Complimentary
Farmers' Voice	Complimentary
Farming	Complimentary
Feather	Subscription
Feathered World	Subscription
Floral Life	Complimentary
Florists' Exchange	Subscription
Flour and Feed	Complimentary
Flour Trade News	Complimentary
Fruit Grower	Complimentary
Fruitman and Gardener	Complimentary
Fuehling's Landwirtschaftliche Zeitung	Subscription
Garden	Subscription
Garden Magazine	Subscription
Gardeners' Chronicle	Subscription
Gardening	Subscription
Gartenwelt	Subscription
Gleanings in Bee Culture	Complimentary
Green's Fruit Grower	Complimentary
Hartwick Seminary Monthly	Complimentary
Hedwigia	Subscription
Herd Register	Complimentary
Hoard's Dairyman	Complimentary
Holstein-Friesian Register	Complimentary
Holstein-Friesian World	Complimentary
Homestead	Complimentary
Horticulture	Subscription

Horticultural Visitor	Complimentary
Hygienische Rundschau	Subscription
Indiana Farmer	Complimentary
Insect World	Complimentary
Ithaca Chronicle	Complimentary
Jahresbericht der Agrikultur-Chemie	Subscription
Jahresbericht Garungs-Organismen	Subscription
Jahresbericht der Nahrungs-und Genussmittel	Subscription
Jahresbericht Pflanzenkrankheiten	Subscription
Jahresbericht der Tier-Chemie	Subscription
Jersey Bulletin	Complimentary
Journal of Agricultural Science	Subscription
Journal of Agriculture, Victoria	Complimentary
Journal of Biological Chemistry	Subscription
Journal de Botanique	Subscription
Journal of the Dept. of Agriculture of Western Australia	Complimentary
Journal of Experimental Medicine	Subscription
Journal of Experimental Zoology	Subscription
Journal fuer Landwirtschaft	Subscription
Journal of Mycology	Subscription
Journal of Physiology	Subscription
Just's Botanischer Jahresbericht	Subscription
Kimball's Dairy Farmer	Complimentary
Lanswirtschaft-Historische Blätter	Complimentary
Landwirtschaftlicher Jahrbuch	Subscription
Landwirtschaftlicher Jahrbuch der Schweiz	Subscription
Landwirtschaftlichen Versuchs-Stationen	Subscription
Live Stock and Dairy Journal	Complimentary
Live Stock Report	Complimentary
Long Island Democrat	Complimentary
Market Fruit-Growers' Journal	Complimentary
Marlboro Record	Complimentary
Memoirs of the Department of Agriculture in India	Complimentary
Metropolitan and Rural Home	Complimentary
Michigan Farmer	Complimentary
Milch Zeitung	Subscription
Milchwirtschaftliches Zentralblatt	Subscription
Minnesota and Dakota Farmer	Complimentary
Mirror and Farmer	Complimentary
Modern Farming	Complimentary
Monthly Weather Review	Complimentary
National Nurseryman	Complimentary
National Farmer and Stock Grower	Complimentary
National Grange	Complimentary
National Stockman and Farmer	Complimentary
Naturaliste Canadienne	Complimentary
Nebraska Farmer	Complimentary
New England Farmer	Complimentary
New York Academy of Science, Annals and Transactions	Subscription
New York Botanical Garden, Bulletin	Complimentary

New York Entomological Society, Journal	Subscription
New York Farmer	Complimentary
New York Fruit and Produce News	Complimentary
New York Tribune Farmer	Complimentary
New Zealand Dairyman	Complimentary
North American Horticulturist	Complimentary
Northwest Pacific Farmer	Complimentary
Nut Grower	Complimentary
Ohio Farmer	Complimentary
Ohio Naturalist	Subscription
Ohio Poultry Journal	Subscription
Pacific Coast Fanciers' Monthly	Subscription
Photo-Miniature	Subscription
Pacific Fruit World	Complimentary
Penn Yan Democrat	Complimentary
Popular Agriculturist	Complimentary
Poultry	Complimentary
Poultry Herald	Subscription
Poultry Husbandry	Complimentary
Poultry Industry	Complimentary
Poultry Keeper	Complimentary
Poultry Monthly	Complimentary
Practical Dairyman	Complimentary
Practical Farmer	Complimentary
Practical Fruit-Grower	Complimentary
Praktische Blätter fuer Pflanzenschutz	Subscription
Psyche	Subscription
Queensland Agricultural Journal	Complimentary
Rabenhorst's Kryptogamen-Flora	Subscription
Reliable Poultry Journal	Subscription
Republic	Complimentary
Revue Generale de Botanique	Subscription
Revue Generale du Lait	Subscription
Revue Horticole	Subscription
Revue Mycologique	Subscription
Royal Agricultural Society, Journal	Subscription
Royal Horticultural Society, Journal	Subscription
Rural New Yorker	Subscription
Salt Lake Herald	Complimentary
Saint Louis Academy of Science, Transactions	Complimentary
Sanitary Inspector	Complimentary
Science	Subscription
Scientific American	Subscription
Scientific Roll, Bacteria	Subscription
Skaneateles Democrat	Complimentary
Society of Chemical Industry, Journal	Subscription
Societe Entomologique de France, Bulletin	Complimentary
Societe Entomologique Belgique, Annales	Complimentary
Societe Mycologique de France, Bulletin	Subscription
Southeast Missouri Farm, Fruit and Poultry	Complimentary

Southern Planter	Complimentary
Southern Tobacconist and Modern Farmer	Complimentary
Southern Farm Magazine	Complimentary
Southwestern Farmer and American Horticulturist	Complimentary
Southwestern Farmer and Breeder	Complimentary
Station, Farm and Dairy	Complimentary
Stazione Sperimentale Agrarie Italiane	Complimentary
Successful Farming	Complimentary
Suffolk Herald	Complimentary
Sugar Beet	Complimentary
Texas Stockman and Farmer	Complimentary
Torrey Botanical Club, Bulletins and Memoirs	Subscription
Transvaal Agricultural Journal	Complimentary
Up-to-Date Farming and Gardening	Complimentary
Utica Semi-Weekly Press	Complimentary
Wallace's Farmer	Complimentary
West Indian Bulletin	Complimentary
West Virginia Farm Review	Complimentary
Western Fruit-Grower	Complimentary
Western Plowman	Complimentary
Zeitschrift fuer Analytische Chemie	Subscription
Zeitschrift fuer Biologie	Subscription
Zeitschrift fuer Entomologie	Complimentary
Zeitschrift fuer Fleisch und Milch Hygiene	Subscription
Zeitschrift fuer Hygiene und Infektions Krankheiten	Subscription
Zeitschrift fuer Pflanzenkrankheiten	Subscription
Zeitschrift fuer Physiologische Chemie	Subscription
Zeitschrift fuer Untersuchung der Nahrungs und Genusmittel	Subscription
Zoological Record	Subscription
Zoologischer Anzeiger	Subscription

METEOROLOGICAL RECORDS FOR 1907.

Reading of Maximum and Minimum Thermometers for 1907.

DATE.	January.		February.		March.		April.		May.		June.	
	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.
1	47.5	33.	35.	14.	39.	12.	30.	21.	50.	33.	65.	42.
2	34.	30.	47.	33.	41.	32.	39.	19.	58.5	28.	54.	45.
3	40.	30.	43.	6.	33.	20.	55.	27.	64.5	36.	72.	41.
4	45.	31.5	20.	9.	22.5	11.5	65.	33.	59.5	34.	72.	45.
5	44.	26.	15.	8.	35.	14.	58.	28.	54.	29.	67.5	50.
6	53.	28.	13.	5.	32.	16.	42.	20.	53.	43.	56.	47.
7	50.	36.	28.	5.	28.	—1.	40.	22.5	54.	33.	67.	48.5
8	48.	32.	30.	9.	34.	21.	46.	33.	63.	34.	67.	43.
9	40.	15.	32.	11.	36.5	32.	44.	29.	69.5	47.	70.	42.
10	34.	12.	41.	25.5	33.	17.	38.	30.	69.	34.	72.	42.
11	37.5	29.	33.	0	43.	14.	44.	28.	45.	28.	72.	42.
12	39.	22.	9.	—4.	42.	25.	42.	28.	57.5	28.	68.	44.
13	34.5	23.5	35.	4.	39.	35.	44.	31.	84.	45.	66.	44.
14	44.	28.	44.	26.	37.	28.	39.	29.	85.	53.	79.	48.5
15	43.	18.	35.	13.	43.5	28.	43.	25.5	84.	54.	77.5	55.
16	19.	8.	40.	31.	54.5	22.	45.	29.	74.	50.	83.	46.5
17	21.5	5.	36.	15.	54.	39.	46.	30.	69.	44.	89.5	53.
18	35.	20.	25.	—4.	42.	25.	42.	27.	77.	51.	94.	59.
19	44.5	30.	38.	19.	39.	27.	42.	28.	72.	49.	92.	60.
20	52.	27.	40.	20.	48.5	30.5	41.	30.	67.	34.	80.	56.
21	28.	12.	37.	10.	50.5	22.5	50.	25.	48.	33.	86.	55.
22	21.	6.	14.	4.	78.	41.	64.	35.	57.	34.	88.5	57.
23	14.	—4.	16.5	0	68.5	42.	66.	35.	61.	44.	90.	64.
24	7.	—18.	21.	—2.	59.	36.5	55.	39.	66.	37.	85.	64.
25	22.5	2.	32.5	14.	57.	29.	64.	37.	67.	32.	85.5	67.
26	18.	8.	15.	2.	64.	39.	45.	35.	60.	41.	85.	63.
27	17.	—4.5	15.	5.	72.	40.	58.	33.	69.	47.	74.	52.
28	22.	9.	25.	—2.	68.	52.	68.	35.	51.5	35.	85.	55.
29	24.	6.	......	......	83.	47.	73.	48.	62.	41.	80.	58.5
30	22.	14.	......	......	72.	41.5	69.	41.	61.	36.	67.	59.
31	23.5	4.	......	......	46.5	29.	......	......	67.	37.	......	......
Mon hly averages	33.1	16.7	29.1	9.9	48.2	28.	49.9	30.4	63.9	38.8	76.3	51.6

READING OF MAXIMUM AND MINIMUM THERMOMETERS FOR 1907 —(*Concluded*).

DATE.	July.		August.		September.		October.		November.		December.	
	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.
1	85.5	58.	82.	62.	76.	50.	59.	39.	59.	35.	37.	29.
2	83.	60.	78.5	59.5	80.	59.	69.	35.	55.	44.	33.5	21.
3	74.	50.	74.	52.	82.	59.	80.	50.	54.	42.	30.5	18.
4	77.	46.	72.	52.	75.	62.	71.	59.	52.	34.	27.	15.
5	82.	50.	77.	50.	81.	60.	61.	46.	54.	34.	27.	17.
6	86.	55.	82.	60.	70.	54.	63.	40.	50.	43.	36.	25.
7	87.	62.	91.	58.	75.	57.	76.	49.	47.	33.	46.	24.
8	86.	56.	85.	61.	72.	58.	71.5	40.	46.	35.	49.	31.
9	80.	63.	86.	52.	77.5	58.	57.	33.	53.	36.	53.	36.5
10	83.	54.5	88.	59.	75.	58.5	60.	44.	50.5	38.	53.	42.
11	80.	58.	93.	61.	71.	62.	54.	44.	41.5	29.	43.	23.
12	75.	60.	96.5	63.	70.	56.	52.5	38.	42.	22.	23.	19.
13	80.5	56.	93.	57.	81.	52.	48.	38.	37.	29.	30.	18.
14	82.	54.	78.5	53.	84.5	56.	49.	39.	37.	25.	28.5	23.
15	83.5	59.5	80.	51.	87.	61.	59.	35.	41.	23.	36.5	23.
16	90.	67.	80.	56.	87.5	62.	64.	36.5	45.5	22.	36.	28.
17	88.	68.	89.	64.	83.	62.	72.	46.5	49.	27.	33.	27.
18	86.	68.	82.	55.	68.5	53.	64.	45.	46.	30.	32.	25.
19	87.	58.	88.	41.5	71.	55.5	49.5	34.	44.	29.	30.	23.
20	89.	69.5	92.	62.	90.	59.	45.	35.	44.	28.	36.	14.
21	84.	58.	77.	58.	85.	60.	45.	26.	55.	33.	36.5	30.
22	83.	62.	78.	52.	73.	56.	63.	29.	53.	43.5	40.	13.5
23	82.	64.	82.	45.	66.	45.	58.	38.	49.	32.	41.	30.
24	83.	59.	83.	60.	76.	57.	48.	28.	37.	26.	44.	30.
25	86.	67.	80.	53.	63.	47.	52.	30.	38.	30.	38.	22.
26	83.	65.	75.	53.	60.5	43.	46.5	29.	37.	27.	39.5	30.
27	79.	53.	73.	55.	58.5	39.	*	34.	39.	31.	49.	29.
28	81.	58.	73.	55.	60.	49.	*	38.	45.	30.	47.	35.
29	86.	61.	75.	48.	59.	50.	*	30.5	38.5	28.	38.	22.
30	85.	59.	76.5	50.	61.5	48.	43.	32.	39.	25.	57.	32.
31	86.	56.	74.	49.	......	......	52.	24.	......	......	45.	22.
Monthly averages	83.3	59.2	81.7	55.1	74.	54.9	58.3	37.6	45.9	31.5	38.6	25.1

* Thermometer broken.

Readings of the Standard Air Thermometer.

DATE.	January.			February.			March.			April.			May.			June.		
	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.
1	37.	37.	34.	18.	32.	34.	13.	34.	38.	23.	26.	22.	35.	45.	49.	50.	56.	53.5
2	32.	32.	32.	35.	40.	43.	36.	37.	33.	24.	32.5	37.	41.	54.	55.	50.	50.	53.
3	35.	37.5	40.	9.	16.	15.	24.	26.5	21.	32.	49.	51.	45.	60.	59.5	52.	68.	71.
4	41.	37.	32.5	10.	16.	15.	12.	21.	22.	38.	60.5	58.	47.	35.	37.5	56.	65.	64.5
5	32.	41.	37.	9.	13.	10.	20.	30.	32.	36.	32.	30.	35.	52.	52.	58.	60.	53.
6	34.	50.	50.	8.	13.	12.	17.	24.	23.	26.	35.	36.	51.	45.	48.	49.	55.	51.
7	46.	46.	36.5	9.	23.	19.	2.	23.	26.5	33.	36.	38.	42.	53.	44.	50.	63.	65.
8	34.	40.5	39.5	12.	24.	26.5	22.	32.	30.	36.	41.	44.	48.	60.5	62.	56.	62.	67.
9	30.	21.	16.	11.5	29.	30.	23.	32.	33.	32.	39.	38.	53.	61.	69.	58.	68.	67.
10	15.	26.	34.	28.	40.	33.	25.	30.	28.	32.	32.	33.	40.	45.	35.	56.	67.	71.
11	30.	34.	32.5	16.	13.	1.	16.5	39.	42.5	31.	38.	42.	35.	44.	42.	56.	67.	67.
12	30.	39.	34.	0	7.5	8.	30.	34.	38.5	33.5	39.	40.	41.	46.	57.	55.	66.	65.
13	25.	25.	29.	8.	23.	34.	37.	39.	37.	33.	37.	39.	54.	80.	83.	57.	63.	53.
14	37.	41.	42.	35.	39.	27.	33.	30.	30.	30.	31.	31.	65.	83.	79.	53.5	71.	77.
15	28.	25.5	19.	15.	30.	33.	30.	41.	38.	29.	36.5	41.5	65.	78.	74.	61.	71.	75.5
16	13.	15.	9.	36.	37.5	36.	27.	39.	53.	33.	39.	39.	50.	58.	58.5	65.	80.	81.
17	16.5	16.5	21.5	25.	20.5	16.	43.5	48.	41.5	34.	41.	41.	53.	61.	67.5	62.	86.	88.
18	26.	32.	32.	—3.	18.	20.	28.	40.	37.	31.	39.	40.	56.	73.	71.5	72.	91.	91.
19	34.	39.	40.	29.5	32.	35.	30.	37.	39.	33.	36.5	40.	57.	55.	66.	68.	75.	70.
20	51.	38.	28.	23.	36.	37.	28.	30.	34.	33.	36.5	37.5	47.5	47.	48.	65.	76.	74.
21	13.	14.5	14.	13.	16.	14.	26.	42.5	50.5	33.	45.	50.	39.	44.	45.	65.	79.	85.
22	16.	21.	13.	5.	11.	5.5	44.	74.	68.5	45.	59.	62.	43.	55.	53.	69.	85.	77.
23	0.	5.	2.5	2.	11.5	12.5	66.	55.	49.	42.	64.	55.	45.	58.	59.	71.	85.	75.
24	—18.	3.	3.	8.	21.	19.	47.	48.	38.	42.	48.	49.	51.	66.	60.	72.	82.5	77.
25	15.	22.	18.	22.	21.	14.	34.	47.	56.	46.	63.	45.	47.5	60.	64.	73.	82.5	85.
26	12.	11.	12.	3.	10.	14.	40.	53.	58.5	37.	39.	39.	44.	50.	55.	71.	76.	71.5
27	—1...	16.	16.5	10.	12.	9.	47.	65.	59.	32.5	47.	58.	55.	66.5	48.	56.5	67.	74.
28	13.	20.	17.	—2.	20.5	23.	61.	64.	61.	44.	60.	68.	39.	48.	51.5	72.	80.5	80.
29	15.	21.	20.5	......	......	......	69.	69.	72.	54.	64.	69.	45.	56.	60.	65.	76.	67.
30	18.	21.	15.	......	......	......	42.	50.	46.5	53.	55.	42.	45.	60.	58.	60.	63.	62.
31	6.	19.	23.5	......	......	......	34.	35.	30.	......	......	......	48.	60.	64.	......	......	......
Monthly averages	23.1	27.3	25.6	14.1	22.3	21.3	32.5	40.9	40.8	35.4	43.3	43.8	47.2	56.8	57.3	60.8	71.2	70.4

READINGS OF THE STANDARD AIR THERMOMETER—(*Concluded*).

DATE.	JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.
1	69.	82.	83.	63.	75.	78.	52.	68.	70.	42.	55.	52.5	41.5	54.	53.	31.	36.	33.5
2	67.	71.	61.5	64.	73.	72.5	65.	76.	80.	45.	60.	66.	46.	52.	53.	23.	29.	25.
3	56.	70.5	69.	60.	70.	69.	60.	68.	72.5	54.	77.5	70.	48.	47.	46.5	20.	30.	26.
4	60.	72.	75.	58.	69.	71.	62.	71.5	72.	67.	65.	60.	35.	41.	43.	19.5	20.	19.
5	64.	78.	78.	61.	73.5	72.	61.	75.	65.	49.	57.5	51.5	36.	52.	50.	18.	24.	27.
6	67.	80.	82.	64.	75.	76.	59.	66.	66.	50.	60.	54.	44.	44.	45.	32.	33.	34.
7	72.	83.5	85.	66.	86.5	85.	60.	75.	65.	56.	72.	71.5	34.	35.	36.	29.	42.	36.
8	69.	80.	80.	67.	77.	75.5	59.	70.	71.	44.	42.5	44.	37.	44.	45.	33.	46.	43.
9	68.5	78.	79.	60.	79.	84.	60.	76.	69.	38.	51.5	54.	38.	49.	50.5	39.	47.	47.
10	66.	79.	80.	69.	82.	86.	62.	74.	70.5	47.	55.	53.	39.	41.	40.5	50.	53.	43.
11	63.5	64.	65.	69.	91.	88.	68.	65.	68.	50.	48.5	47.	34.	38.	35.	27.	26.	23.
12	61.	65.	72.5	70.	90.	93.	60.	66.	70.	40.	48.	46.	24.	37.	35.	22.	22.	19.
13	64.	76.	76.	67.	82.	78.5	59.	77.5	79.5	42.	48.	45.	31.	36.	36.	24.	28.5	25.
14	67.	79.	80.	59.	69.	72.	64.	83.	81.	40.	48.	46.5	26.	30.	29.	28.	26.	24.
15	68.	80.	81.	58.	76.	76.	69.	84.	86.	38.	54.	52.5	25.	40.	35.	34.	36.	36.
16	74.	87.5	88.	65.	77.	68.5	66.	86.	83.	42.	59.	59.	23.	42.	37.	31.	32.	32.
17	72.	80.	84.5	72.5	85.	81.	66.	70.	68.5	49.	68.	64.	29.	46.	42.	29.	31.	28.
18	74.	80.	84.	62.	71.	73.	54.	63.	58.	54.	50.	45.5	36.	43.5	41.	27.	32.	27.
19	71.	83.	84.	56.5	79.	86.	59.5	66.	68.	36.	45.	45.	37.	41.	40.	26.5	29.	26.
20	75.	86.5	75.	68.	88.	77.	62.	81.5	85.	38.	37.5	38.	30.	39.	43.	18.	31.	33.
21	65.	77.	82.	60.	69.	69.	67.	75.	73.	28.	42.	42.	43.	52.5	50.5	31.	34.	32.
22	66.5	71.	81.	58.	72.	76.	57.	63.	59.	31.	55.	58.	47.	51.	49.	17.	35.5	32.
23	66.5	77.	80.	58.	79.	72.	50.	60.	64.5	45.	46.	39.	34.	43.	36.5	35.	36.	39.
24	69.	81.5	73.5	65.	82.	80.	65.	74.	63.	32.	44.	43.5	27.	34.	33.	34.	36.5	34.
25	70.	80.5	83.	61.	71.	74.	49.	53.	52.	49.	49.	45.	32.	37.	35.	28.	35.	37.
26	71.	72.	71.	56.	69.	73.	45.	56.	58.5	31.	40.5	41.	33.	37.	34.	32.	32.5	31.
27	61.	75.	77.	59.	67.5	63.	49.5	55.	55.5	43.	44.	48.	33.	36.	35.	38.5	45.	47.
28	75.	79.	80.	57.	68.	71.5	50.	54.	56.	40.	41.	41.	41.	44.	37.	46.	41.	36.5
29	68.	83.5	85.	56.	70.	73.	58.	58.	50.	39.	45.5	40.	30.	32.5	32.	22.5	36.	36.
30	65.	71.5	71.	56.	70.5	73.	50.	53.5	57.	32.	38.	36.	28.	36.5	32.	40.	50.	44.5
31	66.	80.	82.	55.	65.	65.	......	......	......	25.	48.	46.	......	......	......	27.	31.	33.
Monthly averages	67.5	77.5	78.3	61.9	75.8	75.9	58.9	68.8	67.9	42.5	51.5	49.8	34.7	41.8	40.3	29.4	34.4	32.5

SUMMARY OF MAXIMUM, MINIMUM AND STANDARD AIR THERMOMETERS FOR 1907.

	Maximum.	Minimum.	Standard.		
			7 A. M.	12 M.	5 P. M.
	Average.	Average.	Average.	Average.	Average.
January	33.1	16.7	23.1	27.3	25.6
February	29.1	9.9	14.1	22.3	21.3
March	48.2	28.	32.5	40.9	40.8
April	49.9	30.4	35.4	43.3	43.8
May	63.9	38.8	47.2	56.8	57.3
June	76.3	51.6	60.8	71.2	70.4
July	83.3	59.2	67.5	77.5	78.3
August	81.7	55.1	61.9	75.8	75.9
September	74.	54.9	58.9	68.8	67.9
October	58.3	37.6	42.5	51.5	49.8
November	45.9	31.5	34.7	41.8	40.3
December	38.6	25.1	29.4	34.4	32.5

AVERAGE MONTHLY AND YEARLY TEMPERATURE SINCE 1882.

YEAR.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly av'ges.
1883	17.4	22.3	23.6	43.3	50.	66.6	67.4	65.6	56.3	46.6	39.1	27.5	43.8
1884	17.6	28.3	29.5	40.7	54.3	67.1	66.5	69.9	65.2	50.5	36.5	27.2	46.1
1885	20.6	11.4	18.8	41.2	54.3	63.6	69.7	65.0	58.3	49.2	39.3	27.8	43.3
1886	19.6	22.9	30.2	48.1	55.7	64.	68.	67.5	61.8	49.6	36.8	22.2	45.6
1887	20.2	23.2	26.3	41.1	62.5	65.7	75.6	66.5	57.7	47.0	37.6	27.6	45.9
1888	16.4	22.8	24.6	40.8	54.3	66.5	66.8	68.	62.2	43.9	39.4	29.3	44.6
1889	29.1	18.1	33.9	45.1	58.4	65.3	70.2	66.	60.5	44.	40.3	35.2	47.2
1890	31.2	30.9	28.8	44.2	52.3	67.1	69.5	67.7	60.1	49.3	37.6	21.4	46.7
1891	25.9	28.3	30.8	45.3	52.	66.4	66.4	68.5	66.2	48.3	38.4	35.5	47.7
1892	21.4	25.9	26.5	43.5	52.8	68.6	70.2	69.4	61.3	50.	35.9	25.2	45.9
1893	15.5	20.6	29.5	41.1	54.1	68.2	69.8	68.8	58.	52.	38.2	27.5	45.3
1894	29.7	20.9	38.9	44.1	55.5	67.8	74.2	66.8	64.8	52.7	36.	31.5	48.6
1895	21.8	16.9	26.9	44.4	59.	......	......	71.2	61.7	45.4	39.6	31.4	......
1896	22.4	24.1	24.4	49.3	62.	65.9	71.4	70.	60.2	56.5	42.9	27.1	48.0
1897	23.2	26.1	33.8	45.	55.4	62.3	73.6	67.6	62.3	52.6	39.7	29.2	47.6
1898	26.2	26.8	......	43.2	57.	67.7	74.2	71.	65.9	52.1	37.9	27.9	......
1899	22.1	20.4	30.4	46.6	57.6	69.5	71.2	71.6	60.6	53.4	38.9	30.	47.7
1900	26.	22.6	23.6	43.5	56.7	68.4	72.6	74.1	66.1	57.9	41.1	28.7	48.5
1901	26.1	18.5	32.2	46.5	56.9	68.9	76.6	71.	64.	51.4	34.3	27.7	47.9
1902	23.2	22.2	39.5	46.6	56.1	63.2	71.2	67.6	63.6	43.1	46.3	25.7	47.4
1903	25.7	28.1	42.4	45.9	60.4	63.2	70.8	65.5	64.4	52.5	36.2	23.3	48.2
1904	18.9	23.1	30.9	41.4	60.3	67.8	70.	68.2	61.9	48.4	36.9	22.5	45.9
1905	19.8	18.9	33.1	44.8	57.5	66.4	71.8	68.7	63.7	52.4	37.6	32.	47.3
1906	32.5	26.1	27.6	46.4	57.5	68.2	71.4	72.8	67.3	51.2	37.9	26.1	48.8
1907	24.9	19.5	38.1	40.2	51.3	64.	71.2	68.4	64.4	47.9	38.7	31.8	46.7
Monthly averages	24.1	23.7	31.5	45.9	58.5	66.3	70.8	68.7	62.3	49.9	38.5	28.1	46.7

Monthly Maximum and Minimum Temperature from 1883 to 1907, Inclusive.

Highest and Lowest Record for Each Month in Bold Face Type.)

	January.				February.				March.				April.			
	Max.		Min.		Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883	18.	44.	11.	—9.	17.	48.	24.	—2.	19.	61.	9.	2.	16.	75.	1.	19.
1884	3.	49.	26.	—13.	7.	55.	29	—3.	30.	54.	1.	—4.	28.	74.	1.	23.
1885	1.	61.	29.	—6.	10.	38.	11.	11.5	28.	48.	13.	**—11.**	24.	84.5	10.	20.5
1886	5.	52.5	13.	**—18.7**	9.	50.	27.	—11.	16.	58.	2.	—2.5	24.	80.5	4.	22.
1887	24.	50.7	19.	—8.	9.	54.2	27.	—4.	3.	51.7	1 & 5	8.7	11.	75.7	1.	17.2
1888	2.	43.2	23.	—6.	21.	49.	10.	—7.	28.	57.	13.	0.	29.	82.5	8.	19.
1889	18.	55.	20.	5.	23.	42.	4 & 24	—7.	28.	61.8	30.	18.5	20.	84.	1.	26.
1890	6.	67.	29.	9.	5.	**64.5**	11 & 21	9.5	13.	62.	8.	2.	13.	78.8	1 & 19	23.
1891	3.	46.	17.	4.	26.	56.8	15.	2.5	12.	57.	2.	4.5	28.	81.4	7.	21.
1892	3.	48.	10.	—5.	15.	44.	6.	2.8	27.	52.2	4.	6.	6.	78.	17.	25.5
1893	29.	46.	11.	—6.	15.	47.4	5.	—1.	24.	54.	5.	9.	13.	75.3	26.	25.
1894	5.	59.	13.	11.	20.	47.6	27.	—8.5	18.	73.	26.	15.	21.	71.3	2.	20.
1895‡	7.	45.	19.	4.	25.	46.	8.	—14.	25.	52.	5 & 16	12.	30.	80.	3.	28.
1896	30.	44.	6.	—16.5	29.	49.	17	**—21.**	31.	56.5	24.	—2.	17.	87.	4 & 5	19.
1897	5.	58.	20.	—3.5	18.	49.5	1 & 27	5.5	21.	64.	1.	—1.	26.	82.	20.	19.
1898	13.	57.	30 & 31	—4.	12.	56.5	2 & 3	—2.	11.	*65.	2.	17.5	14 & 18	69.	5.	18.
1899	5.	59.	12.	—4.	21.	52.5	11.	—8.	13.	63.	21.	13.	30.	82.	3.	23.
1900	23.	56.	1.	2.	14.	57.	27.	0.	10.	46.	12.	—3.	30.	†73.5	9.	†22.
1901	16.	48.	20.	—2.	16.	36.	24.	—2.5	24.	67.	6.	—1.	28.	78.	12.	28.
1902	3.	44.	28.	2.	28.	52.	6.	—3.	12.	66.5	19.	14.	22.	**87.**	5.	25.
1903	3.	48.	9.	—2.	28.	62.5	18.	—4.	19.	78.5	1 & 2	19.	30.	86.	5.	21.
1904	23.	48.	19.	—14.	7.	58.	16.	—18.	26.	58.	4.	8.	24.	67.5	14.	**16.**
1905	1.	49.	26.	—2.	20.	45.	5 & 14	—6.	29.	82.	5.	1.	27 & 28	75.	16.	23.
1906	21.	**71.**	9.	4.	24.	64.	6 & 7	—7.	27.	51.	25.	2.	19.	74.	2.	25.
1907	6.	53.	24.	—18.	2.	47.	12 & 18	—4.	29.	**83.**	7.	—1.	29.	73.	2.	19.

† Thermometers broken. Record not taken from April 19 to 24 inclusive.
‡ From data given by Mr. Edgar Parker. Station record not available.
* Maximum for first eleven days only. Record incomplete.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FROM 1883 TO 1907, INCLUSIVE—(*Continued*).

(Highest and Lowest Record for Each Month in Bold Face Type.)

	May.				June.				July.				August.			
	Max.		Min.		Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883..........	11.	87.	1 & 14	31.	7.	86.5	2.	42.	23.	86.	1.	46.	23.	92.	15.	46.
1884..........	24.	88.	30.	32.	25.	90.5	15.	41.	2.	87.5	15.	50.5	20.	95.	25.	44.
1885..........	18.	81.7	3.	27.5	14.	86.5	23.	41.5	18.	90.5	12.	46.5	1.	89.	28.	45.
1886..........	23.	79.5	17 & 18	37.2	14.	86.2	1.	42.2	7.	95.	1.	45.2	30.	91.5	6.	47.7
1887..........	23.	88.2	14.	37.5	17.	89.2	15.	47.7	3.	95.5	11.	58.7	3.	88.5	8.	46.
1888..........	13.	79.8	3.	29.	23.	94.1	4.	40.	5.	89.8	16.	47.	9.	92.6	23.	48.3
1889..........	18.	91.8	29.	32.	22.	85.	5.	46.	11.	90.7	6.	50.5	31.	86.7	16 & 17	50.3
1890..........	4.	80.7	2.	30.	30.	85.6	8.	44.8	9.	94.5	24.	46.5	4.	96.2	24.	46.0
1891..........	11.	85.5	4.	29.5	16.	95.	6.	40.	14.	92.	31.	46.	12.	92.	29.	46.5
1892..........	31.	78.	9.	34.2	14.	92.	11.	45.8	29.	96.3	2.	46.4	10.	95.5	28.	49.
1893..........	25.	88.	9.	35.	21.	94.	1.	44.	26.	95.5	24.	48.4	11.	94.5	13.	49.
1894..........	2.	85.4	14.	32.6	23.	91.6	6.	39.	21.	97.	10.	49.6	25.	93.	27.	45.3
1895..........	31.	**92.**	13 & 21	36.	3.	**96.**	7.	54.	8.	94.	11.	52.	11.	88.	22.	44.
1896..........	11.	87.5	7 & 20	40.	21.	89.	3.	41.	3.	94.	18.	49.	6 & 7	96.	29.	44.
1897..........	24.	80.	8.	32.5	24 & 25	87.5	2.	42.	11.	97.	15.	57.	15.	87.5	21.	46.
1898..........	29.	79.	6.	34.	9.	90.	16.	40.	4.	96.5	12.	**40.**	24.	90.5	28.	47.
1899..........	2.	87.5	15.	32.5	6 & 24	93.	11.	41.5	4.	**97.5**	1.	50.	20.	**97.5**	15.	44.5
1900..........	15 & 16	88.5	7.	27.	25.	93.	10.	45.	17.	96.	1.	50.	11.	97.	2.	51.
1901..........	23.	78.	16.	36.	27, 28 & 29	95.5	2.	42.	1.	97.5	20.	54.5	22.	90.	5.	52.
1902..........	22.	90.	11.	26.	3.	85.	6.	38.	14 & 27	90.	1.	53.	31.	90.	13.	47.
1903..........	19.	89.	2.	**24.**	30.	86.5	1.	39.	9.	94.	15.	50.	18.	85.5	8 & 14	45.
1904..........	25.	88.	12.	31.5	5, 24 & 25	89.	12 & 17	45.	19.	93.	3.	49.	25.	89.5	19.	45.
1905..........	3.	82.	2.	29.5	19.	90.	1.	40.	18.	92.	22.	48.5	10.	93.	27.	**41.**
1906..........	24.	88.5	11 & 21	30.	8.	92.	12.	**37.**	20, 22 & 23	89.	25.	50.	5.	93.	16.	47.
1907..........	14.	85.	2 & 11	28.	18.	94.	3.	41.	16.	90.	3 & 5	50.	12.	96.5	19.	41.5

Monthly Maximum and Minimum Temperature from 1883 to 1907, Inclusive—(*Concluded*).

Highest and Lowest Record for Each Month in Bold Face Type.)

	September.				October.				November.				December.			
	Max.		Min.		Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883..........	17.	80.	11.	37.	11.	78.	17.	25.	22.	70.	17.	13.	10.	43.	23.	—7.5
1884..........	5.	94.	14.	36.	5.	84.2	27.	23.	11.	62.	25.	15.	31.	55.5	20.	**—15.5**
1885..........	27.	83.7	24.	40.	1.	79.	31.	25.	8 & 13	68.	28.	18.	24.	53.	9.	4.
1886..........	11.	89.5	22.	40.	10.	76.7	17.	27.5	3.	68.2	28.	17.	11 & 25	46.	6.	—6.
1887..........	22.	81.7	27.	37.2	9.	78.5	31.	21.2	28.	68.	30.	15.	12.	54.7	2.	—3.
1888..........	1 & 10	83.	7.	40.	6.	62.7	22.	29.	1 & 3	**73.**	23.	**8.**	27.	53.	22.	4.
1889..........	4.	84.	22, 23 & 29	40.	2.	68.7	24.	**21.2**	4.	61.7	17.	17.8	25.	60.5	4 & 5	8.
1890..........	8.	83.6	25.	35.5	5.	69.8	31	32.	8.	65.4	28.	17.	1.	46.2	20.	3.
1891..........	26.	92.8	30.	43.	4.	89.4	12 & 25	27.	1.	68.	29.	12.	5.	57.7	18.	7.
1892..........	26.	88.	20.	39.	1.	82.	2.	33.1	19.	60.	24.	18.	9.	49.2	27.	—3.7
1893..........	5.	80.	26.	37.4	13.	76.	31.	25.	3.	62.2	27.	19.	26.	**62.**	14.	1.5
1894..........	4.	90.	26.	**33.**	1.	76.5	15.	33.	3.	65.	29.	12.	17.	59.	29.	—0.2
1895..........	4.	94.	15 & 30	42.	2.	72.	30.	28.	7.	68.	21.	19.	20 & 21	**62.**	13.	—2.
1896..........	12.	95.	23.	36.	30.	77.5	10 & 19	29.	19.	70.	21.	19.5	14.	58.	28.	2.
1897..........	11.	**98.**	21.	37.5	16.	88.	10 & 18	30.	6.	65.	24.	16.5	12.	61.5	24.	2.
1898..........	4.	94.	21.	40.5	1.	85.5	28.	31.	5.	63.	28.	16.	31.	54.	14.	3.
1899..........	4.	92.	15 & 30	38.	15.	86.	3.	26.	19.	60.	14.	25.	12.	60.	31.	—1.
1900..........	12.	95.	19.	37.	6 & 7	**89.**	20.	28.	22.	70.	17.	19.	4.	55.	10 & 14	4.
1901..........	6.	89.	26.	36.	10 & 11	74.	28.	28.	1.	65.	27.	13.	14.	62.	18.	—1.
1902..........	1.	90.	15.	38.	19.	74.	10, 22 & 30	29.	14.	73.	29.	22.	2.	52.	9.	5.
1903..........	14.	90.	29.	35.	1.	73.	25 & 27	28.	4.	**70.**	26 & 27	12.	3.	46.	19.	—4.
1904..........	3.	88.	23.	33.	10.	81.	31.	22.	3.	65.	29.	9.	23.	53.	16.	—2.
1905..........	30.	88.5	26.	36.	1.	85.	26.	20.5	12.	61.	14.	11.	29.	52.5	15.	1.
1906..........	18.	91.5	25.	38.	5.	79.5	13 & 31	30.	19.	62.	30.	16.	6.	52.	8.	—1.
1907..........	20.	90.	27.	39.	7.	76.	31.	24.	1.	59.	16.	22.	30.	57.	22.	13.5

YEARLY MAXIMUM AND MINIMUM TEMPERATURES FROM 1883 TO 1907, INCLUSIVE.

(Highest and Lowest Record in Bold Face Type.)

	MAXIMUM FOR EACH YEAR.		MINIMUM FOR EACH YEAR.	
	Date.	Temp.	Date.	Temp.
1883	Aug. 23	92.	Jan. 11	—9.
1884	Aug. 20	95.	Dec. 20	—15.5
1885	July 18	90.5	Feb. 11	—11.5
1886	July 7	95.	Jan. 13	—18.7
1887	July 3	95.5	Jan. 19	—8
1888	June 23	94.1	Feb. 10	—7
1889	May 18	91.8	Feb. 4 and 24	—7
1890	Aug. 4	96.2	Mar. 8	2
1891	June 16	95	Feb. 15	2.5
1892	July 29	96.3	Jan. 10	—5.
1893	July 26	95.5	Jan. 11	—6.
1894	July 21	97.	Feb. 27	—8.5
1895‡	June 3	96.	Feb. 8	—14.
1896	Aug. 6 and 7	96.	Feb. 17	**—21.**
1897	Sept. 11	**98.**	Jan. 20	—3.5
1898	July 4	96.5	Jan. 30 and 31	—4.
1899	July 4 and Aug. 20	97.5	Feb. 11	—8.
1900	Aug. 11	97.	Feb. 27	0.
1901	July 1	97.5	Feb. 24	2.5
1902	May 22, July 14 and 27, August 31 and Sept. 1	90.	Dec. 9	—5.
1903	July 9	94.	Feb. 18 and Dec. 19	—4.
1904	July 19	93.	Feb. 16	—18.
1905	Aug. 10	93.	Feb. 5 and 14	—6.
1906	Aug. 5	93.	Feb. 6 and 7	—7.
1907	Aug. 12	96.5	Jan. 24	—18.

‡Mr. Edgar Parker's record.

Precipitation by Rainfall Only by Months Since 1882.

YEARS.	Jan.	Feb.	March.	April	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1882	......	......	......	......	......	3.69	2.42	2.37	1.25	0.62	1.22	0.55	....
1883	0.48	1.44	0.88	1.58	4.45	4.12	2.98	3.47	2.12	2.10	1.54	0.73	25.89
1884	1.83	2.01	2.54	0.83	2.49	2.01	2.33	1.44	3.17	1.67	1.01	0.97	22.30
1885	1.07	0.61	0.12	1.26	1.58	2.49	4.64	5.02	2.11	2.88	1.36	0.76	23.90
1886	1.13	0.95	1.13	4.13	1.92	2.92	4.41	2.86	2.31	1.39	3.48	1.24	27.87
1887	0.18	2.17	0.48	1.37	0.46	2.01	6.37	3.03	0.75	1.74	1.58	1.35	21.49
1888	0.78	1.04	1.43	3.09	2.79	3.88	0.99	4.02	2.73	3.47	2.02	1.24	27.48
1889	2.99	0.25	0.66	3.28	1.21	7.47	4.57	4.98	2.50	3.32	3.44	1.62	36.29
1890	2.16	1.45	2.16	2.20	5.49	5.26	1.07	4.34	5.81	4.54	2.40	......	....
1891	1.44	1.57	3.25	1.63	0.49	4.31	3.52	3.16	0.47	3.65	0.74	3.29	27.52
1892	0.57	0.88	0.55	0.67	4.04	3.95	1.89	4.77	1.12	1.34	2.67	0.72	23.17
1893	1.62	3.71	1.94	2.59	4.92	3.08	3.68	5.38	2.68	1.59	1.09	1.56	33.84
1894	2.21	2.71	1.36	2.43	7.03	1.77	1.50	1.22	4.64	3.59	0.43	0.47	29.36
1895	0.96	......	0.29	1.33	2.88	......	......	2.66	0.94	0.72	2.31	2.49	....
1896	1.19	2.28	0.84	0.41	2.31	3.71	4.12	3.33	4.27	2.26	2.18	0.71	27.61
1897	0.64	0.21	2.12	1.90	2.19	3.16	5.28	1.27	2.36	0.73	2.53	1.39	23.78
1898	1.74	0.83	1.54	2.03	1.90	2.39	1.32	3.60	1.86	3.83	2.03	0.33	23.40
1899	0.37	0.30	1.22	1.12	1.69	1.71	4.15	1.05	2.23	2.69	1.36	1.46	19.35
1900	1.43	2.42	0.02	0.95	1.71	1.45	6.53	1.75	0.91	3.65	6.13	0.78	27.73
1901	0.72	......	2.19	4.43	3.80	2.07	3.97	5.62	2.46	1.35	2.09	3.37	....
1902	0.86	0.66	1.94	1.92	2.84	4.33	5.25	2.41	2.88	2.32	0.74	0.74	26.89
1903	1.81	1.11	5.60	2.60	0.23	7.77	4.86	7.21	1.30	4.19	1.63	0.38	38.69
1904	0.80	1.03	2.41	1.67	4.04	3.37	5.73	2.56	3.26	2.06	0.26	1.42	28.61
1905	0.40	0.27	1.09	2.05	2.01	8.78	3.39	5.44	1.90	3.69	1.32	1.84	32.38
1906	1.46	0.53	1.60	2.08	4.24	5.31	2.37	3.68	2.16	3.56	1.40	1.54	29.93
1907	1.89	0.03	1.14	2.42	1.82	2.34	2.86	1.35	2.73	3.48	2.78	1.89	24.73

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