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TWENTY-FOURTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

PART I.,

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

JANUARY, 1912.

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MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

PART I.

DETAILED REPORT OF THE EXPERIMENT STATION.

284289

INTRODUCTION.

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

WM. P. BROOKS,
Director.

CONTENTS.

Part I.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

OF THE

MASSACHUSETTS AGRICULTURAL COLLEGE,

AMHERST, MASS.

TWENTY-FOURTH ANNUAL REPORT.

Part I.

ORGANIZATION.

Committee on Experiment Department.

Charles H. Preston, *Chairman.*
J. Lewis Ellsworth.
Arthur G. Pollard.
Charles E. Ward.
Harold L. Frost.
The President of the College, *ex officio.*
The Director of the Station, *ex officio.*

Station Staff.

William P. Brooks, Ph.D., Director, 28 Northampton Road.
Joseph B. Lindsey, Ph.D., Vice-Director, 47 Lincoln Avenue.
Fred C. Kenney, Treasurer, Mount Pleasant.
Charles R. Green, B.Agr., Librarian, Mount Pleasant.

Department of Plant and Animal Chemistry.

Joseph B. Lindsey, Ph.D., Chemist, 47 Lincoln Avenue.
Edward B. Holland, M.Sc., Associate Chemist, in charge of Research Division, 28 North Prospect Street.
Fred W. Morse, M.Sc., Research Chemist, 44 Pleasant Street.
Henri D. Haskins, B.Sc., In charge of Fertilizer Section, Amherst House.
Philip H. Smith, M.Sc., In charge of Feed and Dairy Section, 102 Main Street.
Lewell S. Walker, B.Sc., Assistant, 19 Phillips Street.
James C. Reed, B.Sc., Assistant, Nutting Avenue.
Joseph F. Merrill, B.Sc., Assistant, North Prospect Street.
Clement L. Perkins, B.Sc., Assistant, 32 North Prospect Street.
Rudolf W. Ruprecht, B.Sc., Assistant, 31 Amity Street.
James T. Howard, Collector, North Amherst.
Harry J. Allen, Laboratory Assistant, 89 Main Street.
James R. Alcock, Assistant in Animal Nutrition, North Amherst.

Department of Agriculture.

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

Department of Horticulture.

FRANK A. WAUGH, M.Sc., Horticulturist, Massachusetts Agricultural College.
FRED C. SEARS, M.Sc., Pomologist, Mount Pleasant.
JACOB K. SHAW, Ph.D., Research Assistant, 1 Allen Street.
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GEORGE H. CHAPMAN, M.Sc., Research Assistant, 13 Fearing Street.
EDWARD A. LARRABEE, B.Sc., Assistant, Clark Hall.

Department of Entomology.

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

Department of Veterinary Science.

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

Department of Meteorology.

JOHN E. OSTRANDER, A.M., C.E., Meteorologist, 35 North Prospect Street.
R. N. HALLOWELL, Observer, Massachusetts Agricultural College.

Other Officers of the Experiment Station.

HERBERT J. BAKER, B.Sc., Secretary to the Director, Experiment Station.
Mrs. LUCIA G. CHURCH, Stenographer to the Director, 4 Hallock Street.
Miss ALICE M. HOWARD, Stenographer, Department of Plant and Animal Chemistry, North Amherst.
Miss F. ETHEL FELTON, Stenographer, Department of Plant and Animal Chemistry, Phillips Street.
Miss JESSIE V. CROCKER, Stenographer, Department of Botany and Vegetable Pathology, Sunderland.
Miss BRIDIE O'DONNELL, Stenographer, Department of Entomology, Hadley.

REPORT OF THE DIRECTOR.

CHANGES IN STAFF.

During the past year there have been no changes in the more important positions in the experiment station staff. A number of our younger assistants, however, have resigned for various reasons, among which the offer of higher salaries, plans to pursue graduate studies, or to engage in business are among the more prominent. The changes in detail are as follows: —

Sumner C. Brooks, B.Sc., assistant in botany, replaced by Edward A. Larrabee, B.Sc.; Joseph F. Merrill, B.Sc., assistant in plant and animal chemistry, resigned; Clement L. Perkins, B.Sc., assistant in plant and animal chemistry, resigned; David W. Anderson, B.Sc., graduate assistant in department of horticulture, resigned, this position still being vacant. Erwin S. Fulton, B.Sc., assistant agriculturist, resigned, his position being taken by Edwin F. Gaskill, B.Sc., promoted. Charles M. Damon, observer in the meteorological department, replaced by R. N. Hallowell.

The position of second assistant agriculturist has not been filled, but instead the position of secretary to the director has been created. This position has been filled by the appointment of Herbert J. Baker, B.Sc., a recent graduate of the Massachusetts Agricultural College. This change has made possible a sharper division between outdoor and office work, Mr. Gaskill taking charge of the former, while Mr. Baker takes charge of the books, attends to routine correspondence, assists the director in preparation of material for publication, as well as in many other directions.

Two of our most experienced and valuable stenographers, Miss Brown and Miss Cobb, have resigned during the year, their places being taken by Mrs. Church and Miss Felton.

Lines of Work.

There have been no important changes in the general character of station work during the year, although in scope and amount it constantly increases. It includes general experiments both on the home grounds and at substations as well as in co-operation with farmers, research, police or control work, and dissemination of information.

General Experiments.

In order to give a general idea of the nature of the work which is being carried on I cannot do better than to quote a statement in the last annual report: —

> Under this head are included a large number of experiments relative to the following subjects: soil tests with fertilizers, with different crops in rotation; comparisons of different materials which may be used as sources, respectively, of nitrogen, phosphoric acid and potash for different field and garden crops; the results of the use of lime; systems of fertilizing grass lands, both mowings and pastures; comparisons of fertilizers for both tree and bush fruits; different methods of applying manures; variety tests of field and garden crops and of fruits; trials of new crops; determinations of the digestibility of feedstuffs; methods of feeding for milk; systems and methods of management in feeding poultry for eggs; and co-operative work with selected farmers in the trial of crops and systems of fertilizing them.

In addition we have two substations where work of a highly diversified character is being carried on, viz., asparagus substation in Concord and cranberry substation in Wareham. In later pages will be found brief reports on the work in these substations, while a short account of the results of our co-operative experiments with alfalfa will be found in Part II. of this report.

No full general account or discussion of experimental work in progress will be given. Brief reports on some of the general experiments will be found under the departments in which they are being prosecuted.

Research.

The research work in progress at the station is, for the most part, carried on under the Adams fund. The work during the past year along certain lines has been somewhat interrupted owing to the necessity of making extensive additions and improvements in our chemical laboratory. These improvements were, however, very carefully planned and executed under the general supervision of Dr. J. B. Lindsey and his associates, and the extent to which they were allowed to interfere with the progress of laboratory work was, on the whole, surprisingly small.

The following are the principal Adams fund problems which at present engage our attention: —

1. To determine the principles which should underlie practice in the use of fertilizers for the cranberry crop.

2. To determine the principles which should underlie practice in the use of fertilizers for asparagus.

3. Work in plant breeding in the endeavor to produce more rust-resistant types of asparagus. (In co-operation with the Bureau of Plant Industry, United States Department of Agriculture.)

4. Investigation of the solubility effect of ammonium sulfate on the soil of one of our experimental fields. (Field A.)

5. The effect of food on the composition of milk and butter fat and on the consistency or body of butter.

6. The cause of the digestion depression produced by molasses.

7. Why insecticides burn foliage.

8. The relations of climate to development of plants and crops both in health and disease.

9. The causes of calico or mosaic disease as affecting especially the tobacco and the tomato.

10. Malnutrition of plants; causes and prevention.

11. The intensity and amount of sunshine as affecting disease of plants.

12. The causes of winter-killing.

13. Determination of physiological constants.

14. Plant breeding, especially with peas, beans and squashes, to determine the extent to which the Mendelian laws appear to govern heredity.

15. The relations of climate to variation in leading varieties of apples.

16. The economic importance of digger wasps in relation to agriculture.

17. Color vision in bees.

A number of these lines of investigation are well advanced, though none can be regarded as brought to completion. Sufficient progress has, however, been made in connection with a number of them to warrant publication, and technical papers covering some phases of this work will be found in later pages. The more important are as follows: —

The natural fertility of cranberry bogs.

Tobacco injury due to malnutrition or overfertilization.

Variation, correlation and heredity in garden peas.

The effect of fertilizer on variation in corn and beans.

The chemistry of arsenical insecticides.

Cranberry Substation.

Dr. H. J. Franklin remains in local charge of the business and investigational work connected with our cranberry substation. He has devoted himself to the matters in his charge with the greatest faithfulness and enthusiasm, and it is a pleasure to testify to the great value of his services.

During the past year our equipment for work in the interests of cranberry growers at the substation in East Wareham has been much increased and a large amount of construction work has been done. The principal improvement made has been the erection of a building. This building contains a large screening and packing room, living and office rooms for the local officer in charge, a small laboratory, and large basement and cellar storage rooms. The cost of the building was about $2,000.

Dr. Franklin furnishes the following description of special construction at the station bog completed during the year: —

1. *Flooding Areas.* — Five separate areas were diked off on the station bog for experiments in flooding. Four of the areas contain about one-fifteenth of an acre each and the fifth contains about an eighth of an acre. These areas are all separated from each other by dikes and narrow check strips. The dikes were built of turf and sand in the usual way, and average about 20 inches in height and 3 feet in width. In all, about 1,100 running feet of this diking was built. A canal, about 450 feet long and 3 feet wide, was constructed around the margin of the

bog, and connected with the main flooding canal in order to flow and drain these areas. Short side canals were dug to connect this canal with the separate areas. Small canals were also dug to connect the check strips with this canal system. In these various canals 13 wooden flumes were built for controlling the water.

2. *Skinner System Installation.* — On the station bog at East Wareham two lines, 70 and 100 feet long, respectively, of ¾-inch galvanized piping were installed, 60 feet apart, after the usual manner of Skinner system installation. The longer line was supported at intervals by concrete posts of sufficient height to allow a man to walk beneath the piping without stooping. The other line was hung in rings suspended from a wire cable drawn taut between two concrete posts. Both of these methods of support have disadvantages. In the former the concrete posts are too numerous and too heavy to give good satisfaction on the usually soft bottom of a cranberry bog. In the latter it is hard to get rid of a certain amount of sag in the piping, which makes proper pipe drainage difficult in freezing weather. Probably a better method than either of these would be to support the piping on wooden posts reaching up only a foot or two from the surface of the bog, and placed close enough together to prevent the pipe from sagging perceptibly. Skinner "Outdoor No. 2" nozzles were used in this installation. The water for running the system was pumped from Spectacle Pond by means of a Myer's pump driven from the big engine used in flooding the bog. It was arranged to pump this water through 350 feet of 1¼-inch galvanized piping before it reached the Skinner unions, leading into the ¾-inch pipe lines. This 1¼-inch pipe was, for the most part, buried in the ground. A special device driven by water pressure, for turning the pipes back and forth so as to throw the water on both sides, was also installed. The piping in the pump house was arranged to provide for heating the water by pumping it first through the cooling jacket of the 40 horse-power Fairbanks-Morse engine, and then through a coil in the exhaust pot of the engine.

For this installation, the Skinner Irrigation Company, Troy, O., through the courtesy of its president, Mr. W. H. Coles, provided nozzles and Skinner unions and loaned the station a Skinner drilling machine.

The small piece of upland referred to in the last report as desirable in order to give better access to our building has been purchased during the year.

The Crop of 1911.

The yield of fruit on the station bog during the past year was in round numbers 850 barrels of berries. These were sold for the sum of $4,988.33. The ordinary running expenses for the season amounted to $1,817.08. The bog, therefore, yielded a net income over and above ordinary running expenses of $3,-171.25.

The crop of the season was probably better than the average crop will be, and it sold for good prices. We can hardly anticipate so large a net income annually, but there would seem to be no question that the product of the bog will be sufficiently large to furnish a considerable share of the funds that will be needed for paying the costs of experimental work.

Principal Lines of Cranberry Work.

Three principal lines of investigation with cranberries are in progress. These relate respectively to the fertilizer requirements of the crop, the relations of insects to the cranberry industry, and the study of injurious fungi.

Fertilizer Experiments.

The fertilizer experiments in Red Brook bog at Waquoit have again given indecisive results. These experiments will be discontinued. We have found it exceedingly difficult to care for them properly on account of their distance from our center of operations, and we are convinced, moreover, that certain natural inequalities in the character of the bog soil in the different plots must always considerably reduce the value of the results obtained.

During the past season a new series of plots has been laid out in the station bog. The results of the season do not show a well-defined benefit following from the use of either of the different fertilizers employed. The crop where nitrate of soda is applied, indeed, showed a small average decrease. Both acid phosphate and high-grade sulfate of potash show a very small average increase, — not in either case enough to cover the cost of the fertilizer material applied. The results of the year, therefore, do not lend encouragement to the belief that the use of fertilizers on bogs of as good productive capacity as that belonging to the station will be followed by a profitable increase in the crop. It is important, however, to point out that the application of fertilizers this season was not made until about the middle of July. It seems probable that this is too late for the best results.

Dr. H. J. Franklin furnishes the following report concerning some of his principal lines of investigation during the past two years: —

Cranberry Investigations, 1910.

I. INSECTS.[1]

Of the important cranberry pests heretofore known, those which received attention were the fruit worm, the fire worm and the cranberry girdler.

The Fruit Worm (*Mineola vaccinii* (Riley)).

Experiments in submerging cocoons containing larvæ of this insect, for varying lengths of time during the fall of 1909 and winter and spring of 1910, were carried on without very satisfactory results, due, perhaps, to failure to perfectly imitate natural bog conditions.

Spraying experiments were also carried on, the insecticides used being mostly combinations of adhesives and arsenicals. The combination found most effective consisted of the following mixture in 50 gallons of water: —

	Pounds.
Resin fish-oil soap,	4½
Bordeaux mixture: —	
(*a*) Stone lime,	4
(*b*) Copper sulfate,	3
Paris green,	1

As the soap had adhesive and spreading qualities, and the Bordeaux mixture gave body to the combination and also acted to some extent as an adhesive, this combination spread over the smooth surface of

[1] Dr. H. T. Fernald has aided Dr. Franklin in the insect work in an advisory way, and for his helpful suggestions Dr. Franklin acknowledges his indebtedness and expresses his appreciation.

the partly grown berries and adhered to it much better than did any arsenical with water alone. In this mixture, Paris green seemed to give better results than arsenate of lead. Best results were obtained by spraying twice with an interval of at most only a few days between the two applications, the first application thus acting as a basis for putting a thicker coating of poison on the fruit than would be possible with one spraying alone. This spraying was done about July 20 on berries of a late variety on a strictly dry bog (*i.e.,* no winter flowage). The fruit at this time varied greatly in size, the largest berries being nearly half grown. On some plots the fruit worm injury was reduced as much as 60 per cent.

The Fire Worm (*Eudemis vacciniana* (Pack.)).

The work with this insect consisted entirely of spraying experiments. In the spring, arsenicals alone and in combination with Bordeaux mixture and resin fish-oil soap were tested as insecticides for the larvæ. It became evident that an insecticide of good sticking properties was needed for this purpose as the new foliage of the cranberry is smooth and glossy and holds the water sprays very poorly. Furthermore, this new growth develops rapidly during the time of the hatching of the first brood, and sometimes this hatching period is strung out for fully a month. The experiments indicated that a combination of Bordeaux mixture, Paris green and resin fish-oil soap, like the one given above for the fruit worm, would be most effective for this insect also. One test with this combination showed about three-fifths as much arsenic present on the foliage, after an all day's rain followed by a complete ten-hour flooding, as was present when the spray was first applied. The material for this combination is about as cheap as the arsenate of lead capable of doing the same work. The work connected with its preparation, however, is considerable.

Late in the fall, the value of scalecide and commercial lime-sulfur, as insecticides for destroying the eggs of this insect, was tested. Several plots were sprayed with different strengths of each of the two insecticides mentioned. On some plots a plank drag was used in advance of the spraying to turn the vines over, in order better to allow the spray to reach the lower surfaces of the leaves (on which the eggs are usually laid). The results of this spraying were observed early in June, 1911. Though many eggs hatched on all the plots, it was evident that on those treated with scalecide, a large percentage had been destroyed. However, on all plots on which many of the eggs were killed by the treatment, a large percentage of the winter buds were destroyed also. The fire worm injury appeared to be considerably worse on the plots which had been sprayed with the lime-sulfur than on unsprayed portions of the bog, though the reason for this was not apparent. This method of treatment does not appear promising.

Cranberry Girdler (*Crambus hortuellus* (Hübner)).

The work with this insect was confined to applying different depths of sand to infested plots, to find out what depth was necessary to smother the insect and prevent the moths from coming through. The sand was applied evenly, late in May, to depths varying from 1 to 3 inches. Means for catching and counting the moths which came through the sand on the various plots were provided. An unsanded check plot was also placed under observation and control. No moths came through the sand on any of the sanded plots, while a large number were captured from the check plot. Future work may show that less than a full inch of sand, when evenly spread, is sufficient. However, an inch is not too much to be practicable, especially as the vines are usually heavy where this insect becomes troublesome. To be effective, this treatment must be applied between December 1 and the following June 1 (when the insect is in its cocoon under the vines), and the sand must be spread evenly.

A New Pest.

During 1910 a Lepidopterous insect, known to science as *Gelechia trialbamaculella* Chambers, did great injury to a few strictly dry bogs. Neither the food plant nor the life history of this insect had been heretofore known. Its habits and life history were largely worked out during the season. The insect passes the winter in the moth state, as does the yellow-headed cranberry worm (*Peronea minuta* Robinson), and its larvæ, though considerably smaller, resemble somewhat the larvæ of that insect, both in general appearance and in habits. It is heavily parasitized, and will probably never do noticeable injury on winter-flowed bogs.

II. FUNGI.

The 1910 fungus work, done in co-operation with the Bureau of Plant Industry, consisted in obtaining the assistance of certain of the cranberry growers in practical spraying experiments, and in collecting specimens for examination by Dr. C. L. Shear, the expert of the Bureau of Plant Industry.

Investigations during 1911.

During 1911 the cranberry investigation work was divided between experiments and observations and construction work for future investigations.

Experiments and Observations.

This work came under the seven following heads, viz: Insects, Fertilizers, Fungous Diseases, Weather Observations, Fertilization of the Cranberry Blossom, Prolificness of Varieties, and application of Skinner Irrigation System to the Needs of the Cranberry Industry. The work under these heads is here outlined: —

1. *Insects.*

Observations were continued and experiments conducted with the fruit worm and the fire worm (black-headed cranberry worm). Numerous growers treated the yellow-headed cranberry worm (or, as it might be called in Massachusetts, the dry-bog fire worm), under advice given out by the station, apparently with universally satisfactory results. Heavy sanding done by various growers, in some cases, proved successful against the cranberry girdler. In others it failed to give satisfaction, the failure in every case observed being due to the fact that the sand was not applied evenly over the infested areas.

The Fruit Worm (*Mineola vaccinii* (Riley)). — Work was begun on the natural enemies of this insect, with the following objects in view: —

1. To find out what these enemies are.
2. To determine their relative abundance on flowed and dry bogs.

Spraying experiments with arsenicals and adhesives were continued. It was learned that too much resin fish-oil soap had been used in 1910. While the spraying was not timed so as to give the best results, the experience of 1911 indicates that the following formula will be found more satisfactory than the one given as the result of the 1910 experiments: —

Resin fish-oil soap (pounds),	2
Bordeaux mixture: —	
(*a*) Stone lime (pounds),	5
(*b*) Copper sulfate (pounds),	2½
Paris green (pound),	1
Water (gallons),	50

Much more of the soap than is here recommended causes bad clogging of nozzles and pumps.

While the fruit worm injury was reduced about one-third, this gain was largely offset by the loss due to tramping on the vines and berries while spraying, so that the amount of fruit obtained from the sprayed plots was but little greater than that picked from equal areas on the surrounding bog.

The Fire Worm (*Eudemis vacciniana* (Pack)). — The season's observations on this insect seem to indicate that the character of the vine growth has a strong influence on the length of the hatching period of the spring brood. Among thin vines most of the eggs seem to hatch within a few days after hatching begins. With deep, dense vines, this period seems to be so drawn out that numerous eggs are always present throughout the year, the two broods overlapping in this stage. If these observations are correct, the character of the vine growth must have an important bearing on the efficacy of both flowing and spraying treatments. In practice, it seems to be an easy matter, on a thinly vined bog, to control this insect sufficiently to keep it from doing serious injury, either by spraying with arsenate of lead or by flowing, while it is apparently impossible to prevent serious injury on a densely vined bog by either of these treatments. The control of this insect, therefore, seems to hinge on the acquirement and maintenance of a thin vine growth, which is also the most desirable condition for maximum crops. Unfortunately, it seems difficult to get a thin vine growth on some bogs. However, this can probably be readily accomplished in most cases, at least, by heavy sanding and proper adjustment of water conditions. This adjustment might be along either or both of the following distinct lines: —

1. Early withdrawal of winter flowage with no long-continued reflowage.
2. Sufficient drainage.

Experiments to test the methods of controlling this insect, here suggested, have already been started. Observations seem to show that large bogs, when compact (*i.e.*, approaching a circle or square) in general form, are, other conditions being the same, much more troubled with this insect than are small ones. Probably the chief reason for this is the fact that, during the summer, parasitic and predacious insects and spiders do not become so thoroughly distributed over the large bogs, at least until the periods of fire-worm activity are nearly over, and so do not become to so great an extent a controlling factor. On a winter-flowed bog, most of these forms are probably either destroyed or driven ashore by the flooding every year. They should not, during the summer, become as uniformly distributed on a large, compact bog as on a small one for two reasons, viz.: —

1. The distance which the parasitic and predacious forms must go to reach the central portion of the bog is, of course, greater on a large bog.
2. As the area from which these forms come onto the bog is probably restricted, for the most part, to a fringe at most only a few hundred feet wide, the area of the bog as it increases in size, if it is compact in shape, increases out of proportion to the increase of the area of this fringe. This argument agrees well with the following previously reported observations: —

1. The fire worm is only very rarely, if ever, troublesome on strictly dry bogs in Massachusetts.
2. When a winter-flowed bog becomes infested the infestation first noticed is always some distance away from the upland, usually where the winter flowage is deep.

The fact that, on a compact bog, there is a larger acreage within a given distance of any point, up to a distance that would take in the whole bog, than there is on a long, narrow one of equal acreage, may also be, to some extent, a factor in favor of this insect. If it gained a foothold on one portion of such a compact bog, it would more readily and quickly spread to all other portions.

It seems probable, from the various observations made, that if a large bog, round or squarish in shape, is by any means whatever entirely freed from this insect (even by burning or by long-continued summer flowage), it will not, as a rule, long remain so if all the following conditions are allowed to exist: —

1. Winter flowage, especially if it is deep, over a considerable portion of the bog.
2. Not more than one reflowage after the 25th of May.
3. Conditions favoring heavy vine growth.

New Pests. — During the season two new insect pests did considerable injury in some localities on cranberry bogs. One of these is a scale insect (*Aspidiotus oxycoccus* Woglum) which superficially resembles the San José scale somewhat but is very distinct from that species. This species did much injury on a bog in Yarmouth and was noted in smaller numbers in a few other places.

The other insect is a species of white grub (*Lachnosterna* sp.). It caused the dying of circular areas on several bogs, principally in Carver, these patches varying in diameter from 3 to 30 feet. This injury observed superficially might easily be mistaken for the "ringworm" injury caused apparently by fungous disease.

2. *Fungous Diseases.*

This work, as during the previous season, was done in co-operation with the Bureau of Plant Industry. Co-operative spraying experiments were carried on by several practical growers. In addition 3 plots on the station bog, each 4 rods square, were sprayed with fungicides and the results noted, as shown by the quantity and keeping quality of the fruit obtained. The amount of fruit gathered from these plots in every case was somewhat less than that from checks marked on the surrounding bog. This was due, apparently, to the injury done by tramping on the vines while spraying. Loss due to decay up to December 4 was reduced, on an average, about one-half by the treatment. One plot was sprayed three times and the others twice with mixtures and on dates as follows: —

Fungicide.	Plots.				
	A.	B.	C.	D.	E.
Bordeaux mixture, . .	June 22 July 17	July 17	July 17	July 17	July 18
Neutral copper acetate, .	August 2	August 2	August 2	August 3	August 3

The Bordeaux mixture was made up with 3 pounds of lime and 4 of copper sulfate to 50 gallons of water. One pound of the neutral copper acetate was used to 50 gallons of water. Two pounds of resin fish-oil soap were used with the Bordeaux mixture in all cases and with the acetate.

3. *Weather Observations.*

The weather instruments were installed on May 15, from which date until October 15 observations were taken every morning at the station at East Wareham, and records of the following made: —

Maximum thermometer in shelter.
Maximum thermometer on bog.
Minimum thermometer in shelter.
Minimum thermometer on bog.
Precipitation.
Wind direction.
Continuous thermograph readings.
Continuous barograph readings.

The readings of the maximum and minimum thermometers and the amount of precipitation were telegraphed to the local office of the Weather Bureau at Boston every morning after May 15 during the spring and fall periods of frost danger.

4. *Fertilization of the Cranberry Blossom.*

Numerous experiments were carried out and observations made on the cross-fertilization of the cranberry blossom. Bees of all kinds were shut out from half a square rod of vines, during the blossoming period, by means of a mosquito-netting tent, with the result that only about 2⅔ quarts of berries developed, while on any equal area on the surrounding bog as much as 20 quarts were picked, the average crop of the entire bog being about 70 barrels to the acre. From a check plot of equal area laid off close to this tent 28 quarts were gathered. Another larger tent was erected and the honey bee alone allowed to enter it during the bloom, a hive being placed so as to open into it. Under this tent as good a crop developed as on the surrounding bog. These experiments seem to prove that bees are necessary to the satisfactory cross-pollination of the cranberry blossom and that the honey bee is efficient in this work.

As the vines approached full bloom under the tent from which the bees were excluded the blossoms quite generally began to take on a peculiar vivid pink color, and as the blossoming advanced this became more and more striking. Only a small percentage of the blossoms on the bog outside of the tent took on this color, while inside there were few which did not show it strikingly. This tent was on Early Black vines. The tent into which honey bees were admitted was placed on

Howe vines. This variety came to full bloom in the midst of a period of unusually hot weather in July, and had a larger percentage of the pink blossoms than did the Early Blacks which blossomed earlier. The vines under the tent, into which the honey bees were admitted, had a very noticeably smaller proportion of these pink blossoms than did the surrounding bog. They were, in fact, almost entirely absent. These observations seemed to indicate that the peculiar pink color of the bloom was a sign of fertilization failure. This pink coloring certainly always accompanies lack of fertilization with the Early Black variety, for it was just as noticeable in a 1910 experiment, in which bees were shut out by mosquito netting, as it was in the 1911 experiment. To make this matter more certain a large number of Howe blossoms, showing this pink coloring, were marked with yarn and examined late in August. Hardly 2 in 11 had succeeded in producing berries. This was less than one-half of the proportion of berries to blossoms on the bog as a whole. In other words, a much smaller proportion of pink blossoms than of normally colored ones produced berries, thus confirming the indications obtained from the tent experiments. To go with this there is the possibility that fertilization may take place to some extent, though abnormally retarded, after a blossom has taken on the pink color.

After the unfertilized blossoms turned pink in the tent experiments the corolla always hung on abnormally, so that the vines under the tent, from which bees were excluded, appeared to be in full bloom when, on the surrounding bog, the bloom was almost entirely past.

The conclusion arrived at, from these and other observations, is that it will often pay to keep honey bees near cranberry bogs during the blossoming season. There are, undoubtedly, years in which this practice will not repay anything for the extra labor and expense involved. It is probable, however, that it will pay well to keep bees in any season in which wild bees are scarce, or in which there is much bad weather during the blossoming period to reduce the length of time in which the bees can work. Unfortunately, we have not yet sufficient data to make an estimate of the number of hives necessary for the satisfactory pollination of a bog of any given acreage.

With most varieties, an upright having 5 blossoms will probably, as a rule, produce as many berries, if only 2 of those blossoms are cross-fertilized, as it would if all were fertilized. This is because the cranberry, in common with other plants, always produces the means of reproduction far in excess of what it uses. This is borne out by the fact that the crop of berries under the hive-bee tent was not greater than on the surrounding bog, though the lack of pink blossoms seemed to indicate a more perfect pollinization.

5. *Prolificness of Varieties.*

Examination of a considerable number of varieties on numerous bogs showed a marked variation, between varieties, in the average number of berries borne by the individual upright and in the proportion of berries to blossoms. Moreover, this variation seemed, to a certain degree, constant for the different varieties wherever found, even when they were side by side on the same bog and under the same conditions. Some varieties averaged less than 2 berries, and others more than 3, to the upright. Then, too, there was a noticeable varietal variation in the proportion of sterile uprights present. This condition of things obviously is not due to relative lack or abundance of pollen-carrying agents (bees), or to differences in fertility of the bottom on which the vines grow, but is the result of a varying quality of natural prolificness in the vines themselves.

During the season, work was begun with the idea of eventually producing, if possible, a much more prolific variety than any at present known. A large number of uprights of three different varieties were selected and marked for planting in separate plots in the spring. Only uprights were marked which produced during the season 4 or 5 good berries. It will be observed that this is in line with similar work already carried out successfully with corn, potatoes and other crops.

6. *Skinner System of Irrigation.*

This plant has been installed to test thoroughly the value of this system as applied to the following needs of a dry cranberry bog: irrigation, frost protection, winter protection and possibly spraying. This system is not expected to supplant water supply by other methods in vogue, where these methods are available. Late in the fall, the feasibility of heating the water so as to raise the temperature by radiation, without sprinkling over the entire surface of the bog, was tried. It was thought that the amount of piping and the size of the pump necessary in practice might in this way be reduced. The tests, however, showed this to be impracticable.

Asparagus Substation, Concord.

Mr. Charles W. Prescott, to whose hearty interest, enthusiasm and efficient supervision we are greatly indebted, has continued in charge of the details of the work in progress.

Two distinct lines of investigation are being carried on: —

1. Breeding experiments which have for their object the production of a rust-resistant type of asparagus of good commercial quality.

2. Fertilizer experiments planned with a view to determining if possible the relation of different fertilizer elements to the crop as regards yield, quality and capacity to resist rust.

Breeding Experiments. — The breeding work in progress is conducted on the basis of a co-operative understanding with the Bureau of Plant Industry of the United States Department of Agriculture. The details of the work have been looked after the past season by Mr. J. B. Norton, who has carried it forward with the same enthusiasm and energy which has characterized his work heretofore.

A number of rust-resistant types have been produced. From among these those which show the best commercial characteristics and the greatest vigor will be propagated as rapidly as possible for further trial and ultimate distribution. In view of the great improvement already made it is confidently anticipated that complete success in attaining the ends in view will soon be realized.

Fertilizer Experiments. — The results of the fertilizer experiments in progress are not as yet sufficiently decisive to make it seem advisable to publish a full report. Owing to the thorough preparation which the entire field received before it was divided into plots, even those to which no manure or fertilizer has been applied still continue to give an excellent yield. These plots, however, are now beginning to fall behind those which receive the different applications of manure and fertilizer materials which are under trial. The field contains 40 plots of one-twentieth acre each, and the past season was the fifth since the plots were set. The yield was fairly satisfactory both as to quantity and to quality. The cutting season lasted from May 8 to June 24. The total yield of all the plots was 9,347 pounds, 5 ounces.

On the basis of recorded yields and observations the following conclusions appear to be warranted: —

1. Nitrate of soda used in connection with acid phosphate and muriate of potash proves beneficial, but an increase above the rate of 466 pounds per acre does not appear to be useful.

2. Nitrate of soda used in connection with an application of barnyard manure at the rate of 10 tons per acre proves benefi-

cial, but in this case, also, an increase above the rate of 466 pounds per acre of nitrate is not followed by a further increase in the crop.

3. Nitrate of soda has been applied according to three distinct plans: —

(*a*) All applied in early spring.

(*b*) One-half applied in early spring and the balance at the close of the cutting season.

(*c*) All at the close of the cutting season.

These variations in method of applying have been tried with nitrate of soda in differing amounts and in varying combinations.

The variation in season of application is not followed by any well-defined difference in yield, but the amount of rust has appeared to be less with the larger applications applied at least in part after the cutting season. In other words, nitrate of soda so applied and in such liberal quantities as to promote a continuous vigorous growth of the plant after the close of the cutting season seems to increase the capacity of the plants to resist rust.

4. Among the different materials used as the source of potash, viz., muriate, high grade sulfate, low grade sulfate, wood ashes, and kainit, the plot receiving the latter showed the least rust. It is important, however, to point out that this may have been in part a consequence of the fact that the plot was located on the side of the field lying at the greatest distance from the fields which are believed to have been the chief sources of rust infection. The comparative freedom from rust of the plants on the kainit plot, therefore, may have been due in large measure to location. The decided difference, however, in the amount of rust on this plot and on the one immediately adjoining it, the location of which with reference to rust infection is not very different, lends probability, at least, to the conclusion that the kainit exercised a favorable influence in preventing rust.

5. Acid phosphate used in connection with nitrate of soda and muriate of potash has given a considerable increase in crop. This increase is greatest where the acid phosphate is used at the maximum rate of 188.7 pounds per acre.

6. Muriate of potash used in connection with nitrate of soda

and acid phosphate increases the crop, but an increase in the quantity of muriate above the rate of 260 pounds per acre does not result in further increase in the crop.

Control Work.

Reports in full detail covering the various lines of control work carried on by the station have been prepared by the chemists in charge. These will be found in later pages of this report.

Fertilizer Law. — The fact was pointed out in the last annual report that a new law had been drafted for presentation in the Legislature of 1911. This law was enacted by the Legislature and went into effect Dec. 1, 1911. The new law is working smoothly and satisfactorily. It is bringing in the increased revenue needed for more thorough work, and the principal change introduced, viz., bringing agricultural lime under its provisions, is proving of much value to our farmers.

Dairy Law. — The draft for a new dairy law referred to in the last annual report failed of enactment in the Legislature of 1911. It will be reintroduced in the Legislature of 1912, and it is confidently anticipated that it will be enacted. The most important change from the existing law consists in bringing milk inspectors, and the Babcock machines and apparatus which they use, under the provisions of the law.

Feed Law. — The fact was referred to in the last annual report that the appropriation received from the State for carrying out the provisions of the existing feed law were proving insufficient to cover the costs of thorough work. During the past year a draft for a new law has been prepared. Its preparation has involved a great deal of study and many conferences with parties affected by the law. The principal changes proposed are to bring the various wheat offals under the provisions of the law, to require a guarantee of the maximum percentage of crude fiber present, to require the statement of ingredients contained in each feeding stuff, and to require the registration of each brand of feeding stuff before it is sold. The amount of the appropriation provided under the new draft is $6,000 in place of $3,000 as under the present law. Besides these changes the phraseology has been made more explicit, violations are more clearly defined, and the director is given discretionary power regarding prosecutions.

In form and general content the new draft has been closely modeled after the uniform feed law adopted by the Association of Feed Control Officials of the United States. It is believed that the provision of a uniform feed law for the entire country is desirable in the interests alike of the buying public and manufacturers and dealers.

Dissemination of Information.

The station endeavors to reach the public with helpful information in three rather distinct lines: distribution of publications, private correspondence, and lectures and demonstrations.

Publications. — The station issues three classes of publications: an annual report in two parts, bulletins and circulars.

Part I. of our annual report contains the formal reports of the director, treasurer, and heads of departments and technical papers giving the results of research work. Part II. contains papers of a more popular character. It is our aim to include in this part of the report such matters as are of most immediate interest on the farm.

The demand for bulletins and circulars constantly increases. With the further growth and development of the extension department of the Massachusetts Agricultural College it is expected that this demand will be increasingly met by means of its publications, while our own publications will be, for the most part, restricted to such as deal with the results of our investigations. It must be recognized that satisfying this popular demand is extension work rather than experimental.

The following tables show the publications of the year 1911 and those of that and earlier years which are still available for free distribution: —

Publications during 1911.

Annual report: —

Part I., 356 pages; Part II., 95 pages.

Bulletins: —

No. 136. Inspection of Commercial Feed Stuffs, P. H. Smith and C. L. Perkins. 56 pages.

No. 137. The Rational Use of Lime, Wm. P. Brooks; The Distribution, Composition and Cost of Lime, H. D. Haskins and J. F. Merrill. 19 pages.
No. 138. Tomato Diseases, George E. Stone. 32 pages.
No. 139. Inspection of Feed Stuffs, P. H. Smith and C. L. Perkins. 32 pages.
No. 140. Inspection of Commercial Fertilizers, H. D. Haskins, L. S. Walker, J. F. Merrill and R. W. Ruprecht. 86 pages.

Circulars: —

No. 30. Balanced Rations for Dairy Stock, J. B. Lindsey. 7 pages.
No. 31. Lime and Sulphur Solutions, G. E. Stone. 4 pages.
No. 32. An Act to regulate the Sale of Commercial Fertilizers (chapter 388, 1911). 4 pages.

Meteorological bulletins, 12 numbers. 4 pages each.

Publications Available for Free Distribution.

Bulletins: —

No. 33. Glossary of Fodder Terms.
No. 64. Concentrated Feed Stuffs.
No. 76. The Imported Elm-leaf Beetle.
No. 84. Fertilizer Analyses.
No. 90. Fertilizer Analyses.
No. 115. Cranberry Insects.
No. 123. Fungicides, Insecticides and Spraying Directions.
No. 125. Shade Trees.
No. 127. Inspection of Commercial Fertilizers.
No. 130. Meteorological Summary — Twenty Years.
No. 131. Inspection of Commercial Fertilizers, 1909.
No. 132. Inspection of Commercial Feed Stuffs, 1910.
No. 133. Green Crops for Summer Soiling.
No. 134. The Hay Crop.
No. 135. Inspection of Commercial Fertilizers, 1910.
No. 136. Inspection of Commercial Feeds, 1911.
No. 137. The Rational Use of Lime.
No. 138. Tomato Diseases.
No. 139. Inspection of Commercial Feed Stuffs, 1911.
No. 140. Inspection of Commercial Fertilizers, 1911.

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

Index to bulletins and annual reports, 1888–1907.

Circulars: —

No. 12. The Unprofitable Cow and how to Detect her.
No. 20. Lime in Massachusetts Agriculture.
No. 25. Cottonseed Meal.
No. 26. Fertilizers for Potatoes.

No. 27. Seeding Mowings.
No. 28. Rules Relative to Testing Dairy Cows.
No. 29. The Chemical Analysis of Soils.
No. 32. An Act to regulate the Sale of Commercial Fertilizers.
Summer Soiling Crops.
Home-mixed Fertilizers.
Dairymen losing Money on Low-Grade Feeds.
Balanced Rations for Business Cows.
Orchard Experiment.
Fertilizers for Turnips, Cabbages and Other Crucifers.
Fertilizers for Corn.
Annual reports: 10th, 12th, 13th, 14th, 15th, 16th, 17th, 20th; 21st, Part II.; 22d, Parts I. and II.; 23d, Parts I. and II.

Circulation of Publications. — As provided by act of our Legislature, Part I. of our annual report is printed with the report of the secretary of the State Board of Agriculture, and those on the mailing list of that Board will receive this publication. The act provides, also, that 5,000 copies of Part I. shall be furnished to the station. These are used in supplying libraries and directors of agricultural experiment stations, libraries and presidents of agricultural colleges, the public libraries of Massachusetts and other public libraries on our mailing list, individuals on the mailing list of the United States Department of Agriculture, and institutions and periodicals on our exchange list.

The State prints an edition of 16,000 copies of Part II. of our annual report for the use of the station. This part of the report and our bulletins are sent to all those on our general mailing list, to the public libraries of the State, to individuals on the mailing list of the United States Department of Agriculture likely to be interested, and to experiment stations and the agricultural colleges.

It is our practice to reserve a considerable number of each publication to meet subsequent demands, but such demands have of late been so numerous that our supply of most of our earlier editions is exhausted.

Our meteorological bulletins are sent only to agricultural college and experiment station libraries, presidents and directors of agricultural colleges and experiment stations, to the department of agriculture and office of experiment stations, to newspapers and libraries and to individuals who have especially requested them.

The circulars which we issue are not sent out to a regular mailing list. They are prepared for use in connection with the correspondence of the station, for it is by the use of such circulars only that we find it possible to give the full information and advice needed by those consulting us by letter. Any of these circulars, however, will be sent on special request.

The newspapers of the State receive an abstract of all important publications, and as a rule we find them ready to publish such abstracts.

Mailing Lists. — A large amount of work is required in keeping our mailing lists accurate and thoroughly alive. We are constantly dropping names and as constantly adding new ones. The tendency is towards an increase, although just at present our total is a few hundred less than shown in the last annual report, owing to the fact that some lists not previously revised for a number of years have undergone very careful revision resulting in dropping a number of addresses which had undoubtedly been for some time dead. The following table shows the nature of the lists which we maintain and the number of addresses in the several classes: —

Residents of Massachusetts,	12,651
Residents of other States,	2,438
Residents of foreign countries,	242
Newspapers,	518
Libraries,	306
Exchanges,	151
Cranberry growers,	1,395
Beekeepers,	2,866
Meteorological,	389
Total,	20,956

Correspondence. — During the year 1911 the number of letters of inquiry answered by members of the station staff has been about 12,000. This is a somewhat smaller number than for 1910. It is apparent that the public in increasing degree is recognizing that the extension department is especially manned and equipped for service of this character, and it would seem, therefore, that we may confidently anticipate still further relief from this work in the near future, — a consummation long wished for, as it will give station men more time for the more legitimate station work of research and experiment.

Lectures and Demonstrations. — The public demand for lectures and demonstrations has been particularly active, and station men have been frequently engaged in service of this character. The general management and arrangements are, for the most part, looked after by the extension department, but even under this plan the draft upon the time of some of our men has been so heavy as to leave little opportunity for attention to experiment or research. This has been particularly true of the men in our poultry and apicultural departments, which are greatly in need of additional men in order that the requirements of both lines of work — extension and research — may be more fully met.

Buildings.

Extensive improvements and repairs have been made during the year in the chemical laboratory of the station at a cost of $7,500, appropriated by the last Legislature. The following are the principal improvements secured: two additional rooms for research work; enlarged office room; greatly increased space for storage of apparatus, chemicals and samples; a fire-proof vault; and a library and reading room. Central steam heat has been introduced in place of the independent hot-water system. Numerous minor repairs have been made and the entire building has been replumbed, rewired and repainted. As a consequence of the various changes and improvements the building now fairly satisfies the needs of the chemical department of the station, but the chemical work increases so rapidly that it cannot be many years before additional laboratory accommodations will be needed.

There has been but one other important building operation during the year, — the erection of the building at the cranberry substation in East Wareham, already mentioned and briefly described in the report on the work at that substation. The cost of the building (about $2,000) was nearly covered by an unexpended balance of the $15,000 appropriation made by the Legislature in 1910.

WM. P. BROOKS,
Director.

REPORT OF THE TREASURER.

ANNUAL REPORT

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

For the Year ending June 30, 1911.

The United States Appropriations, 1910–11.

	Hatch Fund.	Adams Fund.
Dr.		
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1911, under acts of Congress approved March 2, 1887 (Hatch fund), and March 16, 1906 (Adams fund),	$15,000 00	$15,000 00
Cr.		
By salaries,	$13,269 05	$11,659 35
labor,	321 49	1,079 94
publications,	8 50	–
postage and stationery,	2 89	51 44
freight and express,	–	–
heat, light, water and power,	1 38	170 47
chemicals and laboratory supplies,	31 74	137 54
seeds, plants and sundry supplies,	478 69	356 20
fertilizers,	542 04	75 27
feeding stuffs,	196 35	1 46
library,	–	7 53
tools, machinery and appliances,	–	4 50
furniture and fixtures,	61 75	50 00
scientific apparatus and specimens,	86 12	1,343 17
live stock,	–	–
traveling expenses,	–	18 13
contingent expenses,	–	–
buildings and land,	–	45 00
Total,	$15,000 00	$15,000 00

State Appropriation, 1910–11.

Cash balance brought forward from last fiscal year,	$4,198 48	
Cash received from State Treasurer,	13,500 00	
fertilizer fees,	6,239 83	
farm products,	2,068 85	
expert services,	25 00	
miscellaneous sources,	9,601 69	
		$35,633 85
Cash paid for salaries,	$9,875 92	
labor,	10,342 73	
publications,	2,443 03	
postage and stationery,	982 42	
freight and express,	407 18	
heat, light, water and power,	579 55	
chemicals and laboratory supplies,	636 97	
seeds, plants and sundry supplies,	2,507 67	
fertilizers,	350 99	
feeding stuffs,	1,548 98	
library,	451 10	
tools, machinery and appliances,	69 50	
furniture and fixtures,	408 79	
scientific apparatus and specimens,	649 06	
live stock,	44 00	
traveling expenses,	2,303 89	
contingent expenses,	250 00	
buildings and land,	895 17	
balance,	866 90	
		$35,633 85

REPORT OF THE AGRICULTURIST.

WM. P. BROOKS.

As has been the case for many years, the problems which have chiefly engaged the attention of the department of agriculture during the past year are such as are connected with the selection, adaptations, and methods of application of manures and fertilizers. In most cases a definite and uniform plan of experiment has been followed for a considerable number of years. The work will not be reported in detail, but attention is called to a few of the more striking results.

I. Comparison of Different Materials as a Source of Nitrogen (Field A).

The different materials under comparison are manure, one plot; nitrate of soda, two plots; dried blood, two plots; and sulfate of ammonia, three plots. In the case of both nitrate of soda and dried blood one of the two plots receives muriate as a source of potash; the other, high-grade sulfate. The sulfate of ammonia is used on two plots in connection with muriate, and on one in connection with sulfate of potash. The field contains three no-nitrogen plots, on two of which muriate is used as a source of potash; on the other, high-grade sulfate. All the plots in the field receive an equal liberal application of dissolved bone black as a source of phosphoric acid, while all the different materials furnishing either nitrogen or potash are used on the different plots in such amounts as to furnish, respectively, equal quantities per plot of nitrogen and of potash.

The crops grown in this experiment in the order of their succession have been: oats, rye, soy beans, oats, soy beans, oats, soy beans, oats, oats, clover, potatoes, soy beans, potatoes, soy beans, potatoes, oats and peas, corn, clover for four years and corn.

The corn crop of the past season made an excellent growth, but was rather seriously injured by an exceptionally early and severe frost on September 13. So serious was the injury that it was deemed best to allow the crop to stand until the ears were thoroughly dry. It is believed that the proportion of sound corn obtained by following this plan was greater than it would have been had the crop been cut and shocked in accordance with the usual custom.

On the basis of 100 for nitrate of soda, the relative standing of the different nitrogen fertilizers and the no-nitrogen plots as measured by total yield during the past season was as follows: —

	Per Cent.	
	Grain on Cob.	Stover.
Nitrate of soda,	100.00	100.00
Barnyard manure,	98.20	100.00
Sulfate of ammonia,	101.41	98.25
Dried blood,	101.58	101.58
No nitrogen,	95.67	108.06

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

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	94.26
Dried blood,	92.80
Sulfate of ammonia,	87.53
No nitrogen,	73.04

In making up the table on relative standing for the twenty-two years the grain only for 1911 was included, as, owing to the manner in which the crop was handled, there had been breakage and waste from the frost-bitten stalks and leaves, the amount of which was not uniform for the different plots.

On the basis of increase as compared with the no-nitrogen plots the relative standing for the different nitrogen fertilizers for the twenty-two years is as follows: —

	Per Cent.
Nitrate of soda,	100.00
Barnyard manure,	78.71
Dried blood,	73.29
Sulfate of ammonia,	53.74

It will be noted that nitrate of soda, as in previous years, shows a much greater average increase than either of the other sources of nitrogen.

One of the most striking results of the past season was the relatively large yield produced on the no-nitrogen plots. It amounts to about 95 per cent. of the average yield on all the different plots which have received an application of nitrogen annually. This result, it will be readily understood, was no doubt due to the fact that clover for three years had preceded the corn crop of the past year. The figures emphasize in a most striking way the extent to which rotations including a legume may be made to take the place of the use of nitrogen fertilizers.

II. Muriate as compared with Sulfate of Potash.

These comparisons were begun in 1892. Five pairs of plots are under comparison. From 1892 to 1899 potash salts were used in quantities (varying in different years, but always in equal amounts, on the two members of a pair of plots) ranging from 350 to 400 pounds per acre. Since 1900 the quantity used has been uniform on all plots, and at the rate of 250 pounds per acre annually. The only other fertilizer material applied has been fine-ground bone to each plot at the uniform rate of 600 pounds per acre. The past year is the twentieth year of these experiments. The crops during the year were alfalfa on one pair of plots, clover on one pair, and asparagus, rhubarb and blackberries, each occupying a part of a pair of plots. The rates of yield per acre on the different potash salts are shown in the following table: —

	Rate per Acre (Pounds).				
	Alfalfa.	Asparagus.	Rhubarb.	Blackberries.	Clover.
Muriate of potash, . .	1,627.9	6,181.2	14,128	2,086.5	2,905.4
Sulfate of potash, . .	2,041.4	5,161.6	19,315	5,907.4	3,689.6

It will be noted that the asparagus is the only crop which gives a larger yield on the muriate, and that the superiority of the sulfate is quite marked in the case of each of the others.

There was a characteristic and remarkable difference in the appearance of the alfalfa on the two salts throughout the entire season, that on the sulfate being of a richer, darker green and far more vigorous growth. A similar difference characterized the appearance of the clover on the two salts. In the case of rhubarb the proportion of leaf to stalk, as in previous years, was considerably greater on the sulfate than on the muriate. This appears to be a highly characteristic effect, and is one for which at present we are unable to offer an explanation.

III. Manure alone compared with Manure and Sulfate of Potash.

This experiment has been in progress since 1890. It occupies the south corn acre, which is divided into 4 plots of one-quarter acre each. On two of these plots good barnyard manure from well-fed dairy cows has been applied at the rate of 6 cords per acre. On the other two plots similar manure has been applied, at first at the rate of 3 cords per acre, but since 1895 at the rate of 4 cords per acre, and together with these smaller applications of manure high-grade sulfate of potash at the rate of 160 pounds per acre has been applied. The object in view is to determine the crop-producing capacity of the smaller amount of manure combined with sulfate of potash as compared with that of the larger application of manure.

The general practice has been to apply manure annually, but in a number of instances, when it was feared that if this should be done the newly seeded grass and clover would lodge badly, the customary application has been withheld; but in all cases if withheld from one plot it was of course withheld from all.

The plan of cropping this field for the last thirteen years has been corn and hay in rotation in periods of two years for each. During the past season the crop has been corn. The rates of yield per acre are shown in the following table: —

	Yield per Acre.		
	Hard Corn (Bushels).	Soft Corn (Bushels).	Stover (Pounds).
Plot 1, manure alone,	89.140	2.460	4,780
Plot 2, manure and potash,	85.260	1.430	4,740
Plot 3, manure alone,	88.570	2.230	4,580
Plot 4, manure and potash,	83.490	1.890	4,580
Averages: —			
Plots 1 and 3, manure alone,	88.855	2.345	4,680
Plots 2 and 4, manure and potash,	84.375	1.660	4,660

The crop on all the plots was an excellent one, and it will be noted that the larger application of manure alone gave a yield of hard corn about 4½ bushels greater than that produced on the smaller amount of manure and potash. The combination produced a slightly smaller yield both of soft corn and stover. The difference in crop is not sufficiently great to cover the difference in cost between the two systems of manuring.

IV. Average Corn Fertilizer compared with Fertilizer Richer in Potash.

These experiments are carried on on what is known as our north corn acre, which is divided into 4 one-quarter acre plots. The experiments began in 1891. Continued corn culture was the rule at first, but for the past sixteen years corn and hay, two years of each, have regularly alternated. Two of the plots in the field, 1 and 3, are fertilized with a home-made mixture furnishing nitrogen, phosphoric acid and potash in highly available forms, and in the same proportions in which they are contained in the average corn fertilizer offered on our markets. The other two plots are fertilized annually with a home-made mixture containing much less phosphoric acid and more potash than is applied to the other plots.

The crop of the past season was corn, and it was an excellent one on all plots. The average yields were at the following rates per acre: —

	Hard Corn (Bushels).	Soft Corn (Bushels).	Stover (Pounds).
On the fertilizer rich in phosphoric acid and low in potash,	88.66	1.89	4,230
On the fertilizer low in phosphoric acid and rich in potash,	86.69	2.02	4,486

The larger proportion of phosphoric acid has evidently been favorable to the production of sound, well-ripened grain.

V. Top-dressing for Hay.

Since 1893 we have been using barnyard manure, wood ashes, and a mixture of bone meal and muriate of potash as top-dressing for permanent mowing. The total area included in these experiments is about 9 acres divided into 3 plots, so that each year each system of top-dressing is represented. The order in which the different materials is applied to any given plot is as follows: barnyard manure; next year, wood ashes; and in the succeeding year a combination of fine ground bone and muriate of potash. The rates of application per acre: —

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

The crop of the past year was very much lighter than usual on account of the marked deficiency of rainfall and the extreme heat. The average yield for the entire area this year was at the rate of 3,993 pounds per acre. The yields on the different materials used in top-dressing were at the following rates per acre: —

	Pounds.
Barnyard manure,	3,840
Fine-ground bone and muriate of potash,	4,304
Wood ashes,	3,736

The average yields to date under the different systems of top-dressing have been at the following rates per acre: —

	Pounds.
Barnyard manure,	6,211
Wood ashes,	5,681
Fine-ground bone and muriate of potash,	6,061

Poultry Work.

For a considerable number of years experiments on the best methods of feeding poultry for egg production have been conducted in this department. In the spring of 1911 all poultry work was transferred to the head of the poultry department of the college. There has been so much construction work in this department during the past year, however, in the effort to get it properly established and equipped, that the poultryman has no report to offer at this time.

REPORT OF THE HORTICULTURIST.

FRANK A. WAUGH.

The work in horticulture has gone on during the year on much the same lines as heretofore, but plans have been forming for certain new kinds of work. The work on heredity and variation in peas has developed a considerable mass of data from which publication is made in this report. Certain correlative topics are still under study and will be reported on later.

The work on Mendelism in beans has been going on successfully during the last year. We now have on record full data for about 15,000 plants. It is expected that one or two years further study will be required to bring this subject to the point of publication. Somewhat similar work with squashes is also under way and will be carried forward as fast as opportunity permits. A few minor problems are studied as time and opportunity offers.

The work in apple variation, already reported upon in one or two publications, still progresses. The plan of work now contemplates a more intensive study of variation and its correlation with local climatological factors.

A research experiment in the mutual influence of stock and cion has been planned to extend over a period of twenty years or more. Work has begun on a small scale, but it will probably require another year or two to get the experiment fully under way. The planning and inauguration of this experiment have been chiefly due to the efforts of Dr. J. K. Shaw.

There is a strong demand for experimental work in other lines of horticulture aside from those already taken up at this station. Work is urgently needed in lines of market gardening and floriculture, and some steps should be taken at once to serve these important and significant industries. For this purpose additional funds should be provided by the State.

All the experimental work herein referred to has been under the direct management of Dr. J. K. Shaw. In order to carry out the work now under way, and other work imperatively needed, it will be very desirable to have an additional assistant within the year.

REPORT OF THE CHEMIST.

JOSEPH B. LINDSEY.

This report gives a brief outline of the work of this department for the year ending Dec. 1, 1911.

1. Correspondence.

There have been sent out substantially 5,500 letters during the year, the estimate being based on the number of stamps used. It is not believed that more than the usual number of letters of inquiry have been received by this department. The increase of 500 over the year 1910 was probably due to the increased correspondence in connection with the control and cow testing work.

2. Numerical Summary of Substances examined in the Chemical Laboratory.

The following substances have been received and examined: 114 samples of water, 527 of milk, 2,799 of cream, 204 feedstuffs, 209 fertilizers and fertilizer refuse materials, 63 soils, 36 lime products, 27 ash analyses of plants and 4 miscellaneous. There have also been examined in connection with experiments in progress by the several departments of the station 116 samples of milk and cream, 57 cattle feeds and 377 agricultural plants. In connection with the control work there have been collected 1,063 samples of fertilizer and 773 samples of feedstuffs. The total for the year was 6,369.

The above does not include the work of the research section. In addition, 15 candidates have passed the examination and secured certificates to operate the Babcock test, and 4,466 pieces of Babcock glassware have been tested for accuracy, of which only 12 pieces or .27 of 1 per cent. were condemned as inaccurate.

3. Work of the Research Section.

Work has continued along much the same lines as heretofore. It has been considerably impeded, however, by the extensive repairs made to the laboratory during the summer and autumn.

(*a*) Messrs. Holland and Reed have devoted a large amount of their time to the devising of methods for the making of chemically pure insecticides, and have furnished the entomological department with Paris green, acid arsenate of lead and metarsenite of lime. A paper on this work will probably be found elsewhere in this report. Some progress has been made in the quantitative determinations of the insoluble fatty acids, and numerous factors have been studied such as strength of alcohol, ratio of fatty acids to solvent, amount of precipitant, conditions favoring the formation of a crystalline precipitate, etc. This work will be given more attention during the present year.

(*b*) Mr. Morse has continued his studies relative to the effect of fertilizers on asparagus and has brought together a considerable amount of data on the subject. It is not believed, however, that the work is sufficiently advanced to warrant an extended paper on the project. The same chemist has also continued his work with cranberries, devoting his time principally to a chemical examination of the drainage water in the cylinders. These cylinders, it may be stated, are made of large, glazed tile sunk in the earth and filled with peat and sand so as to represent miniature cranberry bogs.

(*c*) Dr. Lindsey has continued his work on the cause of the digestion depression produced by molasses. Butyric acid — a product of carbohydrate fermentation — has been fed to sheep in different amounts, but without apparently causing any noticeable depression. This work is being continued.

Numerous digestion experiments have been made including plain and molasses beet pulp, grain screenings and Creamo feed.

Attention has also been given and experiments are now in progress relative to calf meal substitutes for milk in rearing dairy calves, and also to the cost of milk production.

Papers relative to the digestibility of cattle feeds and on corn best suited for the silo in Massachusetts will be found elsewhere in this report.

4. Report of the Fertilizer Section.

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

The work of the division has been devoted chiefly to the inspection of commercial fertilizers, although quite a variety of other work has also claimed attention. The collection and analysis of the various brands of agricultural lime sold in the Massachusetts markets was made during the early winter months; these have served in the preparation of a lime bulletin (No. 137), which was published in April. The complete ash analysis of 19 samples of asparagus roots has also been made in connection with the Concord field experiments; analytical work has likewise been completed on 44 samples which was begun during the previous year. Complete ash analyses have been made on 4 samples of corn kernels and 4 samples of corn stover in connection with field experiments conducted by the agricultural department. Considerable work has been done in the study of normal tobacco soils and subsoils in order to obtain comparative data in connection with cases of overfertilization or malnutrition; the analyses will be found in a short article entitled "Tobacco Injury due to Malnutrition or Overfertilization," to be found on later pages in this report. An unusually large amount of time has been devoted to co-operative work in connection with the Association of Official Agricultural Chemists. Work was done on nitrogen and potash, and the writer has served in the capacity of referee on phosphoric acid. The planning of this work, the preparation of the samples to be used by various chemists in obtaining analytical data, and the subsequent preparation of the report presented to the association took both time and energy. As the object, however, is to improve our present methods of analysis, and to introduce new and better methods, the time was unquestionably well spent. The examination of home-mixed fertilizers, refuse by-products and soils sent on by farmers has been attended to as in the past, and a more detailed report of this portion of the work will be found on a subsequent page.

The work of the collection and analysis of registered fertilizers shows a substantial increase over that of the previous year; in fact, a larger number of commercial fertilizers has been registered, collected and analyzed during the season than for *any previous* year. A new fertilizer law was enacted during the season and went into effect Dec. 1, 1911. The full text of the law is given in Bulletin No. 140.

As a result of co-operative studies made by the experiment stations of New England, New York and New Jersey we have been able this year, for the first time in the history of the fertilizer control work, to publish analytical data as to the character of the organic nitrogen supplied by the various brands sold in the State. The additional work entailed has required the assistance of one extra man during the greater part of the season.

On a few subsequent pages will be found summaries covering the fertilizer control work: —

(*a*) Fertilizers licensed.

(*b*) Fertilizers collected.

(*c*) Fertilizers analyzed.

(*d*) Trade values of fertilizing ingredients.

(*e*) Unmixed fertilizing material.

 (1) Nitrogen compounds.

 (2) Potash compounds.

 (3) Phosphoric acid compounds.

(*f*) Grades of fertilizer.

(*g*) Summary of analyses and guarantees.

(*h*) Quality of plant food.

 (1) Nitrogen.

 (2) Phosphoric acid.

 (3) Potash.

(*i*) Miscellaneous fertilizers, by-products and soils for free analysis.

(*a*) *Fertilizers licensed.*

During the year, 88 manufacturers, importers and dealers, including the various branches of the trusts, have secured certificates for the sale of 492 different brands of fertilizer, agricultural chemicals and raw products in the Massachusetts markets. Inspection fees have been paid on 27 more brands than during the previous year. These brands may be classed as follows: —

Complete fertilizers,	332
Fertilizers furnishing phosphoric acid and potash,	10
Ground bone, tankage and dry ground fish,	53
Chemicals and organic nitrogen compounds,	97
Total,	492

(*b*) *Fertilizers collected.*

The samples were taken by our regular inspector, Mr. Jas. T. Howard, assisted by Mr. E. C. Hall and Mr. E. L. Winn. An effort has been made in all cases to get representative samples. At least 10 per cent. of the bags found present have been sampled by means of an instrument taking a core the entire length of the bag. In no case has there been less than 10 bags of each brand sampled wherever that number has been found in stock. In case of bulky mixed goods, which might have a tendency to mechanical separation in transit, a sample has been taken from both sides of the bag, so that in case any of the fine heavier chemicals, such as potash salts, had sifted through the more bulky portion, the sample taken would be more representative.

Whenever possible, samples of the same brand have been collected in various parts of the State, the object being to sample as large a proportion of the tonnage shipped into the State as possible. In most cases, where duplicate samples have been drawn, a composite made up of equal weights of the various samples served for the analysis. In some instances several analyses have been made of the same brand; this has been done at the request of large consumers who have bought heavy shipments of some special brand.

It is difficult to tell how large a per cent. of the total tonnage shipped into the State has been sampled. An effort was made at the end of the season of 1910 to ascertain approximately the number of tons sold, but some of the larger manufacturers refused to furnish the data. As complete and extensive a collection as possible has been made in the limited time at our disposal and with the means available for the work.

During the season 116 towns were visited and 1,063 samples representing 519 distinct brands were drawn from stock found in the possession of 284 different agents, as against 897 samples and 487 distinct brands collected and examined in 1910. Some of these brands represent private formulas which would have been sent to the station for analysis by the consumer had they not been taken by our inspectors. Arrangements can be made in most cases to have large shipments of private formulas sampled by one of our regular collectors, provided notification is given sufficiently early in the season so that the various places may be visited while the collectors are in that vicinity.

(c) *Fertilizers analyzed.*

Six hundred and sixty-two analyses have been made in connection with the 1911 fertilizer inspection. The analyses made may be grouped as follows: —

Complete fertilizers,	427
Fertilizers furnishing phosphoric acid and potash, such as ashes, etc.,	18
Ground bones, tankage and fish,	73
Nitrogen compounds, including the mineral forms of nitrogen; also the various organic forms, both animal and vegetable,	69
Potash compounds,	50
Phosphoric acid compounds,	25
Total,	662

(d) *Trade Values of Fertilizing Ingredients.*

The following table of trade values was adopted by the experiment stations of New England, New York and New Jersey at a conference held the 1st of March, 1911, and have served as the basis of valuing the fertilizers published in this bulletin. The schedule for 1910 is also given for comparison.

Trade Values of Fertilizing Ingredients in Raw Materials and Chemicals for 1910 and 1911.

	Cents per Pound.	
	1910.	1911.
Nitrogen: —		
In ammonia salts,	16	16
In nitrates,	16	16
Organic nitrogen in dry and fine-ground fish, meat and blood,	20	23
Organic nitrogen in fine[1] bone, tankage and mixed fertilizers,	20	20
Organic nitrogen in coarse[1] bone and tankage,	15	15
Organic nitrogen in cottonseed meal, castor pomace, linseed meal, etc.,	–	21
Phosphoric acid: —		
Soluble in water,	4½	4½
Soluble in neutral ammonium citrate solution (reverted phosphoric acid),[2]	4	4
In fine[1] ground bone and tankage,	4	4
In coarse[1] bone, tankage and ashes,	3½	3½
In cottonseed meal, linseed meal and castor pomace,	3½	3½
Insoluble (in neutral ammonium citrate solution) in mixed fertilizers,	2	2
Potash: —		
As sulfate, free from chlorides,	5	5
As muriate (chloride),	4¼	4¼
As carbonate,	8	8
In cottonseed meal, castor pomace, linseed meal, etc.,	–	5

The basis for these trade values was the average wholesale quotations of chemicals and raw materials as taken from the commercial publications during the six months preceding March 1, 1911, plus about 20 per cent. They are supposed to represent the average cost per pound for cash at retail of nitrogen, phosphoric acid and potash as found in unmixed fertilizing material in the principal markets in New England and New York. There has been but little change in the cost of the various forms of plant food, with the exception of the better forms of organic nitrogen which have shown a considerable advance as compared with the previous year.

(e) *Unmixed Fertilizing Material.*

Thirty-three samples of ground bone have been collected and analyzed. Ten were found deficient in phosphoric acid and 5 in nitrogen. The average retail cash price for ground bone has been $31.32 per ton, the average valuation $29.80, and the per-

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

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

centage difference 5.10. Two of the brands analyzed showed a commercial shortage of 50 cents or over a ton.

Eighteen samples of tankage have been analyzed. Three were found deficient in nitrogen and 5 in phosphoric acid. The average retail cash price per ton was $34.14, the average valuation per ton $32.69, and the percentage difference 4.43. Nitrogen in fine tankage has cost on the average 20.89 cents; nitrogen in coarse tankage has cost 15.65 cents per pound. Three samples have shown a commercial shortage of over 50 cents per ton.

Twenty-two samples of dry ground fish have been examined. Three were found deficient in nitrogen and 2 in phosphoric acid. The average retail cash price per ton was $41.90, the average valuation $42.71, and the percentage difference in excess 1.93. Nitrogen from dry ground fish has cost on the average 22.56 cents per pound. None of the brands showed a commercial shortage of over 50 cents per ton.

(1) *Nitrogen Compounds.* — Three samples of sulfate of ammonia have been analyzed and found well up to the guarantee. The average cost of a pound of nitrogen in this form has been 16.78 cents.

Twenty-three samples of nitrate of soda have been analyzed and 3 were found deficient in nitrogen. The average cost of nitrogen in this form has been 16.19 cents per pound.

Four samples of dried blood have been examined which, with one exception, showed overruns in nitrogen. The pound of nitrogen from blood has cost 23.29 cents.

Four samples of castor pomace have been analyzed. The average cost of nitrogen in this form has been 26.11 cents per pound.

Twenty-three samples of cottonseed meal have been examined, all of which were purchased as a nitrogen source for tobacco. Nitrogen from this source has cost on the average 23.08 cents per pound. Six samples have shown a nitrogen deficiency which has, in 3 cases, amounted to 50 cents or more per ton.

(2) *Potash Compounds.* — Twenty-one samples of high grade sulfate of potash have been examined, and the potash guarantee was maintained in all but one instance. The pound

of actual potash in this form has cost on the average 5.2 cents. Two cases of misbranding were discovered by our inspectors. Material put out by the Nitrate Agencies Company as high-grade sulfate of potash proved upon analysis to be muriate of potash. The sale of the material as sulfate of potash was discontinued and the material was properly labeled.

Six samples of potash-magnesia sulfate have been examined and all but 2 were found fully up to the guarantee. The pound of actual potash in this form has cost 5.91 cents. Several cases have been detected where high-grade sulfate of potash has been reduced with sand and kieserit. The parties registering the material have disclaimed any knowledge of such a practice, and state that the material was bought for potash-magnesia sulfate and sold by them in the original bags as imported from Germany. The matter was taken up with the German syndicate, who traced the adulteration back to the mine that originally produced the goods. A statement was made by the importers that the mine had been heavily fined for the practice, and large shipments of the adulterated product had been returned to the mine. The importers offered to compensate the buyers, who in turn would rebate the farmer, for the value of the deficient magnesia less the value of the overrun in potash.

Eighteen samples of muriate of potash have been examined and 3 were found deficient in potash. The pound of actual potash as muriate or chloride has cost on the average of 4.43 cents. Two brands have shown a commercial shortage amounting to 50 cents or over per ton. There seems reason to believe that it is not improbable that some cases of apparent shortage in case of muriate of potash may be due to absorption of moisture, resulting, of course, in a greater weight of the material without any actual loss of potash, provided the material is sold in the original package and each package is only credited with a weight of 200 pounds.

Three samples of kainit have been analyzed and found well up to the guarantee. The pound of actual potash from kainit has cost 4.34 cents.

(3) *Phosphoric Acid Compounds.* — Two samples of dissolved bone black have been analyzed and both showed a commercial shortage of over 50 cents per ton. The pound of avail-

able phosphoric acid from this source has cost on the average 6.11 cents.

Fifteen samples of acid phosphate have been examined and all but 2 were found well up to the minimum guarantee. No commercial shortage of over 50 cents a ton occurred. The pound of available phosphoric acid from acid phosphate has cost 5.44 cents.

Seven samples of basic slag phosphate have been analyzed and all were found well up to the guarantee. The pound of available phosphoric acid from basic slag, as determined by Wagner's method, has cost on the average 5.12 cents.

(*f*) *Grades of Fertilizer.*

The grouping of the complete fertilizers into three different grades furnishes a convenient means of showing the superior advantages to be derived from the purchase of *high-grade fertilizers.* In the tables below the high-grade fertilizers are represented by those brands having a commercial value of $24 or over a ton; the medium grade by those which value between $18 and $24; and the low grade by those which value $18 or less per ton. A table showing average cash price, commercial value, money difference between cash price and valuation, and percentage difference of the three grades of fertilizer follows: —

	High Grade.		Medium Grade.		Low Grade.	
	1910.	1911.	1910.	1911.	1910.	1911.
Average cash price per ton,	$38 40	$40 87	$33 51	$35 08	$27 80	$29 64
Average ton valuation,	$28 81	$28 89	$21 04	$21 04	$15 61	$15 37
Average money difference,	$9 59	$11 98	$12 47	$14 04	$12 19	$14 27
Percentage difference,	33.28	41.47	59.26	66 73	78.08	92.84

Table showing the Average Composition of the Three Grades of Fertilizer.

GRADE.	Number of Brands.	Per Cent. of Whole Number.	Per Cent. of Nitrogen.	Per Cent. of Phosphoric Acid. Soluble.	Per Cent. of Phosphoric Acid. Reverted.	Per Cent. of Phosphoric Acid. Available.	Per Cent. of Potash.	Pounds of Available Plant Food in 100 Pounds of Fertilizer.
High, ...	153	46.22	4.12	4.00	3.32	7.32	7.64	19.08
Medium, ...	103	31.12	2.61	2.93	2.94	5.87	5.12	13.60
Low, ...	75	22.66	1.66	4.53	2.82	7.35	2.90	11.91

What is shown by the above tables: —

1. That the average ton price for the three grades of fertilizer has been nearly $2 more for 1911 than for the previous year, although but little difference is noticed in the average valuation per ton for the two years.

2. That the percentage excess of the selling price over the valuation in the low-grade fertilizers is about two and one-fourth times more than it is in the high-grade goods, and over one and one-half times more than in the medium-grade fertilizers.

3. That with a 38 per cent. advance in price over the low-grade fertilizer, the high grade furnishes about 88 per cent. increase in commercial value.

4. The average high-grade fertilizer with a 16.5 per cent. advance in price over the medium goods, furnishes 47.6 per cent. more plant food and 37.3 per cent. increase in commercial value.

5. That with a 38 per cent. advance in price over the low-grade fertilizer, the high-grade furnishes more than 60 per cent. increase in available plant food.

6. A ton of the average high-grade fertilizer furnishes 49.2 pounds more nitrogen and 94.8 pounds more of actual potash than does a ton of the low-grade goods.

7. A ton of the average high-grade fertilizer furnishes 30.2 pounds more nitrogen and 50.4 pounds more potash than does a ton of the medium-grade goods.

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

Element.	Low-grade Fertilizer.	Medium-grade Fertilizer.	High-grade Fertilizer.
Nitrogen,	38.6	33.4	28.3
Potash (as muriate),	8.2	7.1	6.0
Soluble phosphoric acid,	8.7	7.5	6.4
Reverted phosphoric acid,	7.7	6.7	5.7
Insoluble phosphoric acid,	3.9	3.3	2.8

This table shows: —

1. That the purchase of high-grade fertilizers in place of low-grade goods has saved over 10 cents on every pound of nitrogen and over 2 cents on every pound of potash and phosphoric acid.

2. That the purchase of high-grade fertilizers in place of medium-grade goods has saved over 5 cents on every pound of nitrogen and over 1 cent on every pound of potash and phosphoric acid.

3. Taking the average analysis of the high-grade fertilizer as a basis, the purchase of the high-grade in place of the low-grade goods would mean a saving of $14.23 on every ton purchased; the purchase of the high-grade in place of the medium-grade would mean a saving of $7.12 on every ton purchased.

4. About 54 per cent. of the number of brands sold in Massachusetts are classed as medium or low-grade fertilizers. Assuming that the tonnage of these goods was as large as for the high-grade brands, there would have been a tremendous saving to the Massachusetts farmer had he bought only high-grade fertilizer.

5. The purchaser of fertilizers should look to the guaranteed analysis and remember that he is buying pounds of plant food as well as tons of fertilizer. He should know the form and about the proportion of the various elements of plant food and should purchase the brand which sells for the least money which comes nearest fulfilling his requirements.

6. Every one should consider and profit by the lessons taught by the above data.

(g) Summary of Results of Analyses of the Complete Fertilizers as compared with the Manufacturers' Guarrantee.

Manufacturers.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
W. H. Abbott,	2	–	1	–	2	–
American Agricultural Chemical Company,	73	30	69	29	14	–
Armour Fertilizer Works,	13	8	13	5	–	–
Atlantic Fertilizer Company,	4	1	3	1	1	1
Baltimore Pulverizing Company,	2	1	2	–	1	–
Beach Soap Company,	6	3	5	1	1	1
Berkshire Fertilizer Company,	8	5	8	2	1	–
Bonora Chemical Company,	1	–	1	1	–	–
C. M. Bolles,	1	1	1	–	–	–
Bowker Fertilizer Company,	32	10	26	16	6	–
Jos. Breck & Sons,	3	3	3	–	–	–
Buffalo Fertilizer Company,	8	4	7	3	1	–
E. D. Chittenden Company,	6	3	5	2	1	–
Clay & Son,	1	1	1	–	–	–
Coe-Mortimer Company,	18	1	12	9	7	1
Eastern Chemical Company,	1	1	1	–	–	–
Essex Fertilizer Company,	11	1	8	9	1	–
C. W. Hastings,	1	–	–	1	–	–
Listers Agricultural Chemical Works,	9	4	9	5	–	–
J. E. McGovern,	1	1	1	–	–	–
Mapes' Formula and Peruvian Guano Company,	20	10	19	8	2	–
National Fertilizer Company,	17	7	14	7	3	–
Natural Guano Company,	1	1	1	–	–	–
New England Fertilizer Company,	7	1	3	3	2	1
New England Mineral Fertilizer Company,	1	1	1	–	–	–
Nitrate Agencies Company,	1	–	1	1	–	–
Olds & Whipple,	6	3	6	3	–	–
Parmenter & Polsey Fertilizer Company,	10	1	5	6	2	1
Patrons' Co-operative Association,	2	2	2	–	–	–
Pulverized Manure Company,	1	1	1	–	–	–
Rogers Manufacturing Company,	9	7	9	2	–	–

(*g*) *Summary of Results of Analyses of the Complete Fertilizers as compared with the Manufacturers' Guarantee* — Con.

Manufacturers.	Number of Brands Analyzed.	Number with All Three Elements equal to Guarantee.	Number equal to Guarantee in Commercial Value.	Number with One Element below Guarantee.	Number with Two Elements below Guarantee.	Number with Three Elements below Guarantee.
Rogers & Hubbard Company,	8	5	7	3	–	–
Ross Bros. Company,	4	1	4	2	1	–
N. Roy & Son,	1	–	1	1	–	–
Sanderson Fertilizer and Chemical Company,	7	6	7	1	–	–
M. L. Shoemaker & Company,	2	1	2	1	–	–
Swift's Lowell Fertilizer Company,	17	7	15	5	5	–
20th Century Specialty Company,	1	1	1	–	–	–
Wm. Thomson & Sons,	2	1	2	1	–	–
Whitman & Pratt Rendering Company,	4	2	4	2	–	–
Wilcox Fertilizer Company,	9	6	9	3	–	–
A. H. Wood & Co.,	3	1	3	2	–	–

The above table shows: —

1. That 334 brands of registered complete fertilizers have been collected and analyzed.

2. That 191 brands (57 per cent. of the total number analyzed) fell below the manufacturers' guarantee in one or more elements.

3. That 135 brands were deficient in one element.

4. That 51 brands were deficient in two elements.

5. That 5 brands were deficient in three elements.

6. That 41 brands (over 12 per cent. of the whole number analyzed) showed a commercial shortage; that is, when the overruns were used to offset shortages they did not show the amount in value of plant food as expressed by the smallest guarantee.

The deficiencies found were divided as follows: —

96 brands were found deficient in nitrogen.
90 brands were found deficient in available phosphoric acid.
66 brands were found deficient in potash.

As compared with the previous year the guarantees have not been as generally maintained. Thirty-six more brands were found deficient in nitrogen and 10 more in available phosphoric acid than for the season of 1910. The brands showing a commercial shortage were 17 more than during the previous year; in many cases, however, the commercial deficiency was small, amounting to less than 25 cents per ton.

Table showing Commercial Shortages (25 Cents or Over) in Mixed Complete Fertilizers for 1910 and 1911.

Commercial Shortages.	Number of Brands.	
	1910.	1911.
Between $1 and $2 per ton.	6	9
Under $1, not less than 25 cents per ton, ...	18	17

Some brands have suffered serious deficiencies in some element of plant food without showing any commercial shortage, the deficiency being made up by an overrun of some other element. This is due, probably, either to carelessness or poor mixing rather than a disposition to furnish less plant food value than is called for in the guarantee. It furnishes a condition not to be commended, however, as the fertilizer may be rendered seriously out of balance.

(*h*) *Quality of Plant Food.*

(1) *Nitrogen.* — Sixty or more per cent. of the total nitrogen in the average mixed fertilizer is derived from organic sources, and until recently it has not been possible to tell the consumer much concerning its activity or immediate availability. Heretofore there has been published the nitrogen from nitrates and ammoniates as well as the water soluble and water insoluble organic nitrogen. It has seemed evident, however, that some of the brands contained at least a portion of their nitrogen in low-grade forms, but a lack of a suitable method of analysis has rendered it impossible to procure sufficient evidence to definitely substantiate the supposition. In 1910 the chemists in charge of the fertilizer control work in New England, New York

and New Jersey co-operated in an effort to make a careful study of the Jones' modification of the "Alkaline permanganate method" and Street's "Neutral permanganate method" for testing the activity of the water insoluble organic nitrogen in mixed fertilizers. Satisfactory results were obtained with the Jones' modification, which were confirmed on the same samples by means of vegetation experiments conducted at the Rhode Island Experiment Station. The work proved so satisfactory that in March, 1911, the Jones' modification was adopted provisionally by the New England, New York and New Jersey experiment stations.

All of the complete fertilizers reported in this bulletin have, therefore, been tested as to their organic nitrogen activity. Out of a total of 334 brands analyzed, 43 or nearly 13 per cent. of the whole number, have shown an activity of their water insoluble organic nitrogen of less than 50 per cent.

So far as one is able to judge from the analytical data and the explanations furnished, the following facts may be deduced: —

1. Some manufacturers used nitrogen-containing material of a low availability.

2. In some cases it was used as a direct source of nitrogen to bring the material up to its minimum guarantee. In other cases it was used to raise the guarantee above the minimum. In still other cases it was employed as a filler or to improve the mechanical condition of the fertilizer.

3. It is possible that the inactive materials employed were not sufficiently treated to render their nitrogen available.

It is hoped that manufacturers will endeavor to improve conditions another season, for it is believed that the consumer of commercial fertilizers — at least of the better grades — is entitled to receive all of his nitrogen in such an available form as is called for by the 50 per cent. alkaline permanganate standard.

(2) *Phosphoric Acid.* — Many of the fertilizer mixtures contained large overruns in total phosphoric acid, while the available phosphoric acid on the same brands has shown a considerable shortage. This may have been due to incomplete acidulation of the bone or raw mineral phosphate used, or to the addition of considerable unacidulated rock phosphate, bone

or roasted iron or alumina phosphate. Of the total phosphoric acid found in all of the brands analyzed, 84 per cent. was present in available forms. In case of the available phosphoric acid found, 58 per cent. was present in water soluble form.

(3) *Potash.* — As in previous years, the form in which the potash was present has been noted in every fertilizer analyzed. Very few cases have been found showing the absence of chlorides in those brands where sulfate is guaranteed. In the majority of cases, however, the amount of chlorine found present has been so small as to be counted as incidental. A quantitative test, however, has in all cases been made. In case of some of the tobacco brands, quite a considerable quantity of chlorine has been found where carbonate of potash was guaranteed. This would indicate the use of carbonate of potash from the beet sugar industry. The latter material frequently contains as high as 10 to 12 per cent. muriate of potash. It is reasonable to suppose that if the consumer pays for carbonate of potash he expects that the fertilizer will exclude both soluble chlorides and sulfates.

(i) *Miscellaneous Fertilizers, By-products and Soils for Free Analysis.*

Including the materials which have been tested for the various departments of the experiment station, there have been received and analyzed 339 different substances. They may be grouped as follows: 209 fertilizers and by-products used as fertilizers, 63 soils, 36 lime compounds, 27 ash analyses of plants and 4 miscellaneous products. Whenever possible, the fertilizer and lime samples have been taken by one of our regular inspectors and by means of the regulation sampling tube. In all other cases the samples have been taken according to printed instructions furnished from this office. In reporting results, information has been furnished as to the best manner of using the material, and in case of soils the rational treatment of the same as regards fertilizers, cultivation and crop rotation. The analyses of most of the lime products appear in Lime Bulletin, No. 137. The analyses of home-mixed fertilizers and private formulas collected by our inspectors will appear in a table by themselves in the fertilizer bulletin. The other analyses mentioned will not be published.

5. Report of the Feed and Dairy Section.

Mr. P. H. Smith submits the following: —

The Feed Law (Acts and Resolves for 1903, Chapter 122).

During the year 733 samples of feeding stuffs have been collected and examined. A regularly employed inspector covers the State at intervals during the year, collects samples and ascertains if the provisions of the law are being complied with. Protein, fat, fiber and in some instances moisture and ash determinations are made. It is a matter of satisfaction to note that practically all feeding stuffs are as represented. This statement should not be interpreted to mean that all feeding stuffs offered are of good quality, but that all articles in the market correspond to the guarantee placed upon them.

Violations of Law. — The principal violation of the law as heretofore has been that local dealers, either through carelessness or through the neglect of shippers to furnish tags, fail to guarantee. The experiment station, through its representative, does what it can to prevent violations of this character. In order that the law may be fully enforced in this respect, the co-operation of consumers is needed. The consumer can be of material assistance by insisting that all feeding stuffs that he purchases, with the exception of wheat by-products and ground whole grains, shall bear the guaranteed analysis together with the name and address of the manufacturer.

It is believed that adulteration is seldom practiced. There are some feedstuffs on the market to which low-grade products are occasionally added. Wheat feeds and hominy feed to which ground corn cobs have been added are of this character. The manufacturers ship these goods with the proper guarantee, but they occasionally reach the consumer with the tags removed. It seems evident that the local dealer is responsible for this, desiring to conceal the real identity of the article. The purchaser should not without careful investigation purchase wheat feeds or hominy feeds that are unguaranteed or that are offered very much below the ruling price.

New Law. — The officers in charge of the feeding stuffs law have felt for some time that the present law was inadequate to meet present conditions, and this year a new law will be presented to the General Court for its consideration and adoption. The proposed law differs from the present law in the following particulars: —

1. It is modeled as closely as local conditions will permit after the uniform law proposed by the Association of Feed Control Officials.

2. It carries an increase in revenue which is necessary if it is to be satisfactorily enforced. This increase is also made necessary by the increase in number of brands at present on the market.

3. Wheat feeds, now exempt, have been included.

4. It has been so revised as to render it easier of enforcement and more explicit.

The Dairy Law (*Acts and Resolves for 1901, Chapter 202*).

This law requires that all persons who are using the Babcock test as a basis of payment for milk and cream, either in buying or selling, must secure a certificate of proficiency from the experiment station. It also requires that Babcock machines be inspected by an experiment station official annually, and that all glassware used be tested for accuracy by the station.

Chapter 425, Acts and Resolves for 1909, added to the law by giving the director of the experiment station the authority to revoke a certificate if it is found that an operator is using dirty or untested glassware, or if he is doing the work in an improper manner.

The station makes the following suggestions to operators: —

1. Every operator must have a certificate, and no person without a certificate is legally entitled to make the test. The operator may employ a person without a certificate to *aid* him in his work, but he must work with him and be responsible for the working of the machine, and must read the tests in person.

2. Great care should be taken in getting accurate samples. The test from a sample carelessly drawn will not represent the value of the milk or cream from which it is taken, no matter how carefully the testing is done.

3. Cream and curdled samples of milk should be weighed and not pipetted. The only reason that milk or cream is ever pi-

petted is as a matter of convenience and on the supposition that 18 cubic centimeters of cream or 17.6 cubic centimeters of milk will weigh 18 grams. It is difficult and often practically impossible to get exactly 18 grams of sour milk or thick cream with the use of the pipette.

4. In reading the *milk* test include the *entire* fat column. In *cream* tests read from the lowest point of the fat column to the bottom of the upper meniscus or curve. In case of *cream* tests, if the entire fat column is included the reading will be about 1 per cent. too high.

Summary of Dairy Inspection. — During the year 15 candidates have been examined and given certificates to operate the Babcock test. Four thousand, four hundred and sixty-six pieces of glassware have been examined for accuracy and only 12 have been condemned, a smaller percentage than for any preceding year.

Following is a summary for the eleven years the law has been in force: —

YEAR.	Number of Pieces tested.	Number of Pieces condemned.	Percentage condemned.
1901,	5,041	291	5.77
1902,	2,344	56	2.40
1903,	2,240	57	2.54
1904,	2,026	200	9.87
1905,	1,665	197	11.83
1906,	2,457	763	31.05
1907,	3,082	204	6.62
1908,	2,713	33	1.22
1909,	4,071	43	1.06
1910,	4,047	41	1.01
1911,	4,466	12	.27
Totals,	34,152	1,897	5.56[1]

The testing outfits in 30 creameries and milk depots have been inspected. Nine of these, an exceptionally large number, required reinspection. A machine that vibrates badly, caused

[1] Average.

by worn bearings or an insecure foundation, cannot be expected to do satisfactory work, neither can a machine give a clear separation of fat where the speed is insufficient. A number of operators were found using untested glassware. The director of the experiment station has the right to prosecute the owners of the plant where this is being done, and also to revoke the license of the operator. Thus far this matter has been corrected when called to the attention of the creamery men. Continued violations will, however, make prosecution necessary.

Following is a list of creameries and milk depots visited: —

1. *Creameries.*

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

2. *Milk Depots.*

Location.	Name.	President or Manager.
1. Boston,	D. W. Whiting & Sons,	Geo. Whiting.
2. Boston,	H. P. Hood & Sons,	W. N. Brown.
3. Boston,	Boston Dairy Company,	W. A. Graustein.
4. Boston,	Boston Jersey Creamery,	T. P. Grant.
5. Boston,	Walker-Gordon Laboratory,	G. Franklin.
6. Boston,	Oak Grove Farm,	C. L. Alden.
7. Boston,	Maine Creamery Company,	E. H. Smith.
8. Boston,	Turner Center Dairying Association,	L. L. Smith.
9. Boston,	Plymouth Creamery Company,	W. L. Johnson.
10. Cambridge,	C. Brigham Co.,	J. R. Blair.
11. Cheshire,	Ormsby Farms,	W. E. Penniman.
12. Dorchester,	Elm Farm Milk Company,	J. K. Knapp.
13. Sheffield,	Willow Brook Dairy,	F. B. Percy.
14. Southborough,	Deerfoot Farm Dairy,	S. H. Howes.
15. Springfield,	Tait Bros.,	Tait Bros.
16. Springfield,	Emerson Laboratory,	H. C. Emerson.

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

Milk, Cream and Feeds for Free Examination.

With certain restrictions the resources of the experiment station are available to residents of Massachusetts who desire information relative to the composition of milk, dairy products and cattle feeds. When necessary, samples taken in accordance with the directions furnished will be analyzed free of cost. On account of the large amount of data on file, it is often possible to furnish the information desired without recourse to analysis. The experiment station will not undertake to act as commercial chemists, and, on account of the limited funds at its disposal, must use its own discretion as to what samples it will analyze.

Water Analysis.

The station has analyzed 114 samples of water. All probably came from private water supplies. Public water supplies are under the charge of the State Board of Health, and all matters pertaining to such supplies should be referred to them. Of the 114 samples received 80 were from wells, 30 from springs and 4 were taken from ponds.

The results show that farm wells situated near buildings are quite susceptible to pollution and may become sources of infection for typhoid fever and other bacterial diseases, while springs situated at a distance from all buildings are the most satisfactory and safest. Where a good spring is not available the well should be located as far as possible from dwellings and barns.

Lead pipe was used in 49 cases. In 9 instances water flowing through such pipes contained lead in appreciable amount, rendering the water absolutely dangerous for consumption.

If a water analysis is desired, application should be made to the experiment station, when a container will be shipped to the applicant together with instructions for taking the sample. Water received in receptacles other than those furnished will not be analyzed. A fee of $3 is charged for a water analysis. The experiment station does not make bacterial examinations.

Miscellaneous Work.

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

1. It has co-operated with the officials of the Massachusetts

Corn Exposition in making analyses of corn in connection with the awarding of prizes.

2. It has co-operated with the Bowker and Coe-Mortimer Fertilizer companies in making analyses of corn in connection with the awarding of prizes.

3. It has arranged and furnished exhibits and speakers, in co-operation with the extension department, for fairs, farmers' meetings and expositions.

4. It has co-operated with the agricultural department of the college in making analyses of milk in connection with the awarding of prizes at a dairy show held during "farmers' week."

5. In connection with the experimental work of this and other departments of the experiment station, this section has made analyses of 116 samples of milk, 57 samples of feed and 377 samples of agricultural plants.

6. In addition to the work already enumerated, it has received and tested 527 samples of milk, 2,799 samples of cream for butter fat, and 204 samples of feedstuffs

Testing Pure-bred Cows.

The testing of pure-bred cows for advanced registry is in charge of this section. Work of this character can be grouped under two divisions. The yearly tests for the Guernsey, Jersey and Ayrshire breeds are based upon two-day monthly tests under the supervision of an experiment station representative; while the Holstein-Friesian tests are usually of from seven to thirty days' duration and require the presence of the supervisor during the entire testing period. The large number of yearly tests now in progress require the employment of two men continuously and of an additional man for a portion of the time. Work of this character can be planned ahead and more readily taken care of than the Holstein-Friesian tests. For this latter work a list of available men is kept, and applications for supervisors are filled in the order received. Men who make the Holstein-Friesian tests are recruited largely from the short-course graduates who have gone back to the farm and who do not find it difficult to get away during the winter months. During the summer months considerable difficulty is experienced in getting men for the work. Fourteen different men have been used on work of this character during the year.

From Dec. 1, 1910, to Dec. 1, 1911, 38 Guernsey, 117 Jersey and a number of Ayrshire tests have been completed. There are now on test 43 Guernseys, 99 Jerseys, and 12 Ayrshires, located at 18 different farms.

For the Holstein-Friesian Association there have been completed 103 7-day tests, 2 30-day tests and 1 14-day test.

REPORT OF THE BOTANIST.

G. E. STONE.

The routine and research work of this department during the year has followed prescribed lines, although, as occasion has demanded, new lines of research were taken up. Mr. G. H. Chapman, besides assisting in carrying on the routine work, has had considerable opportunity for the study of special problems. He has completed his investigations on mosaic and allied diseases, as well as a piece of work on the "Microscopic Identification of the Components of Cattle Feeds."

Mr. Sumner C. Brooks, who served one year in the laboratory, resigned his position in October to take up graduate work at Harvard, but unfortunately just before his year expired he was severely stricken with typhoid fever and is at present in a convalescent state. Mr. Brooks is a keen and tireless observer, and our best wishes are extended to him in his graduate work. His place has been filled by Mr. E. A. Larrabee, of the class of 1911 of this college, who has had considerable experience in our laboratory as an undergraduate student. Miss J. V. Crocker, who is thoroughly familiar with our work, has been of great service in attending to correspondence, assisting in the seed work and in other ways. Much help has also been received from Mr. R. E. Torrey and Messrs. Larsen and Ellis, all of whom are associated with the laboratory as undergraduate students.

Besides giving considerable time to such routine work as correspondence and the diagnosis of diseases, our own attention has been directed to the investigation of a dozen or more original problems. Much time has also been spent in studying and devising apparatus designed for the better control of the various foes of plant life.

Besides the correspondence relating to seed work and the control of diseases, we are constantly called upon to answer letters of a very special and technical nature. These inquiries come from everywhere and cover a multitude of subjects, such as electricity and plant growth, electrical injury to trees, illuminating and other gases, chemical treatment of reservoirs, modern tree surgery, court decisions regarding shade trees, different stimulating factors in the growing of plants, requests for advice in regard to devices for the extermination of various pests, etc.

REPORT OF THE ENTOMOLOGIST.

H. T. FERNALD.

The work of the entomological department during 1911 has been mainly on subjects previously outlined, and any report is, therefore, practically a report of progress.

The insect collection of the station has received considerable attention during the year. Numerous additions by gift from former students of the college and others, and the addition of more cases and other equipment in order to provide room for the proper care and growth of the collection as a whole, have made it possible to put it in better condition than ever before. As it is in constant use for reference and study, this improvement has been greatly appreciated.

The time at the disposal of those working in entomology is divided between four different lines of work. These are: correspondence with persons desiring the assistance of the department; care and improvement of the station collections of insects and their work; experimental work and studies under the Hatch act; and research under the Adams fund. These may be considered in the order named.

The correspondence the past year has been as large or somewhat larger than heretofore, but very different in nature from what it was formerly. For many years most of the inquiries received were about noticeably injurious insects. More recently, however, the inquiries have had reference to the less evident, though often equally serious pests. This indicates progress in the knowledge of our injurious insects among those most concerned and is certainly gratifying, being at least indirect evidence of the efficiency of this department and of the other sources through which entomological information has been distributed in this State. From this time on, however, it will be more difficult than formerly to determine from the correspondence itself the nature of the insect concerned, and it is probable that visits to places where damage is being caused will be much more frequently necessary in order to give intelligent advice as to the proper methods of control.

The importance of a collection of insects and of their work would seem to be almost self-evident. Any entomologist taking up duties either State or station in character, who finds no collection or only a small one where he goes, labors under an immense handicap, and within a year or two a number of letters expressing this in most emphatic terms have been received by the writer from friends laboring under such conditions. This station is fortunately situated in this regard, having a good collection, containing many entire life histories, and well cared for. It is far from complete, however, and is deficient in many different stages, even of common forms. To be what it should be, it is important not only to maintain it in its present condition, but to add to it as rapidly as possible specimens of all the injurious insects which can possibly be obtained, in their different stages, together with samples showing the nature of the injuries they cause. As much work of this kind as possible has been carried on during the past year.

Under the Hatch act experimental studies of various kinds have been continued. The destruction of seed corn by wire-worms has been studied as in previous years, in co-operation with Mr. Whitcomb. As stated in the last report, tests of tar and Paris green proved successful, but when tried by many different persons in various parts of the country were not always satisfactory. The trouble in most cases seems to have been that so much tar was applied as to give the corn a waterproof covering, which prevented germination. This was not the fault of the method, but was due to its improper application. A real defect of the method was that it required two treatments, first with the tar and second with the Paris green and dust. To avoid this, tests were made last spring with arsenate of lead diluted to the thickness of paint. The results were not wholly satisfactory, partly because wire-worms were not everywhere abundant throughout the test fields, and partly because the arsenate showed a tendency to flake and drop off the corn. In most cases the corn made a good start and escaped all injury, even though wire-worms were clustered around the seeds in the row. In fact, the treatment, though it did not seem to kill the wire-worms, did appear to protect the corn from injury in nearly every case. Further experiments along this line will be made in 1912.

The testing of new spray materials has not usually been looked upon favorably by this department, as it has no trees under its control upon which these may be used. A new material called "Entomoid," for use against the San José scale, sent to the station last year for trial, seemed so promising, however, that considerable attention was given to it, trees loaned for the purpose by individuals being used. Entomoid is claimed by its inventor to be a combination of lime-sulfur and a miscible oil, and therefore to combine the good qualities of both of these materials. It was applied to young apple and plum trees considerably to badly infested with scale, shortly before the buds opened in the spring, at strengths of 1 part Entomoid to 20 of water, and to 30 of water, using a fine Vermorel nozzle. The trees were under almost continual observation thereafter, until October, and the results were very satisfactory with both strengths. Very few living scales could be found in June, and those were all in such protected positions as would indicate a probable failure of the spray to reach them. By late fall the trees were well infested again, but only to such a degree as would be easily accounted for by the few scales which escaped treatment, and by restocking from badly infested trees nearby. During the past year the inventor has modified his formula somewhat, and it is the intention to continue tests with this modified material the coming spring.

In addition to the experiments outlined above, observations on the dates of hatching of the oyster-shell scale, scurfy scale and pine-leaf scale have been continued, and it is planned to conduct tests of methods for the control of the onion maggot next season, should satisfactory opportunities become available.

While not forming a part of the work done under the Hatch act, it may be well to mention that exhibits of injurious insects and their work, with directions for treatment to control these pests, have been prepared and exhibited at a number of fairs and exhibitions during the past year, the department co-operating with the extension department of the college whenever it has been requested to do so. Samples of pests and their work have also been put up and sent to libraries, schools and individuals in some cases where the material could be obtained and the time necessary to prepare these exhibits could be spared from more pressing duties.

Calls for the fumigation of houses to destroy various household pests have been frequent. As there is no one near Amherst who makes a business of work of this kind, and as experience in handling hydro-cyanic acid gas is necessary, if danger to human life is to be avoided, it has seemed wise to do more or less of this, partly as an educational measure. During the past year perhaps 15 or 20 places have, therefore, been fumigated by members of this department at the request of persons concerned, who were willing to meet the cost of the work.

Under the Adams fund the two projects previously accepted have been continued. Studies of the causes of the burning of foliage by arsenicals, postponed by failure to obtain materials of known composition and purity, have now been taken up, and 120 different spraying tests were made during the season, followed in each case by examination of the results, at least every second day for about a month. The results are interesting, but the work thus far represents only a small fraction of that which will be necessary before this subject has been developed to the point desired, and the results of such a fragmentary part of the work, it is, of course, not desirable to publish.

Study of the real value of wasps as parasitic friends of man have been continued, and one small paper incorporating a few of the more technical preliminary observations has been completed. Both of the Adams fund projects will be prosecuted farther the coming year.

Aside from what has thus far been mentioned, a study of the distribution of insect pests in the State has been continued. It is increasingly evident that some portions of Massachusetts are outside of territory liable to serious injury by certain insects. The determination of the limits of these areas and the reasons for their existence are important problems awaiting solution. The possibility that in one part of the State certain southern crops can be successfully grown is supported by the continued existence in that section of plants, reptiles, birds and insects which normally occur much farther south. If this should prove to mean that some southern crops can be raised in that section, and our city markets be supplied with them after the supply from the south has ended, it might result in marked changes in the crops in that portion of the State. Evidence bearing upon this has been and is being gathered at every opportunity, in the hope that the results may justify practical tests of the idea here suggested.

REPORT OF THE VETERINARIAN.

JAS. B. PAIGE, D.V.S.

During the past year the veterinary department has carried on its work in accordance with the following scheme: —

1. Research.
2. Diagnosis.
3. Correspondence.

Since the inauguration of the department in the experiment station it has been the aim and practice to carry on each year one or more lines of original investigation of some of the obscure animal diseases or phase of the same, preferably one of immediate interest to the stock owners of the State. The large number of diseases occurring among the different farm animals, the cause, course, successful treatment or prevention of which are not fully understood, offers a large field for investigation and profitable study. Such obscure diseases exist among all varieties of farm animals, — horses, cattle, sheep, swine and poultry. The latter presents some of the most difficult and interesting problems for investigation.

For nearly two years prior to last September the head of the veterinary department, in addition to his regular work of instruction in the college, performed the duties, in part, of the dean of the college. This required a greater part of each afternoon of the days when college was in session. It was, therefore, during this time not possible to engage as extensively in the lines of original investigation as was desired. The remainder of the work in the station falling under divisions of diagnosis and correspondence were taken care of in a satisfactory manner.

For something more than two years an original investigation has been carried on to determine to what extent unsterilized, mixed milk from herds of common dairy cattle, not tuberculin tested, may be responsible for the transmission of bovine tuberculosis. The work is nearly completed and will appear as a separate contribution to the report, or in bulletin form, at an early date.

The general plan of the experiment has been to make it of a practical nature by carrying it out under conditions as nearly like those as are found in the farmers' stables and herds, and at the same time sufficiently guarded against error to give it a scientific value in the determination of the relation of milk as an agency for the transmission of the disease under ordinary farm conditions. The investigation has its practical application in the eradication of tuberculosis from herds by the use of tuberculin as a diagnostic and by every other known means. If the disease is to be stamped out in a herd of cattle it is not alone sufficient to discover and remove those animals already affected, but also to discover and remove the source from which the infection comes. The experiences of the past of those who have tried to rid a herd of tuberculosis by the use of tuberculin and by slaughter of affected animals and disinfection of stables, have shown that it is not easily accomplished, owing to the difficulty of detecting the origin of the cases that are almost certain to appear after diseased animals have been removed and the stable thoroughly and effectively disinfected. It frequently happens that after a variable period of several weeks to as many months more indications of the existence of the disease are discovered among the animals which necessitate the repetition of the tuberculin testing and disinfection. The possible source of reinfection has in some instances been directed to milk from infected and nontuberculin-tested animals not showing marked physical symptoms of tuberculosis, but excreting tubercle bacilli in their milk.

In the case of large dairy herds or those of large public institutions, where sufficient milk is not produced by the herd at all seasons to supply a trade or for home consumption, it frequently happens that milk from untested cattle is purchased and brought onto the farm, and possibly some remaining unsold or unused is fed to calves or hogs and proves the source of the infection, which accounts for the recurrence of the disease. To determine to what extent this may be the source of such recurrence of tuberculosis of farm animals is the chief aim of the present investigations.

In addition to the experiment with milk, to determine to what extent it may be the medium for the transmission of bovine tuberculosis, there have been started preliminary studies to determine the nature, cause, means of spread, treatment and prevention of several other animal diseases, including an extremely obscure and fatal one of fowls. The work has not progressed sufficiently, at this date, to warrant more than a mention of the fact in this report.

The diagnosis work consists of the examination of material that is sent in by stockmen from animals suffering with disease, and of material suspected of causing disease. During the past year specimens have been received in larger numbers than ever before, and from practically every part of the State. As soon as such specimens arrive they are subjected to a variety of examinations, microscopic and bacteriological, to determine the nature of the material and the possible relation to the disease causing a loss to the stockman. After the completion of the examination, a report upon the nature of the specimen and directions for the treatment or prevention of the disease is sent to the farmer from whom the material was received. While not possible to arrive at a correct diagnosis in every instance, in many cases it is possible to return to the sender of the specimen such definite information as to the nature of the material and the disorder as to enable him, by following the directions sent in the report, to eradicate, cure or prevent the disease.

Some of the most interesting and important specimens that have come under observation in the diagnosis work the past year are: tuberculosis of garbage-fed hogs; tubercular orchitis of bull; pulmonary phthisis of man; pericarditis of cattle due to foreign bodies; lobar pneumonia; papilloma and fibroma of bovines; Paris green poisoning of pigs; chicken pox; coccidiosis and favus of birds.

In addition, a large number of samples of fodder, grain, beef scrap and other food materials have been examined as to quality and the presence of substances liable to cause disease when fed to animals. One particularly interesting sample of poor quality corn stover and corn on the ear was received that had caused the death of several cattle in a herd owing to the presence of large amounts of alcohol and other products of fermentation and decomposition that it contained.

Several samples of milk sent in for examination have been found to be contaminated with bacteria, giving rise to disagreeable odors, bitter tastes and offensive discolorations.

While the diagnosis work requires a great amount of time it certainly is fruitful of the best results. Notwithstanding the fact that it is not possible from the nature of the specimen sent, or the condition in which it may be received, to make a correct diagnosis in every instance, in the majority of cases it is possible to return to the farmer information of value that may enable him to avoid or arrest diseases that cause considerable loss. It is a means of bringing the veterinary service of the experiment station to the aid of those farmers who are so situated that they cannot avail themselves of the services of the private veterinary practitioner.

The correspondence branch of the service is closely co-ordinated with the diagnosis work. It frequently happens that farmers write to the department for information relative to some disease that exists among their animals. From the details of symptoms given in such cases it is often possible to arrive at a correct diagnosis of the trouble and advise the writer what course to follow to stamp out, successfully treat or prevent the disease. In other instances no satisfactory conclusions can be reached from the communication received and a specimen is asked for, by which a correct diagnosis of the trouble can be made and satisfactory directions given, by mail, for the successful treatment of the case. Specimens from diseased animals obtained in this manner not only furnish a means for making a correct diagnosis, and enable us to give intelligent advice to the owner of the animals, but they also supply materials of the best quality for classroom and laboratory demonstrations for students taking the courses in veterinary science and bacteriology in the department.

The correspondence of the past year has called for information covering a wide range of subjects relative to the care and feeding of farm animals and numerous animal diseases, among which may be mentioned: milk fever of cows; contagious and sporadic abortion; hog cholera; intestinal parasites of horses, cattle, sheep and swine; tuberculin testing, etc.

An especially large number of letters have been received asking for information concerning the source, symptoms and treatment of hog cholera. From the increase of inquiries over previous years and the press reports, it appears that this disease has been much more prevalent in the State during the past twelve months than ever before.

If the stockmen could only realize that the great majority of the outbreaks of hog cholera have their origin in swill containing scraps of uncooked western pork from centers of infection, and that thorough cooking will destroy the infection, many of the troublesome outbreaks could be easily prevented, and the swill from hotels and boarding houses into which such contaminated pork scraps are almost certain to find their way could be fed with safety and profit in the rearing and growing of hogs in Massachusetts.

HEREDITY, CORRELATION AND VARIATION IN GARDEN PEAS.

J. K. SHAW.

During the past five years a portion of the time devoted to experimental work in the department of horticulture has been directed toward the solution of problems of plant breeding, the work being done mostly with garden peas. Certain phases of this work have been previously reported.[1] It is felt that sufficient progress has now been made to warrant a more complete and definite statement of results attained.

The original purpose of the work was a study of variation, and the subsequent development along lines of correlation and inheritance has been a gradual one, with no endeavor to prove or disprove any of the current theories bearing on these questions, but with an earnest purpose to secure facts. After five seasons' work it was felt that sufficient data had been accumulated to afford a basis for a few deductions, and following last season's crop, results have been worked over and are here presented. This explanation may make clear the seeming lack of definiteness and direction of the work towards the results obtained.

The work began in 1907 with a study of variation in a commercial lot of Excelsior peas, and in 1908 a lot of First of All was added; since then various commercial sorts have received more or less attention. The most important results have been reached by means of the Excelsior variety. This is a second early wrinkled pea growing usually about 40 centimeters in length and bearing about four pods to the vine. It is a sort considerably grown by gardeners in New England.

The principal characters dealt with have been vine length and pods per vine. The first gives a good measure of the vegetative

[1] Reports, Massachusetts Experiment Station, 20, p. 171; 21, p. 167; 22 Part I., p. 168.

vigor of the plant and the second of its productiveness, — two qualities of the greatest economic importance.

All the measuring for the past three years, when most of the plants have been handled, has been done by one individual, thus avoiding the slight differences that might result from the work of different men.

The vines have been carefully pulled when well ripened and carried to a convenient table where the measurements have been made. Vine length has been taken from the surface of the ground to the uppermost node of the main stem. Where there were branches they have been measured, but are not used in the computations, though it might have been more desirable to have done so. However, it is not felt that in that case the results would have been materially different. All pods have been counted whether large enough for commercial purposes or not, as have the peas in the pod. The measurements have been recorded on 5 by 8 cards, recording the data as shown in Fig. 1.

Plant.	Vine Length.	No. Pods.	Peas per Pod.	Total Peas.	Notes.
B-10-7-1	62	5	7-7-5-6-6	31	
2	85	6	5-6-3-6-7-4	31	
3	64	6	1-4-6-0-5-6	22	
4	70	6	4-6-5-6-5-5	31	
5	70	5	6-1-5-5-0	17	
6	53	5	4-2-0-4-4	14	
7	54	4	2-5-5-2	14	Seed
8	63	6	5-6-6-4-3-2	26	
9	50	3	3-6-2	11	
10	44	4	4-4-5-1	14	
11	52	5	4-5-6-5-3	23	
12	70	5	5-5-6-5-5	26	
13	64	6	0-6-6-6-6-4	28	
14	55	4	5-3-3-3	14	
15	63	6	5-5-5-7-5-2	29	
16	35	4	4-4-3-3	14	
17	45/36	8	4-3-5-2/3-4-3-3	27	
18	63	6	4-6-6-6-5-6	33	

Fig. 1. — Pea Record Card.

The plants have been grown each year upon a different plot of ground and these have not always been as satisfactory, especially as to uniformity, as might be desired. In 1908 the plot, while fairly uniform, was gravelly, and suffered somewhat from drought, which modified the character of the plants grown to a considerable degree. In 1909 the soil was heavier, but one end of the plot was inferior as shown by the appearance of the plants grown. In 1910 the soil of the plot seemed fairly uniform, but the error was made of applying fertilizer in the row. While an effort was made to have this uniform all through the plot, it appeared that it was not fully successful, some portions of the rows receiving more stimulus than others. The plots used in 1911 appeared to be more desirable than those used previously, and were so on the whole, yet they were not all that could be desired, some portions being evidently poorer than the average, as indicated by the slightly less flourishing plants. Perfect uniformity of soil, however desirable in work of this kind, is very difficult and perhaps impossible to attain, and this must be compensated for by duplication of results. It is felt that in this work sufficient duplication has been carried out to neutralize this variation in soil conditions, and that the conclusions reached are not materially affected thereby.

The mathematical calculations have been carried out with the aid of millionaire and comptometer calculating machines and fully checked, and it is felt that they are free from errors that could sensibly affect the results. The methods that have been used are for the most part the usual ones and substantially as set forth in " Principles of Breeding," by E. Davenport.

Heredity.

In what degree may individual pea plants be expected to transmit their characters to their descendants? Table I. sums up the measure of inheritance of vine length and productiveness of about 10,000 plants in an effort to throw light on this question. Before discussing this table it is necessary to set forth the history and nature of the four groups dealt with.

TABLE I. — *Coefficients of Heredity.*

Vine Length.

PLANT.	1908-09.	1909-10.	1910-11.	Average.
First of All,	-	+.0486 +.0242	+.0407 +.0257	+.0447
Excelsior I.,	+.2159 ±.0167	+.0236 ±.0170	+.0583 ±.0196	+.0993
Excelsior II.,	-	+.3095 ±.0172	+.0892 ±.0236	+.1994
Variety "C,"	—.0801 ±.0392	+.0372 ±.0241	—.0161 ±.0409	—.0197
Pods per Vine.				
First of All,	-	+.0435 +.0242	—.0564 +.0256	—.0065
Excelsior I.,	+.0782 ±.0174	—.0159 ±.0170	+.0140 ±.0197	+.0254
Excelsior II.,	-	+.0145 ±.0189	+.2317 ±.0225	+.1231
Variety "C,"	—.0433 ±.0395	—.0914 ±.0239	+.0046 ±.0399	—.0434

The plants grouped as First of All are from a lot of commercial seed of the variety bought in the open market. They were first grown in 1907, but the seed from individual plants was not saved separately until the fall of 1909, so that no coefficients of heredity are available except for the crops of 1910 and 1911. The number of plants of this group grown each year is in the vicinity of 700. The method of choosing seed plants is as follows: In the fall of 1908 seed from every tenth plant was saved, a special effort being made to make the tenth plant a random choice. In the following year the seed of one plant, chosen at random from the descendants of each of these tenth plants, has been saved for planting. In this way the number of plants has been kept fairly constant.

The same remarks will apply to the group Excelsior II., except that the number of plants has been greater, varying from 800 to 1,200 each year.

The groups called Excelsior I. and Variety " C " are both from the same lot of commercial seed, originally as Excelsior II., but these are descended from 10 plants selected in the fall of 1907, the seed of each being saved separately. In the spring of 1908 the seed of each of these plants was sown separately and 227 plants grown therefrom. The seed of each of these was separately saved and grown in 1909, resulting in 1,770 plants.

In the fall of 1909 and subsequent years a random selection of one plant from each of the groups of 1909 has been made, thus keeping the number of plants fairly constant. It will be seen that Excelsior I. and Variety " C " are made up of the descendants of 10 plants selected from commercial seed. The reason for separating one of the 10, " C ", is that it has proved to be a distinct variety, being larger, more productive and a week or ten days later than the other 9. This difference was not suspected when the original plant was selected. Between these 9 lines of descent there are no evident differences, though some are shown later in this paper to be present.

With these explanations in mind we may proceed to a discussion of the figures shown in Table I. The following conclusions seem warranted: —

1. With three exceptions the coefficients are very small, many are insignificant and some are even negative.

2. They are very irregular both in the same groups in different years and in different groups in the same year.

3. They are generally lower for pods per vine than for vine length.

4. They are on the whole lower for Variety " C " than for the other groups.

It will be remembered that Variety " C " comprises the descendants from 1 of 10 plants selected from a lot of Excelsior in 1907, the progeny of the other 9 being brought together to form the group Excelsior I. We have the figures for these 9 lines taken separately, and we may inquire if they, like Variety " C ", are insignificant or nearly so. They are given in Table II.

TABLE II. — *Coefficients of Heredity of Single Lines.*

Vine Length.

Plant.	1908-09.	1909-10	1910-11.	Average.
A,	+.1701 ±.0482	−.0632 ±.0454	−.1737 ±.0516	−.0223
B,	+.2202 ±.0515	+.2841 ±.0460	+.0075 ±.0545	+.1706
D,	−.0556 ±.0471	−.0016 ±.0459	+.1242 ±.0477	+.0223
E,	+.0823 ±.0865	−.2122 ±.0587	−.0610 ±.0611	−.0636
F,	+.1472 ±.0812	+.1820 ±.0810	+.1651 ±.1110	+.1648
G,	−.1380 ±.0390	−.1652 ±.0351	−.0391 ±.0490	−.1141
H,	−.0549 ±.0462	+.1232 ±.0450	+.1353 ±.0498	+.0679
J,	+.1563 ±.0591	+.2165 ±.0663	+.2535 ±.0859	+.0679
K,	+.0298 ±.0554	+.2348 ±.0570	+.0689 ±.0720	+.1112
Average,	+.0619	+.0663	+.0534	+.0450 +.0605
Pods per Vine.				
A,	+.1372 ±.0488	−.1948 ±.0438	−.2106 ±.0508	−.0894
B,	+.2392 ±.0511	+.1748 ±.0485	−.1423 ±.0534	+.0906
D,	−.0521 ±.0471	+.0872 ±.0456	−.0477 ±.0483	−.0042
E,	+.0626 ±.0867	−.2371 ±.0642	−.0147 ±.0613	−.0631
F,	−.3311 ±.0775	+.0986 ±.0835	+.1414 ±.1102	−.0304
G,	+.0277 ±.0390	−.2317 ±.0341	−.0453 ±.0490	−.0498
H,	+.0681 ±.0436	−.0658 ±.0456	+.1165 ±.0500	+.0396
J,	+.1398 ±.0594	−.0469 ±.0696	−.1180 ±.0905	−.0084
K,	+.1337 ±.0545	+.2293 ±.0572	+.0463 ±.0718	+.1364
Average,	+.0472	−.0207	−.0305	+.0024 −.0013

A study of this table shows it to be in harmony with the first three conclusions drawn from Table I. It indicates further that the true coefficient of heredity within these single lines of Excelsior peas is about +.06 for vine length and practically zero for pods per vine.

There is generally a positive correlation between seed weight and the size of the plant produced. The question which now arises is whether this is sufficient to account for the small plus correlation in vine length shown in Table II. We have a few figures bearing on this point, but not enough to determine positively whether this is the case or not. The seed weights available were taken from another selection of plants from Excelsior I., not already dealt with, and from a commercial lot of Alaska. The latter is a variety with small, round, green seeds and with somewhat longer vines than Excelsior. These selections were of the long and short vines, and the more productive and less productive vines. This explains the small number of medium-length vines in Tables III. and IV. A few points brought out in Table III. should be noted: —

Table III. — *Correlation of Vine Length and Average Weight of Seeds borne, Excelsior I.*

Average Seed Weight (Grams).	Vine Length (Centimeters).													
	13	18	23	28	33	38	43	48	53	58	63	68	7	Total.
.10, . .	1	–	–	–	–	–	–	–	–	–	–	–	–	1
.15, . .	–	2	–	–	–	–	–	–	–	–	–	–	–	2
.16, . .	–	–	–	2	–	–	–	–	–	–	–	–	–	2
.17, . .	–	1	2	1	–	–	–	–	–	–	–	–	–	4
.18, . .	–	–	–	1	–	–	–	–	–	–	–	–	–	1
.19, . .	–	–	–	–	–	–	–	–	–	–	–	–	–	–
.20, . .	4	6	4	2	2	–	–	–	–	–	–	–	–	18
.21, . .	–	–	–	–	–	–	–	–	–	–	–	–	–	–
.22, . .	–	–	3	5	–	1	–	–	–	–	–	–	–	9
.23, . .	–	4	1	3	1	1	–	–	2	–	1	–	–	13
.24, . .	–	–	3	–	1	–	1	1	1	2	–	–	–	9
.25, . .	1	1	4	2	1	–	–	2	2	–	–	–	–	13
.26, . .	–	1	1	3	1	–	2	4	7	–	–	2	–	21
.27, . .	–	4	2	3	–	1	2	–	5	5	1	–	–	23
.28, . .	–	–	1	–	1	–	–	1	4	1	1	1	–	10
.29, . .	–	–	–	–	–	1	1	1	3	–	–	–	–	6
.30, . .	–	3	3	1	5	1	–	1	2	–	1	–	–	17
.31, . .	–	–	–	–	–	–	–	–	–	1	–	–	–	1
.32, . .	–	–	–	–	–	–	–	–	1	–	–	–	–	1
.33, . .	–	–	–	1	–	–	–	–	–	1	–	–	–	2
.34, . .	–	–	–	–	–	–	–	–	1	–	–	–	–	1
.44, . .	–	–	–	–	–	–	–	–	–	1	–	–	–	1
Total, .	6	22	24	24	12	5	6	10	28	11	4	3	–	–

TABLE IV. — *Correlation of Vine Length and Average Weight of Seeds borne, Alaska.*

Average Seed Weight (Grams).	Vine Length (Centimeters).																		
	18	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	98	103	108	Total.
.08,	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
.09,	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
.10,	1	2	5	2	–	1	2	1	–	–	–	–	–	–	–	–	–	–	–	14
.11,	–	–	–	1	–	–	1	–	–	–	–	–	1	–	–	1	–	–	–	4
.12,	–	–	2	2	4	3	5	2	1	–	1	1	1	1	–	–	–	–	–	23
.13,	–	1	–	4	4	2	3	–	–	2	–	1	1	–	1	1	–	–	–	20
.14,	–	–	–	–	3	5	5	3	1	–	1	2	3	3	1	–	–	–	–	27
15,	–	1	1	3	2	5	6	5	2	1	1	–	2	4	5	2	–	–	–	40
.16,	–	–	–	–	–	5	7	4	–	1	1	3	4	4	3	2	2	–	–	36
.17,	–	2	–	1	2	6	3	1	–	–	–	1	6	2	3	3	1	2	–	33
.18,	–	–	–	–	1	2	2	1	2	–	2	–	1	3	1	1	–	–	–	16
.19,	–	–	–	–	–	–	–	–	–	1	1	–	2	2	1	2	1	–	–	10
.20,	–	2	–	–	–	–	1	–	–	–	–	1	–	1	–	1	–	–	–	6
.21,	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	2
.22,	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1
Total,	1	8	8	14	16	30	35	17	7	5	7	9	21	22	15	13	4	2	–	–

1. No vine over 35 centimeters long produced seeds averaging less than .22 grams each.

2. Vines 35 centimeters or less produced many light seeds and also many fairly heavy seeds, but none as heavy as the long vines produced; the average weight is far more variable.

The same is true of the Alaska peas as shown in Table IV., though less strikingly so owing to the smaller variability of average seed weight in this variety.

TABLE V. — *Correlation of Vine Length and Average Weight of Seeds.*

Excelsior I., 40 centimeters or less,	+ .3038 ± .0635
Excelsior I., 41 centimeters or more,	+ .1669 ± .0833
Alaska, 60 centimeters or less,	+ .2779 ± .0534
Alaska, 61 centimeters or more,	+ .1662 ± .0663

In order to compute fairly the coefficient of correlation in these two groups it is necessary to compute for the short and long vines separately. The coefficients are given in Table V.

This table shows, in the case of both varieties, fairly large coefficients, and they are in both cases larger for the short vines than for the long vines. These figures form a too slender basis for a definite conclusion as to the correlation between vine length and the average weight of peas produced, but so far as they go they consistently favor the supposition that the correlation does exist and is fairly large. The average of the four is +.2287.

TABLE VI. — *Correlation of Average Seed Weight and Vines produced.*

Strain A, D, F, G, K,	+ .0710 ± .0234
Strain B, E, H, J,	+ .1045 ± .0286
Alaska,	+ .0146 ± .0178
First of All,	— .0290 ± .0390

Turning now to the consideration of the question as to whether the heavier peas produce larger vines than do the lighter ones, we have the figures shown in Table VI. For reasons shown a little further on in this paper, the group Excelsior I. is divided into two strains, one of 5 lines and the other of 4 lines as shown in the table. The group First of All is from a selection of this variety that is of the same nature as the others. The number of vines is relatively small, and the figures, therefore, of less value than the other groups. It is because of the small numbers that the correlation of parent vine length and weight of their seeds are not given, but as far as they go they are in reasonable agreement with those of the two groups that are given.

It appears from the limited data given in Table VI. that the correlation is larger for the wrinkled Excelsior peas than for the starchy Alaska and First of All varieties. Only the coefficients for the first two groups should therefore be compared with the correlation of about +.06 found to exist between parent and offspring as shown in Table II.

No positive conclusion in this matter can be drawn. The indications are that a part and possibly all of the correlation of .06 may be accounted for by the correlation between length of vine and seed weight.

TABLE VII. — *Averages of the Single Lines.*

Original Plant.	Vine Length (Centimeters).	Mean Vine Length.				
		1908.	1909.	1910.	1911.	Average.
A, . . .	70	39.53 ±0.74	42.19 ±0.47	51.86 ±0.44	42.88 ±0.57	44.12
B, . . .	53	30.19 ±0.76	36.16 ±0.50	45.61 ±0.46	35.75 ±0.52	36.93
C, . . .	64	47.10 ±0.67	59.75 ±0.41	70.95 ±0.25	54.81 ±0.47	58.15
D, . . .	57	37.78 ±0.78	47.56 ±0.54	43.46 ±0.48	42.43 ±0.51	42.81
E, . . .	68	33.06 ±1.14	36.75 ±0.89	43.70 ±0.54	37.42 ±0.60	37.73
F, . . .	63	41.43 ±1.48	48.83 ±1.02	37.62 ±0.66	41.71 ±1.07	42.40
G, . . .	69	42.50 ±0.77	46.36 ±0.39	42.66 ±0.49	43.61 ±0.49	43.78
H, . .	61	34.35 ±0.61	41.15 ±0.41	36.44 ±0.36	38.76 ±0.46	37.68
J, . . .	65	36.72 ±0.55	38.77 ±0.53	33.80 ±0.60	35.69 ±0.84	36.25
K, . . .	55	44.88 ±0.67	46.55 ±0.51	38.24 ±0.54	35.90 ±0.75	41.39

Original Plant.	Pods per Vine.	Mean Vine Length.				
		1908.	1909.	1910.	1911.	Average.
A, . . .	11	3.00 ±.13	5.23 ±.11	4.78 ±.08	5.85 ±.15	4.72
B, . . .	17	2.91 ±.03	5.00 ±.13	4.70 ±.09	5.13 ±.13	4.44
C, . . .	9	5.32 ±.31	12.45 ±.27	7.77 ±.08	8.62 ±.17	8.54
D, . . .	7	3.26 ±.04	6.79 ±.14	3.88 ±.08	5.34 ±.11	4.82
E, . . .	4	2.81 ±.05	5.52 ±.22	4.18 ±.11	5.36 ±.13	4.47
F, . . .	3	3.57 ±.19	6.10 ±.26	3.16 ±.09	4.80 ±.20	4.41
G, . . .	9	4.70 ±.09	5.96 ±.09	3.59 ±.05	5.61 ±.12	4.97
H, . . .	11	3.15 ±.03	4.78 ±.09	3.02 ±.05	4.64 ±.11	3.90
J, . . .	4	3.05 ±.03	4.92 ±.12	3.16 ±.11	4.56 ±.21	3.92
K, . . .	4	3.75 ±.05	6.11 ±.20	3.62 ±.09	4.30 ±.12	4.45

A study of the averages of vine length and pods per vine of the 9 lines of descent, comprehended in the group Excelsior I., is of interest. These are shown in Table VII. and the remaining line, otherwise known as Variety "C", is included for purposes of comparison. The most striking thing brought out in the table is the fact that averaging the mean vine length for the four years under observation, we find that 5 of the lines A, D, F, G and K are grouped very closely around 43 centimeters while 4 others, B, E, H and J, are grouped closely around 37 centimeters.[1] The remaining line C being, as already stated, obviously a distinct variety, has a vine length much greater than any of the others.

The two groups above designated may be spoken of as strains, their component parts being known as lines, each of which is, as before explained, composed of the descendants of a single plant. The means of the several lines vary greatly from year to year, due to the varying conditions of weather and of the soil of the different plots on which the crops were grown. The relations of the mean lengths of the several lines in the same years also vary greatly. Much of this is obviously due to varying soil conditions. They are more consistent with the four-year averages, in 1911, than in the previous years, the only very marked departure being the case of line K, which is much below the average. They are extremely variable in 1910, when, as already stated, the unwise method of applying fertilizer in the row was followed.

Whether the slight departure of the averages of the different lines of either strain have any significance in inheritance is questionable. Only further testing under more uniform conditions would determine this.

Great differences are shown in the mean number of pods per vine. They follow the mean vine lengths only in a general way, and do not show very clearly the segregation into two strains as do the mean vine lengths. This might be expected in consideration of the slight coefficient of heredity of pods per vine already shown. Nevertheless, the average number of pods in the long-vined strain is about 15 per cent. greater than in the other, while the vine length is only about 16 per cent. greater. We have here a result of the greater variability of pods per vine over vine length that will be more fully discussed later in this paper.

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[1] This explains the division of Excelsior I. in Table VI.

Table VIII. — *Coefficients of Heredity within Strains.*

Vine Length.

	1908-09.	1909-10.	1910-11.	Average.
A, D, F, G, K, ...	+.0081 ±.0225	—.0646 ±.0215	+.0682 ±.0260	+.0039
B, E, H, J, ...	+.1733 ±.0270	+.0355 ±.0276	+.0200 ±.0300	+.0763
Average, ...	+.0907	—.0146	+.0441 +.0401	+.0401

Pods per Vine.

	1908-09.	1909-10.	1910-11.	Average.
A, D, F, G, K, ...	—.0169 ±.0220	—.0072 ±.0216	+.0059 ±.0261	—.0061
B, E, H, J, ...	+.0343 ±.0280	—.0722 ±.0276	+.0292 ±.0299	—.0032
Average, ...	+.0087	—.0397	+.0176 —.0045	—.0047

If these strains are homogeneous, and if the positive correlation shown in the first three groups in Table I. is due chiefly to the mixture of distinct strains or lines having different means, as appears to be the case, we should get when we compute for each of the strains as a unit, coefficients similar to those given in Table II. They are given in Table VIII. It is seen that they are similar on the average, having a little lower positive correlation for vine length and an insignificant negative correlation for pods per vine.

Correlation.

The data on vine length and pods per vine already presented give some evidence of a positive correlation between these two characters which is in accordance with common observation. In Table IX. are given some figures that show the value of this

Table IX. — *Correlation Coefficients, Vine Length and Pods per Vine.*

Plant.	Year.	Coefficient of Correlation.	Mean Vine Length.
Variety "C", ...	1910	.4070 ±.0101	71.0
Variety "C", ...	1911	.3104 ±.0359	54.6
Strain A, D, F, G, K, ...	1910	.6544 ±.0124	43.9
Strain A, D, F, G, K, ...	1911	.5653 ±.0178	41.8
Strain B, E, H, J, ...	1910	.7189 ±.0133	39.9
Strain B, E, H, J, ...	1911	.6016 ±.0191	37.2
Telephone, ...	1911	.4297 ±.0277	98.9
Champion of England, ...	1911	.4766 ±.0371	98.5
Gradus, ...	1911	.5152 ±.0264	52.3
Evolution, ...	1911	.5293 ±.0266	72.2
Alaska, ...	1911	.6103 ±.0231	56.3
Thomas Laxton, ...	1911	.6180 ±.0236	53.7
American Wonder, ...	1911	.6950 ±.0174	23.0

correlation. The nature of the groups in the first part of the table has already been explained. The remaining varieties have been grown from commercial seeds bought in the open market. The table shows that the correlation coefficient is closely related to the mean vine length in different varieties. The rule that is generally, though not invariably, followed is that the longer the vine the lower the correlation between vine length and pods per vine. This is reversed in the case of the different years shown in the first part of the table. This is due to the fact that the vines branched more freely in 1911, owing presumably to weather conditions. Vine length is taken as the length of the main stem, and when there are one or more branches bearing pods it is obvious that the correlation is lessened.

To this same factor is due in part, but not wholly, the smaller correlation in the groups having longer vines.

One or two pods may be borne at each node of the plant, but at many nodes no pod is produced. Whether or not a pod is produced depends presumably on environmental conditions at the time when the early development of the node has reached a certain stage. The period of growth and node production is much longer with long-vined plants, and the plant is subjected to a greater variation of conditions. As successive nodes develop some will experience favorable and some unfavorable conditions, and this will not be in very close correlation with vine growth. In some varieties and in some seasons the production of doubled podded peduncles is more common, and this operates to disturb the correlation. This question will be further dealt with in connection with the later discussion of variation in productiveness.

Variation.

We may now proceed to a discussion of the amount and nature of the variation that has been in evidence in the different groups from season to season.

In Table X. are given the standard deviations and coefficients of variability that are available, and the means are inserted for convenience of immediate comparison, though most of them have already been given in another connection.

TABLE X. — *Variation in Vine Length and Productiveness.*

Plant.	Year.	Vine Length.			Pods per Vine.		
		Mean.	Standard Deviation.	Coefficient of Variability.	Mean.	Standard Deviation.	Coefficient of Variability.
A,	1908	39.53 ±0.74	4.80 ±0.53	12.15 ±1.34	3.00 ±0.13	.86 ±0.09	28.67 ±3.49
	1909	42 19 ±0.47	9 45 ±0.33	22.40 ±0.83	5.23 ±0.11	2 12 ±0.07	40.54 ±1.64
	1910	51.86 ±0.44	9.68 ±0.31	18.67 ±0.62	4.78 ±0.08	1.79 ±0.06	37.45 ±1.36
	1911	42.88 ±0.57	10.70 ±0.40	24.96 ±1.00	5.85 ±0.15	2.78 ±0.10	47.52 ±2.15
D,	1908	37.78 ±0.78	6.01 ±0.54	15.91 ±1.50	3.26 ±0.04	.29 ±0.03	8.90 ±0.74
	1909	47.56 ±0.54	11.40 ±0.38	23.97 ±0.85	6.79 ±0.14	3.06 ±0.10	45.07 ±1.78
	1910	43.46 ±0.48	10.46 ±0.34	24.07 ±0.82	3.88 ±0.80	1.68 ±0.06	43.30 ±1.65
	1911	42.43 ±0.51	10.47 ±0.36	24.68 ±0.89	5.34 ±0.11	2.36 ±0.08	44.24 ±1.79
F,	1908	41.43 ±1.48	5.80 ±0.00	14 00 ±2.57	3.57 ±0.19	-	-
	1909	48.83 ±1.02	12.33 ±0.72	25.24 ±1 57	6.10 ±0.26	3.03 ±0.19	49.59 ±3.72
	1910	37.62 ±0.66	7.91 ±0.47	21.03 ±1.30	3.16 ±0.09	1.11 ±0.07	35.13 ±2.34
	1911	41.71 ±1.07	9.36 ±0.75	22.44 ±1.89	4.80 ±0.20	1.75 ±0.14	36.46 ±3.30
G,	1908	42.50 ±0.77	6 29 ±0.55	14.80 ±1.23	4.70 ±0.09	.71 ±0.02	15.11 ±1.31
	1909	46 36 ±0.39	9.93 ±0.27	21.42 ±0.62	5.96 ±0.09	2.27 ±0.63	38.09 ±1.19
	1910	42 66 ±0.49	9.47 ±0.24	22.20 ±0.59	3.59 ±0.05	1.41 ±0.04	39.28 ±1.14
	1911	43.61 ±0.49	9.91 ±0.34	22.72 ±0.83	5.61 ±0.12	2.54 ±0.09	45.28 ±1.86
K,	1908	44.88 ±0.67	3.95 ±0.48	8.80 ±1.06	3.75 ±0.50	.28 ±0.03	7.47 ±0.89
	1909	46.55 ±0.51	9.24 ±0.36	19.85 ±0.81	6.11 ±0.20	3.55 ±1.39	57.63 ±1.87
	1910	38.24 ±0.54	8.96 ±0.38	23.43 ±1.05	3.62 ±0.09	1.54 ±0.07	42.54 ±2.12
	1911	35.90 ±0.75	10.47 ±0.53	29.16 ±1.60	4.30 ±0.12	1.73 ±0.09	40.28 ±2.35
A, D, F, G, K,	1908	40.70 ±0.42	6.30 ±0.30	15.48 ±0.76	3.75 ±0.08	1.19 ±0.06	31.64 ±1.65
	1909	45.97 ±0.22	10.00 ±0.16	21.67 ±0.36	6.05 ±0.06	2.80 ±0.05	46.28 ±0.88
	1910	43.92 ±0.23	10.56 ±0.16	24.04 ±0.39	3.90 ±0.03	1.60 ±0.02	41.03 ±0.72
	1911	41.86 ±0.28	10.61 ±0.20	25.35 ±0.50	5.37 ±0.06	2.47 ±0.05	45.90 ±1.01

TABLE X. — *Variation in Vine Length and Productiveness* — Con.

Plant.	Year.	Vine Length.			Pods per Vine.		
		Mean.	Standard Deviation.	Coefficient of Variability.	Mean.	Standard Deviation.	Coefficient of Variability.
B,	1908	30.19 ±0.76	5.37 ±0.54	17.79 ±1.81	2.91 ±0.03	.21 ±0.02	7.22 ±0.72
	1909	36.16 ±0.50	9.18 ±0.35	25.38 ±1.04	5.00 ±0.13	2.31 ±0.09	39.65 ±1.74
	1910	45.61 ±0.46	9.16 ±0.32	20.09 ±0.73	4.70 ±0.09	1.82 ±0.06	38.72 ±1.56
	1911	35.75 ±0.52	9.55 ±0.37	26.72 ±1.10	5.13 ±0.13	2.40 ±0.09	46.78 ±2.16
E,	1908	33.06 ±1.14	6.74 ±0.80	20.39 ±2.52	2.81 ±0.05	.28 ±0.03	9.96 ±1.19
	1909	36.75 ±0.89	10.23 ±0.63	27.84 ±1.84	5.52 ±0.22	2.58 ±0.16	46.74 ±3.44
	1910	43.70 ±0.54	8.17 ±0.38	19.00 ±0.92	4.18 ±0.11	1.65 ±0.08	39.35 ±2.10
	1911	37.42 ±0.60	9.80 ±0.42	26.18 ±1.21	5.36 ±0.13	2.15 ±0.09	40.15 ±2.00
H,	1908	34.35 ±0.61	5.29 ±0.42	15.40 ±1.29	3.15 ±0.03	.26 ±0.02	8.25 ±0.68
	1909	41.15 ±0.41	9.35 ±0.29	22.72 ±0.73	4.78 ±0.09	2.14 ±0.66	44.86 ±1.63
	1910	36.44 ±0.36	7.99 ±0.26	21.93 ±0.74	3.02 ±0.05	1.13 ±0.37	37.42 ±1.37
	1911	38.76 ±0.46	9.12 ±0.33	23.53 ±0.89	4.64 ±0.11	2.08 ±0.08	44.83 ±1.90
J,	1908	36.72 ±0.55	3.72 ±0.37	10.13 ±1.06	8.05 ±0.03	.19 ±0.02	6.23 ±0.65
	1909	38.77 ±0.53	8.82 ±0.38	22.75 ±1.02	4.92 ±0.12	2.04 ±0.87	41.46 ±2.05
	1910	33.80 ±0.60	8.61 ±0.42	25.47 ±1.33	3.16 ±0.11	1.53 ±0.08	48.26 ±2.87
	1911	35.69 ±0.84	9.16 ±0.59	25.67 ±1.77	4.56 ±0.21	2.28 ±0.15	50.05 ±3.97
B, E, H, J,	1908	34.47 ±0.40	5.80 ±0.28	16.82 ±0.84	3.03 ±0.05	.76 ±0.04	25.08 ±1.30
	1909	38.86 ±0.27	9.49 ±0.19	24.42 ±0.51	4.94 ±0.06	2.23 ±0.04	45.04 ±1.06
	1910	39.94 ±0.27	9.69 ±0.19	24.26 ±0.50	3.76 ±0.05	1.69 ±0.03	45.01 ±1.04
	1911	37.19 ±0.28	9.47 ±0.20	25.45 ±0.57	4.93 ±0.07	2.24 ±0.05	45.44 ±1.15
C,	1908	46.12 ±0.67	8.55 ±0.48	18.53 ±1.58	5.32 ±0.31	2.60 ±0.22	48.87 ±4 81
	1909	59.75 ±0.41	10.38 ±0.29	17.38 ±0.51	12.45 ±0.27	6.71 ±0.19	53.90 ±1.86
	1910	70.95 ±0.25	10.34 ±0.18	14.56 ±0.25	7.77 ±0.08	3.22 ±0.06	41.44 ±0.82
	1911	54.81 ±0.47	11.95 ±0.36	21.80 ±0.64	8.62 ±0.17	4.33 ±0.12	50.24 ±1.73
Excelsior I.,	1908	37.67 ±0.33	6.81 ±0.23	18.09 ±0.64	3.40 ±0.05	1.06 ±0.04	31.29 ±1.17
	1909	43.20 ±0.19	10.68 ±0.13	24.72 ±0.32	5.63 ±0.05	2.66 ±0.03	47.25 ±0.70
	1910	42.41 ±0.18	10.39 ±0.13	24.50 ±0.31	3.85 ±0.03	1.66 ±0.02	43.12 ±0.61
	1911	39.85 ±0.21	10.43 ±0.15	26.17 ±0.39	4.57 ±0.03	1.73 ±0.02	37.86 ±0.60

Excelsior II.,	1909	37.68 ±0.23	11.50 ±0.16	30.52 ±0.48	4.47 ±0.05	2.34 ±0.03	52.35 ±0.93
	1910	44.73 ±0.19	9.89 ±0.13	22.11 ±0.31	5.39 ±0.05	2.51 ±0.03	46.57 ±0.75
	1911	45.78 ±0.19	7.79 ±0.13	17.03 ±0.29	4.71 ±0.04	1.83 ±0.03	38.90 ±0.75
First of All,	1909	41.24 ±0.40	16.02 ±0.28	38.83 ±0.78	3.51 ±0.05	1.84 ±0.03	52.42 ±1.14
	1910	61.89 ±0.42	17.19 ±0.29	27.78 ±0.51	3.99 ±0.04	1.53 ±0.03	38.21 ±0.74
	1911	68.07 ±0.38	14.73 ±0.27	21.64 ±0.39	4.86 ±0.05	2.06 ±0.04	42.45 ±0.90
American Wonder,	1911	23.65 ±0.27	8.15 ±0.19	34.48 ±0.91	3.71 ±0.06	1.74 ±0.04	46.82 ±1.33
Early Prize,	1910	49.21 ±0.72	11.99 ±0.51	24.36 ±1.08	8.95 ±0.27	4.55 ±0.19	50.84 ±2.64
Gradus,	1911	52.29 ±0.56	15.50 ±0.40	29.64 ±0.82	2.18 ±0.04	1.14 ±0.03	52.54 ±1.67
Daniel O'Rouke,	1910	57.04 ±0.52	12.32 ±0.37	21.60 ±0.68	4.56 ±0.08	1.89 ±0.06	41.48 ±1.44
Thomas Laxton,	1910	59.46 ±1.47	19.68 ±1.04	33.10 ±1.93	3.83 ±0.11	1.48 ±0.08	38.65 ±2.32
Thomas Laxton,	1911	53.66 ±0.67	17.57 ±0.47	32.75 ±0.97	3.39 ±0.07	1.85 ±0.05	54.52 ±1.85
Alaska,	1910	64.99 ±0.32	14.88 ±0.23	22.90 ±0.37	3.61 ±0.03	1.41 ±0.02	39.09 ±0.68
Alaska,	1911	56.39 ±0.59	15.93 ±0.42	28.25 ±0.79	4.34 ±0.09	2.33 ±0.06	53.72 ±1.75
Evolution,	1911	72.14 ±0.61	16.56 ±0.43	22.91 ±0.63	4.52 ±0.10	2.65 ±0.07	58.71 ±1.96
Telephone,	1911	98.88 ±0.73	21.47 ±0.52	21.73 ±0.55	3.14 ±0.06	1.68 ±0.04	53.31 ±1.60
Champion of England,	1910	131.80 ±1.15	22.88 ±0.80	17.36 ±0.62	12.89 ±0.36	7.46 ±0.26	57.90 ±2.61
Champion of England,	1911	98.73 ±1.08	22.69 ±0.77	22.98 ±0.82	4.21 ±0.11	2.38 ±0.08	56.52 ±2.46

Considering first the figures for vine length, we find that in 1908 the standard deviation and coefficient of variability were much lower than in any of the following three years. This is due to two factors, the more potent of which, doubtless, was the soil of the plot on which the plants were grown; this was gravelly and the plants suffered severely from drought. The other was the small number of plants grown, the total of 1908 being 227, while in subsequent years the total of the same groups has been more than 1,000. During the years 1909–11 there seems not to have been in Excelsior I., or any of its sub-groups, any constant differences in variation that cannot be ascribed to seasonal influences. In Excelsior II. both constants are notably low in 1911. This may be due to the fact that they were planted later this year than previously and encountered the unusually hot weather of July, 1911, at an earlier stage of development than either the other lots of Excelsior, or this lot in earlier years had encountered the less severe midsummer heat of those years. A comparison of the two strains of Excelsior I. shows that A, D, F, G, K has had uniformly greater standard deviation than B, E, H, J, but this has not been in proportion to the higher mean, so the coefficient of variability is less in the longer vined strain. This same tendency is seen in the distinct varieties, although it is not invariably the case.

We may ask if the variation within the lines of the two strains of Excelsior I. give evidence of individuality of these several lines? Is any line constantly more or less variable than the others of the same strain? With the possible exception of line D, which has a standard deviation uniformly larger or at least as large as its fellows, there seems to be no evidence of such a condition of affairs. It appears that the differences in the variability within the different lines is mostly, if not entirely, environmental and due chiefly to varying soil conditions.

We may now turn our attention to the figures for the number of pods per vine. We see first of all that the coefficient of variability is nearly twice as large as that for vine length, and in many cases the difference is even greater than this. In general, a high variability in vine length is accompanied by a high variability of pods per vine and vice versa, as would be expected from the strong correlation already shown to exist between these two characters. The differences in mean between different groups, more especially in different seasons, is marked. All through the groups of Excelsior I., 1909 was the most productive year, followed in order by 1911, 1910 and 1908. This order is not always followed in the other groups, owing to the fact that different planting dates and varying periods of growth caused the plants to experience different weather conditions at corresponding periods of development. These figures bring out in a striking way that fact familiar to all practical men, that productiveness is a delicate and uncertain character and tremendously influenced by environmental conditions.

The 10 plants of Excelsior selected in 1907 have given rise to at least three types of peas referred to as strains A, D, F, G, K and B, E, H, J and Variety "C." The groups Excelsior II. and First of All contain over 100 lines similar to those arising from these 10 plants, but in no case have we over 25 or 30 individuals in any one year. We may ask whether we have here any evidence of similar differences. No line is as distinct as Variety "C", but whether there are any of the more similar types, such as the two strains referred to, cannot be positively determined, owing to the small number of individuals grown. If we admit the general application of the very low heredity coefficients shown in Table II. to all such lines, a coefficient materially greater than these must indicate the presence of distinct strains. Reference to Table I. indicates a possibility of such condition in the case of Excelsior II., but with First of All the figures are about the same as those for single lines; it should be remembered, however, that the indications are that the correlation between seed weight and vine length is less in starchy peas. A study of the means of single lines for the two years available has been made, but is of no value, as the variation obviously due to environment, and the small number of individuals grown, totally obscures any inherited likeness that may exist. The existence of a relatively large coefficient of variability should indicate the presence of distinct strains, but these figures for Excelsior II. and First of All are variable and inconclusive.

The conclusion on this point is that there is some evidence of the presence of distinct strains in both Excelsior II. and

First of All, though we cannot say that their presence in either group is conclusively proven. In the opinion of the writer only the growing of these lines in greater numbers, for a period of two or three years under the most uniform conditions possible, can determine whether they are homogeneous or are, like Excelsior I., made up of distinct strains.

Discussion of the Results.

This work deals with two somewhat distinct characters of the garden pea, — vegetative vigor as expressed by vine length and the reproductive power as expressed by the number of pods per vine. The former seems much the more stable character, while the latter is extremely variable and much the subject of environmental influences. Vine length is, therefore, more dependable in studying heredity. The figures for vine length seem to indicate that some and perhaps all varieties of garden peas are composed of strains which have different hereditary vine lengths, which is in harmony with much of the recent investigation along these lines. They do not, in the opinion of the writer, indicate that the progeny of each individual under observation form distinct units which may be distinguished from each other, but rather that there are comparatively few distinguishable units composed of individuals of equal hereditary value to be found within the limits of what we commonly understand as a garden variety.

This work indicates nothing as to the origin or permanency of these units or strains. They may have arisen by mutation, by a gradual differentiation or by hybridization; they may endure permanently or they may not. It will require much further investigation to settle these questions.

It is a little unfortunate that no records of the number and length of internodes have been kept, for they would probably throw light on certain questions of productiveness. Each node, excepting possibly the lower ones, may be considered a possible location for a pod. It is probable that whether or not a pod is produced from any given node is entirely a matter of environment. We see no reason to believe that the number of pods per vine is in itself inherited in any degree. Vine length and presumably the number of nodes may be in some degree inherited, and inasmuch as a longer vine, and presumably more nodes, gives more opportunities for pod setting, productiveness may be thus indirectly passed over from one generation to another; but we see no indication in this work, or any other with which we are familiar, that the ability to produce pods is an inheritable character.

It follows from this that in careful work in selecting for productiveness in peas it will probably be more effective to follow the indirect method of selecting the long vines rather than to select directly the more elusive and variable character of pods per vine.

The difficulties in the way of studying heredity in plants lie largely in differentiating the inherited variations from the environmental; they may be reduced to a minimum by securing as uniform conditions as possible and growing large numbers of individuals. In such ways we may hope to learn the laws of breeding and reduce its practice to a science.

SEED WORK FOR THE YEAR 1911.

G. E. STONE.

The seed work for 1911 has included, as before, seed germination, seed separation and testing for purity. The 355 samples of seed sent in for germination exceeded the number for 1910, and was the largest number received since the work was inaugurated. Sixty-eight samples were tested for purity, and 135 samples were separated. This is not the largest number ever received for separation; the weight in pounds, however — 6,320 — was four times as great as ever before. Eighty-seven samples of tobacco seed and 42 of onion were sent in for separation. The smaller number of samples received is due to a co-operation among the farmers in buying their seed.

The average germination of onion seed for 1911 was 70 per cent., the highest 98 per cent. and the lowest 20 per cent. The average for tobacco was 84 per cent., the highest 95 per cent. and the lowest 21 per cent., neither seed being quite up to the standard.

TABLE I. — *Records of Seed Germination, 1911.*

Kind of Seed.	Number of Samples.	Average Per Cent.	Per Cent. of Germination.	
			Highest.	Lowest.
Onion,	126	70.4	98.5	20.0
Tobacco,	11	84.9	95.0	21.0
Clover,	25	81.3	97.0	61.5
Rye,	5	84.5	97.0	63.0
Grasses,	38	77.7	99.0	15.5
Lettuce,	43	48.7	99.0	3.0
Celery,	21	30.2	91.0	-
Tomato,	9	58.3	98.0	-
Parsley,	5	56 4	85.0	20.0
Spinach,	7	28.0	39.5	12.0
Parsnip,	7	7.5	30.0	-
Miscellaneous,	65	42.8	98.5	-
	355	-	-	-

More seed separation is apparently being done at this station than at any other, and this work is constantly increasing. The advantages to be derived from seed separation are not fully appreciated as yet. Onion and tobacco growers, we believe, are realizing these advantages more fully year by year, and this is true of some lettuce and celery growers, but much more use could be made of the practice by market gardeners. Seed separation results in better seed, more perfect germination and much more uniform and larger plants, which in seedbeds saves space and a great deal of labor in selecting uniform seedlings.

The selection from strains is also being made much of in the growing of corn and other crops, but market gardeners and farmers are by no means making use of all the opportunities in any of these directions.

TABLE II. — *Records of Seed Separation, 1911.*

Kind of Seed.	Number of Samples.	Weight (Pounds).	Per Cent. of Seed retained.	Per Cent. of Seed discarded.
Onion,	42	6,206.210	72.1	27.9
Tobacco,	87	85.820	86.3	13.7
Lettuce,	3	27.720	83.6	16.4
Celery,	6	.926	84.8	15.2
Total,	135	6,320.676	-	-

The percentage of onion seed discarded runs higher than usual, a fact due, apparently, to the relatively larger number of small seeds present than usual.

A summary of the seed work carried on at the station for a period of twelve years is shown in Table III. Previous to 1899 little seed testing and separation were done here, and no systematic records were kept of the work. Table III. gives a recapitulation of the work done in seed germination, purity testing and seed separation since 1899.

Table III. — *Showing Number of Samples of Seed Purity and Germination Tests made, and Seed Separation Work done, at the Station since 1899.*

Year.	Number of Samples.			Pounds separated.
	Germination.	Purity.	Separation.	
1899,	27	-	-	-
1900,	17	-	-	-
1902,	53	-	-	-
1903,	42	-	-	-
1904,	131	-	-	-
1905,	217	-	-	-
1906,	126	18	87	144
1907,	247	27	112	472
1908,	196	12	160	1,370
1909,	273	100	143	1,501
1910,	296	30	115	1,552
1911,	355	68	135	6,320
Total,	1,980	255	752	11,359

This table gives some idea of the increased interest manifested in seed work by the farmers and market gardeners of the State. Nearly 2,000 tests have been made for germination. 255 tests for purity, and 752 separations made. The total weight of seeds separated is 11,359 pounds. It must be remembered that all the seeds separated were small, particularly tobacco seed, of which it requires a great many to make a pound. A record of the number of samples, with the average, maximum and minimum germination of onion, tobacco and celery seed, is shown in Table IV.

TABLE IV. — *Showing Germination of Onion, Tobacco and Celery received at the Station since 1899.*

Year.	Onion.				Tobacco.				Celery.			
	Number of Samples.	Average.	Maximum.	Minimum.	Number of Samples.	Average.	Maximum.	Minimum.	Number of Samples.	Average.	Maximum.	Minimum.
1899, . .	27	72.0	90.0	45.0	-	-	-	-	-	-	-	-
1900, . .	12	85.6	92.0	70.0	-	-	-	-	-	-	-	-
1902, . .	6	89.0	94.0	83.0	-	-	-	-	-	-	-	-
1903, . .	21	85.5	97.0	52.5	-	-	-	-	-	-	-	-
1904, . .	25	77.8	96.5	45.5	-	-	-	-	-	-	-	-
1905, . .	15	91.8	98.5	84.0	-	-	-	-	4	89.0	97	79
1906, . .	32	79.0	100.0	28.0	-	-	-	-	6	67.0	99	43
1907, . .	40	86.0	98.5	57.0	2	91.0	92	90	3	83.0	91	70
1908, . .	65	74.2	98.5	-	10	78.0	97	20	24	79.0	98	35
1909, . .	92	82.2	97.0	25.0	8	93.6	97	85	8	69.0	85	25
1910, . .	75	77.4	100.0	3.0	7	95.0	99	89	-	-	-	-
1911, . .	126	70.4	98.5	20.0	11	84.9	95	21	21	30.2	91	-
Total, .	536	-	-	-	38	-	-	-	66	-	-	-

During the period from 1899 to the present time 536 germination tests of onion seed, 38 of tobacco and 66 of celery have been made, representing about one-fourth of the seed which we have tested. The principal feature to be noted is, perhaps, the variation in the percentage of germination occurring from year to year in different seeds. While it is perhaps not legitimate with the data at hand to draw too close deductions, we have noted in our seed work the effects of unfavorable climatic conditions upon the size and weight of seeds and seed vitality. The lowest average for onion seed was obtained in 1911, most of this seed probably having been grown in 1910; the highest average germination for onion in 1905, and for tobacco in 1910. The tobacco seed are practically all grown in the Connecticut valley, and obtained from carefully selected plants the year before. The variation in vitality is of some significance here. The celery seed tested is of uncertain origin, and the variation has little significance for us. There is no doubt but that unfavorable seasons and other factors show their effect in the percentages of germination given in these tables. In the case of tobacco seed another factor probably enters in, viz., gradual improvement in the vitality brought about by care in the selection of the seed plants.

TABLE V. — *Showing Number of Samples and Pounds of More Important Varieties of Seeds separated from 1906 to 1911, inclusive.*

KIND OF SEED.	Number of Samples.	Weight (Pounds).	Per Cent. of Seed retained.	Per Cent. of Seed discarded.
Onion,	187	8,923.30	83.6	16.3
Celery,	29	555.64	89.3	10.7
Tobacco,	418	272.43	85.4	14.6
Lettuce,	6	67.72	86.8	13.2
Total,	640	9,819.09	-	-

In Table V. is shown the number of samples and pounds of four typical seeds, with the percentage retained and discarded in our separation work, covering a period of five years, from 1906 to 1911. It will be seen from this table that the total number of samples separated is 640, equalling nearly 10,000 pounds in weight. The average percentage discarded was about 15 per cent., representing small, inferior seeds. Since these were all small seeds the weight in pounds is rather insignificant, as the number of onion seed in a pound is approximately 130,-000, that of celery seed 2,000,000, of lettuce, 400,000 and of tobacco 7,000,000. All the seed work has been done here gratuitously since its inauguration, the only exception being in the case of retailers who sometimes wish their seed tested in large quantities. The only expense incurred by the grower at present is return postage or express charges, and we are glad to say that this condition is almost invariably complied with.

In our opinion this work has proved of great value to our agriculturists. So far as seed separation is concerned, the value is greater than some of them realize, and perhaps less than others of the more enthusiastic may believe. The many careful tests which we have been making for years have shown us what seed separation actually accomplishes, and we therefore desire neither to overrate nor underrate the value of the work. The seed work of this station has shown a very healthy increase and growing interest on the part of the farmers. It has not been extensively advertised nor the value exaggerated, as we have regarded a slow, constant growth as of more value than one of a sporadic nature. The work, however, is now becoming so important in our State that it requires the services of a seed analyst who would devote most of his time to this work. We are of the opinion that this work should be done gratuitously for farmers and citizens, for the present at any rate, as it is more or less educational in nature, and that provision should be made for an assistant and improved testing appliances. Constant experimentation should be carried on to improve upon the existing methods of germination and separation. The work should be done systematically and collections of samples obtained throughout the State from dealers and farmers, and the results of these tests published here in bulletin form. This would greatly improve the seed problem as existing in this State.

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

RUST ON VINCA.

G. E. STONE.

An outbreak of rust on Vinca was recently brought to our attention by Mr. O. C. Bartlett, a graduate student at this institution. Mr. Bartlett, who is engaged in the summer in inspection work, became acquainted with this trouble through J. W. Adams & Co., of Springfield, Mass., a firm which maintains a nursery and general greenhouse establishment. The rust appears to be new in this country, and is apparently the same species as that occurring in Europe on Vinca,[1] although the specimens obtained by us do not correspond in every way to the European descriptions of this fungus. We have in our herbarium no European species with which to compare our specimens, but they were sent to Prof. W. G. Farlow, of Harvard University, and to Dr. J. C. Arthur of Purdue University, Indiana, who is a rust specialist. Professor Farlow writes that from a casual examination of material which we sent him, and which he compares with material in his own herbarium, the species differs considerably from his own type, *Puccinia Vincæ (DC) Cast.* Dr. Arthur states that there are two distinct forms in Europe, both of which are referred to as *Puccinia Berkelei, Pass.,* and *Puccinia Vincæ (DC),* Berk., the former being a synonym of the latter, and that the specimens sent correspond with one of the European types.

The rust has apparently been present in the vicinity of Springfield and Chicopee for at least two or three years, corresponding to the period when there was more or less of an unusual epidemic of rust in this State and elsewhere. Vinca is grown out of doors during the summer from greenhouse cuttings, but we could find no evidence of the disease affecting

[1] Tubeuf & Smith, "Diseases of Plants," p. 356.

outdoor plants in the summer or early fall. It makes its appearance in the greenhouse in the late fall and persists during the winter, affecting the leaves of the young, vertical shoots more seriously than those of the older, pendant ones. We observed both the euredospore and teleutospore outbreaks, which occurred on the underside of the leaves on our material. In the spring it appears to affect the plants less seriously, probably owing to the practice of frequently cutting off the affected parts and destroying them, and to the vigorous growth of the plants in the spring. When starting new plants care has been taken to use only healthy cuttings from year to year, and in this way the rust has, perhaps, been held in check to some extent.

The disease affects both the green and variegated varieties, although the latter are usually more severely affected. It has been found on a large number of plants, but the loss has not been serious owing to a tendency on the part of the plants to outgrow the trouble.

We have not been able to learn whether the mycelium is perennial in the stem or not, or whether infection comes from the field, but the rust does not seem to be so serious this year as the past two years, agreeing in this respect with other rusts which have been more or less epidemic. If the infection occurs on outdoor plants, as in the case of chrysanthemum rust, it can easily be controlled by indoor or tent-cloth culture, or by any other means which would keep the dews off the plants, and even if the mycelium is present in the stem to some extent the disease can no doubt be practically controlled by careful selection of cuttings. We have been unable to trace the disease beyond the points mentioned. The stock in use was obtained from the immediate neighborhood where the infection occurred, although no doubt the rust at some time or other came in on stock imported from Europe.

FROST CRACKS.

G. E. STONE.

Many trees of different varieties are subject to frost cracks. These often remain open for several years, and so far as our observations go are almost always to be found on the sunny side of the tree, generally towards the south. They occur in winter, and it is generally believed that they are caused by sudden changes in temperature, and especially by very severe cold. They were very common in this section during the remarkably cold winter of 1903–04, when some fruit trees, 8 or 10 inches in diameter, had frost cracks which opened 4 or 5 inches wide.

In this section the elm tree is more liable to cracks from the action of frost than other varieties. These are often 12 or 15 feet long, and give rise to more or less serious bleeding during the summer months. Cracks in trees occur not infrequently from other causes, such as the splitting of limbs, and we have known a number of sugar maples to gradually bleed to death from the loss of sap.

Frost cracks open in winter when the temperature is low, and close in summer. When not very large they sometimes heal over and disappear through the activities of callus growths, but more often they persist for some years, and an extensive opening of the cavity prevents permanent healing, making the tree subject to bleeding in summer.

Frost cracks are difficult to treat satisfactorily by tree surgery methods, as they often extend quite deeply into the wood, and the orifice is constantly changing in width owing to changes in the temperature. For the same reason certain other cavities in trees are hard to treat, as they sometimes open in winter and allow water to enter, which often results in the displacement of the cement fillings. To obviate this difficulty we have experimented largely with elastic cement applied to the edge of the filling as a means of preventing the access of water between the cement and the wood, but have found it practically impossible so far to prevent the bleeding of frost cracks or cavities in trees. There is no substance now in use which can successfully overcome the pressure exerted by the sap, which is bound to exude under certain conditions.

During the winter of 1907 Mr. E. G. Bartlett, at that time assistant in the laboratory, at my suggestion made measurements of the opening and closing of the orifices of some large frost cracks on the south side of elm trees located on the college campus. In the following table are given the results of these measurements, together with the mean temperature for the same period. The meteorological data were taken from the local station on the college grounds, and not a great distance from the trees.

Table showing Variation in the Width of Frost Cracks in Elm Trees (Ulmus Americana).

Date.	Tree No. 1.	Tree No. 2.	Mean Temperature (Degrees F.).
February 4,	23	20	16.5
5,	24	21	11.0
6,	26	24	5.3
7,	32	28	2.5
8,	28	24	16.0
9,	26	23	13.0
11,	22	18	17.0
12,	36	32	1.3
13,	38	35	2.5
14,	24	20	31.7
15,	26	22	28.5
16,	21	17	26.7
18,	22	20	21.5
19,	22	18	14.5
20,	22	18	30.7
21,	25	21	20.5
22,	28	24	8.0
23,	32	28	.5
25,	22	28	20.3

Table showing Variation in the Width of Frost Cracks in Elm Trees (Ulmus Americana) — Concluded.

Date.		Tree No. 1.	Tree No. 2.	Mean Temperature (Degrees F.).
February	26,	28	24	7.7
	27,	29	25	12.0
	28,	28	24	7.5
March	4,	20	16	27.5
	5,	20	16	21.3
	6,	20	16	23.7
	7,	21	17	22.5
	8,	20	16	24.0
	9,	20	16	23.7
	10,	21	17	20.5
	11,	20	16	29.7
	12,	18	14	25.5
	13,	18	14	37.3
	15,	11	8	35.7
	17,	9	9	41.7

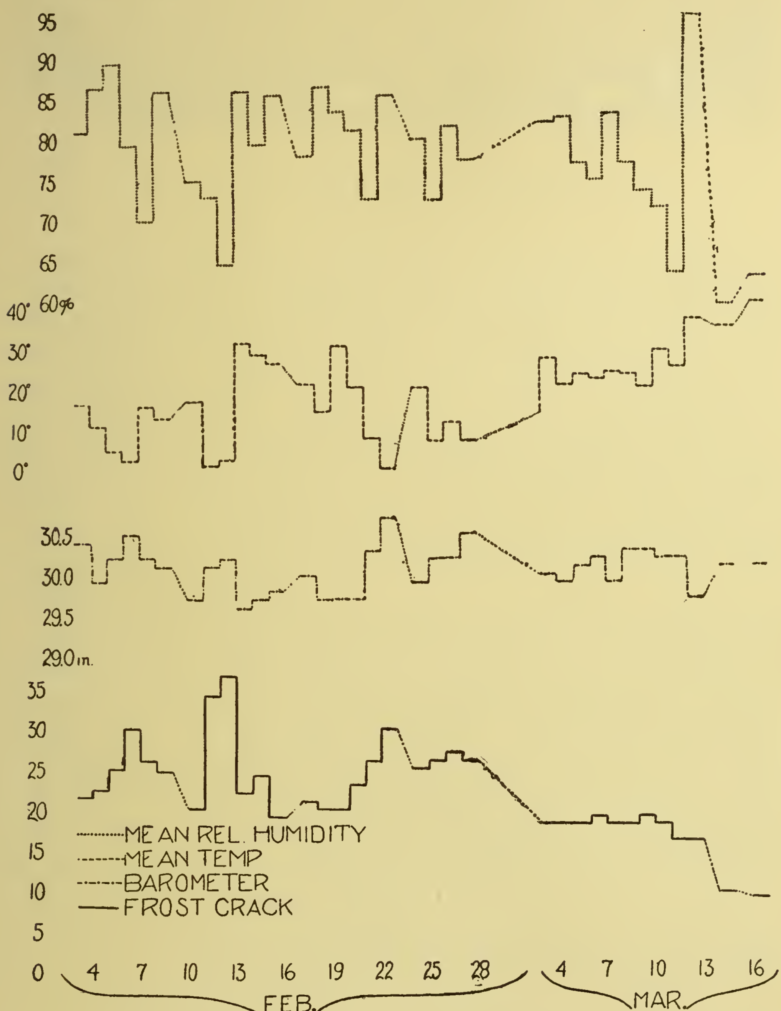
Measurements were not taken on February 10, 17 and 24 (Sunday). The remainder of March the cracks were too small to measure conveniently.

In the following diagram are shown graphically the variations in the opening and closing of frost cracks based upon the average measurements of tree No. 1 and No. 2; also the barometer, mean temperature and mean relative humidity curve.

It will be noticed that the barometer and temperature curves coincide closely with those given by the opening and closing of the frost cracks, and the same is true to a certain extent of the curve given by the relative humidity. The temperature curve is based upon the mean of the maximum and minimum for each day.

During the periods of low temperature the cracks opened, and closed when the temperature was higher. They open wider in February than in March, as shown by the higher readings in the table.

The relative mean humidity curve in general corresponds with that of the opening and closing of the frost cracks. When the humidity is low the cracks show a tendency to open, and to close when the humidity is great. The rise and fall of the



Showing curve of opening and closing of frost cracks in elm trees. The lower curve represents the variations in the opening and closing (scale, 1/64 of an inch); the others represent the mean relative humidity, mean temperature and barometer in the order named.

barometer curve coincides very closely with that of the frost cracks; in fact, there was such a close relationship between the temperature and barometer readings and opening and closing of frost cracks that considerable information as to the weather conditions might be obtained from observations on frost cracks. During the latter part of March, when the temperature was higher, the frost cracks did not open so wide, and it became more difficult to read them accurately. The same degree of variation in frost cracks may not occur in the summer months as in the winter; at any rate, the change was not so noticeable.

A NEW METHOD FOR THE APPROXIMATE MECHANICAL ANALYSIS OF SOILS.

G. E. STONE AND G. H. CHAPMAN.

According to the best authorities, and giving the definition used by the authors of Bulletin No. 24 of the United States Department of Agriculture, "The mechanical analysis of a soil consists in the separation of the soil particles into groups dependent upon the size of the grains, and in the determination of the percentage by weight of the particles constituting each group. The limits of these groups are arbitrarily chosen with reference to the ease in making the separation, and to the importance of the particles of any given size in determining the physical characteristics of the soil."

Many methods have been devised at different times by investigators, but the whole matter was somewhat hazy on account of each one using his own measurements for grading the soil particles, etc., until the present method of centrifugal analysis was devised by the authors of the bulletin previously noted. Since that time the methods described therein have been made use of by the United States Department of Agriculture and the experiment stations in general, where absolutely accurate results are desired for all characters of soils.

The chief objection to the methods heretofore devised has been the length of time necessary to carry through an analysis, even of the simplest soil.

In the work of this station there have arisen many occasions when it would have been of great advantage to know approximately the composition of a soil, more particularly of those used in greenhouses and market gardening. With a large amount of other routine station work always on hand it was found impossible to devote the time necessary to make an analysis of the soil samples by the ordinary centrifugal, or as we shall hereafter call it, the "long" method, so it became necessary to devise a method which would materially shorten the process and still give accurate results within a reasonable limit of error.

After considerable experimentation a satisfactory method was devised and has been used with success in our work here the past year. It is not claimed that this method is absolutely accurate, nor is any for that matter, as the limit of error, even when using the most approved centrifugal methods where the greatest care is used, is admittedly large, dependent somewhat of course on the manipulator.

A great number of comparisons have been made of the results obtained by analysis of soils by the long method and the short method and are given in the following pages. The method used by us is more or less of an adaptation of the centrifugal method in general use.

In brief, the centrifugal method in general use is as follows: the soil is carefully sampled and a part of the sample which passes through a 2-millimeter sieve is used for analysis. Five grams are usually taken and dried at 110° C. This sample is then shaken with water, to which a few drops of ammonia have been added, for six hours or more. The sample is then placed in tubes and centrifuged until all but the clay particles have subsided; these, with the water, are then decanted off and evaporated to dryness and weighed. The silts are found by allowing everything larger in size than .05 millimeter to subside, decanting the liquid, evaporating, drying and weighing. The remaining sands are dried and weighed and then sifted by four sieves into five grades. The organic matter is determined usually by the chromic acid method, but should not be confounded with the "loss on ignition" which is often erroneously termed organic matter.

This process, as can plainly be seen, takes a long time to carry through, and is not applicable where quick results are desired.

The briefer method in use at this station is as follows: the sample of soil as brought to the laboratory is first thoroughly mixed and then dried at 110° C. It is then sifted through a 2-millimeter sieve and all that passes through is classed as soil. This is again mixed and 10 grams taken for analysis. This is heated to obtain the "loss on ignition," in a platinum or porcelain crucible, and the organic matter, water, etc., is driven off. The sample is then cooled and weighed and loss of weight recorded as "loss on ignition." It is then placed in a small mortar and rubbed gently with a medium hard rubber-tipped pestle to disintegrate the soil particles as far as possible. Then the sample is sifted carefully with constant brushing with a stiff camel's hair brush through 1-millimeter, .5-millimeter, .25-millimeter and .1-millimeter sieves, the last two being bolting cloth, as in the long method. The residue remaining consists of the very fine sand, the silts and clay. This remainder is weighed and the weight recorded, and one gram or fraction thereof is weighed out and used in the remainder of the process to determine the percentage of very fine sand, silts and clay.

This determination is made in the following piece of apparatus (see Fig. 1): A is a circular test tube having a diameter of approximately 2 centimeters and a length to the contraction of about 7 centimeters; B is a flat glass tube with thin walls,

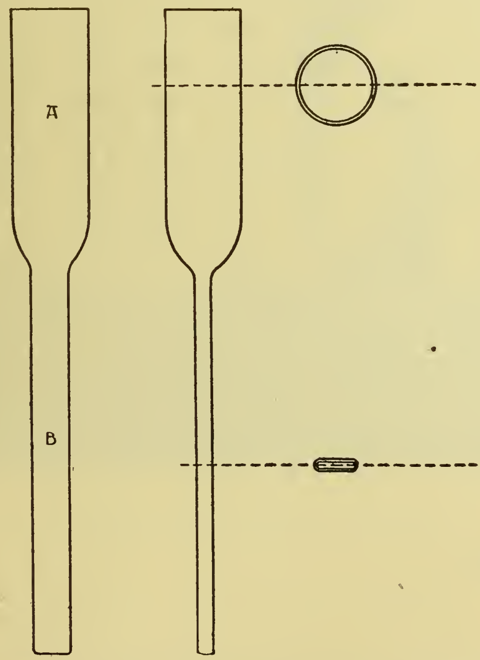


Fig. 1. — Showing special tube for mechanical analysis of soils: *A*, upper or circular part of the tube; *B*, lower or flat part of the tube. The figures to the right show cross sections, etc., of the tube.

one of which at least is perfectly flat, having an inside breadth of .8 centimeter and a width 1 to 1.5 millimeters. This tube is about 10 centimeters long. The lengths of A and B may be varied, however, but it has been found that tubes of these dimensions work well in the ordinary laboratory centrifuge. The method of procedure is as follows: the tube is filled to within about 4 centimeters of the top with distilled water and the gram of soil added. A rubber stopper is then placed in the tube and the soil thoroughly incorporated with the water by shaking for a few minutes. The tube is then placed in the centrifuge and run for a period of five minutes at a speed of about 1,200 revolutions per minute. The tube is then removed and clamped to an upright stand shown in Fig. 2, and a millimeter scale is attached so that with a horizontal microscope the size of the soil particles as shown by the eyepiece micrometer and the reading on the scale may be had at the same time or by swinging the microscope in a horizontal plane. 0 millimeter on the scale corresponds with the bottom of the soil column in the tube. The microscope is then focussed on the soil particles and raised until a majority of the particles are less than the minimum size of those of fine sand, *i.e.,* less than .05 millimeter; the scale reading is then taken and noted. The microscope is then raised until the particles are less than those of the minimum size for silts, viz., .0005 millimeter; the scale reading is again noted and the scale reading at the top of the soil column also noted. We have the readings as follows: —

	Millimeters.
Very fine sand,	3.0
Very fine sand and silts,	4.5
Very fine sand and silts and clay,	7.0

The column is divided, therefore, into volume per cents. as follows: —

	Per Cent.
Very fine sand,	42.85
Silts,	21.43
Clays,	35.72

If there were 2.34 grams of soil left after the last sifting we should have weights of very fine sand, silts and clays as follows,

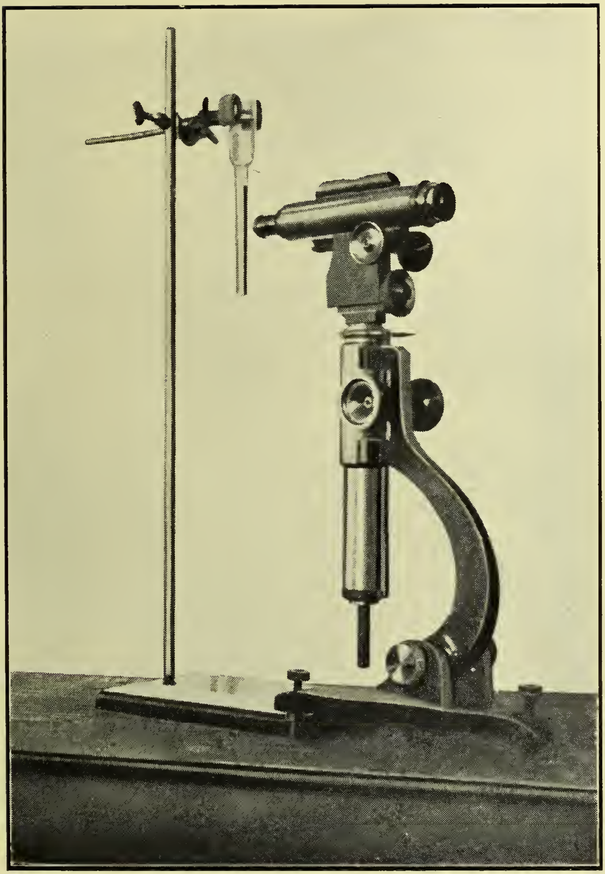


Fig. 2.—Photograph showing a horizontal microscope and methods of reading different percentages of soils in the tube..

using these volume percentages as weight percentages, which may be done, as experiment has shown that in the small tube the error is not great enough to be taken into consideration.

Very fine sand = 2.34 × 42.85 per cent. = 1.00 + grams.
Silts = 2.34 × 21.43 per cent. = .49 + grams.
Clay = 2.34 × 35.72 per cent. = .84 + grams.

Thus we have the weights of the very fine sand, silts and clay, and by following the same system used in calculating the percentages of the sands obtained by sifting in the whole sample we get the percentages of these constituents.

Below are given results of several typical soils which were analyzed by the long method and by the short method. It will be seen that the results vary but little and that for a close approximate analysis the results are accurate enough to warrant the use of this method where time is an important factor.

A criticism of this method may be raised, but its accuracy and ease of manipulation cannot be doubted, as it has been repeatedly proved to give as good results for general use as the long method, and in about half the time. Soils were analyzed by outside parties, and then the same soils were analyzed in the laboratory by the shorter method, and the results were well within the acknowledged limit of error, as can be seen from the following table: —

Table showing the Results obtained on Various Soils from Analyses by the "Long Method" and by the New Method.

[Per cent. of organic matter, gravel, sand, silt and clay in 20 grams of soil.]

Number.	Organic Matter.	Gravel (2–1 mm.).	Coarse Sand (1–.5 mm.).	Medium Sand (.5–.25 mm.).	Fine Sand (.25–.1 mm.).	Very Fine Sand (.1–.05 mm.).	Silt (.05–.01 mm.).	Fine Silt (.01–.005 mm.).	Clay (.005–.0001 mm.).	
55, . .	2.30	5.33	17.70	10.13	11.97	14.08	23.43	4.49	3.58	Long method.
	4.93	8.33	15.60	12.37	12.95	15.84	26.14		3.56	Short method.
49, . .	7.44	6.55	9.20	4.23	23.52	22.36	15.89	3.92	5.12	Long method.
	8.70	6.03	8.76	9.74	20.84	21.11	17.66		4.94	Short method.
54, . .	5.37	0.03	0.20	0.25	6.30	37.87	32.85	5.12	5.01	Long method.
	6.54	0.00	0.00	0.60	10.21	41.12	32.59		7.34	Short method.

There are admittedly several places where orthodox ideas have been differed from, but we have been unable to detect any bad effects as the result of these differences. The breaking up of the soil after beating in the mortar with a medium hard rubber pestle is one of these, and while error might creep in by careless or thoughtless manipulating, it is believed that with care any appreciable error can be easily obviated.

As there is a limit of error of from 2 to 5 per cent. by the long method in an analysis of the same soil, and as we came well within this limit in every case, we believe that we are justified in using this method for the breaking up of the soil particles.

In all probability it may not break up all the agglomerates, but so far in our experience the method has given perfectly satisfactory results, when reasonable care is used.

There may also be a slight loss of the finer particles in the sifting, but no more than is usual even by the long method.

In conclusion it may be said that where absolute accuracy is desired we do not recommend this short method, but for a close approximation it works very well.

Fig. 1. — Showing the effects of soil sterilization on the growth of melons. Two plants at the left grown in unsterilized loam; those at the right in the same loam sterilized.

THE PRESENT STATUS OF SOIL STERILIZATION.

G. E. STONE.

The term "soil sterilization" has long been applied by commercial growers to a system of heating soils, generally by the use of steam, to a temperature ranging from 180° to 212° F. for the purpose of destroying certain disease germs. In practice the heat is applied for only a short time, and as a matter of fact, only a comparatively small number of bacteria are destroyed. The process as usually employed by commercial men merely accomplishes what is termed "pasteurization."

The stimulating effects of sterilized soil on plant growth have long been recognized, and some large growers of lettuce and other crops have made extensive use of the practice largely for the effects produced on plant growth. Even as a young boy I remember observing the peculiar stimulating effects sterilized soil had on plant growth where charcoal pits had been burned. The soil and turf used in covering coal pits in the process of making charcoal are steamed and heated for many days, and become thoroughly sterilized. When the charcoal is taken out the soil is left spread out, and it often supports a vigorous and rank vegetation.

The extensive experiments which we made some years ago demonstrated that crops growing in sterilized soil are greatly stimulated; some crops, and lettuce in particular, showing the effects much more than others, however. This stimulation makes a different handling of lettuce necessary, and lower night temperatures must be maintained so that the characteristic heads will form properly and topburn be prevented.

Our experiments showed that while sterilization gives beneficial results with certain soils rich in organic matter, other soils deficient in this respect may cause injury to the crop when sterilized.

We have maintained that the benefits resulting from soil sterilization are largely chemical in nature, as shown by experiments with seeds, etc. In two series of experiments,[1] in which a large number and several varieties of seeds were employed, we found not only a marked acceleration in germination, but considerable increase in the number of seeds that germinated in sterilized soil when compared with the same soil unsterilized. The stimulating effects produced in these tests were undoubtedly chemical in nature; that is, there were certain substances in the soil which were chemically changed by the process of steaming, and these being absorbed by the seed, increased germination followed. It is, however, not at all improbable that part of the stimulating effects on seeds grown in sterilized soils is due to the renovation of the gases contained in the soil, since the old gases are driven out by the process of steaming. Steaming, in other words, has to a certain extent the same effect as aerating the soil, which process greatly stimulates seed germination and growth. In one experiment where 3,000 lettuce seed were grown in two boxes, 1,500 in each box and one being aerated and the other not, it was found that 86 per cent. germinated in the aerated soil, while only 64 per cent. germinated in the unaerated soil. The average weight of seedlings was 46 per cent. greater in the aerated than in the unaerated soil.[2]

Our experiments [3] in germinating seeds in decoctions of sterilized soil showed that the decoctions exerted a chemical stimulation, and that even decoctions from unsterilized loam had a similar effect on germination. The soil we used had never received any commercial fertilizer, but was a typical market-garden soil, frequently enriched with decomposed horse manure. It is well known that a great variety of chemicals stimulate seed germination, and it is not surprising that decoctions of soils would do the same.

The increase in the number of bacteria in sterilized soil has

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[1] Hatch Exp. Sta., 15th Ann. Rept., 1903, p. 41; also Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 126.

[2] Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 124.

[3] Hatch Exp. Sta., 18th Ann. Rept., 1906, p. 129.

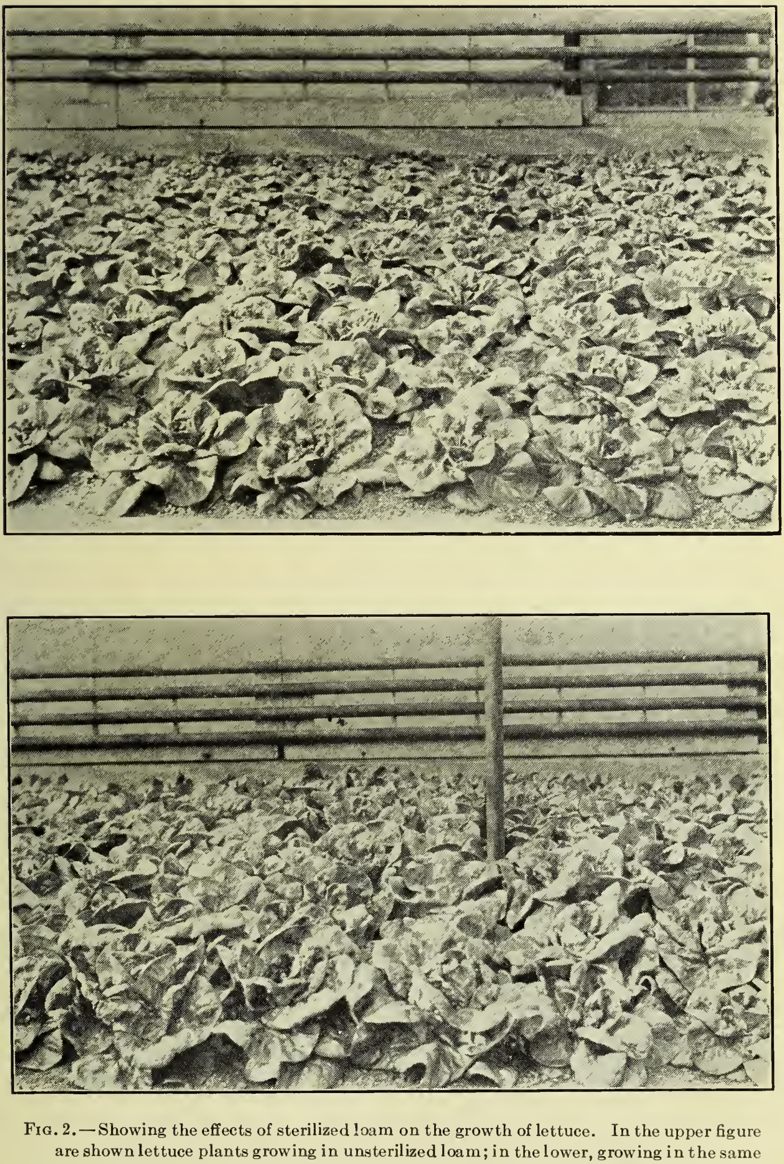

Fig. 2.—Showing the effects of sterilized loam on the growth of lettuce. In the upper figure are shown lettuce plants growing in unsterilized loam; in the lower, growing in the same loam sterilized. The difference in the average weight of these two crops, growing in the same house and the same soil, was 35 to 40 per cent.

been demonstrated by Prof. A. Vincent Osmun [1] and others, and the interpretation of these results we believe can be found in chemical stimulation. However, it is not at all unlikely that even in this case the aeration of the soil resulting from steaming may play a small rôle in the increased number of bacteria, since it is known that cultivation gives rise to an increase in the number of bacteria in soils.

There are great differences in soils as regards the stimulating effects of sterilization, and judgment must be exercised in drawing deductions from this fact alone. Many commercial florists and market gardeners in various parts of the United States have had some experience in growing different crops in sterilized soil, and the results of their experience in this work are not always the same. The best results which we have observed as arising from sterilization have invariably been given by lettuce.

The soils used in growing lettuce are rich in organic matter from the repeated application of horse manure year after year, and it is such soils as these, rich in humus, that sterilization affects most advantageously for plant growth. Some experiments, however, which we have made, with decomposed leaves (leaf mold) and decayed vegetable matter obtained from florists, gave results somewhat different from those obtained from soils rich in organic matter largely derived from horse manure. When seeds were soaked in decoctions of either sterilized or unsterilized leaf mold they showed little or no stimulation, and when the decoction was strong we obtained positive injury to seed. Neither did we obtain any stimulus to crops in sterilized forest humus except when the humus was first washed out and then sterilized.

The idea recently advanced by Russell and Hutchinson, that the increased bacterial flora characteristic of sterilized soil is biological rather than chemical, does not in the least appeal to us, at least for our conditions. The theory is to a certain extent an adaptation or application of the Metchinikoff phagocyte theory to the soil. Russell and Hutchinson report finding protozoa devouring bacteria in the soils, and they account for the increase of bacteria in sterilized soils by the absence of protozoa

[1] A Comparison of the Numbers of Bacteria in Sterilized and Unsterilized Soils, by A. Vincent Osmun, Hatch Exp. Sta. Rept., 1905.

and allied forms of animal life which prey upon micro-organisms.

It would be unjust for us to affirm what might take place in the soils of England or those on the continent, and it is to be assumed that the soil and climate, as well as the biological conditions, are different from those here; nevertheless, we are convinced that the biological theory does not hold in the soils we have experimented with for years, and as far as we are able to determine it possesses no significance. The matter, however, will be discussed in the following article prepared at our suggestion by Messrs. Smith and Lodge. These investigations were made under our direction in our laboratory during 1910 and 1911, when the men were taking senior work in the college, and prove to our satisfaction that protozoa, at least in our soil, have little or no part in accounting for the increased number of bacteria in our soils, although we cannot affirm that they do not play a more important rôle in England and elsewhere.[1]

The stimulating effects which sterilized soils have upon bacteria are chemical in nature, and so far as we can determine with our soils biological factors exert no influence in this respect. Most observers, we believe, agree that ammonia is given off from sterilizing soils, owing apparently to dentrification, and in this connection we might relate that in some cases where horse manure was applied freely and sterilization followed we noted that if certain plants, such as tomatoes, were transplanted in the soil too soon after the sterilizing had been done, their leaves would present symptoms of ammoniacal burning.

The sterilizing of soils has been carried on very extensively for some years in this country, particularly in greenhouses, and we have had opportunities to observe various crops growing in many acres of treated soil. In practically all cases moist heat, that is, steam, is employed for this purpose, although hot water has been used with practically the same results. There are, as might be expected, a variety of opinions as to the effects which stimulation has upon plants, since a large variety of soils have been treated, and the crops have been grown under very variable conditions. Moreover, as has already been stated, some crops

[1] Mr. David Larsen, who is associated with the Hawaiian Sugar Planters' Experiment Station in Honolulu, informs me that protozoa are quite abundant in Hawaiian soils, and that carbon bisulfid applied to the soils there acts as a great stimulus to crop production.

are stimulated much more than others by this treatment. Most crops require special handling in sterilized soils, otherwise trouble is likely to follow.

Many different methods of sterilizing soils have been developed, and the writer has experimented with practically everything there is in this line. There is no doubt that many soils can be greatly improved by sterilization, and in the future it will be more extensively employed not only for the destruction of pathogenic organisms, but, like electricity and other stimuli, as a means of hastening crop production.

The writer at one time had experience with a soil which would not grow lettuce. When it was sterilized, however, no further difficulty was experienced with it. Even muck soils, which are rich in organic matter and generally injurious to plant growth, can be greatly improved by leaching and sterilizing.

In the south there are many acres of soil seriously affected with Sclerotinia which can be treated effectively at no great cost, and in the future soil sterilization is bound to become of practical use for field work. There is no reason why methods cannot be adapted for cheap and effective sterilizing of outdoor soils if the land be fairly level and free from stone.

INFLUENCE OF SOIL DECOCTIONS FROM STERILIZED AND UNSTERILIZED SOILS UPON BACTERIAL GROWTH.

C. A. LODGE AND R. G. SMITH.[1]

An attempt has been made in the following experiments to ascertain the cause underlying the effects which sterilized and unsterilized soil decoctions have upon bacterial development. These questions have often arisen: In what manner does soil sterilization affect bacterial development? Is the cause underlying the development of bacteria in soils of a chemical or biological nature? Some investigators maintain that the increase of bacteria in sterilized soils is due to a chemical stimulus, while others insist that it is biological; *i.e.,* that minute animal organisms known as protozoa affect the bacterial flora of soils. In all probability the chemical factor is the important one, the biological factor playing little or no part in either increasing or retarding bacterial growth, at least in any of our soils.

We selected for use in our experiments two types of soils, — one an Amherst greenhouse soil or loam, somewhat modified by the addition of coarse sand and quite rich in organic matter, and which will be designated as loam; and the other a yellow loam or a typical Amherst subsoil, deficient in nitrogen and containing only a slight amount of organic matter, which will be designated as subsoil.

TABLE I. — *Showing Mechanical Analysis of Two Types of Soils used in these Experiments.*

[Per cent. of organic matter, gravel, sand, silt and clay in 20 grams of soil.]

	Organic Matter.	Gravel (2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.).	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay (.005-.0001 mm.).
Loam, . . .	10.45	13.97	24.48	17.33	21.60	20.00	5.00	1.50	.12
Subsoil, . .	3.60	1.75	4.45	6.95	23.85	35.95	11.10	5.20	5.25

[1] This work was done at the instigation and under the direction of Dr. G. E. Stone when Messrs. Smith and Lodge were seniors in the college.

The soil decoctions used in our experiments were made as follows: four hundred grams of soil were placed in a percolation tube and lukewarm distilled water was allowed to percolate several times through the soil. This method was followed in each instance. The decoctions thus made (the percolated water) were then placed in flasks, each flask containing 100 cubic centimeters of percolate. Then these decoctions, composed of percolates from sterilized and unsterilized soils, were placed in the autoclave and subjected to steam pressure of 15 pounds for forty-five minutes at a temperature of 250° F.

Three series of experiments were carried on with each soil. In series No. 1 a sterilized and unsterilized loam were used, and the sterilized decoctions inoculated with ordinary soil bacteria. In the second series of experiments a sterilized and unsterilized loam, and in addition a sterilized and unsterilized subsoil, were used, and the sterilized decoctions inoculated with ordinary soil bacteria. In our third series of experiments a sterilized and unsterilized loam and subsoil were used, as in our second series of experiments, but with this difference, — inoculations were made from a pure culture of Bacillus subtilis. In the above series of experiments, where a sterilized loam or subsoil was used, sterilization was done as follows: about 1 liter of soil was placed in the autoclave and subjected to steam pressure of 15 pounds for forty-five minutes at a temperature of 250° F.

The following method of inoculation was used in our first two series of experiments, where ordinary soil bacteria were used. Ten grams of loam were placed in 100 cubic centimeters of sterilized water,[1] and this decoction placed in an incubator for three days, where a large number of bacteria developed. We used these decoctions to inoculate our sterilized percolates of sterilized and unsterilized soil in the two series of experiments, these percolates being inoculated with 1 cubic centimeter of the above culture and then incubated for twenty-four hours. The decoctions were removed from the incubator and plated, and the ordinary dilution methods followed. Cultures were made by adding ½ cubic centimeter of the dilution to agar-agar in Petri-dishes, and these were incubated for twenty-four hours, after which the colonies were counted. The agar-agar was .5 per cent.

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[1] Distilled water was used in all cases in all the experiments.

normal acid in all the experiments. In the third series of experiments, where inoculation was made with Bacillus subtilis, the following method was used. A pure tube culture of Bacillus subtilis was made; from this pure culture a number of bacteria were transferred with a platinum loop to 100 cubic centimeters of sterilized water. From here on the method was followed as above indicated.

EXPERIMENTAL.

TABLE II. — *Showing Comparison of the Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam. (Inoculations made with Ordinary Soil Bacteria.)*

Soil.	Number of Bacteria in 1 Cubic Centimeter of Decoction.			
	Experiment 1.	Experiment 2.	Experiment 3.	Average.
Sterilized loam,	5,680,000	3,842,000	5,218,800	4,913,600
Unsterilized loam,	276,000	402,000	391,240	343,746

The results shown in Table II. are of special interest for the following reason: in the three experiments recorded in this table the sterilized loam decoctions were found to contain a far greater number of bacteria per cubic centimeter of contents than the unsterilized loam decoction.

TABLE III. — *Showing Comparison between the Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam and Subsoil. (Inoculations made with Ordinary Soil Bacteria.)*

Soil.	Number of Bacteria in 1 Cubic Centimeter of Decoction.		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam,	5,724,000	4,693,060	5,208,530
Unsterilized loam,	203,520	199,308	201,414
Sterilized subsoil,	76,320	81,134	78,726
Unsterilized subsoil,	178,080	185,138	181,608

The results given in Table III. are important since they show that decoctions made from different soils affect the growth of bacteria in them in a decidedly different manner. When a sterilized loam is used we find a greater number of bacteria present as compared with the number in the unsterilized loam decoction; thus the experiments with loam soil in Table III. bear out the results recorded in Table II., where the same kind of loam soil was used in the decoctions. When a sterilized and unsterilized subsoil were used in the decoctions we found that a greater number of bacteria were present in the unsterilized decoction. This fact proves that the sterilizing of this particular soil resulted in adverse conditions for bacterial increase.

At this point it might be of interest to insert a table taken from a previous report of the Hatch Experiment Station,[1] showing the growth of soy bean in sterilized and unsterilized loam and subsoil. A glance at this will show that the greatest gain in plant growth was made in the loam soil, and the least in the subsoil. These results coincide with the relative growth of bacteria in the two soils, as shown in Table III.

TABLE IV. — *Showing Growth of Soy Bean in Sterilized and Unsterilized Loam and Subsoil (from Hatch Experiment Station Annual Report, 1906).*

	Total Number of Pots used.	Average Length (Centimeters) of Stems in —		Gain or Loss in Sterilized Soil (Per Cent.).
		Unsterilized Soil.	Sterilized Soil.	
Loam,	4	9.53	10.87	+14.05
Subsoil,	4	9.79	4.14	—57.70

Glancing over this table one can readily see that there is a connection between the development of bacteria and the growth of soy beans in sterilized and unsterilized soils. The soy beans showed an increase of growth in the sterilized loam over that given in the unsterilized loam. In the subsoil the unsterilized soil produced a greater growth than the sterilized. The same held true in regard to the development of bacteria. Decoctions of the sterilized loam produced about twenty times the number of bacteria as the unsterilized. In the sterilized subsoil there is a decrease in numbers as compared with the unsterilized, or in other words, the unsterilized subsoil produced twice as many bacteria as the sterilized.

[1] Comparison of Sterilized Loam and Subsoil, by G. E. Stone, 18th Ann. Rept. of the Hatch Exp. Sta., pp. 125, 126, 1906.

That sterilization of soils produces different effects on crops according to the nature of the soil cannot be disputed. In this experiment we used two distinct types of soil, and found that sterilization affects both soils differently. In loams well supplied with organic matter the effect is a stimulation from the beginning on certain crops. In other soils, notably deficient in organic matter (like the subsoil used in this experiment), the effect may be a detrimental one.

Lyon and Bizzell [1] have shown us that steaming reduces the nitrates of the soil to nitrites and to ammonia, but most of the ammonia comes from the organic nitrogen. Russell and Hutchinson [2] claim that the increased productiveness of sterilized soils is due to an increase in the amount of ammonia present, and that the excess of ammonia is the result of the increased decomposition of soil substances by bacteria.

TABLE V. — *Showing Comparison of the Amounts of Ammonia in Decoctions of Sterilized and Unsterilized Loam. (Inoculations made with Ordinary Soil Bacteria.)*

Soil.	Amount of Ammonia in Decoction of 100 Cubic Centimeters (Grams).			
	Experiment 1.	Experiment 2.	Experiment 3.	Average.
Sterilized loam, . . .	.0051	.0052	.0051	.0051
Unsterilized loam, . .	.0032	.0031	.0030	.0030

Analysis of the soil decoctions from soils similar to those used in the experiments given in Table IV. show an increase of ammonia in the sterilized loam as compared with the unsterilized. In the subsoil we find just the reverse condition, the unsterilized subsoil containing more ammonia than the sterilized.

Analyses of the soil decoctions used in the experiments shown in Tables II. and III. give the same results as regards the ammonia content of the decoction as those enumerated above, but in our experiments (Tables II. and III.) we have sterilized decoctions of the various soils inoculated with soil bacteria. The increase and decrease in the number of bacteria found in these

[1] Effects of Steam Sterilization on the Soluble Matter in Soils, Lyttleton Lyon and J. A. Bizzell, Cornell Agr. Exp. Sta., Bul. No. 275, April, 1910.

[2] Effects of Partial Sterilization of Soil upon the Production of Plant Food, by E. J. Russell and H. B. Hutchinson, Journal of Agricultural Science, Vol. III., Part II., October, 1909.

decoctions correspond with the increase and decrease of ammonia content in each case, more ammonia being found in the decoctions which possessed the largest number of bacteria. This fact is not new, as it has been shown by Russell and Hutchinson in recent years.

TABLE VI. — *Showing Comparison between the Amounts of Ammonia in Decoctions of Sterilized and Unsterilized Loam and Subsoil. (Inoculations made with Ordinary Soil Bacteria.)*

Soil.	Amount of Ammonia in Decoction of 100 Cubic Centimeters (Grams).		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam,	.0050	.0050	.0050
Unsterilized loam,	.0031	.0032	.0031
Sterilized subsoil,	.0020	.0021	.0020
Unsterilized subsoil,	.0030	.0032	.0031

TABLE VII. — *Showing Comparison between the Amount of Ammonia in Decoctions of Sterilized and Unsterilized Loam and Subsoils. (Inoculations made with Water Cultures of B. subtilis.)*

Experiment 1.

Soil.	Amount of Ammonia in Decoctions of 100 Cubic Centimeters (Grams).	Soil.	Amount of Ammonia in Decoctions of 100 Cubic Centimeters (Grams).
Sterilized loam,	.0031	Sterilized subsoil,	.0010
Unsterilized loam,	.0020	Unsterilized subsoil,	.0020

This increase in the amount of ammonia in each case is certainly brought about by the action of the bacteria upon the organic matter in the soil. Now the question arises: What change takes place within the soil, when sterilized, in order to produce this increase in the number of bacteria? In the case of the subsoil, where the increase takes place in the unsterilized soil, it is a question as to what change takes place upon sterilizing that has a detrimental effect on bacteria.

Russell and Hutchinson [1] tried the effect of untreated soil

[1] The Effects of Partial Sterilization of Soil on the Production of Plant Food, by E. J. Russell and H. B. Hutchinson, Journal of Agricultural Science, Vol. III., Part II., October, 1909, p. 117.

upon sterilized soil and found a decrease in the number of bacteria and in the amount of ammonia present. This would show that there is some limiting factor in the original soil that limits bacterial action. They claim that this limiting factor is not chemical but biological.

In the experiments which we have described and in those which follow we are unable to comprehend how protozoan forms play any rôle whatsoever in the decrease of bacteria. If this is true this limiting factor must be a chemical or physical property of the soil, and one on which sterilization has a marked effect.

Protozoa as a Factor in the Bacterial Flora of Soils.

The remaining contents of the soil culture used in inoculating decoctions in the experiments of Tables II. and III. were subjected to a careful microscopic examination for various forms of protozoa. Our labors were without results, however, no protozoa being found; but it is quite possible that a few might have been introduced at the time of inoculation of the decoctions. To avoid any possibility of introducing protozoa into decoctions the experiments shown in Table VIII. were made.

Table VIII. — *Showing Comparison of Number of Bacteria in Decoctions of Sterilized and Unsterilized Loam and Subsoils. (Inoculations made with Water Culture of B. subtilis.)*

Soil.	Number of Bacteria in 1 Cubic Centimeter of Decoction.		
	Experiment 1.	Experiment 2.	Average.
Sterilized loam,	5,952,960	4,913,800	5,423,300
Unsterilized loam,	127,484	111,964	117,324
Sterilized subsoil,	279,840	283,380	281,610
Unsterilized subsoil,	2,060,640	2,901,244	2,480,942

The data given in the above table show that Bacillus subtilis multiply in great numbers in all the decoctions. About the same relative number of bacteria were found here as in the decoctions shown in the experiments given in Tables II. and III. A greater number of Bacillus subtilis were found in the sterilized loam decoctions as compared with the unsterilized; also a greater number of Bacillus subtilis were found in the unsterilized subsoil decoctions as compared with the sterilized decoctions.

A careful consideration of our work leads us to believe that protozoa were absent in all our decoctions, and the experiments shown in Table VIII. seem to substantiate this belief; moreover, protozoa were uncommon in the soils used. A number of samples of the loam and subsoil were subjected to examination, but very few protozoan forms [1] were found. In this vicinity great numbers of protozoa are found in pools of standing water, while few are observed in garden soils. In other localities protozoa may be more abundant in soil; however, no data are available. For protozoa to reduce the bacterial flora of the soil to an appreciable degree by devouring the bacteria, it is certain that the number of protozoa present in the soils of Amherst would have to be increased manyfold; besides, all protozoa do not consume bacteria. G. N. Calkins, professor of protozoölogy at Columbia University of New York, is the authority for the following: "All classes of protozoa except Sporozoa are bacteria eaters except the carnivorous forms." The same authority in a recent work [2] says: "Two of the most striking phenomena among the protozoa are the apparent choice of food and the selection of certain materials for building shell." The author notes that certain protozoa will live almost exclusively on other protozoa and such vegetable forms as Oscillaria, Spirogyra and diatoms. "Each protozoan will eat only its favorite food, although other food is abundant." If the above is true it means that hundreds of protozoan forms of the soil do not feed on bacteria, therefore it is impossible to credit the difference in the numbers of bacteria in a gram of soil [3] — 7,000,000, and a gram of treated soil (sterilized) 37,000,000 — to the elimination of the protozoa. This remarkable increase in the number of bacteria of over fivefold of the original number in the untreated soil can only be explained by an increased food supply. In our experiments with soil decoctions, where the protozoa were entirely eliminated, we obtained a difference in numbers of bacteria present in the decoctions of sterilized and unsterilized soils ranging from fifteen to twenty

[1] The following species were observed: Halteria, Enchelys, Paramœcum, Amœba, Euglena, Euplotes, Dileptus, Strombidium and Oxytridia.

[2] The Protozoa, Columbia Biol. Ser., VI., p. 305.

[3] Hall, Harper's Magazine, October, 1910, p. 681.

times as many in the sterilized as compared with the unsterilized decoctions. However, in the experiments where sterilized and unsterilized subsoil were used we found more bacteria in the unsterilized decoctions as compared with the sterilized decoctions. This fact proves that sterilization does not in every case result in an increased number of bacteria in the soil thus treated.

Conclusions.

1. The development of bacteria may be retarded or accelerated in soil decoctions by the use of sterilization.

2. In decoctions of soil rich in organic matter the development of bacteria is greatly increased, while in soils deficient in organic matter the development of these organisms is retarded by sterilization.

3. The stimulating or retarding effects on the development of bacteria of the two types of sterilized soil used by us are similar to those produced upon the growth of crops in these soils. (*Cf.* Table IV.)

4. From numerous microscopic examinations made of Amherst soils we do not find that protozoa are abundant; neither were they observable in our soil decoctions.

5. The question of protozoa as a biological factor was eliminated in the experiments. The stimulating or retarding effect on the development of bacteria was due to other causes.

6. Our experiments therefore, made with Amherst soils, do not confirm those of Russell and Hutchinson, who maintain that protozoa influence the number of bacteria in soils, since the development of bacteria differs in soil decoctions according to the composition of the soil used; that is, the number of bacteria which develop in a soil depends upon the chemical and physical condition of the soil rather than upon the number of protozoa.

7. These experiments do not necessarily preclude the idea that protozoa might play a much more important rôle in soils other than those with which we experimented.

THE EFFECTS OF POSITIVE AND NEGATIVE ELECTRICAL CHARGES ON SEEDS AND SEEDLINGS.

G. E. STONE.

Considerable interest is now being manifested in the effects of electricity on plant growth, and experiments are being made in this country and abroad to study this influence. Most of the experimenters at the present day are making use of high tension wires, the aim being to charge the atmosphere rather than the soil.

For many years we have been carrying on experiments along this line, and many of the results have been published from time to time.[1] However, we still have considerable data on the various phases of the subject of electrical stimulation which have not been published, as in many cases the experiments have not been completed.

The experiments given here were made under my direction in 1904 by Mr. N. F. Monahan, a former assistant in the laboratory, who while with us paid quite a little attention to the subject of electrical stimulation and plant reaction. They were made to determine the relative stimulating effect of positive and negative charges on seed germination and growth of seedlings. The seeds of lettuce and radish which we used were first moistened by soaking in water for a few hours and were then charged from a small friction machine, Töpler-Holtz model. They were then placed in electro-germinators, which consisted of a modified Leyden jar and Zurich germinator, and 10 small sparks from a Töpler-Holtz machine were applied to each germinator, which

[1] Electro-Germination, Hatch Exp. Sta., Bul. No. 43, 1897; The Influence of Current Electricity upon Plant Growth, Hatch Exp. Sta., 16th Ann. Rept., 1904; The Influence of Atmospheric Potential on Plants, Hatch Exp. Sta., 16th Ann. Rept., 1904; The Influence of Electrical Potential on the Growth of Plants, Hatch Exp. Sta., 17th Ann. Rept., 1905; Comparisons of Electrical Potential in Trees and in the Free Air, Hatch Exp. Sta., 17th Ann. Rept., 1905; Injuries to Shade Trees from Electricity, Hatch Exp. Sta., Bul. No. 91, 1903; Influence of Electricity on Micro-organisms, Bot. Gazette, 48; No. 5, November, 1909; Effects of Electricity on Plants, Bailey's Cyclopedia of American Agriculture, Vol. II., p. 30.

resulted in stimulation of the seed. The germinator was then placed in an autoclave and kept at a temperature of about 25° C. The results of the experiments follow: —

TABLE I. — *Showing the Results of the Stimulating Effect of Positive and Negative Electrical Charges on Radish Seeds and Seedlings (Raphanus sativus, L.).*

[Average of two experiments in each of which 60 seeds were used. Moist treated seed charged with 10 small sparks from a Töpler-Holtz machine. Measurements in millimeters, temperature 25° C.]

Treatment.	Average Length of —		Per Cent. gained in Length of —	
	Hypocotyl (Centimeters).	Radicle (Centimeters).	Hypocotyl.	Radicle.
Normal,	1.13	1.07	-	-
Negative charge,	1.39	1.24	23.00	15.88
Positive charge,	1.72	1.76	52.21	64.48

It is quite evident that the electrical treatment stimulated the seed very materially, as shown by the growth of the hypocotyls and radicles given in this table. The average increased length of the radicles and hypocotyls of the negatively charged seeds over that of the normal was 23 per cent. for the hypocotyl and 15.88 per cent. for the radicle. The positively charged seeds gave an average increase of 52.21 per cent. for the hypocotyl and 64.48 per cent. for the radicle over that of the normal; showing that the positive charges induced the greater growth. No attention was given to accelerated germination in this experiment.

TABLE II. — *Showing the Results of the Stimulating Effect of Positive and Negative Electrical Charges on Lettuce Seeds and Seedlings (Lactuca sativa, L.).*

[Average of two experiments in each of which 60 seeds were used. Moist treated seed charged with 10 small sparks from a Töpler-Holtz machine. Measurements in millimeters, temperature 25° C.]

Treatment.	Average Length of —		Per Cent. gained in Length of —	
	Hypocotyl (Centimeters).	Radicle (Centimeters).	Hypocotyl.	Radicle.
Normal,	0.96	1.52	-	-
Negative charge,	1.08	1.77	12.50	16.40
Positive charge,	1.21	2.18	26.00	43.42

In the experiments shown in Table II. the accelerated growth of the hypocotyl and radicle is somewhat similar to that shown in Table I., namely, the negative charges gave for the hypocotyl 12.5 per cent. increase, for the radicle 16.4 per cent., while the positively charged seeds gave 26 per cent. for the hypocotyl and 43.42 per cent. for the radicle. Here, too, the positively charged seeds gave the largest average increased growth for both hypocotyl and radicle.

The experiments shown in Tables I. and II. are typical of others made along the same line, although we have repeatedly found that it is quite an easy matter to charge the seed too strongly and obtain retardation in growth. Instead of using ten-minute sparks to stimulate the seeds in the electro-germinator we have found by subsequent experiments that it is better to use only two or three, and these should be very slight charges. The stimulating effect of positive and negative charges on germination is similar to that on growth, but there is no evidence to show that the treatment affects the germinating capacity of seeds, and we have stimulated many thousands. The following table gives an average of four experiments with seed germination.

TABLE III. — *Showing Results of the Stimulating Effects of Positive and Negative Electrical Charges on Germination of Lettuce Seed (Lactuca sativa, L.).*

[Average of four experiments, 20 seeds being used in each treatment; otherwise the same experiments as shown in Tables I. and II.]

TREATMENT.	Total Number of Seeds.	NUMBER OF SEEDS GERMINATED IN —		
		24 Hours.	48 Hours.	72 Hours.
Normal,	80	19	35	64
Negative charge,	80	24	51	64
Positive charge,	80	48	69	72

From the experiments in Table III. it will be observed that germination is accelerated to a considerable degree by electrical stimulation, and that the positive caused greater acceleration than the negative charges, corresponding to the effects produced on the growth of the hypocotyl and radicle. In Fig. 1 is shown a diagrammatic representation of seedlings based upon an average of all the data given in Tables I. and II. It will be noticed that the radicles are stimulated more in all cases than the hypocotyls, this difference being more pronounced in the positively than in the negatively charged seedlings. In Fig. 2 are shown

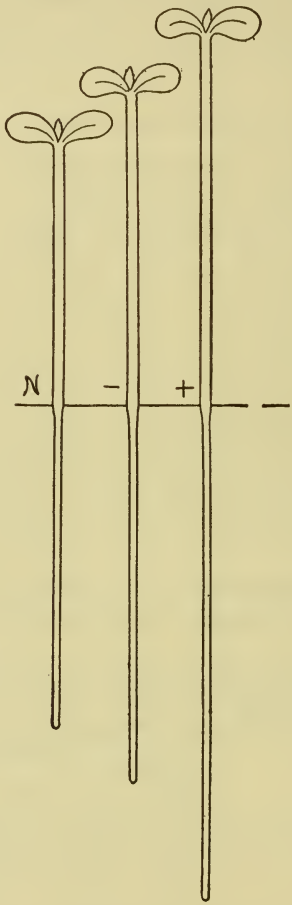

Fig. 1.—Showing the effects of positive and negative electrical charges on the growth of lettuce and radish seedlings. Average of the results in Tables I. and II.

the effects of positive and negative charges on the growth of radish seedlings, being an average of two experiments. Fig. 3 shows the effects of positive and negative electrical charges on the growth of lettuce seedlings, being an average of three experiments.

It is not surprising that the radicles show greater development than the hypocotyls since the former develop first, and for this reason electrical stimulation would show itself more prominently in the radicle than the hypocotyl. Accelerated germination is

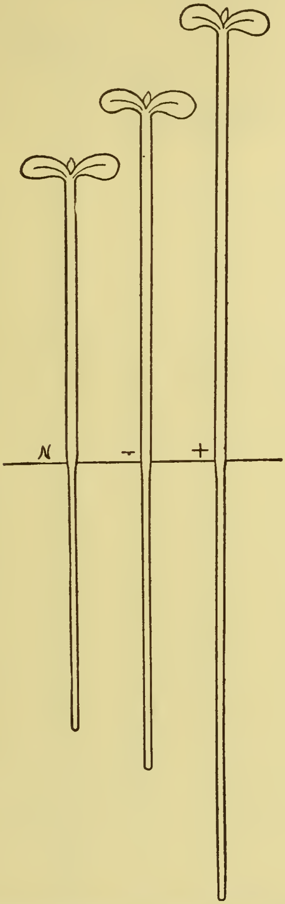

Fig. 2. — Showing the effects of positive and negative electrical charges on the growth of radish seedlings. Average of two experiments.

shown more prominently in the positively than the negatively charged seeds. The positive charges stimulated both the hypocotyl and radicle more than the negative charges, and if the difference in the time of the development of the hypocotyl and radicle is taken into consideration it will be seen that there is little or no difference in the effects of the stimulation on the radicle and hypocotyl.

The effects of a series of charges from a static machine last only two or three days, the maximum effect of the stimulus showing itself shortly after stimulating.

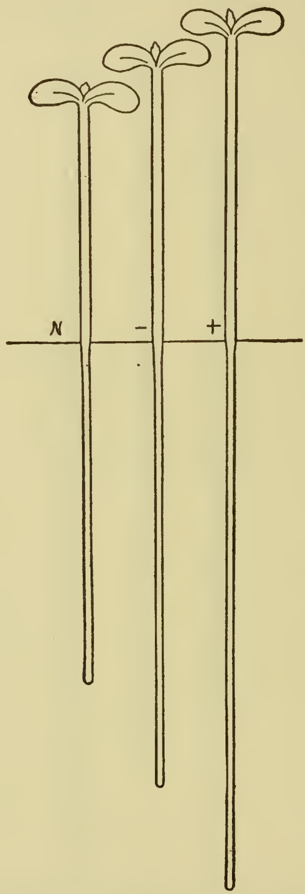

FIG. 3. — Showing the effects of positive and negative electrical charges on the growth of lettuce seedlings. Average of three experiments.

The roots and stems of plants react positively and negatively to various stimuli such as are afforded by gravity, light, moisture, chemical substances, etc. It is also well known that the same stimuli will induce reactions of an exactly opposite character in the same organism, or even in the same organ. Usually, however, the stem reacts one way and the root another; for example, roots are positively and stems negatively geotropic. It is well known that the anode and cathode behave quite differently and characteristically when acting on metals, etc. Similar characteristic differences might be expected in the reaction of plants. Where trees have been injured by burning from direct current wires the extent of the injury is about 90 per cent. greater near the positive than near the negative point of contact, showing that the positive electrode is more disastrous to plant tissue.

In our various experiments, where we have employed electricity as a stimulus, we have never observed any difference in the behavior of plants in close proximity to either positive or negative electrodes, although in some of our previous experiments with radish plants, made some years ago, in which the plants were grown in soil, we found that the tops responded much more freely to electrical stimulation than the roots when acted on by galvanic currents. We found, however, that by substituting lettuce, which is cultivated exclusively for the leaves, the leafy part responded more freely to electrical stimulation than did the underground part or fleshy roots of radish.

On the other hand we found in our experiments in growing radishes in tightly closed, insulated glass cases, the atmosphere of which was charged each day positively to an electrical potential averaging 150 volts, that the reverse was true, viz., the roots or underground parts were stimulated more than the leaves or tops. The soil itself is generally negative, and the atmosphere positive; the roots therefore are accustomed to a negatively charged, and the aerial parts to a positively charged, environment.

In the decomposition of water by electrolysis it is assumed that the oxygen is in a negatively electrical condition and is attracted by the positive pole, while the hydrogen is in a positively electrical condition and is attracted by the negative pole. Metals are described as electro-positive elements, and are usually attracted to the negative pole, while the nonmetals are spoken of as electro-negative elements and are attracted to the positive pole. In the experiments just cited with radishes, which were grown in insulated glass cases where the atmosphere was charged positively, the leaves were stimulated least and the roots most; that is, the roots, which are normal to an environment negatively charged, were stimulated most by the positive charges. In the case of galvanic stimulation of roots it is known that weak currents induce negative bendings; that is, towards the cathode, while strong currents induce positive bendings, or towards the anode. In the negative reactions, which are induced by weak currents, there is a greater growth on the side of the root towards the positive pole or anode than towards the negative pole or cathode, but there is some doubt as to whether the reverse holds true for positive galvanotropic bendings. In the case of positive galvanotropic bendings Brunchorst has pointed out that the reaction is the result of pathological conditions, and it is maintained that bendings towards the anode are due to injury of the delicate root tip by the strong currents employed. This interpretation of the phenomena appears to harmonize with the results which we have obtained with positive and negative electrical charges on plants. The positive charges give the greatest and the negative the least accelerated growth. Since the positive charges stimulate mostly those cells on the surface of the root nearest to the anode, those cells would grow more rapidly and the normal downward direction of the root would be directed towards the negative pole or cathode. The burning effect on trees from positive and negative electrodes is similar, the positive producing the greater injury, and this coincides with our results obtained by using strong positive static charges on plants, viz., strong positive static charges cause a greater degree of retardation and injury than negative charges. The use of strong positive currents would result in the cells on the anode side of the root being retarded, hence bendings towards the anode would result.

To summarize we might state that the effect of positive and negative stimulation on plants offers a mechanical explanation of the positive and negative galvanotropism in roots. When plants are grown between positive and negative electrodes, each electrode exerts a characteristic influence on the root, and that surface of the root nearest to the anode will be affected according to the nature of the stimulus on that side; and conversely, that part of the root adjacent to the cathode will be affected according to the nature of the stimulus characteristic of that pole. When weak currents are employed the positive current or anode gives the greatest stimulation to those cells on the anode side of the root, and induces bendings in the root towards the negative pole or cathode. On the other hand, when strong currents are employed the positive current induces bendings towards the anode due to a retardation or injury to the cells on the side of the root towards the anode.

From our various experiments in electrical stimulation we are of the opinion that increasing the electrical tension or potential of the atmosphere, either by the use of static charges or from high tension wires, gives rise to a greater degree of stimulation than passing the current through the soil. Alternating currents appear to be superior to direct currents in stimulating plants. There is, however, the question of increasing the number of micro-organisms in the soil by electrical stimulation as well as the importance of nitrification and nitrogen fixation resulting from electrical stimulation, a line of research on which we are now engaged and on which we hope to report later.

ELECTRICAL RESISTANCE OF TREES.

G. E. STONE AND G. H. CHAPMAN.

It has long been known that trees offer considerable resistance to electric currents, but at the time our experiments were undertaken we were not aware that much attention had been given to this subject, especially regarding the influence of certain factors on resistance. The effect of lightning strokes indicates that trees possess relatively high resistances, and that there is a difference in the resistance of their various tissues. Little or no data appear to be available concerning this subject, nor so far as we know concerning the resistance of different trees at different seasons of the year.

In a former publication [1] we have given the results of some observations on the electrical resistance of trees, and the numerous data which we obtained by passing electrical currents through trees and various plants helped to give us some idea of their electrical resistance. Our object in carrying on these experiments was to determine whether there were any variations in the electrical resistance of different sides of a tree trunk as regards points of the compass. Originally it was our purpose to learn whether the electrical resistance varied greatly from month to month during the year, and if so, what causes led to this variation; in fact, to study the effects of various influences on electrical resistance. But the temporary suspension of our work, made necessary by moving from one laboratory to another, and the change of assistants interrupted our plans somewhat, and the original idea of our investigation was not followed.

It might be supposed that since the several sides of a tree are exposed differently to light and heat they would show slight

[1] Injuries to Shade Trees from Electricity, by G. E. Stone, Mass. Agr. Exp. Sta., Bul. No. 91. 1903.

variations in temperature, and that there would also be differences in the flow of sap and the translocation of plastic substances. That this is true is shown by the fact that trees make more growth on one side than on another, the more or less localized photosynthesis causing a greater transmission of plastic substances on that side.

Some of these experiments were begun in 1907, a part of the observations being made by Mr. N. F. Monahan, our former assistant, while others were obtained in 1909 and later by Mr. G. H. Chapman.

These resistances were determined by a Weston Electric Company combination bridge, rheostat and galvanometer, provided with a battery of 6 or 8 large Samson cells.

TABLE I. — *Showing Daily Records of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), April 7–26, 1907. Resistances taken on the North, South, East and West Sides of the Tree at Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Temperature.	East.	South.	West.	North.
April 7,	35	19,000	18,840	22,000	22,000
8,	33	19,500	19,000	23,400	23,000
9,	31	23,000	23,000	23,000	24,000
10,	35	23,000	23,000	23,000	23,500
11,	39	22,000	21,500	23,000	23,500
12,	38	21,000	21,000	22,500	23,000
13,	37	21,500	21,000	22,900	23,000
14,	42	20,000	19,400	22,000	22,000
15,	39	19,100	18,900	21,200	20,800
16,	40	19,500	19,000	20,000	21,500
17,	40	20,500	20,500	21,500	21,000
18,	39	21,500	23,000	21,000	17,000
19,	34	21,000	20,000	19,000	21,000
20,	37	18,000	18,300	21,300	20,800
21,	36	19,500	19,500	22,000	21,000
23,	52	15,000	14,600	16,300	16,000
24,	49	16,000	17,300	17,000	16,500
25,	52	16,900	17,200	17,400	19,100
26,	56	15,700	15,000	16,000	18,200
Average,	–	19,857	19,055	19,310	20,890

TABLE II. — *Showing Daily Records of Electrical Resistance (in Ohms) of Elm (Ulmus Americana, L.), April 7–26, 1907. Resistances taken on the North, South, East and West Sides of the Tree at Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Temperature.	East.	South.	West.	North.
April 6,	35	29,000	29,000	29,500	29,000
7,	35	28,200	28,000	29,000	29,400
8,	33	29,000	28,500	29,500	29,500
14,	42	25,000	25,000	26,500	23,000
15,	39	25,500	26,500	26,000	26,000
16,	40	26,000	23,500	26,500	27,000
17,	40	26,000	29,000	25,000	23,000
18,	39	25,000	30,000	27,000	25,000
19,	34	25,600	32,000	24,900	24,200
20,	37	25,000	29,000	27,800	24,000
21,	36	25,000	29,900	28,000	25,000
23,	52	23,200	26,200	22,500	21,000[1]
24,	49	19,600	26,000	22,100	18,000
25,	52	22,000	26,000	23,000	20,000
26,	56	19,000	21,400	19,300	19,700
Average,	–	24,666	27,466	25,777	25,253

The data shown in Tables I. and II. give the electrical resistance of a maple and elm tree covering a period of nearly one month in the spring, when there was an occasional flow of sap. The elm was a large tree, over 2 feet in diameter, and the maple was nearly as large. In both cases the electrodes, which were about 3 inches long and made of galvanized iron nails, were driven through the bark and into the wood. These were connected by solder with insulated copper wires leading to a combination bridge, from which the readings were made. The batteries consisted of half a dozen cells employed to take the readings. In these experiments the electrodes were 10 feet apart on the north, south, east and west sides of the trees. The lowest electrodes were placed about 2 feet above the ground, and the highest about 12 feet.

[1] Warm.

By comparing the results given in these tables it will be seen that the resistances obtained from the north, south, east and west sides of the tree showed some variation from day to day, and also on different sides of the tree. In the maple a slightly higher average resistance was shown on the north side of the tree than on any other side, followed by the east, west and south sides.

In the case of the elm (Table II.), however, the highest average resistance was shown on the south side for the same period, this being followed by the west side, while the east side showed the least resistance. The resistance in both cases showed a tendency to decrease towards the latter part of April, when the temperature increased, as is shown by a comparison of the mean daily minimum and maximum temperature records which were taken from the station's meteorological observatory located nearby, and which are given in both tables. The highest average resistance for the maple was given on the 9th of April, when there was the lowest mean temperature. The highest average resistance given by the elm occurred on April 6 and April 8 (the records were not taken on the 9th), while the lowest average resistance for the maple occurred April 23, during one of the highest mean temperature days. The lowest average resistance for the elm occurred April 26, which date gave the highest mean temperature.

TABLE III. — *Showing Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), covering a Period of Nearly Three Months. Resistances taken on the North, South, East and West Sides of the Tree about Midday.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

DATE.	Temperature.	East.	South.	West.	North.
April 7,	35	19,000	18,840	22,000	22,000
14,	42	20,000	19,400	22,000	22,000
21,	36	19,500	19,500	22,000	21,000
26,	56	15,700	15,000	16,000	18,200
Average for month,	–	18,550	18,185	20,500	20,800

Table III. — *Concluded.*

Date.	Temperature.	East.	South.	West.	North.
May 8,	58	18,500	21,000	19,000	23,000
14,	68	14,000	14,600	15,000	16,000
21,	46	24,000	23,600	23,000	33,000
28,	45	27,800	23,000	29,600	26,000
Average for month,	–	21,075	20,550	21,650	24,500
June 4,	55	18,600	19,100	23,600	21,700
12,	59	21,000	22,000	23,900	23,000
Average for month,	–	19,800	20,550	23,750	22,350
Average for three months,	–	19,775	19,761	21,883	22,550

Table IV. — *Showing Electrical Resistance (in Ohms) of Elm (Ulmus Americana, L.), made Weekly and covering a Period of Nearly Three Months. Resistances taken on the North, South, East and West Sides of the Tree.*

[Electrodes 10 feet apart. Mean daily temperatures given in degrees F.]

Date.	Temperature.	East.	South.	West.	North.
April 7,	35	28,200	28,000	29,000	29,400
14,	42	25,000	25,000	26,500	23,000
21,	36	25,000	29,900	28,000	25,000
26,	56	19,000	21,400	19,300	19,700
Average for month,	–	24,300	26,075	25,700	24,275
May 8,	58	17,200	18,000	16,400	19,000
14,	68	10,800	11,200	11,000	12,600
21,	46	13,000	16,300	16,000	18,900
28,	45	11,100	17,500	15,900	19,000
Average for month,	–	13,025	15,750	14,825	17,375
June 4,	55	9,000	13,000	12,000	12,300
12,	59	6,300	15,000	12,000	11,700
Average for month,	–	7,650	14,000	12,000	12,000
Average for three months,	–	14,992	18,608	17,508	17,883

The data in Tables III. and IV. cover weekly observations extending over a part of three different months, the same trees being used as in the preceding experiments. The results shown in these tables present similar features to those in the preceding ones.

The lowest average resistance during any single day for the maple occurred May 14, when the temperature was highest, while the highest average resistance was on May 28, when the temperature was low, but not the lowest. The average resistance for the different sides of the tree for the whole period was the highest on the north side, followed by the west, east and south sides. For the elm the lowest average resistance for a single day was shown on May 14 and June 12, days when the temperature was highest. The highest average resistance shown corresponds to the lowest temperature, which was recorded on April 7. The average resistance for the different sides of the elm during the whole period was the highest on the south, followed by the north, west and east sides.

The experiments shown in Table V. were supervised by Mr. Chapman during the spring of 1909. The resistances were obtained from a large maple tree located near our laboratory which was a different specimen from the one used in the preceding experiments. The tree was a typical rock maple of this region, in fairly vigorous condition, slightly over 2 feet in diameter at the base. The resistance readings were obtained from a combination bridge, as in previous experiments, and a battery of 8 Samson cells was used. The electrodes consisted of galvanized iron nails about 3 inches long, which were driven through the bark into the wood for about 1½ inches. The part of the electrodes extending beyond the surface of the wood was enclosed within porcelain insulators. Before the electrodes were inserted into the tree at the various points a part of the bark extending to the wood was removed with a chisel for a space of 2 inches. The electrodes were 8 feet apart in each case, the lower ones being placed about 2½ feet from the ground, and the highest about 10½ feet, hence the resistances were taken from that part of the tree between 2½ and 10½ feet of the trunk. The wires, 8 in all, were connected with the electrodes by means of solder and were run into the laboratory about 50 feet away, all the readings being taken under cover. The resistances were read three times each day, viz., at 8 A.M., 12 M. and 4 P.M. from March 18 to March 30, inclusive.

TABLE V. — *Showing Daily Records of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh), March 18–31, 1909. Resistances taken Three Times Daily on the North, South, East and West Sides of the Tree.*

[Electrodes 8 feet apart.]

Date.	8 A.M.				12 M.				4 P.M.			
	North.	West.	South.	East.	North.	West.	South.	East.	North.	West.	South.	East.
March 18,	138,500	147,500	157,700	136,300	79,980	82,670	105,900	33,980	73,100	84,540	93,200	74,200
19,	56,460	63,500	76,500	62,000	37,900	38,760	44,140	36,470	35,900	34,100	36,500	35,600
20,	121,000	126,400	86,870	68,850	99,700	85,400	62,000	68,200	77,988	54,360	46,530	62,120
21,	182,000	170,000	86,200	58,180	78,500	53,100	42,000	35,900	43,100	30,000	32,750	33,800
22,	52,100	45,800	45,700	38,360	38,640	33,650	34,750	31,100	34,350	30,000	31,050	29,950
23,	32,100	32,100	31,680	28,990	28,890	28,870	28,600	26,980	29,910	29,800	30,000	27,950
24,	31,580	30,000	30,070	25,850	26,680	26,250	26,500	23,990	33,800	22,050	23,700	22,800
25,	69,860	73,700	58,960	52,870	66,400	49,980	37,650	35,600	37,100	26,000	32,100	31,000
26,	38,700	38,600	50,100	40,000	30,390	30,320	37,000	30,200	29,110	29,100	33,100	25,000
27,	29,100	32,080	37,000	26,400	23,100	27,500	29,600	23,000	28,000	29,760	32,100	27,900
28,	40,100	46,300	48,400	38,500	40,000	44,000	47,050	37,500	29,910	31,000	39,100	29,000
29,	37,000	–	38,500	34,700	35,400	–	37,750	29,400	32,000	–	31,400	28,700
30,	51,000	56,000	60,000	41,000	39,000	43,050	47,000	36,050	38,000	38,000	47,000	38,000
Averages,	67,654	71,832	62,130	50,155	48,044	45,300	44,610	37,567	40,174	36,560	39,580	35,847

TABLE VI. — *Showing Temperature Conditions, etc., during the Month of March.*

Date.	8 A.M.			12 M.			4 P.M.		
	Weather.	Sap.	Temperature.	Weather.	Sap.	Temperature.	Weather.	Sap.	Temperature.
March 18,	Overcast, cool, no wind.	No flow.	37.0	Overcast, snow, no wind, cold.	No flow.	35.0	Overcast, sleet, no wind, cold.	No flow.	30.0
19,	Overcast, cool, no wind.	No flow.	34.0	Fair, cold, no wind.	No flow.	39.0	Fair, sunshine, windy, cold.	No flow.	35.5
20,	Fair, sun, wind.	No flow.	41.0	Fair, cool, no wind.	No flow.	37.5	Overcast, cold, no wind.	No flow.	32.0
21,	Clear, sun, slight wind.	Slow flow.	36.5	Clear, sunshine, no wind.	Flow.	46.5	Fair, cool, no wind.	No flow.	35.5
22,	Clear, sun, wind west.	Flow.	46.5	Clear, sunshine, wind west.	Flow.	48.5	Clear, cool, wind west.	Flow.	45.5
23,	Clear, sun, wind southwest.	Great flow.	45.5	Overcast, warm, no wind.	Great flow.	53.5	Overcast, rain, no wind.	Flow.	47.0
24,	Clear, sun, wind southwest.	Great flow.	50.0	Fair, sun, wind southwest.	Great flow.	55.5	Fair, warm, wind southwest.	Flow.	52.0
25,	Clear, sun, wind.	No flow.	35.0	Clear, sun, wind.	Flow.	35.5	Clear, cool, wind.	Great flow.	35.0
26,	Overcast, cold, windy.	Slow flow.	41.0	Clear, cold, high wind.	Flow.	53.5	Fair, cool, wind.	Great flow.	58.0
27,	Cloudy, warm, no wind.	Slow flow.	53.0	Fair, warm, no wind.	Flow.	64.5	Fair, warm, no wind.	Flow.	54.5
28,	Cloudy, warm, no wind.	No flow.	44.0	Rain, cool, no wind.	Flow.	46.5	Clear, warm, wind.	Flow.	61.0
29,	Rain, cool, no wind.	No flow.	47.5	Rain, cool, no wind.	No flow.	48.5	Rain, cool, no wind.	Flow.	46.5
30,	Clear, cool, moderate wind.	Flow.	42.0	Clear, cool, moderate wind.	Flow.	45.0	Clear, cool, moderate wind.	Flow.	44.0

The resistances in Table V. were taken in March and represent considerably higher readings than those given in the preceding tables, although there the distance between the electrodes was 10 feet, while in the readings shown in Table V. the distance was only 8 feet. The higher resistance is due, as shown in this table, to the cutting away of some of the outer tissue around the electrodes, a feature which will be discussed later; and also in part to the measuring of the resistances in March instead of in April, May and June, as was the case with the preceding observations.

The results obtained from these readings, however, are somewhat similar to those given in the preceding tables; the highest resistance occurring on cold days and the lowest on warm days. The highest resistance shown in any one observation was on March 21, at 8 A.M., on the north side of the tree. The temperature for this same period was 36.5° F., which is one of the lowest recorded. The lowest resistance was on the 24th of March, at 4 P.M., on the east side of the tree following one of the high temperature periods. The highest average resistance for any single day occurred March 18, and this coincides with the lowest average temperature. The lowest average resistance for any single day occurred March 24, followed by March 27, which were the two warmest days. The average temperature records for both days, taken at the time of the observation, was as follows: March 24, 52.5° F., the average temperature for the 27th being 57.3° F. The mean temperature (maximum and minimum) on this date was 38, and that for March 27 was 41. By referring to Table VI. it will be observed that March 24 was clear and sunshiny, with the wind southwest, and March 25 was fair and warm, and occasionally cloudy, with no wind. The average resistance for all periods was the greatest in the morning, followed by those given at 12 M. and 4 P.M. At 8 A.M. it was 62,942, at 12 M., 43,880, and at 4 P.M., 38,040 ohms.

Table VII. — *Showing Maximum and Minimum Resistances based on the Averages obtained from the North, South, East and West Sides of Maple Tree (Acer saccharum, Marsh) for Different Periods during the Day, March 18–31, 1909.*

8 A.M.	West, highest,	71,832
	North,	67,654
	South,	62,130
	East, least,	50,155
12 M.	North, highest,	48,044
	West,	45,300
	South,	44,610
	East, least,	37,567
4 P.M.	North, highest,	40,174
	South,	39,580
	West,	36,560
	East, least,	35,847

This table is adapted from Table V. It will be noticed that the highest average resistance was obtained on the west side for the 8 A.M. observations, and the north side gave the highest average resistance for the two following observation periods, viz., at 12 M. and 4 P.M. The lowest average resistance from March 18 to 31 occurred on the east side for each of the three periods. The average daily resistance for the whole period — 9 A.M. to 4 P.M. — was as follows: north side, 51,957; west side, 51,230; south side, 48,773 and east side, 41,189. These results coincide with those given in the preceding tables, that is, the north side shows in general the highest resistance.

Table VIII. —*Showing Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh) from March 18-31, 1909. Resistances taken at 8 A.M., 12 M. and 4 P.M. on the South Side of the Tree.*

[Electrodes 8 feet apart. Temperature same as in Table VI.]

Date.	8 A.M.	12 M.	4 P.M.
March 18,	46,890	27,700	27,200
19,	23,350	20,400	20,900
20,	42,320	26,830	23,840
21,	53,900	22,510	19,300
22,	25,800	19,820	18,300
23,	18,790	16,700	16,500
24,	18,000	17,150	16,540
25,	39,690	21,000	15,600
26,	23,300	17,200	14,900
27,	18,300	15,700	15,100
28,	25,400	23,600	14,950
29,	20,200	16,800	16,000
30,	29,000	20,600	19,000
Averages,	29,610	20,462	18,318

The resistances given on the south side of the same maple tree as in Table V. are given here; in this case, however, the electrodes were attached differently, being driven through the bark into the wood, and none of the tissue around them was cut away.

The resistances given here run considerably lower than those shown in Table V. for the same tree for the same period, due to the fact that the electrodes were inserted differently into the tree. If we compare the average resistances obtained from the two experiments, those in Table VIII. and those in Table V., we obtain the following for the same period, with the same tree. The average resistances on the south side of the tree shown in Table V. are as follows for the three different periods: 8 A.M., 62,130; 12 M., 44,610; 4 P.M., 39,580, while those given in Table VIII. are 29,610, 20,462 and 18,318 ohms.

The higher resistance shown in Table V. represents not only that of the cambium, but of some of the wood as well.

The highest resistance readings were obtained at 8 A.M., while the lowest were obtained at 4 P.M. The midday temperatures were highest, as might be expected, with little difference in the morning and afternoon.

The after effects of the higher temperatures influenced the resistances taken at 4 P.M., since the tree, being generally exposed to the sun's rays for a considerable period in the day, would become warmer, and the heat would be retained for some time. It was thought desirable to make one experiment when the observations could be recorded hourly. The results of these observations are shown in Table IX.

TABLE IX. — *Showing Record of Electrical Resistance (in Ohms) of Maple (Acer saccharum, Marsh) for One Day, the Records being taken hourly, April 27, 1907.*

[Electrodes 10 feet apart.]

TIME.	East.	South.	West.	North.	Weather.	Remarks.	Temperature (Degrees F.).
6.15 A.M.,	24,700	23,100	22,400	26,000	Wind, cold.	Sap not started.	39
7.15 A.M.,	24,600	23,100	22,300	25,900	Wind, cold.	Sap not started.	40
8.15 A.M.,	24,600	23,000	22,200	26,000	Wind, cool.	Sap just started.	44
9.15 A.M.,	24,500	20,200	21,000	25,400	Wind, cool.	Sap flowing more freely.	48
10.15 A.M.,	23,500	18,600	19,000	24,700	Light wind, warm.	- - -	52
11.15 A.M.,	22,100	19,500	18,100	23,600	Light wind, warm.	- - -	55
12.15 P.M.,	21,200	18,800	17,700	22,500	Light wind, warm.	- - -	58
1.15 P.M.,	20,000	17,300	16,800	22,200	Calm, warm.	- - -	59
2.15 P.M.,	18,800	17,000	16,600	21,800	Calm, warm.	- - -	59
3.15 P.M.,	19,300	18,300	16,800	22,500	Calm, warm.	Sap flowing less freely.	60
4.15 P.M.,	19,800	18,700	16,800	22,500	Calm, warm.	- - -	60
5.15 P.M.,	20,000	19,400	16,900	22,700	Calm, cool.	Sap ceased flowing.	59
6.30 P.M.,	20,000	19,600	16,900	23,000	Calm, cool.	- - -	57
Averages,	21,769	19,738	18,576	23,753			

The data obtained from hourly readings on the north, south, east and west sides of the tree are given in Table IX. These were taken from the same tree (rock maple) as the records shown in Table I., and while they were continued only for one day, they undoubtedly show typical variations which occur. The resistances given are for 10 feet of the tree trunk, and the day selected for the readings was free from clouds, the sun being quite bright throughout the day for this period of the year (April 27).

At times, however, a slight haze was present which affected to some extent the intensity of the light. The highest resistance was shown in the early morning, when the temperature was the lowest, and as it had become warmer the resistance decreased. The lowest resistance occurred at 2.15 P.M., after which time there was a slight increase in the resistance. It will be noticed, however, that the least increase in the resistance after 2 P.M. occurred on the west side of the tree, which received at that time the benefits of the heat from the sun's rays during the afternoon. On the other hand, the north, east and south sides showed a greater increase for this period, as they were more or less shaded from the sun's rays. The north side of the tree gave the highest average resistance, followed by the east, south and west sides. The lowest average resistance occurred on the west side of the tree.

Sap commenced flowing freely at 9.15, and at 2.15, the time of the lowest resistance, it had commenced to cease flowing. As is well known, there is a relationship between the flow of sap and temperature, but there is no indication from these observations or from any of our experiments that there is any relationship between resistance and flow of sap.

Experiments with Cut Branches of Trees.

A number of resistances were obtained from cut branches of maple trees by Mr. Chapman. These were taken when the trees were in a dormant condition, and in some cases when the buds were developing.

Experiment A.

A maple branch $1\frac{1}{2}$ inches in diameter and several feet long was used for this purpose. The branches showed slight bleeding at first. Heavy galvanized iron nail electrodes were driven into the branch 20 inches apart, and several half-hour readings were taken. The branches were left out of doors where the temperature varied only a few degrees, and at the time the readings were taken it was just above freezing. The results follow: —

	Ohms.
8.30 A.M.,	136,000
9.00 A.M.,	132,000
9.30 A.M.,	131,000
10.00 A.M.,	132,000
10.30 A.M.,	120,000

This experiment was repeated several times with approximately the same results, and is not conclusive as regards influences of temperature.

Experiment B.

The same branch of maple was kept in the laboratory for five days at a room temperature (about 70° F.), the only difference between this experiment and the one preceding being the fact that the electrodes were placed 1 foot apart instead of 20 inches. The readings obtained are as follows, taking half-hour periods: —

	Ohms.
8.30 A.M.,	72,000
9.00 A.M.,	72,000
9.30 A.M.,	74,000
10.00 A.M.,	75,000
10.30 A.M.,	77,000

Very little variation was shown in the resistances.

Experiment C.

A branch of another maple of about the same diameter as the preceding was cut under water and allowed to stand at room temperature for five days, when a fresh cut was made under water. During this time the leaves and flowers had started, and there was evidently some transpiration. The electrodes were 1 foot apart. The following readings were obtained: —

	Ohms.
8.30 A.M.,	64,400
9.00 A.M.,	65,000
9.30 A.M.,	68,000
10.00 A.M.,	67,000

It will be seen that these resistances were all ranged between 64,000 and 67,000, and coincide very closely with those given in Experiment B.

Experiment D.

Another experiment, using the same branch as was used in Experiment C, was undertaken, but in this case the water in which the branches stood was heated to a temperature ranging from 100 to 130° C. The readings were taken at half-hour intervals, with the following results: —

	Ohms.
9.30 A.M.,	67,000
10.00 A.M.,	68,000
10.30 A.M.,	67,500
11.00 A.M.,	67,600
11.30 A.M.,	73,000
12.00 M.,	72,000
1.00 P.M.,	72,000
1.30 P.M.,	71,000
2.00 P.M.,	69,000
2.30 P.M.,	70,000
3.00 P.M.,	73,000
3.30 P.M.,	75,000
4.00 P.M.,	76,000

The rise in temperature had little or no effect on the resistance. On the other hand, the readings in some cases were slightly higher.

Experiment E.

The same branch was used in this experiment. After standing over night and the water brought to room temperature a space of ½ inch down to the wood was removed halfway between the electrodes; in other words, the branch was girdled for this distance. The following readings were obtained: —

	Ohms.
8.30 A.M.,	122,000
9.00 A.M.,	121,000
9.30 A.M.,	124,000

all averaging not over 123,000. The results here show greatly increased resistances as the effect of girdling.

Experiment F.

The same branch was used here as in E, except the girdling was increased to 3 inches. The following readings were taken: —

	Ohms.
1.00 P.M.,	128,000
1.30 P.M.,	130,000
2.00 P.M.,	127,000
2.30 P.M.,	130,000
3.00 P.M.,	129,000

It will be noticed that these readings were slightly higher than those in Experiment E, due to girdling.

Experiment G.

The same branch under the same conditions was used for this experiment, except that the branch was completely girdled between the electrodes. The results follow: —

	Ohms.
8.30 A.M.,	150,000
9.00 A.M.,	151,000
9.30 A.M.,	150,000
10.00 A.M.,	150,000
10.30 A.M.,	149,000

It will be noticed that the readings obtained here are higher than in F or E, due to the greater girdling. These experiments demonstrate that the wood gives much higher resistance than the cambium, and shows that the resistance increased as the bark and cambium were removed. The highest resistances were given where there was the greatest amount of girdling. Even cutting away the bark for a distance of ½ an inch or more in each direction from the electrodes greatly increases the resistance. This is what occurred in the experiment shown in Table V., where the bark was cut away from the electrodes, whereas in experiments shown in Table VIII. for the same distance, and where no bark was removed, the resistances were much lower.

Experiment H.

In this experiment a freshly cut branch about 1 inch in diameter was used, and the bark cut away for a space of 1 inch around the electrodes, which were inserted 1 foot apart, as in the other experiments. The branch was placed in water at room temperature of from 68° to 70° F. The following results were obtained: —

	Ohms.
10.00 A.M.,	110,000
10.30 A.M.,	100,000
11.00 A.M.,	100,000
11.30 A.M.,	105,000

Experiment I.

The same branch was used as in Experiment II, and a fresh cut made under water, the water being heated for three hours at a temperature ranging from 149 to 150°. After three hours at this temperature the following readings were obtained: —

	Ohms.
1.30 P.M.,	140,000
2.00 P.M.,	135,000
2.30 P.M.,	138,000
3.00 P.M.,	142,000
3.30 P.M.,	150,000

It will be noted that the resistances were higher here than in the others, although the temperature of the water in the latter case was very much higher than in the former experiment.

Experiments with Small Plants.

Some experiments were made with small plants in the greenhouse in February to determine the electrical resistance. For this purpose we made use of tobacco plants in pots, the plants being 3 feet high. The results of these experiments, made by Mr. Chapman, follow: —

Table X. — *Showing the Electrical Resistance of a Tobacco Plant (Nicotiana tabacum, Linn.).*

[Resistance in ohms.]

Time.	Experiment I.	Temperature (Degrees F.).	Experiment II.	Temperature (Degrees F.).	Experiment III.	Temperature (Degrees F.).	Experiment IV.	Temperature (Degrees F.).
8.00	–	–	–	–	132,000	–	–	–
8.30	–	–	–	–	130,000	68	128,000	62
9.00	131,000	–	108,000	60	136,000	73	129,000	63
9.30	116,000	–	140,000	60	134,000	78	124,000	63.5
10.00	110,000	–	137,000	61	110,000	83	127,000	63
10.30	133,000	–	146,000	62	129,000	79	–	–
11.00	117,000	–	151,000	62	136,000	73	128,000	64
11.30	117,500	87	147,000	61	133,000	77	123,000	67
12.00	125,000	84	147,000	62	116,000	82	121,000	71
12.30	–	–	–	–	–	–	–	–
1.00	137,000	81	136,000	62	–	–	–	–
1.30	126,000	80.5	147,000	63	143,000	69	–	–
2.00	129,000	80.5	–	–	144,000	65	–	–
2.30	131,000	80	139,000	63	143,000	67	–	–
3.00	125,000	81	135,000	63	151,000	67	–	–
3.30	128,000	70	144,000	63	155,000	66	–	–
4.00	153,000	67	146,000	59	161,000	64	–	–
4.30	156,000	67	143,000	61	161,000	62	–	–
5.00	156,500	66	150,000	60	164,000	60	–	–

The object of the experiment was to determine what influence other factors might have on resistance, such as temperature, etc., but more particularly whether variations in temperature were discernible in resistance. The plants were under tolerably uniform conditions, although the temperature varied, as will be seen in the tables. Platinum electrodes were used, these being driven into the plant at a distance of 14 inches apart. One was driven in at the base and the other near the apex of the stem. There were no very marked coincidences between the changes of temperature and resistance in these experiments, but it should be remarked that the lowest resistance coincides with the highest temperature in Experiments I., II. and IV., while in Experiment III. there was little variation in temperature, although variation in resistance occurred. In averaging up the temperature and resistance for those periods where all the data are present it is found that there is a relationship between the temperature and the resistance. For example, it was found that the lowest temperature occurred on the last three periods, that is, from 4 P.M. to 5 P.M., and that the highest average resistance occurred during these periods also. On the other hand, the lowest average resistance coincides in a general way with those periods which gave the highest temperature readings.

Relation of Electrical Resistance to Flow of Sap.

Some observations were made on a rock maple in regard to the relation of electrical resistance to the flow of sap, but these were not extensive and lasted only a few days. The following results were obtained by collecting sap on the north, south, east and west sides of the tree. The amount of sap represents the amount of flow between 9 A.M. and 12 M., and 12 M. and 4 P.M., but the table gives the total amount obtained as well as the average resistances for the whole period.

	North.	South.	East.	West.
Average resistance, ...	34,720	40,340	32,217	37,140
Total sap flow in cubic centimeters, .	5,945	6,180	5,820	5,150

The highest average resistance and greatest sap flow occurred on the south side of the tree. The sequence of the average resistance was as follows: north, south, east and west, and that for the sap flow, south, north, east and west. Our records, moreover, showed that sap flowed more freely in the morning than in the afternoon, also that the average resistance was higher in the morning than in the afternoon. Since these observations were not prolonged the results are not conclusive, but we do not believe that electrical resistance is affected materially by sap flow. Since our resistance readings were obtained from the trees offering the least resistance, which is no doubt in all cases the cambium layer, it is questionable whether sap flow, which is characteristic of the woody tissue, would affect our results.

The flow of sap, as is well known, is influenced by various conditions, a very important one being night temperature, as well as the conditions which prevail during the day. Temperature records were taken for the same period, but there was little or no direct relation between the temperature of this period and the sap flow. In all cases the air temperature was at freezing or below this point during the night, while in the daytime it ranges from 43 to 57°.

Jones, Edson and Morse [1] found that the maximum yield of sap occurred quite generally between the hours of 9 A.M. and 12 M. They also maintain that on a typical sap day the tree will yield more sap and sugar on a southern exposure than on any other, while on a cloudy day, when all the sides of the trees are subject to a uniform temperature, there is little or no difference in the sap flow as regards the cardinal points of the compass. It is known that the percentage of sugar varies in the tissues of a tree from day to day, and it is doubtful whether this variation in the chemical composition of the sap, or even the amount of flow, would affect resistance even if our observations were confined to the woody tissues alone. This opinion is based on laboratory experiments.

Electrical Resistance of Different Tissues.

It might be expected that there would be found considerable difference in the electrical resistance of various trees, as well as of the different tissues found in trees. The heartwood, sapwood, cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as would seem from various observations on lightning discharges. The minute burned channel found in trees caused by comparatively insignificant lightning discharges follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

[1] The Maple Sap Flow, by C. H. Jones, A. W. Edson and W. J. Morse, Vt. Agr. Exp. Sta., Bul. No. 103, December, 1903.

The resistance, however, may equal 25,000 ohms more or less, in 10 feet of the trunk of an elm or maple tree. This constitutes a comparatively high resistance. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the electrical resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. Chapman found the resistance of a freshly cut rock maple stem, 1½ inches in diameter, to be 70,000 ohms when intact, *i.e.*, with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart.

Some experiments which have been made indicate that next to the cambium the phloem has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when this is moist, as during rain storms, the resistance may be somewhat decreased. When leakage occurs, owing to grounding of the electric currents from high tension wires in moist weather, burning results, but this is due to the presence of a film of water on the bark, and what is termed "arcing" occurs. The resistance obtained from an elm tree, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloem we obtained 11,300 ohms resistance. When driven ¼ inch into the wood the resistance was 98,700 ohms. The outer bark gave 198,800 ohms resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It must not be understood, however, that these readings gave the electrical resistance of 10 feet of the various tissues enumerated except in the case of the cambium, since if these tissues were isolated the resistance would be much greater. They show that there is much difference in the resistance of different tissues, but in all cases here we obtained merely a resistance of the cambium, together with that of a part of the other tissues, which the current had traversed from its various points of entrance to the cambium.

It is quite evident from our observations on the resistance of trees that the cambium gives the least resistance, the phloem next, and it is not at all unlikely that in some trees there may be some variation in this respect.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms, and the resistance given by a tobacco plant in which the distance between the electrodes was only 14 inches, was much higher (110,000 to 165,000 ohms) than that shown by trees. In the case of the pear tree, which was in a large box, filled with soil, one of the electrodes (metal plate) was in contact with the small roots, the other being in contact with the apex of the plant.

The presence of water and various salts undoubtedly plays a rôle in resistance, and it might be expected that the various plastic substances in the plant would influence resistance.

The path of a current in a tree, as already stated, follows the line of least resistance, but this line may not necessarily be a straight one between one electrode and another. Although in many lightning strokes a straight line is generally followed, we have seen instances where the whole cambium zone was involved, and when the tissue in a tree is twisted the discharge will follow the tissue. A lightning discharge may therefore completely circle a tree trunk, passing from the apex of the tree to the ground. In earth discharges the path follows up the trunk and is generally diverted to the branches, often causing them to split. When heavy lightning discharges occur and the tissues of the tree become shattered, as is often the case, the line of least resistance seems to be an unimportant factor, and in this respect the electric discharges resemble an avalanche in their behavior. In some of our experiments, where trees were connected with wires carrying relatively high currents and the electrodes were 1 foot apart vertically, all of the injury was done by burning on one side of the tree in close proximity to the electrodes, but even here the burning of the tissue covered an area of more than 1 foot in width on the trunk. Burning under these conditions, however, occurred only when the bark of the tree was moist, and was not caused by a decrease in resistance in the tissue, but by the presence of a film of water, which is a far better conductor, on the bark, which became heated and killed the underlying tissue. In the case of some large trees which we observed and which had been killed by direct currents from trolley wires, the tissue was as a rule affected nearly equally around the entire trunk of the tree, although the point of contact was on one side of the tree. In both cases it was a heating of the film of water on the trunk caused by the escaping electric current which caused the injury.

The cambium ring is very insignificant in size, practically 1/500 to 1/1000 in diameter, and even on a large tree the total area is small. In all probability it is the protoplasm itself which offers the least resistance to the transmission of an electric current; and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was contiguous or there existed continuity, the strands would be so very small that they would undoubtedly offer some resistance. Whatever conditions prevailed trees showed relatively high electric resistances, a feature which is no doubt of some biological importance as trees are often struck by lightning. The high resistance of trees, therefore, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance they would be much more subject to injuries from burning from lightning strokes, and would be more seriously affected by currents from high tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low or even high tension wires except that produced by grounding when the bark of the tree is moist. Any escaping current which can be transmitted even through the least resistant tissue is likely to be insignificant.

The amount of current necessary to kill a plant depends upon its size, etc. A current equal to .01 amperes may be sufficient to kill a small plant, whereas a current ten times as great would cause no perceptible injury to a large tree even when passed through the tissue for months. The higher resistance shown by small branches or woody stemmed plants may possibly be due to the presence of less conductive tissue, whereas in a tree the conductive zone, if we include the phloem, is larger.

It is known that there are minute currents of electricity in plants, but we have never noticed their effects on our galvanometers nor have we detected them by the use of a milliammeter. Trees frequently become charged with electricity, and sparks are given off from the apices of the leaves. Vegetation in general responds quickly to electrical stimulation, and trees undoubtedly play an important part in equalizing the differences in electrical potential between the atmosphere and earth. In this respect conifers appear to behave differently from deciduous trees, and in our experiments we have found that the atmospheric electrical potential under thick conifers was the same as that which characterizes the earth.

Relationship of Electrical Resistance to Other Factors.

We had little or no opportunity to observe the effects of winds, if such exist, on electrical resistance. Most of our records were taken while the tree was in a dormant condition. In some cases the trees were well protected from the winds. It is known that transpiration is increased by wind, and the movements of water in the tissues of the tree are accelerated. No relationship, however, between the wind and electrical resistance has been noted by us in comparing the records of the local meteorological station with our data, neither was there any specific relationship observable between barometer pressure and electrical resistance. A careful study of the humidity conditions, also, did not seem to affect the electrical resistance so far as we could observe. Aside from the temperature effects coincident with light intensity no special changes in resistance were observable except such as would naturally follow from the variations in temperature.

Influence of Temperature on Resistance.

The most important factor which we have observed as influencing the electrical resistance of trees is temperature. The effects of temperature on various metals give rise to an increased resistance, whereas plant tissues show a greatly reduced resistance when heated.

Our numerous experiments in subjecting seeds to electric currents have shown that when they have been soaking in water for some hours and are quite moist, and a relatively strong current is passed through them, the resistance is largely decreased owing to the development of heat, and the current increases very perceptibly. This also occurs to plants when subjected to currents of electricity of sufficient intensity, as it induces heat. The injury caused to plants by electricity generally arises from decreased resistance, which is likely to follow after a more or less prolonged application of the current; in other words, the injurious effect is caused by heat, although it is possible that electricity will kill plants without generating heat sufficient to injure the protoplasm.

Experiments made some years ago by us seemed to indicate that when strong currents are applied to small plants and they become excessively heated, after a short period of time the protoplasm is destroyed, and the current, which first increases in strength very rapidly, suddenly drops to almost nothing.

A low temperature in trees gives rise to a high resistance, and a high temperature to a low resistance; in other words, the resistance of trees resembles that of moist seeds in their behavior to temperature, and the relationship between temperature and resistance is quite general. There may be, of course, other factors which influence resistance besides temperature, such as, for example, the degree of moisture in the tissue, as well as the nature of the substances in the tissue.

The relationship existing between temperatures and resistance is shown in Figs. 1, 2 and 3. Fig. 1 shows the curve given by an elm tree, and is based upon the data given in Table II., being the average daily resistance obtained from the north, south, east and west sides of the tree during April, the upper curve with broken lines being that of the mean temperatures for the days when the observations were made. In Fig. 2 A the average electrical resistance of the south side of a maple tree is shown from the data given in Table VIII. The readings are averages of three daily readings at 8 A.M., 12 M. and 4 P.M., and in B is given the average electrical resistance of a maple tree from data obtained in Table I., the curve being based on daily readings on the north, south, east and west sides of the tree. All of these figures show that there exists a marked relationship between the temperature curve and that for the electrical resistance, since as the temperature curve goes up the resistance curve goes down.

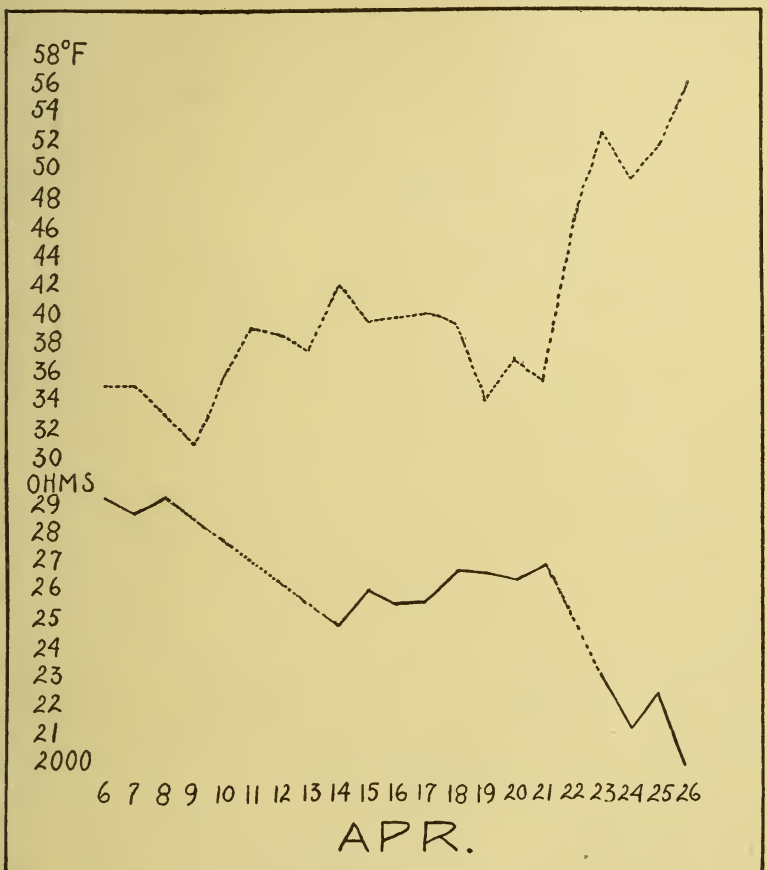

FIG. 1. — Showing curve of electrical resistance and temperature of elm, *Ulmus Americana* (Table II.). The lower curve gives the average resistance of the north, south, east and west sides of the tree from April 6 to 26; the upper curve gives the mean of the minimum and maximum temperature for the same period obtained from the local meteorological station.

In Fig. 3 is shown the hourly temperature and electrical resistance of the north side of a maple tree for a single day, the data being obtained from Table IX. In both Figs. 1 and 2 the temperature is taken from mean temperature records, while in the case of Fig. 3 they correspond with the hours of observation.

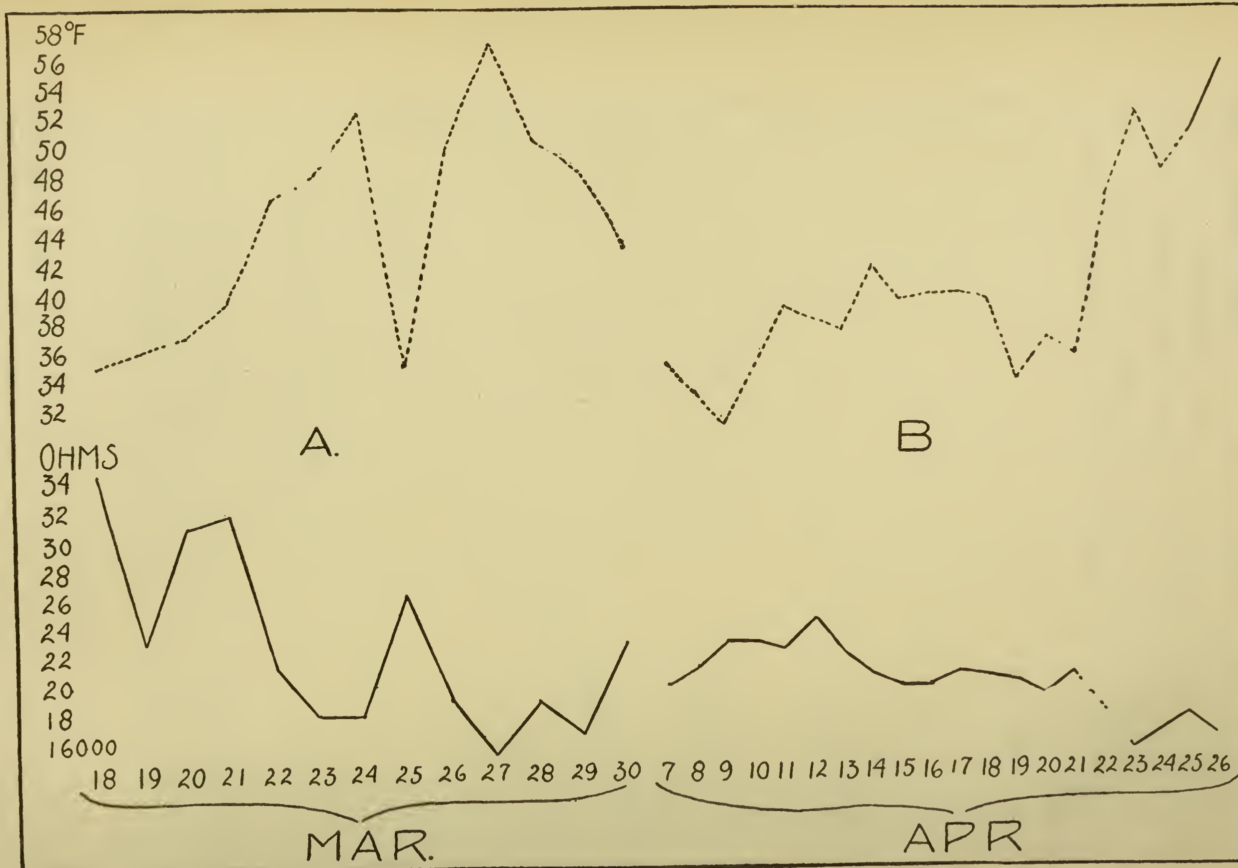

FIG. 2. — Showing electrical resistance and temperature curve of maple tree, *Acer saccharum*. The lower curves give the resistance of trees in ohms; the upper curves give corresponding mean temperatures obtained from the local meteorological station. A. Resistance given by the south side of a maple tree from March 18 to 30, inclusive, the resistance being averages of three daily observations taken at 8 A.M., 12 M. and 4 P.M. (See Table VIII.) B. Average resistance of the north, south, east and west sides of a maple tree. Observations taken daily from April 7 to 26. (See Table I.)

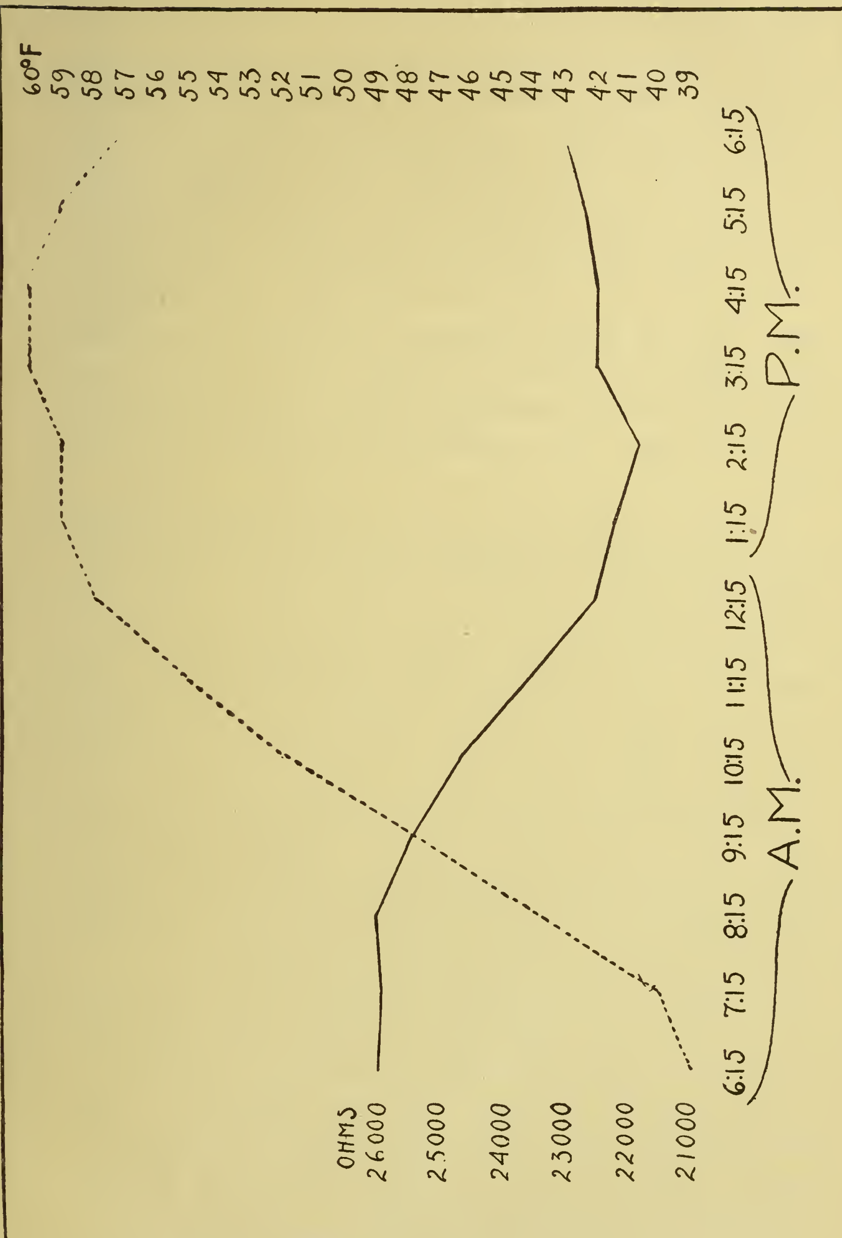

FIG. 3. — Showing electrical resistance and temperature curve of north side of maple tree, *Acer saccharum*. (See Table IX.) Observations taken hourly for one day, from 6.15 A.M. to 6.30 P.M. Lower curve represents the resistance curve, and the upper, the hourly temperature obtained from Draper records of the local meteorological station.

In the curve shown in Fig. 3 it will be observed that there is a close relationship between temperature and resistance.

Light, so far as we have observed, influences resistance only so far as it modifies temperature. The southeast side of the tree receives the most light, since the morning light is more intense than the afternoon light. Photosynthesis is more active on that side of the tree, and growth greater. Since there is a relationship between photosynthesis and light intensity, and also between growth, there occurs more activity, as a rule, on the southeast side of the tree than on any other, but whether the greater flow of plastic substances in any given tissue would affect resistance, our data do not show. So far, however, as the greater light intensity is associated with increased temperature, we should expect to find corresponding modifications in resistance.

Influence of temperature is shown in the difference existing between the resistance occurring on the north and south sides of trees. Some of our temperature records taken on the north, south, east and west sides of a rock maple were not satisfactory on account of the constant breakage of thermometers. These temperatures were taken three times daily, at 8 A.M., 12 M. and 4 P.M., for a period of five days. The records, however, gave the lowest average temperature on the north side of the tree, followed by the west, east and south sides respectively.

Other observations carried on for a brief period on a rock maple tree gave the following results. In both cases the thermometers were inserted into holes bored in the tree. The records obtained in the second series of observations, which are averages for a period of seven days, are as follows: —

The average of three observations daily, at 8 A.M., 12 M. and 4 P.M. on the north, south, east and west sides of a rock maple tree, gave the lowest temperature on the north, this being followed by the west, east and south sides respectively. These temperatures were taken in December, when the tree was in a dormant condition, and the temperature given by the north side of the tree was invariably the lowest.

Jones, Edson and Morse obtained careful temperature records from a rock maple tree. The observations were made on the north and south exposures, and extended from February 8 to March 20, and were made at 8 A.M., 12 M. and 6 P.M. each day. Corresponding air temperatures were made for the same period. These observations were made with centigrade thermometers, which were carefully protected from external influences. We transposed their readings into Fahrenheit and found that the average temperature given by the south side of the tree was 31.43° F., while that for the north side was 30.57° F. The air temperature for the same period, as might be expected, was variable, averaging slightly higher than that for the inside of the tree.

The average temperature readings obtained by Jones, Edson and Morse from the north and south sides of the tree showed that the temperature on the north side was about 3 per cent. lower than on the south side. The average obtained from all our electrical resistances and temperature readings are given below in sequence: —

	Average Electrical Resistance.	Average Temperature of Trees (Degrees F.).
North side,	27,081	30.91
West side,	25,714	32.14
South side,	25,566	33.60
East side,	23,708	32.28

It will be noticed that the highest average resistance of trees was given by the north side, followed by the west, south and east sides, and this sequence was closely followed by the temperature readings, the lowest being given by the north, followed by the west, east and south sides. The temperature readings lasted seven days only, and were too incomplete to obtain a true average. It will be noticed, however, that there was a difference of about 8 per cent. between the resistance of the east and west sides of the tree, a feature which would result from the greater intensity of the morning light. In our temperature readings, which are probably not as good averages as those obtained by the authors noted above, we find that the north side of the tree showed a temperature equal to 7 per cent. lower than the south side, as compared with 3 per cent. given by Jones, Edson and

Morse, whereas the average resistance for the north side of the tree runs about 5 per cent. more than that for the south side. The relationship of temperature to resistance manifests itself throughout; the higher temperature giving rise to a low, and conversely a low temperature giving rise to a high resistance.

The sun strikes the tree on the east, south and west sides, and each side is exposed for the same length of time; but the angle of the sun is variable as it strikes the tree's surface. In the early morning and late afternoon the sun's rays are more or less at right angles to the tree trunk, whereas at noon the angle is more oblique. The surface of a tree is not a good reflector of light and heat, and in the early morning and late afternoon, when the rays are more at right angles to the surface of the trunk, there is less loss of light and heat by reflection. Assuming that the light intensity is uniform throughout the day, and that the temperature is the same, we would expect to find fairly uniform resistances for the east, south and west sides of the tree. This, however, is not the case, as the temperature is seldom uniform, neither are the light conditions, as is shown by the flow of sap.

The north side of the tree gives the highest average resistance, followed by the west, south and east sides. From the point of view of influence of temperature this might be expected, especially during seasons when there is considerable difference between the night and day temperatures, and very likely for long periods of observations thermometers placed in trees would demonstrate this. Electrical resistances taken in the afternoon usually run lower than those taken in the morning on all sides of the tree, which results from a general increase in the temperature of the surrounding air and of the tree occurring in the daytime. The electrical resistance is less in the warm than in the cold months, and less on warm than cold days. In the morning the sun affects the east side of the tree most markedly, and in the afternoon the west side.

In experimenting with cut branches of maple trees we did not find, however, that this held true. The resistances obtained from branches placed out of doors when it was cold were in no wise different from those taken from the same branch when placed in the laboratory, where it was warm, or even when they were placed in hot water, although trees and various potted plants with an intact root system all showed the influence of temperature on resistance.

Conclusions.

1. The electrical resistance of trees shows a close relationship to temperature, their higher resistance corresponding with the low temperature, and the low resistance corresponding with the higher temperature.

2. The electrical resistance of trees is lower during warm than cold days, and less during warm than cold seasons. It is usually less during afternoons than mornings; in other words, it corresponds to changes in the temperature.

3. The average electrical resistance of trees is highest on the north side, followed by the west, south and east sides respectively.

4. The temperature of trees given by our experiments, which were of limited duration, is less on the north side, followed by the west, east and south sides, and coincides in a general way with the variation in the resistance of the different sides of the tree. Extensive observations regarding temperature and resistance would undoubtedly show very close relationship between these two factors.

5. The average electrical resistance for the east side of the tree is about 8 per cent. lower than the west side, due, undoubtedly, to differences in temperature existing between the east and west exposures. The difference, however, in the light intensity of morning and afternoon is variable from day to day and from year to year, and may range from 1 or 2 per cent. to 30 per cent. or more per month, but averages between 10 per cent. and 17 per cent. per annum.

6. The difference in the average electrical resistance of the north and south sides of the tree is about 5 per cent., the average difference in the temperature being about the same.

7. The cambium layer offers the least electrical resistance, as shown by lightning discharges and by our experiments. This is followed by the phloem and sapwood.

8. Small plants and branches of trees in general give higher electrical resistances than trees, probably due to the greater

amount of conductive tissue, possessing less resistant qualities in the trees.

9. The high resistance and consequent nonconductivity of trees serves, no doubt, as a protection for the tree against lightning stroke and other electrical discharges.

10. Sap flow did not, so far as we were able to observe, exert any influence on the electrical resistance.

11. Temperature constitutes a determinative factor in variations of electrical resistance of trees. Other meteorological factors, such as relative humidity, barometric pressure, winds, etc., exert no discernible specific influence.

THE CHEMISTRY OF ARSENICAL INSECTICIDES.

BY E. B. HOLLAND AND J. C. REED.

General Introduction.

The work on arsenical insecticides, at the chemical laboratory of this station, has advanced sufficiently to warrant a second report [1] on the subject dealing particularly in this instance with the composition, manufacture and use of Paris green, lime arsenite and lead arsenate. In this connection it may be of interest to consider briefly the monetary loss resulting from injurious insects, and note the insecticides available to check their depredations previous to the introduction of arsenicals.

The aggregate loss in the United States from insect injury to agricultural products of all kinds including live stock, forest and shade trees and ornamental plants, together with the subsequent damage to manufactured goods, is impossible to compute with any degree of accuracy. It has been estimated [2], however, at $1,000,000,000 annually, and may exceed that amount. Without question the successful production of many, if not most, crops is dependent in a large measure upon their protection from noxious insects. The rapidity with which such pests multiply and are disseminated, and the readiness with which they adapt themselves to new conditions, occasionally undergoing considerable change in character, size and appearance, demands thorough scientific treatment for their control, as eradication is practically impossible. The tendency of injurious insects to feed on a greater variety of plants and to become more destructive in a new country than where indigenous, due to more favorable climatic conditions or absence of natural enemies, renders the problem even more difficult to handle.

[1] First report in Mass. Exp. Sta. Rept., 23, p. 122 (1911), entitled The Determination of Arsenic in Insecticides.

[2] Economic entomologists allow 10 per cent. loss on all produce.

The substances formerly employed as insecticides were usually characterized by offensive or caustic rather than poisonous properties. An acrid or bitter taste and a pungent odor were evidently deemed necessary qualifications for insecticides, and the more unpleasant the greater merit they were supposed to possess. Among the more prominent, enumerated by early writers,[1] might be mentioned water, hot water, brine, urine, lye, lime water, whitewash, clay wash, soapsuds, vinegar, petroleum, tar infusion, turpentine, fish oil, whale oil, sulfur, decoctions of aloes, dwarf elder, pepper, quassia chips, rue, tobacco, walnut leaves, wormwood and dustings of wood ashes, quick lime, soot, sulfur, hellebore and tobacco. It is not surprising that the use of such repellants (as a class they could not be designated otherwise) was often ineffectual. The farmers were hampered further by a very imperfect knowledge of the life history and habits of the insects to be combated. To be sure, some of the materials had insecticidal value, largely, however, as contact [2] rather than as internal poisons, effective as an irritant, also, by penetrating the cuticle or entering the body tissue through breathing pores, and possibly in some cases by closing the tracheæ,[3] resulting in the asphyxiation of the insect. The application of these substances, singly or several together, constituted the best recognized treatment both in this country and abroad previous to 1860–70.

Several materials deserve especial notice not only because they possess merit, maintaining a place even to the present time, but more particularly on account of the part taken in the development of modern practice. These are hellebore, pyrethrum, kerosene and lime-sulfur. Hellebore, though known to possess poisonous properties, received little attention until about 1842 in England [4] and later in this country.[5] Pyrethrum has been a

[1] Wm. Speechly, A Treatise on the Culture of the Pine-Apple (1779); J. A. E. Goeze, Geschichte einiger schadlichen Insecten (Leipzig, 1787). Cited by E. G. Lodeman, The Spraying of Plants, p. 5, (1902); Samuel Deane, The Newengland Farmer or Georgical Dictionary, 2d edition (1797); Wm. Forsyth, A Treatise on the Culture and Management of Fruit Trees (1802); Jas. Thatcher, The American Orchardist (1822); Thos. G. Fessenden, The New American Gardener, 6th edition (1832); Wm. Kenrick, The New American Orchardist (1833); Thos. Bridgeman, The Young Gardener's Assistant (1857); J. C. Loudon, The Encyclopedia of Gardening (1878).

[2] How Contact Poisons Kill, Geo. D. Shafer, Mich. Exp. Sta. Tech., Bul. No. 11 (1911).

[3] No attempt was made to differentiate tracheal poisons from contact poisons in general.

[4] A. Mitchell in Gard. Chron., 1842, p. 397.

[5] J. Harris in Country Gentleman, 1865, p. 413.

commodity of southwestern Asia for a long time, but appears to have been overlooked by early European and American agriculturists, being introduced into France about 1850. The efficacy of kerosene, fish and whale oils, and turpentine was acknowledged comparatively early, though they were seldom used on account of the liability to injure the plant. The fact that such substances must be miscible with water to be applied safely was recognized long prior to an understanding of how it could be accomplished. An emulsion [1] of kerosene with soap and water was apparently not used until 1870. Soap and water has probably been more extensively employed in the past than any other substance, both for its effect and as a vehicle. Whale oil soap [2] was recommended in 1842. Lime and sulfur were almost invariably mentioned by early writers on insecticides. They jointly appeared in a number of mixtures, and where heat was employed in their preparation [3] partial combination, at least, must have taken place. This product was a forerunner of the lime-sulfur compounds which have since proved so valuable in checking the San José and other scales.

While the above summary may fail to convey a clear understanding of the subject, it will serve to show that practically no active "food" poison had been used as an insecticide previous to 1860.

The advent of the potato beetle [4] in Nebraska in 1859 and its rapid spread eastward created a demand for a more powerful insecticide than those commonly employed. In a measure this was true also of the imported currant worm which appeared in the eastern States about 1858. The poisonous nature of arsenic was well understood, and its salts would naturally be expected to possess a like property. Paris (Schweinfurt) green had long been known as a pigment under various trade names and was first applied [5] as an insecticide for the potato beetle about 1868, from which time its use was gradually extended to the cotton worm, cankerworm, codling moth and other insects. Subsequently a number of other arsenicals were recommended, of

[1] Geo. Cruickshank in Gardener's Monthly, 1875, p. 45.
[2] David Haggerston in History of Mass. Hort. Soc., 1829–78, p. 256.
[3] Kenrick, *loc. cit.*, p. XXXVI., and for grape mildew, p. 328 (1833).
[4] C. V. Riley, Potato Pests, pp. 12–24 (1876).
[5] Geo. Liddle, Sr., in Amer. Ent. 1, p. 219 (1869).

which Scheele's green [1] in 1875, London purple [2] in 1877, lime arsenite [3] in 1891 and lead arsenate [4] in 1893 are the most important. Paris green and lead arsenate are to-day the most extensively employed food poisons for leaf-eating insects. Lime arsenite is more particularly a farm preparation. Scheele's green and London purple have been largely superseded by the other compounds.

The Investigation.

The object of the investigation, planned by Dr. H. T. Fernald of the entomological department, was "to ascertain why and under what conditions insecticides burn foliage." The principal arsenicals were to be applied "under differing known conditions of light, temperature and humidity," and where injury resulted, its character and extent carefully determined. Work of this type would naturally extend over a considerable number of growing seasons to furnish sufficient data to warrant positive deductions. The chemical department of the experiment station was required to co-operate so far as to provide the necessary amount of chemicals of known composition, suitable for the purpose intended, together with any information relative to solubility, hydrolysis and power of suspension, that would be of service in their application.

At the outset the laboratory phase of the project appeared an easy matter, — simple analytical work on a relatively small number of samples of similar nature. In February, 1908, letters were sent to several large manufacturers of high-grade chemicals stating the object of the investigation and asking if they could supply Paris green, copper arsenite, lime arsenite and lead arsenate of the necessary purity and, if not, the best method of securing such salts. The replies were rather unsatisfactory, though the order was finally placed with a firm making a specialty of guaranteed reagents. The dry salts were received, but on examination proved unfit for the purpose intended. Work on methods of analysis and study of arsenical reactions were continued, so far as other duties would permit, during the next two years.

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[1] C. V. Riley, Potato Pests, p. 67.
[2] E. G. Lodeman, Spraying of Plants, p. 65.
[3] N. Car. Exp. Sta., Bul. No. 77b, pp. 7-8, (1891).
[4] Mass. Bd. Agr. Rept., 41, p. 282 (1894).

In March, 1910, a persistent effort was made to obtain all help possible in furtherance of the work, as it was then thought that it would be necessary for us to prepare the salts in the station laboratory. A circular letter was sent to manufacturers of chemicals, particularly those firms making insecticides, asking for information relative to the general process of manufacture of the several products. A statement was inserted to the effect that the station was not in quest of trade secrets, but merely wished to secure a fairly broad knowledge of the difficulties attending the manufacture, and of the impurities likely to be present, so as to be in position to handle the problem intelligently. The replies in general contained little or no information of value. Two large concerns, however, took a more liberal view of the matter and readily furnished any data at their command. One of these companies volunteered to supply any insecticides needed free of cost. Inasmuch as a manufacturer of arsenicals with adequate facilities was unquestionably in a better position to handle the matter, the offer was gratefully accepted. In May large, dry samples of Paris green, copper arsenite, lime arsenite and neutral and acid lead arsenates were received from the factory. A laboratory examination showed that not one of these specially prepared insecticides was entirely satisfactory, the Paris green alone being set aside for actual use in spraying tests.

The matter now began to assume rather a serious aspect. Was it possible to produce arsenicals of definite molecular ratios or not? Two companies had signally failed in the attempt, presumably using all the precautions they knew. Letters somewhat similar to those sent the manufacturers had also been addressed to several eminent chemists, requesting their opinions as to the preferable precipitants and conditions of manipulation to insure the proper equilibrium for the production of compounds of theoretical composition. The substance of their replies, while general in character, was to the effect that "the difficulties are inherent in the nature of the compounds," and that arsenites (particularly) are unstable, hydrolizing in the presence of water. The latter fact had long been a matter of record [1] and might excuse slight discrepancies in composition,

[1] See p. 186 of this article.

but the gross differences noted in the several samples were evidently due to incorrect methods of production. This view was substantiated by a large number of tests in the station laboratory, the resulting compounds varying in composition with differing conditions attending their preparation. To be sure, our work was conducted in a small way (2 to 3 ounces at most), but there was no reason to doubt that it would hold equally true on a commercial scale under like circumstances.

After having failed to obtain satisfactory salts from two different companies, and realizing more than ever the lack of manufacturing facilities in the laboratory, the matter was brought to the attention of one of the largest American manufacturers of analytical chemicals with whom the problem had previously been discussed. This firm agreed to undertake the preparation of the arsenicals, following general directions furnished by the laboratory. Dry calcium metarsenite and neutral and acid lead arsenates were received from them early in August, and while all were more or less impure the results, on the whole, were encouraging though showing the necessity of further study in order to give more specific directions. Precipitations under varying conditions were continued into January, 1911, at which time the data at hand warranted placing another order with the last-mentioned firm for acid lead arsenate and calcium metarsenite in form of paste. Explicit directions were furnished by this laboratory as to the method of manufacture. The resulting lead salt proved to be approximately 97 per cent. pure and was accepted. The first lot of lime arsenite was rejected, but the next shipment, over 94 per cent. pure, was accepted and employed in spraying tests during the summer of 1911, together with the acid lead arsenate and Paris green.

The above is a brief statement of some of the difficulties encountered in securing these three insecticides. In the papers that follow will be found under the headings of Paris green, calcium arsenite and lead arsenates a somewhat detailed description of the work performed in this laboratory relative to the several insecticides. Deductions drawn from a small number of samples must be considered indicative rather than conclusive, and their accuracy can be proved only by additional work.

A. Paris Green.

Historical.

Paris green was produced by Russ and Sattler [1] in 1814. The process was kept a factory secret until revealed by the independent investigations [2] of J. Liebig and Henri Braconnot in 1822. Liebig [3] treated 4 parts of verdigris in acetic acid with 3 parts of arsenous oxide in boiling acetic acid. The acid retained the material in solution until the excess was expelled. Braconnot [4] prepared a solution of potassium arsenite by boiling 6 parts of arsenous oxide with 8 of potassium carbonate, poured it while warm into 6 parts of copper sulfate, dissolved in a small quantity of warm water, and added acetic acid until the odor was perceptible. The methods of Liebig and Braconnot have since been modified by many chemists, but substantially they typify the two distinct manufacturing processes employed to-day, *i.e.,* the *instantaneous* and the *slow.*

The instantaneous method is thus described in Watts' "Dictionary of Chemistry:" [5] "Five parts of verdigris are made up to a thin paste, and added to a boiling solution of 4 parts or rather more of arsenous acid [6] in 50 parts of water. The boiling must be well kept up, otherwise . . . acetic acid must be added."

The slow process, as given by a manufacturing company,[7] is as follows: 1,000 pounds of blue vitriol are dissolved in 480 gallons of hot water and run into a 1,200-gallon "striking vat." Four hundred and fifty pounds of sodium carbonate (Solvay) are dissolved in 480 gallons of hot water, and 795 pounds of arsenic "sprinkled" on and boiled to remove carbonic acid.

The boiling arsenic solution is "let down" into the blue vitriol solution, the temperature of which is about 140° F., well stirred, and 210 pounds of acetic acid (100 per cent.) mixed with an equal weight of cold water added. The mixture is

[1] B. B. Ross, Ala. Exp. Sta., Bul. No. 58, p. 4 (1894).
[2] H. Sattler, Ztschr. Angew. Chem., 1888, p. 35.
[3] Repert. für die Pharm. 13, pp. 446-457 (1822).
[4] Ann. Chim. et Phys. Ser. 2, 21, pp. 53-56 (1822).
[5] 3d edition, 1, p. 10 (1893).
[6] C. L. Bloxam states equal parts by weight of arsenic and copper acetate. (See Chemistry, 9th edition, p. 271 (1907).)
[7] From correspondence on file.

allowed to stand two hours, then well stirred, after half an hour stirred again, and finally at the end of a quarter of an hour the liquid is drawn off and filtered. The resulting Paris green is dried on racks for four or five days at 185° F., or in a steam vacuum oven about 260° F. The yield is 985 pounds.

An electrolytic process for making Paris green from metallic copper, arsenous oxide and acetic acid was patented by Richard Franchot in 1902. No information relative to the character of the product is available.

Paris green is a copper aceto-arsenite for which Eugène Ehrmann's formula [1] is generally accepted.

$$Cu(C_2H_3O_2)_2 \cdot 3\,Cu(AsO_2)_2.$$

As a double salt it may be said to consist of 1 part of copper acetate to 3 of copper metarsenite, equivalent to 17.91 per cent. of the former to 82.09 per cent. of the latter. The structure of Paris green and its homologues was carefully studied by Avery, and while his results [2] most frequently approached a ratio of 1:3, there was invariably a deficiency in arsenic. As the product is not recrystallizable he recognized that purity must be assured largely by a microscopical examination, which proved a questionable guide for so unstable a compound.

Although some chemists claim that the formula is only empirical it certainly expresses the proportion of cupric oxide to combined arsenic trioxide as found in well-formed greens. Four hundred and ninety-nine samples [3] collected in the open market by the Pennsylvania department of agriculture contained on the average: —

	Per Cent.
Cupric oxide,	29.41
Total arsenic trioxide,	56.56
Water soluble arsenic,	1.41

The relation of cupric oxide to "insoluble" arsenous oxide is 1:1.875, theory 1:1.865. Similar results are reported by others.

The comparatively high specific gravity of Paris green, as

[1] Bul. Soc.: ind., Mulhausen 7, pp. 68-80 (1834).
[2] Jour. Amer. Chem. Soc., 28, p. 1155 (1906).
[3] J. W. Kellogg, Bul. No. 192, p. 37 (1910).

recorded by Miles [1] and by Fernald [2] of 3.29 and 3.42 respectively, results in a low power of suspension as shown by Colby [3] of five minutes for a coarse sample and seventeen minutes for a fine, in 1 foot column of water at the proportion ordinarily applied. Woods and Hanson [4] show as a result of a microscopical examination of 21 commercial samples of Paris green, slow process with possibly one exception, that on the average only 5.27 per cent. of the green particles exceeded a diameter of 19.2 microns (.00077 of an inch). The ammonia test for purity mentioned by Riley [5] and by Paddock [6] is now considered of little value except in determining the presence of insoluble materials such as flour and gypsum added as a filler.

The presence of free arsenic in Paris green in any appreciable amount is deemed objectionable by all investigators on account of possible injury to the foliage due to its corrosive action. While free arsenic can usually be detected by the microscope, its quantitative determination for a time proved a more difficult matter, and results by the earlier methods were of questionable value except in a comparative sense. Haywood [7] found that Paris green continued to yield arsenic to successive portions of warm water at 50° to 60° C., and also to repeated washings of cold water on a filter. He secured practically constant results by treating 1 gram of green in a flask with 500 cubic centimeters of water for twelve days, but subsequent tests [8] showed the presence of soluble copper, indicating either solution or breaking down of the green. He favored the latter view, but assumed that the decomposition was in proportion to original content and corrected the results accordingly.

Hilgard [9] acknowledged that warm water was not permissible and recommended a treatment conforming more nearly to orchard practice, 1 gram to 1,000 cubic centimeters of cold water for twenty-four hours with prolonged agitation. He questioned any dissociation of the green, but admitted that continued

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1 Va. Exp. Sta., Bul. No. 24, p. 16 (1893).
2 Mass. Bd. Agr. Rept., 45, p. 355 (1898).
3 Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).
4 Me. Exp. Sta., Bul. No. 154, p. 114 (1908).
5 U. S. Ent. Com., Bul. No. 3, p. 56 (1880).
6 N. Y. Exp. Sta., Bul. No. 121, p. 219 (1897).
7 Jour. Amer. Chem. Soc., 22, p. 579 (1900).
8 Jour. Amer. Chem. Soc., 22, p. 705 (1900).
9 Jour. Amer. Chem. Soc., 22, p. 691 (1900).

percolation gave free arsenic. Avery and Beans,[1] working with a sample of perfect structure and of nearly theoretical composition, found that when treated in a stoppered flask, ½ gram to 500 cubic centimeters of water, the arsenic continued to pass into solution for sixteen weeks, the duration of the experiment. Upon breaking the granules of Paris green by grinding in a mortar the disintegration was more rapid until a state of equilibrium was reached. Carbonic acid also increased the solubility of the arsenic. The decomposition was evidently due to hydrolysis, as the arsenic dissolved in much greater proportion of the original content than did the copper. They concluded that any method based on solubility in water was merely arbitrary, as "the amount of arsenic trioxide in solution appears to depend almost entirely on the length of time of action, the concentration of the solution and the state of division of the particles of Paris green." To distinguish free arsenic from that rendered free by hydrolysis, Avery and Beans recommended boiling 1 gram of green five minutes in 25 cubic centimeters of sodium acetate solution (1 to 2). It was found that the sodium acetate solution readily dissolved the free arsenic and at the same time largely prevented hydrolysis of the green. The Hilgard method, 1 gram to 1,000 cubic centimeters of water for twenty-four hours with agitation, indicates free and loosely combined arsenic, and while such results are invariably higher than the former, the increase for greens of perfect structure, free from broken particles, is comparatively slight. These two processes are now quite generally employed. The Association of Official Agricultural Chemists[2] recognizes the acetate method and the ten days' extraction method recommended by Haywood as provisional methods.

To prevent arsenical injury to foliage, Gillette[3] and Kilgore[4] advised mixing Paris green with milk of lime to neutralize the free arsenic, and Weed[5] suggested combining the green with Bordeaux mixture.

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[1] Jour. Amer. Chem. Soc., 23, p. 111 (1901).
[2] Methods of Analysis Bur. Chem. Bul. No. 107 (revised), p. 27 (1908).
[3] Iowa. Exp Sta., Bul. No. 10, pp. 410–413 (1890).
[4] N. Car. Exp. Sta., Bul. No. 77b, pp. 4–7 (1891).
[5] Ohio Exp. Sta., Bul. (Vol. 2) No. 7, p. 186 (1889); *Ibid.*, (Vol. 4) No. 2, pp. 39–42 (1891).

Experimental Results.

The terms "instantaneous" and "slow process" are used to designate Paris greens of different physical structure. While this classification may not be in strict conformity with some writers it appears, nevertheless, the most desirable for the purpose intended.

Instantaneous green is the result of a quick boiling process as previously shown. The ultimate reaction is illustrated by the following equation: —

$$3\ As_2O_3 + 4\ Cu(C_2H_3O_2)_2H_2O$$
$$= Cu(C_2H_3O_2)_2 \cdot 3\ Cu(AsO_2)_2 + 6\ C_2H_4O_2 + H_2O.$$

If the process could be carried out with the ingredients in the proportion given there would be very little waste. In practice, however, instead of 1 part by weight of arsenous acid to 1.34 parts of copper acetate, an equal amount appears necessary to insure the desired change. This is probably due to the weak acid properties of the arsenic.

Slow process green is generally formed less rapidly and at a lower temperature than the instantaneous. From what could be learned the slow process seems to be the one employed by most of the large manufacturers. Blue vitriol is used as the source of copper, and sodium arsenite ($NaAsO_2$) in place of arsenous oxide, on account of its greater solubility and the necessity for a base to neutralize the sulfuric acid. Sodium arsenite is easily prepared by adding a thin paste of arsenous oxide in slight excess to a boiling solution of caustic soda or of a carbonate.

$$Na_2CO_3 + As_2O_3 = 2\ NaAsO_2 + CO_2.$$

The soda and arsenic readily combine with volatilization of carbonic acid. As commercial salts were often employed in our work the analyses of two are given: —

Sodium Arsenite.

	Baker and Adamson (Per Cent.).	Kahlbaum (Per Cent.).	Theoretical (Per Cent.).
Arsenic trioxide,	78.68	74.71	76.15
Sodium oxide,	18.45	22.63	23.85
	97.13	97.34	100.00

The sodium oxide was calculated from the alkalinity, determined by direct titration with methyl orange as indicator, a process sufficiently accurate for the purpose of checking quality.

The several reactions taking place in the manufacture of slow process green may be summarized in a single equation: —

$$4\,CuSO_4 5\,H_2O + 8\,NaAsO_2 + 2\,C_2H_4O_2$$
$$= Cu(C_2H_3O_2)_2 \cdot 3\,Cu(AsO_2)_2 + As_2O_3 + 4\,Na_2SO_4 + 6\,H_2O.$$

Sodium arsenite reacts upon the blue vitriol with the production of a bulky, yellowish-green precipitate of copper arsenite (Scheele's green), which in turn is acted upon by the acetic acid with the formation of a greatly reduced volume of Paris green. Experience has shown, as indicated by the above formula, that about ⅓ more arsenic is required for the production of the green than actually enters combination, as was the case with the instantaneous process. Acetic acid in excess of the 2 molecules stated (by nearly 66 per cent.) is needed for the reaction. It is evident from what has been said that the manufacture of slow process green requires considerable equipment, expensive reagents and expert control which, together with the unavoidable waste of chemicals, insures a costly product.

The two general processes for making Paris green and their several reactions were carefully studied in the station laboratory to ascertain the character of the product that might reasonably be expected. As a result of numerous experiments a combination process, using copper acetate and sodium arsenite, together with sufficient acetic acid to offset the alkalinity of the arsenite, was found the most acceptable.

$$4\,Cu(C_2H_3O_2)_2H_2O + 6\,NaAsO_2 + 6\,C_2H_4O_2$$
$$= Cu(C_2H_3O_2)_2 \cdot 3\,Cu(AsO_2)_2 + 6\,NaC_2H_3O_2.$$

The reaction was easy to control, could be carried out at any temperature from that of the laboratory to boiling and gave a product of variable physical structure and of fine color. Solutions of different concentrations were tried, of which ⅕ molecular (M/5) for the acetate and ½ molecular (M/2) for the arsenite proved satisfactory. This process appeared to require less arsenic in *excess* than the ordinary method, although the work was performed on too small a scale to warrant positive statements to that effect.

Attention has already been called, on pages 180 and 181 to two samples of Paris green supplied by different manufacturers for the investigation, of which the second was employed in actual spraying tests. The sample of instantaneous green was made according to the method described, with the exception that crystallized copper acetate was substituted for verdigris. The slow process sample was selected from a factory run of commercial green manufactured substantially as has been stated.

Paris Green from Chemical Manufacturers.

	Instantaneous Green.	Slow Process Green.	Theoretical.
Manufacturer,	A	B	-
Character of product,	Dry powder.	Dry powder.	-
Color,	Pale green.	Bright green.	-
Shape of green particles,[1]	Irregular, angular.	Mostly perfect spheres.	-
Size of green particles,[1]	Average 10 μ.	12–30 μ, average 17.39 μ.	-
Uniformity,[1]	Very little variation.	Considerable variation.	-
Nature of impurities,[1]	Crystalline matter.	Crystalline matter.	-
Amount of impurities,[1]	Large amount.	Small amount, less than 5 per cent.	-
Flow,	Poor.	Excellent.	-
Film test,	Whitish.	Green.	-
Water (per cent.),	.78	1.46	-
Cupric oxide (CuO) (per cent.),	31.74	30.94	31.39
Arsenic trioxide (As_2O_3) (per cent.),	56.94	56.34	58.55
Acetic anhydride ($C_4H_6O_3$) (per cent.),	10.37	9.94	10.06
Ferric (Fe_2O_3) and aluminum oxides (Al_2O_3) (per cent.).	-	.53	-
Sulfuric acid (SO_3) (per cent.),	-	.29	-
Insoluble matter (per cent.),	.00	.05	-
	99.83	99.55	100.00
Arsenic (As) (per cent.),	43.13	42.68	44.35
Suspension in water,	-	17 minutes.	-
Suspension in filtered lime water,	-	48 minutes.	-

Both greens contained an excess of cupric oxide and acetic acid, and may have been hydrolyzed somewhat by washing with

[1] Determined by the entomological department of this station.

the formation of a basic acetate. Sample B showed a considerable amount of impurities. Any hypothetical combination of the various constituents that might be offered would be decidedly arbitrary, and a discussion seems inadvisable at this time. A careful study of the results would indicate that the slow process green, exclusive of moisture, was at least 96 per cent. pure. To be of standard quality Paris green should contain not less than 50 per cent. of arsenous oxide combined with copper, and not more than 3.50 per cent. of arsenous oxide soluble in water. The poisonous character of Paris green is dependent on the arsenic content, but the form in which the arsenic exists largely fixes its value as an insecticide. Adulteration is seldom practiced under the inspection laws now in force.

Paris green is a dry, impalpable powder that readily passes a 100-mesh sieve, and to the touch resembles flour. A microscopical examination is required to determine the size, shape and uniformity of particles as well as the general character and amount of impurities. The latter may consist of Scheele's green that was not transformed or by-products such as arsenic, sodium sulfate, sodium acetate and possibly other compounds not intentionally added but present in the original chemicals. The sample of instantaneous green under examination was of a pale green color, and consisted of very small, irregular, angular particles with considerable impurity. It was cohesive, had a poor "flow," and the film test [1] on glass appeared whitish. The slow process green, on the other hand, had a brilliant green color of metallic luster, and was composed of minute green spheres of various sizes, together with a small amount of crystalline and fragmentary matter. It had an excellent "flow," and the film test on glass was green. The size of the particles is affected by the concentration, temperature and amount of agitation at the time of formation. The smaller the globules with retention of perfect form and similar size, the more desirable the product.

Paris green has a high specific gravity and a low power of suspension. In the station laboratory suspension was determined [2] in a foot column containing the insecticide at the proportion of 1 gram of dry salt to 1,000 cubic centimeters of

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[1] C. W. Woodworth, Cal. Exp. Sta., Bul. No. 126, p. 13 (1899).

[2] Modification of the California method. G. E. Colby, Cal. Exp. Sta., Bul. No. 151, pp. 33–35 (1903).

water. The mixture in a closed cylinder was thoroughly agitated, and the reading, in minutes, taken with a horizontal microscope, using a 1-inch eyepiece and ½-inch objective, when movement of the particles midway of the column (6 inches down) was no longer apparent. The slow process green gave a reading of seventeen minutes in water and forty-eight minutes in filtered lime water. As lime tends to flocculate the particles of Paris green, the test should be performed immediately after mixing.

Although copper aceto-arsenite is termed insoluble in water, decomposition readily takes place under certain conditions; therefore, the determination of so-called "free" and "loosely combined" arsenic is closely related to stability of product and should be considered in that connection.

Solubility.

	Instantaneous Green.	Slow Process Green.
Manufacturer,	A	B
Water (per cent.),	.78	1.46
Sodium acetate soluble "free arsenic" (Avery and Beans Method): —		
Cupric oxide,	Trace.	Trace.
Arsenic trioxide (per cent.),	1.45	.74
Copper acetate soluble: —		
Arsenic trioxide (per cent.),	1.09	.45
Water soluble "free and loosely combined arsenic" (Hilgard Method):—		
Cupric oxide,	None.	Trace.
Arsenic trioxide, (per cent.)	2.06	.86
Solids (per cent.),	3.08	1.96
Lime water soluble: —		
Cupric oxide,	None.	–
Arsenic trioxide (per cent.),	.97	1.52
Ammonia insoluble (per cent.),	–	.11

Neither of the greens contained an excessive amount of free or of free and loosely combined arsenic, judging by the standard, although the slow process was decidedly the better in that respect. This was to be expected, as the finely divided angular particles of the instantaneous green offered greater surface and apparently less resistance to a solvent than the nearly perfect spheres of the slow process. The copper acetate soluble results are of uncertain value. Filtered lime water, with .12 per cent. calcium oxide, contained insufficient lime to prevent solution of the arsenic. Ammonia dissolves Paris green and the normal by-products concomitant with its manufacture, such as copper arsenite, arsenous oxide, sodium sulfate and sodium acetate; the residue, .11 per cent. in case of the slow process green, was organic and other insoluble materials.

To ascertain the solvent action of various substances in solution on Paris green, a series of tests were conducted with the slow process sample. The green in stoppered flasks was treated with water and with solutions of the respective compounds at the rate of 1 gram to 1,000 cubic centimeters for twenty-four hours at laboratory temperature, with occasional agitation during the working day.

Solubility Tests, Slow Process Green.

Solvent.	Amount of Solvent in a Liter of Water (Grams).	Soluble As_2O_3 (Per Cent.).	Copper.	Remarks.
Distilled water,	–	.84	None.	– –
Water saturated with CO_2,	–[1]	6.16	Much.	– –
Ammonium hydroxide (concentrated).	1	.86	None.	– –
Ammonium hydroxide (concentrated).	5	13.49	Much.	Residue darker green.
Ammonium carbonate,	1	6.83	Much.	Blue solution.
Ammonium carbonate,	5	55.93	Excessive.	Blue, nearly complete solution.
Ammonium chloride,	1	2.41	Considerable.	– –
Ammonium nitrate,	1	2.03	Trace.	– –
Ammonium nitrate,	5	4.70	Much.	– –
Ammonium nitrite solution,	1	.36	– –	– –
Ammonium nitrite solution,	5	.36	– –	– –
Ammonium sulfate,	1	4.20	Considerable.	– –
Sodium carbonate (anhydrous),	1	3.15	None.	– –
Sodium bicarbonate,	1	.84	Very slight trace.	– –
Sodium chloride,	1	.96	None.	– –
Sodium nitrate,	1	.86	None.	– –
Sodium nitrite,	1	.88	– –	– –
Sodium sulfate (anhydrous),	1	1.67	Very slight trace.	– –
Boiling water, one hour,	–	14.93	Much.	Change in color of residue.

[1] About 5 gallons of gas used, water pressure.

Cold water dissolved a small amount of arsenic, boiling water very much more. The green appeared to resist hot water for a considerable time after which the change was noticeable. If the boiling had been continued all the arsenic would probably have passed into solution. The .10 per cent. ammonium salts, exclusive of nitrite, dissolved on the average 58 per cent.[1] more arsenic than the corresponding sodium salts. In both instances the carbonate was the most active, followed respectively by the sulfate, chloride and nitrate. Sodium bicarbonate was apparently inactive under the conditions employed. Free carbonic acid was effective and so was ammonia when in sufficient amount to overcome the resistance of the green, and jointly, carbonic acid and ammonia dissolved the most arsenic.

It is evident from what has been stated that carbonic acid and ammonia of the atmosphere in conjunction with dew, fogs or light rains and high temperature will materially increase the dissociation of Paris green. Data more or less contradictory have been offered by various investigators relative to the influence of weather conditions on the effect of arsenic on foliage. While more or less problematical, certain deductions seem warranted: conditions favoring a rapid drying of the green and its continuance in a dry state are propitious. For instance, a relatively high temperature, low humidity and a good circulation of air at the time of application, followed by warm, dry weather should tend toward a minimum of arsenical injury. On the other hand, factors conducive to solubility of the arsenic and its passage by osmosis into the substance of the leaf are detrimental; as, for example, warm, "muggy" weather or warm weather accompanied by fogs or heavy dews. Rains are not necessarily injurious if of sufficient quantity to remove the soluble arsenic from its sphere of influence. The addition of milk of lime to Paris green tends to reduce arsenical injury by forming, with the free arsenic, arsenite of lime insoluble in the presence of excess lime. As lime flocculates the particles of green, it is not advisable to prepare the spray mixture until shortly before application.

In conclusion, it may be said that Paris green contains a fairly high per cent. of arsenic, is nominally insoluble in water

[1] Direct comparison.

but unstable, hydrolizing readily under favorable conditions. It has a low power of suspension though its fineness permits of reasonable distribution. It is a poor indicator without lime of the leaf surface covered, but possesses fair adhesive qualities.

B. Calcium Arsenite.

Historical.

Early attempts to use arsenous oxide as an insecticide by Riley [1] in 1869 and Saunders and Reed [2] in 1871 were unsatisfactory. John Smith [3] in 1868 appears to have been more successful, applying it in water, but the practice proved too hazardous to warrant its continuance, although freshly prepared mixtures have been applied in numerous instances without injury. The relatively high cost of Paris green and London purple, and the necessity of adding lime to neutralize the free arsenic, led to the production of lime arsenite. So far as known this has always been a farm preparation and not a commercial product.

Kilgore [4] recommended adding 1 pound of white arsenic to 2 pounds of lime in 2 to 5 gallons of water and boiling thirty minutes. Taft [5] advised adding 2 pounds of freshly slaked lime to 1 pound of arsenic in 2 gallons of water and boiling forty minutes. Kedzie [6] suggested dissolving the arsenic in a solution of sal soda and offered the formula which bears his name. Boil 2 pounds of arsenic with 8 pounds of sal soda in 2 gallons of water until dissolved. Slake 2 pounds of lime, add to 40 gallons of water and stir in 1 pint of the arsenic solution. Stewart [7] evidently noted the undue amount of sal soda in the Kedzie formula and reported better results, using equal parts, 2 pounds of arsenic and 2 pounds of sal soda. E. L. Smith [8] recommended 2 pints of Kedzie mixture to 6 to 10 pounds of lime in 50 gallons of water, and claimed that the additional lime increased safety and adhesiveness.

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[1] Potato Pests, p. 60 (1876).

[2] Can. Ent., 3, pp. 45–47 (1871).

[3] Western Pomologist, 2, p. 125 (1871). Cited by Lodeman.

[4] N. Car. Exp. Sta., Bul. No. 77b, pp. 7–8 (1891).

[5] Mich. Bd. Agr. Rept., 35, p. 119 (1897). In Rept. 37, p. 466 (1899), the amount of lime was increased 8 pounds on application.

[6] Mich. Farmer, 31, p. 132 (1897).

[7] Penn. Exp. Sta., Bul. No. 99, p. 11 (1910).

[8] Cal. Exp. Sta., Bul. No. 126, p. 24 (1899).

Authorities differ as to the arsenite that results from the union of lime and arsenic. Prescott and Johnson [1] state that the arsenites of the alkaline earth are usually ortho compounds, Merck & Co.[2] and Gooch and Walker [3] give neutral orthoarsenite of lime, while Comey [4] and Watts' Dictionary [5] recognize the ortho, $Ca_3(AsO_3)_2$, the meta, $Ca(AsO_2)_2$, and the pyro, $Ca_2As_2O_5$, salts. The latter is designated a mixture of basic salts with 1 molecule of water, $2CaO.As_2O_3.H_2O$. So far as noted the formula acknowledged by experiment station workers has been that of the neutral ortho salt, although the subject has been given little attention.

As determined by Colby [6] the suspension, in 1 foot column, of arsenite of lime made according to directions published by Taft was forty-four minutes, and by Kedzie formula fifty-seven minutes. Headden [7] noted that arsenite of lime was almost entirely soluble in water and in dilute solutions of sodium sulfate and sodium chloride.

Experimental Results.

For the preparation of a high-grade arsenite of lime required for the work in view, precipitation from soluble salts of lime and of arsenic, while more costly, promised a more definite and uniform product. As lime arsenite is noncrystallizable, precipitation from perfect solutions insured better combination and greater freedom from admixtures. The comparative insolubility of lime, CaO, necessitated the use of a soluble salt. Lime salts of strong oxidizing acids were deemed objectionable on account of possible action on the arsenite and were excluded. The acetate of organic compounds and the chloride of the halogens were selected for trial, but after several tests the chloride was considered preferable. The fused salt was almost invariably employed. It should be free from other bases forming insoluble compounds with arsenic. The direct use of arsenous oxide is not advisable with a lime *salt*, not only for

[1] Qual. Chem. Anal., 6th edition, p. 57 (1905).
[2] Merck's 1907 Index, p. 113.
[3] Outlines of Inorg. Chem. Pt. 2, p. 184 (1905).
[4] Dict. of Chem. Sol., p. 41 (1896).
[5] Watts' Dict. of Chem., 3d edition, 1, p. 306 (1893).
[6] Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).
[7] Col. Exp. Sta., Bul. No. 131, p. 22 (1908).

the reason that ordinary porcelaneous arsenic in pulverulent condition is difficult to moisten and of low solubility, but more particularly because it would induce a secondary reaction from lack of base to satisfy the acid that was previously combined with the lime. Sodium arsenite, $NaAsO_2$, is readily soluble and proved a satisfactory source of arsenic. A salt of fair quality can be procured on the market, or is easily prepared by adding 1 part of arsenous oxide to a boiling solution of 1.45 parts of sal soda, or an equivalent amount of soda in the form of anhydrous carbonate, bicarbonate or hydroxide. A slight excess of arsenic is required to insure complete volatilization of the carbonic acid.

$$Na_2CO_3 \cdot 10\,H_2O + As_2O_3 = 2\,NaAsO_2 + CO_2 + 10\,H_2O.$$

The resulting arsenite should be free from arsenates, carbonates, sulfates or other acids forming insoluble compounds with lime.

Any decision as to concentration of solutions is naturally more or less arbitrary; dilution tends to make difficult precipitation with considerable loss of salt, and the opposite an unwieldy precipitate with greater occlusion. As a compromise solutions of ½ molecular strength (M/2) were finally adopted. Another factor studied was the influence of temperature of solutions on the resulting precipitate, ranging from that of the laboratory to nearly boiling point at the moment of precipitation. Room temperature with two hours' standing gave a product of practically the same composition, and of probably better physical characteristics, than the higher temperatures and was considered more desirable.

As the alkalinity of the soda in sodium arsenite is not destroyed by the arsenous acid, it should be run into the calcium chloride solution slowly with constant agitation in order to prevent any precipitation of calcium hydroxide. An excess (10 per cent.) of sodium arsenite was found desirable to perfect the salt. After standing several hours the liquor was removed by means of a Buchner funnel, and the lime arsenite washed rapidly with cold water until nearly free from chlorides. A centrifuge or filter press might give equally good or better results provided the work was done rapidly. Undue washing was avoided, as it was thought safer to retain a small amount of sodium chloride than to take chances on *possible* hydrolysis and decomposition of the arsenite, an action readily inferred from the behavior of Paris green under similar conditions. The above method of preparation was employed in all subsequent work unless otherwise noted. Minor changes were attempted in some instances from which no apparent benefit was derived.

As previously stated there was considerable uncertainty as to the composition of the lime precipitate. To ascertain whether the resulting product was a definite compound and, if so, its composition, salts were produced from an excess of sodium arsenite into calcium chloride and *vice versa*, observing the usual precautions as to dilution, precipitation of calcium hydroxide, oxidation of the arsenic, etc. Incomplete analyses of a few laboratory samples are given.

Calcium Arsenite produced in the Laboratory (*Per Cent.*).

	Excess $NaAsO_2$ into $CaCl_2$.			Excess $CaCl_2$ into $NaAsO_2$.
	Precipitated Hot.	Precipitated at 90° C.	Precipitated and held at 90° C. for Two Hours.	Precipitated Hot.
Water,	.12	.12	–	.12
Arsenic trioxide,	77.01	77.04	76.75	76.80
Insoluble matter,	–	–	–	.03

The small samples were of uniform composition, indicating a definite compound of about 77 per cent. arsenic content. This amount of arsenic exceeds the requirements of the ortho and pyro salts, and substantially conforms to that of the meta compound with a theoretical content of 77.92 per cent. The following equation illustrates the reaction that must have occurred: —

$$CaCl_2 + 2\,NaAsO_2 = Ca(AsO_2)_2 + 2\,NaCl.$$

Attention has been called on pages 180, 181 and 182 to 5 samples of lime arsenite supplied by several firms for the investigation. Manufacturer C was furnished directions deduced from experimental work in the station laboratory. A and B evidently employed a different method.

Calcium Arsenite from Chemical Manufacturers.

	As received.					In Dry Matter.	Theoretical.
Manufacturer,	A	B	C_1	C_2	C_3	C_3	-
Character of product,	Dry, granular.	Moist powder.	Dry, granular.	Gritty [2] paste.	Smooth paste.	-	-
Color,	White.	White.	Slightly pink.	Pink. [2]	Nearly white.	-	-
Water (per cent.),	.67	16.27	.80	-	67.87	-	-
Calcium oxide (CaO) (per cent.),	-	-	21.63	-	6.78	21.10	22.08
Arsenic trioxide (As_2O_3) (per cent.),	29.39	29.36	76.31	-	23.87	74.28	77.92
Arsenic pentoxide (As_2O_5) (per cent.),	-	-	-	-	.09	.28	-
Magnesium oxide (MgO) (per cent.),	-	-	-	-	.05	.16	-
Chlorine (Cl) (per cent.),	-	-	-	-	.80	2.49	-
Sodium oxide (estimated) (Na_2O) (per cent.),	-	-	-	-	.70	2.18	-
Insoluble matter (per cent.),	5.63	.20	.02	-	.01	.03	-
	-	-	-	-	100.17	100.52	100.00
Less oxygen equivalent to chlorine (per cent.),	-	-	-	-	.18	.56	-
	-	-	-	-	99.99	99.96	-
Arsenic (As) (per cent.),	-	-	-	-	18.14	56.46	59.02
Suspension in lime water, hours,	-	-	-	-	56	-	-
Suspension in lime water after drying, hours,	-	-	-	-	48	-	-

[1] A, B and C refer to individual manufacturers, the numerals to different samples.

[2] Gritty on account of compressed air being used to agitate and pink due to the presence of manganese.

Sample C_1 and C_3 confirmed the former analyses as to arsenous oxide, and the molecular ratio of calcium oxide to arsenous oxide was almost theoretical for calcium metarsenite. It would, therefore, appear safe to assume that lime arsenite precipitated from soluble salts of lime and of arsenic is invariably the meta salt.

Sample C_3 was employed in spraying, although in the process of manufacture it had been imperfectly washed, contained a small amount of magnesia and showed a slight oxidation of arsenic. Any arrangement of constituents is of doubtful value; still, the following may be suggested: —

Calcium Arsenite employed in Spraying.

Manufacturer,	C_3
Water (per cent.),	67.87
Calcium orthoarsenate ($Ca_3(AsO_4)_2 \cdot 3\,H_2O$) (per cent.),	.18
Magnesium metarsenite ($Mg(AsO_2)_2$) (per cent.),	.30
Calcium metarsenite ($Ca(AsO_2)_2$) (per cent.),	30.31
Sodium chloride (NaCl) (per cent.),	1.32
Insoluble matter (per cent.),	.01
	99.99

The above analysis would indicate a purity, on a water-free basis, of 94.34 per cent.

Calcium metarsenite, prepared according to the directions given, is a smooth white gelatinous mass or jell of very fine, adhesive particles. The power of suspension which has to be determined in lime water to prevent partial solution is extremely high but lessened by drying. Sample C_3 gave phenomenal results, though the actual figures are indicative rather than absolute. A moist paste of arsenite of lime proved unstable, gradually changing to arsenate with the separation of free arsenic (As). Calcium arsenite is probably the most soluble arsenical insecticide in use as shown by the following results: —

Solubility.

Manufacturer,	A	B	C_1	C_2	C_3
Water (per cent.),	.67	–	.80	–	67.87
Calcium acetate soluble: —					
Arsenic trioxide (per cent.),	27.55	–	11.62	–	–
Water soluble (Hilgard Method): —					
Calcium oxide (per cent.),	–	–	10.98	–	3.14
Arsenic trioxide (per cent.),	24.78	–	40.88	–	11.58
Solids (per cent.),	64.90	–	53.48[1]	–	16.54
Lime water soluble: —					
Arsenic trioxide (per cent.),	.14	–	.17	–	.05

The calcium acetate soluble appeared to have no particular significance, and the test was eventually dropped. The water soluble results are only approximate, as slight variations in temperature or agitation caused marked differences. Solubility is apparently not a result of hydrolysis, as proportionally the lime passed into solution almost as rapidly as the arsenic. If hydrolysis played any part it would seem to be inappreciable. Lime arsenite was nearly insoluble in lime water. In order to secure additional data relative to the solubility of lime arsenite, 1 gram of sample C_3, after drying, was subjected to the action of various solvents for twenty-four hours in stoppered flasks with occasional agitation, the results of which are stated below: —

Solubility Tests, Sample C_3 Dried.

Solvent.	Amount of Solvent in a Liter of Water (Grams).	Soluble As_2O_3 (Per Cent.).	Lime.	Remarks.
Distilled water,	–	38.45	Present.	–
Water saturated with CO_2,	–[2]	62.22	Present.	–
Ammonium hydroxide (concentrated),	1	36.66	Present.	–
Ammonium carbonate,	1	64.36	Trace.	–
Ammonium chloride,	1	53.40	Present.	–
Ammonium nitrate,	1	51.97	Present.	–
Ammonium nitrite solution,	1	43.06	Present.	–
Ammonium sulfate,	1	52.71	Present.	–
Sodium carbonate (anhydrous),	1	59.32	None.	–
Sodium bicarbonate,	1	62.19	None.	–
Sodium chloride,	1	41.20	Present.	–
Sodium nitrate,	1	40.53	Present.	–
Sodium nitrite,	1	40.72	Present.	–
Sodium sulfate (anhydrous),	1	41.08	Present.	–
Boiling water, 1 hour,	–	58.63	Much.	–

[1] Contained .39 per cent. of ferric and aluminum oxides and .08 per cent. of magnesium oxide.
[2] About 5 gallons of gas used, water pressure.

Calcium metarsenite was fairly soluble in cold water, but much more so in boiling water. The ammonium salts, exclusive of nitrite, dissolved about 19 per cent.[1] more arsenic than the corresponding sodium salts. The carbonate in both instances proved very effective, followed by the chloride, sulfate and nitrate with only slight differences between the latter. An interchange of bases must have resulted in many instances to permit the high solubility recorded. Carbonic acid, combined and free, was the most active of any single agent, consequently excess lime should afford one of the best methods of protection under atmospheric conditions. Ammonium hydroxide depressed slightly the solubility of the arsenic.

Calcium metarsenite contains the highest per cent. of arsenic of all the common insecticides, and is quite soluble except in presence of excess lime; the fineness of its particles and the high power of suspension insure uniform distribution; the white film readily indicates the surface covered; and its adhesiveness provides protection for a reasonable period under average weather conditions.

C. Lead Arsenates.

Historical.

F. C. Moulton,[2] chemist for the Massachusetts Gypsy Moth Commission, was the first to prepare arsenate of lead for insecticidal purposes. He employed lead acetate and sodium arsenate. The work was continued by F. J. Smith,[3] who studied the composition of the chemicals used, the reactions and other matters pertaining to the manufacture. He stated that ordinary spray material was not a single salt, but a mixture of neutral and acid arsenates, and believed that the relative amount of each depended principally upon the source of the soluble lead salt, although temperature and concentration at the moment of precipitation affected the results; in other words, that acetate of lead had a tendency, other factors being equal, to yield the neutral salt and the nitrate the acid arsenate.

An electrolytic process for making arsenate of lead was patented by C. D. Vreeland in 1907, using lead, sodium arsenate

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[1] Direct comparison.

[2] Mass. Bd. Agr. Rept., 41, p. 282 (1894).

[3] *Ibid.*, 45, pp. 357-371 (1898).

and an electrolyte of sodium nitrate. Patents have also been taken out on various other methods of manufacture, references to which are found in technical journals. I. W. Drummond patented a dry preparation of lead nitrate, sodium arsenate and corn starch to be mixed with water when applied.

Most authorities recognize neutral orthoarsenate of lead, $Pb_3(AsO_4)_2$, and acid arsenate, $PbHAsO_4$, and a few mention pyroarsenate, $Pb_2As_2O_7$. W. H. Volck[1] claims the latter salt may occur in commercial pastes, though Lefevre[2] states that it is decomposed by cold water. Pyroarsenate differs from 2 molecules of the acid salt by 1 molecule of water.

$$Pb_2As_2O_7 + H_2O = 2\,PbHAsO_4.$$

So far as noted, the presence of pyroarsenate in insecticides has not been proved.

The low specific gravity of lead arsenate, 1.00668 according to Smith[3] (salt not specified), results in a high power of suspension as shown by Colby,[4] from nitrate one hundred and thirty minutes and from acetate two hundred and forty minutes. Investigators have found lead arsenates comparatively little affected by hot water or carbonic acid. Dilute solutions of sodium carbonate, sodium chloride and sodium sulfate have an appreciable action as shown by Headden[5] and others. The acid salt has invariably proved the more unstable. Volck[6] noted that under alkaline conditions it tends to decompose with the formation of the ortho salt and arsenic acid, and he states that this reaction appears to take place in the orchards of the Pacific coast as a result of the continuous fogs and heavy dews. P. J. O'Gara[7] also claims that the acid salt is very injurious under certain climatic conditions. Haywood[8] recommended the addition of lime to arsenate of lead to prevent injury to delicate foliage.

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[1] Science, 33, p. 868 (1911).
[2] Cited by A. M. Comey, Dict. of Chem. Sol., p. 35.
[3] Mass. Bd. Agr. Rept., 45, p. 355 (1898).
[4] Cal. Exp. Sta., Bul. No. 151, p. 34 (1903).
[5] Col. Exp. Sta., Bul. No. 131, p. 22 (1908); Bul. No. 157, pp. 29, 30 (1910).
[6] *Loc. cit.*
[7] Science, 33, p. 900 (1911).
[8] Bur. Chem., Bul. No. 131, p. 49 (1910).

Experimental Results.

In the production of lead arsenates pure chemicals are a prime requisite for a high-grade product. The lead salts should be free from other bases forming insoluble arsenates, and the sodium arsenate ($Na_2HAsO_47H_2O$) from arsenites, carbonates, chlorides and sulfates. Acetate of lead is objectionable as a source of lead in that it readily carbonates on exposure to air. As to concentration of solutions, our experience has shown that for salts of such high molecular weight dilute solutions not exceeding ⅕ molecular (M/5) are preferable. At that dilution, laboratory temperature gives a very finely divided precipitate which is highly desirable from the standpoint of suspension. The arsenate should be run into the lead salt *very slowly* with thorough agitation in order to prevent precipitation of lead hydroxide due to the alkalinity of the sodium salt. The reverse precipitation, lead into the arsenic, proved less satisfactory both as to formation and behavior of the precipitate. While arsenic acid is stronger than arsenous, it neutralizes only about one-half the alkalinity of the soda in disodium hydrogen arsenate.

Neutral Lead Arsenate. — After many attempts, employing di and tri sodium and ammonium arsenates, salts containing arsenic and lead in proper molecular ratio were finally produced according to the following equation: —

$$3\,Pb(C_2H_3O_2)_2 3\,H_2O + 2\,Na_2HAsO_4 7\,H_2O$$
$$= Pb_3(AsO_4)_2 + 4\,NaC_2H_3O_2 3\,H_2O + 2\,C_2H_4O_2 + 11\,H_2O.$$

To obtain these results it was necessary to prepare the disodium arsenate in order to exclude carbonic acid which was present in the commercial salts purchased. The principal difficulties, however, arose from failure to add the strongly alkaline sodium arsenate slowly and with sufficient agitation to prevent the precipitation of lead hydroxide and to maintain an excess of at least 5 per cent. of lead to prevent the formation of the acid salt. The usual precautions as to concentration, temperature and thoroughness of washing were carefully observed. The following analyses of two samples show the material to be practically of theoretical composition: —

Neutral Lead Arsenate produced in the Laboratory.

Sample number,	31	32
Water 100° C. (per cent.),	.75	.70
Arsenic pentoxide (per cent.),	25.10	25.18
Lead oxide (per cent.),	73.15	73.20
Water occluded (per cent.),	.98	.82
	99.98	99.90

The lead salt invariably contained a small amount of water probably held by occlusion which is not volatilized at 100° C.

Acid lead arsenate is readily prepared from nitrate of lead and sodium arsenate provided dilute solutions are employed and the sodium salt added carefully in excess (10 per cent.).

$$Pb(NO_3)_2 + Na_2HAsO_4 7\,H_2O = PbHAsO_4 + 2\,NaNO_3 + 7\,H_2O.$$

By this method of procedure no difficulty was experienced in producing salts of theoretical composition. The acetate can be used as a source of lead, but is less satisfactory.

Six samples of lead arsenate were supplied by three manufacturers for the spraying tests. Manufacturer C was furnished full directions as outlined above for making the acid salt. The detailed process for preparing the neutral salt was not deduced until later.

Lead Arsenates from Chemical Manufacturers.

	Supplied as —								
	Unknown.	Neutral.			Acid.				
	–	–	–	Theoretical.	–	–	–	In Dry Matter.	Theoretical.
Manufacturer,[1]	A	B_1	C_1	–	B_2	C_2	C_3	C_3	–
Character of product,	Dry, granular.	Dry, powder.	Dry, slightly granular.	–	Dry, powder.	Dry, powder.	Smooth paste.	–	–
Color,	Yellowish.	Dirty white.	White.	–	White.	White.	White.	–	–
Water (per cent.),	–[2]	.34	6.39	–	.66	.35	46.99	–	–
Lead oxide (PbO) (per cent.),	–	66.11	69.74	74.43	63.63	65.39	34.58	65.23	64.28
Arsenic pentoxide (As_2O_5) (per cent.),	–	29.47	22.75	25.57	29.50	30.92	17.11	32.27	33.12
Water in combination (per cent.),	–	–	–	–	–	1.06	1.33	2.51	2.60
Chlorine (Cl) (per cent.),	–	–	–	–	–	–	.04	.08	–
Insoluble matter (per cent.),	–	.36	.01	–	.08	.00	.01	.02	–
	–	–	–	100.00	–	–	100.06	100.11	100.00
Less oxygen equivalent to chlorine (per cent.),	–	–	–	–	–	–	.01	.02	–
	–	–	–	–	–	–	100.05	100.09	–
Arsenic (As) (per cent.),	–	–	–	16.67	–	–	11.16	21.05	21.60
Suspension in water, minutes,	–	–	–	–	–	–	81	–	–
Suspension in water after drying, minutes,	–	–	–	–	–	–	42	–	–

[1] A, B and C refer to individual manufacturers, the numerals to different samples. [2] Sample rejected.

Neutral and acid arsenates of lead are quite insoluble, although both salts will undoubtedly yield arsenic slowly to continuous percolation, the acid salt decomposing the more readily.

Solubility.

	Supplied as —					
	Neutral.			Acid.		
Manufacturer,	A	B_1	C_1	B_2	C_2	C_3
Water (per cent.),	–[1]	.34	6.39	.66	.35	46.99
Water soluble (Hilgard method): —						
Lead oxide (per cent.),	–	None.	.01	None.	.14	.06
Arsenic pentoxide (per cent.),	–	.48	.05	.16	.02	.03
Solids (per cent.),	–	2.33	1.13	4.21	2.10	.30

The acid salt C_3 was practically insoluble under the conditions tested, and nearly free from soluble by-products.

The legal standard[2] for commercial lead arsenate in form of paste specifies not more than 50 per cent. of water nor less than 12.50 per cent. of arsenic pentoxide and not more than .75 per cent. of arsenic pentoxide soluble in water. Sample C_3, acid salt, which was used in experimental work, exceeded standard requirements in all particulars. A careful study of the analytical results, C_3, might warrant the following combination: —

Acid Lead Arsenate employed in Spraying.

	Per Cent.
Water,	46.99
Acid lead arsenate ($PbHAsO_4$),	51.61
Lead chloride ($PbCl_2$),	.16
Lead hydroxide ($2PbO \cdot H_2O$),	1.34
Insoluble matter,	.01
	100.11

Exclusive of water, the purity was approximately 97.36 per cent. There was a small amount of lead chloride, but the most objectionable feature appeared to be the precipitated lead hydroxide due to careless preparation.

[1] Sample rejected.

[2] The insecticide act of 1910, section 7.

There is evidently a difference in stability between acid and neutral lead arsenates as measured by boiling ammoniacal solutions, but, contrary to general belief, it is apparently only a matter of degree. Both salts are decomposable, yielding soluble arsenic acid.

Neutral arsenate, sample 31, page 204, after being twice heated with ammonia and washed, gave a residue which was practically stable and tested as follows: —

	Per Cent.
Water,	.44
Arsenic pentoxide,	23.84
Lead oxide,	75.02
Occluded water,	.64
	99.94

Stability was apparently the result of a reversible reaction, ammonia setting arsenic acid free, and lead hydroxide, when present in sufficient excess (10 per cent.), completely reprecipitating it. Similar results were obtained by adding freshly precipitated lead hydroxide, litharge and lime to neutral arsenate, the excess base preventing the separation of arsenic acid.

If properly made, neutral and acid arsenates of lead are smooth, white pastes of very fine particles, low specific gravity, excellent suspension and exceptional adhesiveness. The power of suspension is injured by drying. The readings reported for sample C_3 are not the maximum, but were taken when no movement of particles was perceptible, although the mixture continued milky for a considerable period thereafter.

Both acid and neutral lead arsenates are slow-acting poisons of low arsenic content, and that in the form of pentoxide. They are practically insoluble in water and fairly stable. The fineness of the particles and low specific gravity insure a high power of suspension and uniform distribution. The white mixture readily indicates the leaf surface covered and dries to a film which adheres with great persistence.

THE NATURAL FERTILITY OF CRANBERRY BOGS.

BY F. W. MORSE, M.SC.

Years of experience by practical men have shown that cranberries are best grown on a peat bog the surface of which has been covered with a thin layer of sand. Furthermore, the best results with this soil are obtained only when there is an abundance of water by which at times the land may be flooded and at other times irrigated; and at the same time there must be opportunities for thoroughly draining the land at some stages of growth. This combination of peat subsoil, sandy surface and varying amounts of water is unusual in any other line of crop production, and most of the present methods pursued in cranberry culture are wholly empirical in their character.

One important problem now puzzling the cranberry grower is that of fertilization; is it necessary or unnecessary? The potential fertility of a true peat soil, that is, the amount of the elements of plant nutrition contained in its dry matter, is known to be high. Hopkins [1] states that a peat soil contains in the upper layer (6⅔ inches thick) of 1 acre, 35,000 pounds of nitrogen, 2,000 pounds of phosphorus and 2,900 pounds of potassium, while a layer 40 inches deep over 1 acre contains 197,000 pounds of nitrogen, 8,600 pounds of phosphorus and 21,400 pounds of potassium. He further states [2] that but little of this enormous store of material is in an actively available form, and estimates that a corn crop can get at not more than 7 pounds of potassium per acre, while in an experiment on a poorly drained field, corn was benefited by the addition of nitrogen.[3] The sand on the surface of the peat may be disregarded as a source of plant nutrients, but it is an important agent in making availa-

[1] Hopkins, C. G., Soil Fertility, Ginn & Co., 1910, pp. 83-87.

[2] *Ibid.*, p. 471.

[3] *Ibid.*, p. 472.

ble the elements contained in the peat. The water used in flooding and irrigating may be regarded in a similar way, since it is as pure as the average public water supply and often purer.

Analyses of the cranberries and cranberry vines reveal an unusually low proportion of nitrogen and ash constituents, especially in the fruit which, as a rule, is all that is removed from the bog.

TABLE I. — *Composition of Cranberries and Vines.*

	Water.	Ash.	Nitrogen.	Phosphoric Acid.	Potash.	Lime.	Magnesia.
Berries, Massachusetts,[1]	89.40	0.195	0.07	0.025	0.08	0.03	–
Berries, New Jersey,[2]	–	0.175	0.05	0.020	0.07	0.01	0.009
Vines, Massachusetts,[1]	13.07	2.450	0.77	0.270	0.33	0.40	0.250
Vines, New Jersey,[2]	–	2.070	0.61	0.180	0.24	0.49	0.190
Vines, New Jersey,[2]	–	2.100	0.65	0.310	0.40	0.50	0.190

A crop of 100 barrels of cranberries per acre, weighing 10,000 pounds, will contain only 7 pounds of nitrogen, 3 pounds of phosphoric acid and 8 pounds of potash. One ton of dried vines would contain 15 pounds of nitrogen, 6.2 pounds of phosphoric acid and 8 pounds of potash. These figures show clearly that the cranberry crop will never exhaust the potential fertility of the bog; but it is equally plain that it has become accustomed to a scanty nourishment, and they do not answer the question, "Shall fertilizers be used?"

There are on record only three series of fertilizer tests on the cranberry crop. They are somewhat empirical and throw little light on the problem.

An experiment in New Jersey was reported in 1895.[3] A complete fertilizer gave the best results, with the next best from the nitrogen with phosphorus and nitrogen with potash. This was indicative of the actual need of nitrogen; but the soil was described as a black sand somewhat too dry for a good bog.

In Wisconsin Whitson began a series of fertilizer tests in 1904,[4] the last detailed report of which was published in 1907.[5]

[1] Mass. State Exp. Sta. Rept., 1889, p. 274; 1893, pp. 330, 370.
[2] N. J. Agr. Exp. Sta. Rept., 1898, pp. 122, 123.
[3] Ann. Rept., N. J. Agr. Exp. Sta., 1895, p. 110.
[4] Whitson, A. R., Ann. Rept., Wis. Agr. Exp. Sta., 1905, pp. 291 and 292.
[5] Ann. Rept., Wis. Agr. Exp. Sta., 1907, p. 305.

The largest increase in fruit was from the use of sodium nitrate with acid phosphate, and the next best yield was from the nitrate with potash salts, while nitrate of soda alone was more effective than either of the other substances used singly. The actual character of the soil to which the fertilizers were applied is not stated, but from the general description of the bog it is inferred that the soil was a deep peat with the usual surface layer of sand.

In Massachusetts Brooks began a fertilizer test in 1906.[1] Three years later he reported [2] that nitrate of soda greatly promoted the growth of vines, and seemed to be favorable to fruitfulness, but when used in excess of 100 pounds per acre the growth of vines was liable to be too luxuriant. High-grade sulfate of potash was decidedly favorable, and the maximum yield was obtained from a heavy dressing of this salt supplemented by a moderate application of nitrate of soda and acid phosphate. The soil of the Massachusetts bog was not a deep peat, but a sand colored with peat as shown by a chemical analysis which revealed less than 2 per cent. of organic matter. In this instance there is evidence of a low potential fertility, which does not help clear up the problem of the use of fertilizers on a true peat soil.

When peat soils have been well drained and planted to common farm crops like corn, they have not been found to require nitrogen, but have been noticeably improved by the addition of potash salts and phosphates.[3] The conditions required by corn and staple farm crops differ, however, very much from those required by the cranberry. In the former conditions drainage is maintained continuously as a rule, while in the latter case the soil is saturated and even flooded through nearly three-fourths of the year. In the former case nitrification is favored, but in the latter case it is hindered, which may account for the agreement of all three fertilizer tests in showing an increase of fruit upon applications of nitrate of soda.

A consideration of the methods followed by cranberry growers in regulating the water supply of their bogs is helpful in connec-

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[1] Brooks, Wm. P., Ann. Rept., Mass. Agr. Exp. Sta., 1908, p. 17.

[2] Ann. Rept., Mass. Agr. Exp. Sta., 1910, p. 32.

[3] Hopkins, C. G., Soil Fertility, Ginn & Co., 1910, pp. 471–472; Whitson, A. R., Ann. Rept., Wis. Agr. Exp. Sta., 1905.

tion with a study of the natural fertility of the soil. Where conditions permit the bog is completely overflowed from some time in November until May, sometimes until the latter part of this month. During this period the changes within the soil must be limited to solution of matter in the water and putrefactive decomposition in the vegetable matter. Both will be at the lowest point because of the winter temperature. In the spring, when the sluices are opened, there is a rapid run-off from the surface followed finally by seepage into the ditches. The water table falls in the soil to a point a little higher than the level maintained in the drains. It is only above this water table that the activities of useful bacteria can occur, and while it is not definitely known how deep the cranberry roots penetrate, it is probable that they do not extend below the permanent water table. Through a large part of the growing season the water is maintained in the ditches at a level 12 to 15 inches below the surface of the soil. This permits oxidation changes and free root development in a soil depth of not more than 1 foot.

Moist sand is a well known medium for ærobic bacterial action, and the same is true of peat when it contains the optimum amount of water. Sewage filters are constructed of both types of soils, while several proposed processes for production of nitrates are based on the rapid nitrification known to take place in peat under favorable conditions.

During the summer season there must be a movement of water upward from the level of the water table into the surface peat and sand. This upward current is produced mainly by the transpiration of water from the plants, as they cover the surface so completely that actual evaporation must be small. But this makes little difference since it has been shown that transpiration follows the same laws as evaporation from a free surface.[1] Botanists have also observed that bog plants, for some reason, take on the character of desert plants and resist transpiration. The peat which is continually saturated or submerged must be constantly yielding soluble material to the enveloping water, and the solution must be nearly saturated. This soluble matter is poisonous to plants of many families, but

[1] Montgomery, Proc. Am. Soc. Agronomy, 1911, pp. 261, 283.

its influence on cranberry vines is not known. In the aerated surface soil, however, it will be transformed into the beneficial highly oxidized compounds, as nitrates and sulfates.

The present use of water on cranberry bogs is empirical, but a consideration of the conditions under which soil changes occur leads me to believe that water should be withdrawn from the surface at the earliest possible moment in the spring consistent with safety from frost, and held at the lowest possible level at which the vines can secure sufficient moisture for free growth during dry and hot weather. By this arrangement the period of active soil change, and the volume of soil in which it can take place, will be at a maximum, with a consequent increase in the amount of available nutrients for the plants. Flooding the bogs followed by the spring draining undoubtedly causes some loss of soluble fertility, and, on account of the close approach to saturation of the soil during the summer, heavy rains will also result in loss through seepage into the ditches.

This experiment station has begun an investigation of the problem of cranberry-bog fertility, and Director Brooks has devised a series of 30 miniature bogs described by him in a recent article.[1] Each bog is constructed in a 24-inch tile, 48 inches deep, and connected with it is a 6-inch tile that corresponds to the ditch on a large bog, by which the bog can be drained or irrigated. Analyses of the drainage water during the past two summers throw some light on the development of soluble material in the peat and its transformation into active nutrients for the vines. The first analyses were made on samples collected July 14, 1910. Other samples were analyzed at intervals until October 19. During most of this period frequent additions of water were required by the bog because the rainfall was abnormally small. All the water was applied to the surface of the bogs in order to promote diffusion into the small drainage cylinders.

There was much variation in the composition and also in the color of the different samples, which continued until the collection of September 12. There was, however, a steady progress toward uniformity. A few days previous to September 12, viz., on the 8th, there was an exceptionally heavy rainfall which

[1] Brooks, Wm. P., Proc. Soc. Promotion Agr. Sci., 1911, pp. 23-28.

flooded the bogs, covering the surface with an inch of water. The percolation which followed forced the bog water into the drainage cylinders. The water from nearly every bog on September 12 was a dark coffee color, whereas before this date there had been a wide range of tints from dark coffee to light amber. The total solids, and particularly the volatile solids, had now reached a maximum in all but two or three samples, and the amounts were of the same order of magnitude. When sampled for the last time in 1910, on October 19, there was another noticeable change in the water. Nearly all the samples were now a greenish black in color, and opaque and inky in appearance. They also were filtered with difficulty. All the samples collected during the season had been filtered through dry paper filters to remove suspended matter and sand. The water ran rapidly through the paper and in the earlier collections left little or no stain behind. As the colors deepened the later collections stained the filters more and more. The last series deposited a colloidal film on the paper which hindered the passage of the water through the pores and caused the filtration to occupy several hours, in some cases nearly twenty-four hours, while the filtered water had lost its inky appearance and was as a rule a light coffee color. This behavior, together with the appearance of a maximum point in the total solids and volatile solids, points conclusively to a saturated solution with respect to the organic constituents of the peat.

TABLE II. — *Inorganic Solids in Bog Waters, 1910.*

[Parts in 100,000.]

Bog Number.	July 14.	July 27.	August 22.	September 12.	October 19.
1,	11.8	34.8	53.0	62.4	59.6
2,	19.8	56.2	67.6	58.6	64.0
3,	31.4	49.8	76.6	64.6	63.8
4,	83.2	60.4	62.0	64.6	50.0
5,	73.6	69.4	70.0	53.8	59.6
6,	11.0	23.6	40.2	54.6	62.8
15,	11.2	–	52.0	73.4	68.0
16,	11.4	–	39.0	63.0	78.8
17,	54.6	49.4	51.4	63.0	–
18,	50.8	53.8	56.8	49.8	–
22,	63.4	56.2	58.6	49.0	–
25,	23.8	41.0	55.0	52.0	53.0

TABLE III. — *Organic Solids in Bog Waters, 1910.*

[Parts in 100,000.]

Bog Number.	July 14.	July 27.	August 22.	September 12.	October 19.
1, ...	5.8	12.8	18.6	94.0	73.6
2, ...	8.2	25.8	37.6	107.4	80.2
3, ...	10.4	16.4	28.0	112.6	94.0
4, ...	25.0	66.2	78.0	106.6	67.2
5, ...	44.8	62.6	70.4	131.2	101.2
6, ...	5.8	11.8	20.4	114.8	96.0
15, ...	3.2	–	22.0	102.8	104.2
16, ...	4.6	–	15.4	65.8	64.4
17, ...	54.4	89.2	101.6	93.8	–
18, ...	70.6	108.2	113.2	92.0	–
22, ...	48.6	60.2	118.0	96.6	–
25, ...	–	21.6	32.0	93.2	88.8

The inorganic solids were more or less influenced by the cement used in the construction of the cylinders.

The samples of 1911 are best considered in two groups, one of which represents the bog water in the spring, while the other shows its composition at the end of the summer. The first group consisted of two series of samples which were taken from 10 of the bogs on the 10th and 12th of May, before the flood water was drained off. The samples therefore represented the results of six months of solution, diffusion and precipitation on the organic and inorganic matter in the bogs. One set of samples was filtered through dry paper filters before they were analyzed, while the other set was allowed to stand over night to settle, and then used without filtering. The samples were inky in appearance when taken and changed but little on standing. Filtration required from twenty-four to forty-eight hours and a change of filter papers, because their surfaces were soon covered with a dark slime which rendered them nearly impervious. The filtered water was much lighter in color than the original sample. The material removed by the filters was largely organic in its nature, since the organic solids in the filtered water were lower proportionally than the inorganic solids when compared with the corresponding figures for the unfiltered water.

TABLE IV. — *Average Composition of Bog Waters, May 10–12, 1911.*

	Organic Solids.	Inorganic Solids.
Unfiltered,	63.0	48.0
Filtered,	38.8	34.0

The behavior of the samples in filtering, their opaque appearance before it, and the lower solids compared with the results of the previous season, point toward a saturation of the water in the bogs by the soluble material in the soil.

On June 2 chemical fertilizers were added to 22 of the 30 bogs, and the bogs were renumbered in pairs; 1A, 1B to 15A, 15B, and each cylinder of a pair was a duplicate of the other.

TABLE V. — *Scheme for Fertilizers on Bogs, 1911.*

BOG NUMBER.	Nitrate Soda (Grams).	Acid Phosphate (Grams).	Sulfate Potash (Grams).	Calcium Hydrate (Grams).
1A, 1B,	3.25	–	–	–
2A, 2B,	–	13	–	–
3A, 3B,	–	–	6.5	–
4A, 4B,	3.25	13	–	–
5A, 5B,	3.25	–	6.5	–
6A, 6B,	–	–	–	–
7A, 7B,	–	13	6.5	–
8A, 8B,	3.25	13	6.5	–
9A, 9B,	6.50	13	6.5	–
10A, 10B,	–	–	–	–
11A, 11B,	–	–	–	–
12A, 12B,	3.25	26	6.5	–
13A, 13B,	3.25	13	13.0	–
14A, 14B,	–	–	–	–
15A, 15B,	3.25	13	6.5	65

NOTE. — Area of bogs, 1/14,000 of an acre.

After the fertilizers were added all irrigation of the bogs was executed by adding water to the drainage cylinders instead of to the surface of the bogs. The rainfall was scanty during the summer, and frequent additions of water were necessary to maintain the water level within 14 to 16 inches of the surface. Beginning in the latter part of August, and continuing throughout September and October, frequent rains, some very heavy, caused copious percolation and resulted in considerable overflow from the drainage cylinders. Numerous samples were collected during this period and form the second group already mentioned. About two-thirds of these samples were analyzed after subsidence of sediment without filtration, and one-third were filtered through porcelain filter tubes under a pressure of 40 to 45 pounds per square inch. The character and appearance of the samples were like those of the May group. They were inky in color until filtered, and were then transparent and of varying shades of coffee color. The amount of solids was remarkably uniform and a little higher in the unfiltered water than was found in May, but much lower than the figures obtained the previous year. It is pretty conclusive that the peat had now become a stable bog soil, and the bog water had reached a stage of equilibrium with its soil environment.

TABLE VI. — *Organic Solids in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

Bog Number.	September 5.	September 11.	September 20.	October 3.	October 25.
1,	75.2	–	–	–	–
2,	84.6	–	–	–	–
3,	–	–	71.6	–	–
4,	–	–	87.2	89.2	–
5,	78.0	–	74.2	82.4	–
6,	–	–	–	–	86.4
7,	–	–	64.2	71.4	–
8,	80.0	79.0	–	79.0	86.4
9,	–	69.4	74.2	65.4	82.0
10,	–	–	–	64.6	89.1
11,	–	69.8	60.8	–	–
12,	82.8	–	–	64.8	88.6
13,	–	–	–	82.0	92.4
14,	63.4	79.2	75.8	77.0	92.0
15,	94.2	–	85.2	92.8	97.6

TABLE VII. — *Inorganic Solids in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	September 5.	September 11.	September 20.	October 3.	October 25.
1,	50.4	-	-	-	-
2,	71.6	-	-	-	-
3,	-	-	68.8	-	-
4,	-	-	63.6	56.2	-
5,	61.4	-	63.8	51.6	-
6,	-	-	-	-	48.8
7,	-	-	58.6	48.6	-
8,	54.6	52.6	-	47.0	51.0
9,	-	50.6	47.8	41.0	49.4
10,	-	-	-	58.0	55.6
11,	-	63.8	56.9	-	-
12,	66.4	-	-	45.8	50.8
13,	-	-	-	43.0	51.0
14,	70.6	58.4	63.4	53.0	50.0
15,	68.6	-	66.2	54.4	65.2

TABLE VIII. — *Organic and Inorganic Solids in Bog Waters, Filtered, 1911.*

[Parts in 100,000.]

BOG NUMBER.	ORGANIC.			INORGANIC.		
	August 24.	September 11.	October 25.	August 24.	September 11.	October 25.
1,	-	35.8	-	-	41.4	-
5,	29.8	-	-	36.6	-	-
6,	-	-	27.4	-	-	33.8
7,	20.0	-	-	21.4	-	-
8,	-	32.4	30.8	-	39.2	38.0
9,	14.4	28.0	35.0	20.4	34.2	44.8
10,	21.6	-	32.2	19.8	-	37.6
12,	-	-	47.2	-	-	43.6
13,	-	-	38.2	-	-	35.6
14,	-	37.4	33.6	-	47.1	32.2
15,	-	-	46.0	-	-	40.0

Since the primary object of the cranberry experiment is to ascertain the needs of the crop for fertilizers and the fate of the fertilizing materials added to the soil, numerous determinations of the total nitrogen, free ammonia and nitrates were made on samples of water from the drainage cylinders between July 14 and Oct. 25, 1911. Nitrates were invariably found, but in insignificant amounts, and there was no practical difference between the water from bogs treated with nitrates and from those without them. Twenty-nine samples from bogs with nitrates contained 0.0299 part of nitric nitrogen in 100,000 parts of water, while 23 samples from bogs without nitrates contained 0.0298 part in 100,000. Free ammonia was much more prominent than nitrates and formed about one-third of the total nitrogen. There was a slight difference in favor of the fertilized bogs, since 34 samples from bogs fertilized with nitrate of soda contained 1.358 parts of ammonia in 100,000 parts of water, while 21 samples from bogs receiving no nitrates contained 1.227 parts of ammonia in 100,000. This slight difference indicates a possible denitrification and loss of nitrates in the form of ammonia. In determining total nitrogen about one-third of the samples were filtered through porcelain tubes before making the analysis. The slimy precipitate thus removed contained nearly two-fifths of the nitrogen present in the unfiltered waters. Forty-eight samples of unfiltered water contained 3.296 parts of nitrogen in 100,000 parts of water, while 27 samples of filtered water contained 2.058 parts of nitrogen in 100,000 parts of water.

TABLE IX. — *Total Nitrogen in Bog Waters, Unfiltered, 1911.*

[Parts in 100,000.]

Bog No.	FERTILIZER.	September 5.	September 11.	September 21.	October 3.	October 9.	October 25.
1	Nitrate,	2.993	–	–	–	–	–
2	No nitrate,	3.977	–	–	–	–	–
3	No nitrate,	–	–	3.485	–	–	–
4	Nitrate,	–	–	4.100	3.767	–	–
5	Nitrate,	3.485	–	3.362	3.362	3.726	–
6	Nothing,	–	–	–	–	–	3.198
7	No nitrate,	2.911	–	2.993	2.788	3.280	–
8	Nitrate,	–	3.034	3.157	2.952	3.485	3.378
9	Double nitrate,	–	3.034	3.034	2.911	3.378	3.075
10	Nothing,	–	–	–	3.280	3.526	3.075
11	Nothing,	–	3.017	2.788	–	–	–
12	Nitrate,	3.485	–	–	3.280	3.526	–
13	Nitrate,	–	–	–	3.198	3.485	3.321
14	Nothing,	3.280	3.157	3.362	3.485	3.567	3.034
15	Nitrate,	3.977	–	3.936	3.854	–	3.485

Average nitrogen in 27 samples from nitrate bogs, 3.399 parts.

Average nitrogen in 18 samples from no nitrate bogs, 3.233 parts.

TABLE X. — *Total Nitrogen in Bog Waters, Filtered, 1911.*

[Parts in 100,000.]

Bog Number.	August 9.	August 14.	August 24.	September 11.	October 25.
1,	-	-	-	2.583	-
4,	-	1.312	-	-	-
5,	-	1.476	1.722	-	-
6,	-	-	-	-	2.173
7,	-	0.820	1.107	-	-
8,	-	-	2.419	2.419	2.337
9,	-	-	-	2.337	2.419
10,	-	-	1.148	-	2.173
11,	-	0.984	-	-	-
12,	2.337	-	2.720	-	-
13,	2.173	-	-	-	2.337
14,	2.378	-	2.214	2.706	2.173
15,	2.665	-	2.829	-	2.747

In 1910 total nitrogen was determined in the waters from all the bogs on September 12, at the time of maximum total solids. The 29 samples of that date averaged 3.260 parts nitrogen in 100,000 parts of water, or practically like the average for 1911 in the unfiltered water.

A few determinations of phosphoric acid and potash were made in 1911 in the unfiltered waters. Samples were taken from bogs receiving fertilizers and from those without. The results were too nearly alike to justify any statements about the two groups, and only averages will be used to show the composition of the bog water. Eighteen samples representing 7 pairs of bogs contained an average of 1.772 parts of phosphoric acid in 100,000 parts of water. Sixteen samples representing 6 pairs of bogs contained an average of 5.15 parts of potash in 100,000 parts of water. A few analyses of filtered samples showed that the potassium compounds in the water were completely soluble and passed through the filters with the water; but practically all the phosphoric acid in the unfiltered water was removed by the filter with the slime. Since the slime when burned showed marked evidence of iron in the residue, it is probable that any phosphoric acid which dissolves in the bog water soon becomes iron phosphate, which is well known as a highly gelatinous precipitate when formed in dilute solutions.

Summarizing the composition of the bog water from the analyses of September and October, 1911, we have the following figures as the average composition of the water standing in contact with the peat in a saturated condition.

TABLE XI. — *Average Composition of Bog Water.*

[Parts in 100,000.]

	Unfiltered.	Filtered.
Organic matter,	79.2400	31.8600
Inorganic matter,	55.6500	35.3600
Total nitrogen,	3.2960	2.0580
Free ammonia,	1.4500[1]	1.4500
Nitrogen in nitrates,	0.0417[1]	0.0417
Phosphoric acid,	1.7720	Traces.
Potash,	5.1500	5.1500

This preliminary study does not throw much light on the problem of fertilizing cranberry bogs. It points, however, to certain conditions worthy of consideration in the use of fertilizers. The cranberry crop does not draw heavily on the soil. Its period of growth is, however, comparatively short, especially if the flood water is retained late, and its soil volume is relatively small when the water level is maintained near the surface. Bog conditions do not favor nitrification and oxidation on account of the saturated soil and low temperature, hence the bog water is low in active fertilizing constituents, especially in nitrates. Therefore it is probable that small amounts of soluble chemicals applied in the late spring would be effective in stimulating growth.

[1] Ammonia and nitrates averaged somewhat higher during this period than for the season as a whole.

TYPES OF CORN SUITED TO MASSACHUSETTS CONDITIONS.

BY P. H. SMITH AND J. B. LINDSEY.

Introduction.

Since 1903 experiments have been in progress with corn to determine, if possible, those varieties, or rather types, best suited to Massachusetts conditions. With this end in view the total yield of dry matter per acre, the digestibility, the relative proportions, and in some cases the composition, of the various parts of the plant (stalk, leaf, ear and husk), and the relation of the stage of development to the relative proportion of different parts as affecting the food value have been carefully studied.

Soil, Cultivation, Size of Plots, Fertilizers used.

With the exception of the Eureka and Pride of the North, varieties tested in 1904, the corn was grown upon one-twentieth acre plots (30 by 73 feet), rows running east and west. The soil consisted of a light sandy loam such as might be considered satisfactory corn land. Each plot was liberally and uniformly fertilized.

1906. — Varieties: Leaming and Pride of the North.

Fertilizers used per acre: —

200 pounds high-grade sulfate of potash, equivalent to about 100 pounds potash.
300 pounds acid phosphate, equivalent to about 45 pounds available phosphoric acid.
200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
200 pounds dry ground fish, equivalent to about 16 pounds organic nitrogen.

The corn planted in 1906 produced an exceptionally fine crop. This was evidently due to very favorable weather conditions. The yield may also have been favored to some extent by the growth of medium green soy beans on the same plots the preceding year.

1907. — Varieties: Leaming and Pride of the North.

Fertilizers used per acre: —

200 pounds high-grade sulfate of potash, equivalent to about 100 pounds potash.
500 pounds phosphatic slag, equivalent to about 75 pounds available phosphoric acid.
200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
300 pounds dry ground fish, equivalent to 24 pounds organic nitrogen.

1908. — Varieties: Sanford, Longfellow, Rustler, Early Mastodon, Klondike, Red Cob Silage and White Cap Yellow.

Fertilizers used per acre: —

300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
500 pounds acid phosphate, equivalent to about 75 pounds available phosphoric acid.
200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

1909. — Varieties: Twitchell's, Rustler, Brewer's, Early Mastodon, White Cap Yellow, Wing's Improved White Cap.

Fertilizers used per acre: —

300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
700 pounds acid phosphate, equivalent to about 105 pounds available phosphoric acid.
200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

1910. — Varieties: Rustler, Brewer's, Longfellow, Eureka.

Fertilizers used per acre: —

300 pounds high-grade sulfate of potash, equivalent to about 150 pounds potash.
700 pounds acid phosphate, equivalent to about 105 pounds available phosphoric acid.
200 pounds nitrate of soda, equivalent to about 30 pounds nitrogen.
500 pounds dry ground fish, equivalent to about 40 pounds organic nitrogen.

A larger amount of fertilizer was added during the last few years of the experiment in order to insure the maximum development of the crop. The yield of corn when planted on the same land for several successive years is likely to decrease, and it was thought that the additional amount of plant food applied would in a measure check this probable shrinkage.

The chemicals were mixed, sown broadcast and harrowed in just before the corn was planted. While the application of commercial fertilizer was liberal, it is believed that larger yields might have been secured, in some cases at least, if more organic matter had been added to the soil either through the medium of barnyard manure or as a cover crop to be ploughed under in the spring.

The Pride of the North and Eureka corn grown in 1904 were not planted on the twentieth-acre plots, but were grown on one-half acre plots in an adjoining field. It was fertilized with cow manure at the rate of six cords to the acre and the land well fitted. In this case the rows ran north and south and the corn was sown in drills and thinned to one plant to the foot at the time of hoeing.

The corn grown on one-twentieth acre plots was planted in hills 3½ by 3½ feet, and thinned to four plants at the time of hoeing. It was seeded May 20–25 and harvested September 15, which is about as late as it is advisable to allow corn to stand and be safe from frosts.

Description of Varieties.

Twitchell's. — A small growing yellow flint bred in Maine. On account of its early maturing qualities (with us in the vicinity of August 20) it may be grown as far north as corn culture can be considered profitable. It has a short stalk of small diameter and a good-sized ear, in some cases two ears being noted on each stalk. It cannot be considered well suited for forage or silage where larger varieties will mature.

Sanford White. — A white flint corn, quite like Longfellow in general appearance, size of plant and time of ripening.

Longfellow. — An old established yellow flint variety extensively grown in Massachusetts. It is one of the best of the yellow flint varieties.

Pride of the North. — One of the earliest and apparently most satisfactory yellow dent varieties for Massachusetts. It does not usually make as large a growth as the Leaming, but in an average season will reach maturity.

Rustler Minnesota Dent. — A white dent corn believed to have been first raised in Massachusetts, on the Agricultural College farm, from seed procured in Minnesota. It has given uniformly good results and can be considered a satisfactory dent variety in spite of the fact that the ears do not usually develop well at the tip. It is believed that this corn can be greatly improved by careful breeding.

Leaming. — Yellow dent. Somewhat like the Pride of the North, but makes a larger growth and matures a little later. It is extensively grown for silage in Massachusetts, and, unless the season is unusually backward, will mature sufficiently for this purpose.

Brewer's. — Yellow dent. This is believed to be a western dent variety improved by N. H. Brewer of Hockanum, Conn. Mr. Brewer has raised enormous crops by following an intensive system of fertilization and cultivation. We have not been successful in ripening it on the station farm. At the time of cutting (September 15) the ears were hardly in milk, and consequently not suitable to harvest for grain. It evidently needs a somewhat longer growing season than is usually experienced in the vicinity of Amherst.

Early Mastodon. — Yellow dent. Bred by C. S. Clark of Ohio. A large growing variety evidently rather too late for grain in Massachusetts.

Klondike. — Yellow dent. Quite like the Early Mastodon in appearance, but noticeably later and unsuited to New England conditions.

Red Cob Silage. — White dent. Medium late.

White Cap Yellow Dent. — Resembles Leaming in size, but matures rather later. Fairly satisfactory for silage.

Wing's Improved White Cap. — Originated by J. E. Wing of Ohio. Some of the stalks bore two ears. It would probably form a very satisfactory variety in the middle western States, but the season is not sufficiently long to enable it to reach maturity in New England.

Eureka White Dent. — A large growing southern variety. It reaches a height of some 13 or more feet and has very coarse stalks. It has never matured in Amherst. The ears set very high on the stalk and the kernels are forming by September 15.

Yield Per Acre of Entire Corn Plant (Pounds).

Year.	Variety.	Condition.	Total Yield.	Dry Matter.
1909	Twitchell's,	Mature,	13,800	4,236
1908	Sanford White,	Mature,	28,400	8,148
1908	Longfellow,	Mature,	34,960	8,981
1910	Longfellow,	Mature,	25,400	6,480
1904	Pride of the North,	Fairly ripe, kernels glazing,	27,800	6,253
1906	Pride of the North,	Mature,	42,600	11,664
1907	Pride of the North,	In milk, not quite ripe,	28,500	5,141
1908	Rustler,	Mature,	23,067	7,843
1909	Rustler,	Mature,	27,100	5,328
1910	Rustler,	Mature,	22,400	6,772
1906	Leaming,	Mature,	51,560	12,307
1907	Leaming,	In milk, not quite ripe,	28,200	5,144
1909	Brewer's,	In milk, green,	35,100	6,286
1910	Brewer's,	In milk, green,	28,100	7,226
1908	Early Mastodon,	In milk to dent stage, green,	39,320	9,488
1909	Early Mastodon,	In milk to dent stage, green,	36,220	6,436
1908	Klondike,	Green and poorly eared,	37,340	9,069
1908	Red Cob Silage,	In milk to dent stage, green,	43,500	11,210
1908	White Cap Yellow,	In milk to dent stage, green,	35,300	11,038
1909	White Cap Yellow,	In milk to dent stage, green,	24,900	5,784
1909	Wing's Improved White Cap,	In milk, green,	28,300	5,671
1904	Eureka,	Immature, kernels scarcely formed,	40,800	6,671
1910	Eureka,	Immature, ears just forming,	43,800	9,044

The preceding table shows the total yield per acre as cut and also the total yield of dry matter. The entire crop for each one-twentieth acre plot was cut and immediately hauled to the barn and weighed. The dry matter was determined by taking a representative sample at the time of harvesting, running it through a cutter, subsampling, placing the subsample in a glass-stoppered jar and drying at 100° C.

Twitchell's corn was well matured in spite of the unfavorable season, and although the 4,236 pounds of dry matter were much less than for any of the other varieties, it probably represented a fair average yield of its kind.

The yields of Longfellow and Sanford, both grown in favorable seasons, may be considered normal in amount. The season of 1908 was rather better than 1910, which would probably account for the larger yield of Longfellow corn in the former year.

Pride of the North was grown during three seasons. The seasons of 1904 and 1907 were both unfavorable, while 1906 was especially satisfactory, and in this year it yielded approximately twice as much dry matter as was secured in the average crop of the other two seasons.

Rustler, also grown for three seasons, showed a reasonably uniform dry matter content with the highest yield in the more favorable season (1908).

Leaming, grown in a favorable and unfavorable season, yielded over twice as much dry matter in the favorable year.

Brewer's dent, which evidently needs a longer growing season for its maturity than the average in Massachusetts, did not show a very decided variation between the two years.

Early Mastodon and White Cap Yellow, both grown in 1908 and 1909, showed the larger yields in 1908, the more favorable year.

Klondike and Red Cob Silage were both grown in 1908, a favorable year. Neither ripened satisfactorily, but showed good yields of dry matter. The former was noticeably immature when harvested.

Wing's Improved White Cap — grown in 1909, a poor corn year — did not yield well, and evidently needs a longer growing season.

Eureka, grown in 1909 and 1910, showed the better yield in 1910. In neither case was the corn well matured, nor did it show a larger yield of dry matter than some of the smaller varieties that showed a very much larger percentage of mature ears.

The total yield of dry matter, rather than the green material, gives a much better indication of the value of the crop for feeding purposes. A green, immature crop will often furnish a large apparent yield, but it contains an excessive amount of water. This fact is especially evidenced by the Eureka and Klondike which, while they gave high yields of green material, did not show the highest production of dry matter.

Morrow,[1] as a result of four years' observations, states that in no year was there more than half the total amount of dry matter when the plant had reached its full height, and not more than 75 per cent. of the maximum when the ears were in dough stage. Ladd,[2] as a result of a two years' experiment, found the greatest weight of green fodder to be between the period of full silking and milky stage of kernel, and that while the total weight diminished after this date the total dry matter increased. Our own results, corroborated by those of other investigators, indicate that such varieties as the Twitchell, Sanford, Longfellow, Pride of the North (in one case) and Rustler can be considered as having reached a maximum weight in dry matter under the conditions in which they were grown. The remaining varieties, with the exception of the Eureka, would surely have increased in dry matter and decreased in total weight had their growing season been longer, while the Eureka would probably have increased in both total weight and dry matter. On account of their high water content and less mature condition the last 8 varieties in the preceding table cannot be considered as valuable pound for pound as the more mature types.

Effect of Season on Yield.

The following data, taken from the Massachusetts Crop Report, will show the weather conditions for the years during which the corn was grown: —

1904. Season, as a whole, cool and dry which made corn unusually late and poorly ripened.

1906. Season, as a whole, warm, especially in July and August. Good rainfall in June and July, hot and humid weather in August, with warm, dry weather the first part of September. The weather conditions were very favorable for corn and the crop ripened exceedingly well.

1907. Season, as a whole, hot and dry. August being the hottest month for thirty-six years. A late spring, together with succeeding dry weather, hindered the development of the crop which was below normal.

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[1] Bul. No. 25, Ill. Exp. Sta., p. 200.

[2] Eighth Ann. Rept., N. Y. Exp. Sta., p. 90.

1908. Season variable, with high temperature and rainfall at opportune times. July hot with little rain till the last part. August cool with plenty of rain. The early part of September dry and warm which hastened the development of the crop that was exceptionally good.

1909. Season, as a whole, dry and cool. The crop germinated well, but the growth was checked by drought and cool weather to such an extent that in many cases the ears did not ripen in spite of no killing frosts until late.

1910. Season, as a whole, hot and dry. Rain at such times as to greatly benefit crop, which was above normal and well matured.

The most striking feature brought out by the preceding table is the extreme variation in yield, not only between different varieties, but between the same varieties grown in different years. This point is well illustrated by Pride of the North, grown in 1904, 1906 and 1907, the yield being a third more for 1906, a very favorable corn year. Morrow[1] found this to be the case in experiments conducted in Illinois, and states that the rain and heat were more influential on the rate of growth than the difference in the variety of corn. It is believed that the total yield of dry matter can be affected by climatic conditions in two ways: a lack of rain at critical periods may cause the corn to ripen before it has obtained its maximum growth, while a cold, wet season will retard the growth of the crop so that it does not reach maturity in the growing season.

The data in the above table make especially clear that: —

1. The small varieties as represented by the Twitchell, because of the relatively low yield of total dry matter, are not economical for Massachusetts conditions.

2. The flint varieties, such as Longfellow and Sanford and the medium dents — Rustler and Pride of the North — are quite well suited for grain and also serve fairly well for silage.

3. The larger medium dents — including the Leaming, White Cap Yellow, Red Cob and Early Mastodon — give a very good yield of dry matter, and in average season bring their ears to the milk stage. All conditions considered, these varieties are rather preferable for silage purposes.

4. The coarse, late maturing varieties as represented by the

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[1] Bul. No. 31, Ill. Exp. Sta., p. 363.

Klondike, Wing's Improved, Brewer's, and particularly the Eureka, while yielding a fair average amount of dry matter are not satisfactory because of their failure to mature; the resulting silage has been repeatedly shown by other observers as being watery, sour and of less nutritive value.

5. The season has a marked influence upon the yield of the corn crop, the same variety of corn under otherwise identical conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

Composition of Different Varieties of Corn Fodder (Entire Plant) (Per Cent.).

[As harvested.]

Number of Analyses.	Variety.	Water.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1	Twitchell's,	69.11	3.03	.94	20.21	5.34	1.37
1	Sanford White,	71.31	1.97	.75	19.03	5.78	1.16
1	Longfellow,	74.31	2.30	.60	16.38	5.03	1.38
6	Pride of the North,	75.33	2.02	.60	15.74	5.18	1.13
3	Rustler,	71.62	2.17	.68	18.36	5.94	1.23
4	Leaming,	76.85	1.77	.47	14.21	5.60	1.10
2	Brewer's,	81.35	1.82	.27	10.90	4.72	.94
3	Early Mastodon,	77.77	1.86	.41	13.77	5.14	1.05
1	Klondike,	75.71	1.31	.42	14.09	6.98	1.49
1	Red Cob Silage,	74.23	1.58	.40	15.69	6.93	1.17
2	White Cap Yellow Dent,	72.75	2.17	.50	17.38	6.02	1.18
2	Wing's Improved White Cap,	80.39	1.72	.32	12.06	4.53	.98
1	Eureka,	82.58	1.63	.27	9.26	4.78	1.08

Composition of Different Varieties of Corn Fodder (Entire Plant) (Per Cent.).

[Dry Matter.]

Number of Analyses.	Variety.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1	Twitchell's,	9.82	3.05	65.43	17.28	4.42
1	Sanford White,	6.85	2.61	66.36	20.13	4.05
1	Longfellow,	8.96	2.34	63.77	19.56	5.37
6	Pride of the North,	8.18	2.43	63.08	21.01	4.58
3	Rustler,	7.66	2.39	64.68	20.94	4.33
4	Leaming,	7.63	2.01	61.40	24.19	4.77
2	Brewer's,	9.75	1.43	58.43	25.33	5.06
3	Early Mastodon,	8.37	1.85	61.97	23.10	4.71
1	Klondike,	5.43	1.72	57.99	28.74	6.14
1	Red Cob Silage,	6.12	1.57	60.87	26.90	4.54
2	White Cap Yellow Dent,	7.98	1.83	63.78	22.10	4.33
2	Wing's Improved White Cap,	8.75	1.65	61.48	23.10	5.02
1	Eureka,	9.34	1.54	55.52	27.41	6.19

The varieties of corn given in the preceding tabulation can be divided into four different groups according to their period of ripening.

1. Mature (dents and flints): Twitchell's, Sanford White, Longfellow, Pride of the North and Rustler.

2. Medium mature (coarse dents): Leaming, Early Mastodon, Red Cob Silage and White Cap Yellow Dent.

3. Immature (very coarse dent): Brewer's, Klondike and Wing's Improved White Cap.

4. Very immature (very coarse dent): Eureka.

The average water content of the four groups was as follows: —

	Per Cent.
Mature,	74.34
Medium mature,	75.40
Immature,	79.15
Very immature,	82.58

While there is a gradual diminution in the water content from the time that the ears are formed until maturity, as shown by this table, the total dry matter gradually increases to maturity.[1]

It is not believed that, owing to individual variations, conclusions can be readily drawn relative to the chemical composition of the different varieties. By averaging the four groups previously given the following results are obtained: —

Dry Matter (Per Cent.).

	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Mature,	8.29	2.56	64.81	19.78	4.55
Medium mature,	7.52	1.82	62.00	24.07	4.59
Immature,	7.97	1.60	59.30	25.72	5.41
Very immature,	9.34	1.54	55.52	27.41	6.19

The very green, immature corn contains a larger relative percentage of protein, but more of it in the amido form.[2] The fat, and particularly the nitrogen-free extract matter, increase the more mature the variety. This is to be expected, for the corn is a carbohydrate plant, and stores up large amounts of starch in the latter stages of its growth. As the starch increases the percentage of fiber and ash relatively decrease. The ash is always at its highest point in the early stages of development.

[1] Ladd, N. Y. Exp. Sta., Rept., 1889.

[2] Eighth Ann. Rept. N. Y. Exp. Sta., p. 90.

The preceding facts are substantiated by the investigations of Schweitzer,[1] Jordan,[2] Ladd [3] and others.

The general conclusion can be drawn that the changes in chemical composition which the plant undergoes in its development are such that its maximum feeding value exists at its maturity.

Digestibility of the Plant.

The digestibility of 7 representative varieties of the entire plant was determined with sheep. The method followed in conducting such experiments is illustrated and described in detail elsewhere.[4] The entire data of the several experiments have been presented in previous reports; only the digestion coefficients, therefore, are given in this connection. As only four sheep were available, but two duplicate digestion trials could be completed in a single season. The method of procedure was as follows: each experiment was begun about September 5th, when the sheep received their first feeding. The corn was allowed to stand in the field, sufficient being cut for only two consecutive days. The entire digestion period lasted fourteen days, the first seven of which were preliminary. The corn was cut in 2-inch pieces before being fed. Two days' feeding were weighed out in advance, and samples taken for dry-matter determinations and for complete chemical analysis. The difference between the amount and chemical composition of the fodder fed and the amount and chemical composition of the feces excreted served as a basis for computing the amount digested and utilized by the animals.

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[1] Bul. No. 9, Mo. Exp. Sta.

[2] Ann. Rept. Me. Exp. Sta., 1893.

[3] Eighth Ann. Rept. N. Y. Exp. Sta., 1899.

[4] Eleventh Rept. of the Mass. State Agr. Exp. Sta., pp. 126–149; also 22d Rept. of the Mass. Agr. Exp. Sta., p. 84.

Digestion Coefficients.[1]
[Per Cent. Dry Matter digested.]

Variety Corn.	Condition of Crop at Time of Harvest.	Digestion Coefficients.					
		Dry Matter.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
Pride of the North,	In dough to denting,	71	63	76	77	65	34
Pride of the North,	In dough to denting,	77	63	84	84	66	36
Rustler,	In dough to denting,	69	43	76	78	59	28
Leaming,	Corn in late milk,	70	60	76	77	61	36
Brewer's,	Corn in milk,	72	69	68	77	69	46
Early Mastodon,	Corn in milk,	72	57	81	79	60	36
Wing's Improved White Cap,	Corn in milk,	70	63	70	76	65	39
Eureka,	Kernels just forming,	67	67	66	72	60	42
Pride of the North stover,	– – –	54	45	64	54	60	31
Eureka stover,	– – –	54	48	67	53	59	45

A study of the above coefficients shows no wide variations in the relative digestibility of the several varieties. Naturally the larger the percentage of ear present the higher should be the digestibility of the entire plant, the grain having a much higher digestibility than the stalk. This in a general way is made clear by classifying the results according to the stage of growth. Corn that is immature and with ears partially formed may show nearly as high an absolute digestibility as a mature variety because of the soft, incompletely developed stalks. If it had been possible to determine the net available energy of each variety according to the method employed by Kellner,[2] those varieties having the mature ears would unquestionably have shown a much larger amount of energy than the less mature varieties.

Attention may also be called to the variation in the percentage of nitrogen-free extract of the several varieties. With one exception [3] the digestibility varies to a limited extent inversely

[1] For figures in detail see supplement.

[2] The Scientific Feeding of Animals, pp. 48-50.

[3] In case of Rustler Dent rather more was fed than the animals could well utilize, which explains the low coefficient for this variety.

with the percentage of nitrogen-free extract, or, otherwise explained, the larger the percentage of extract or starchy matter present, the higher the digestibility of the corn plant.

A division and tabulation of the results according to the stage of growth of the varieties gives us the following results:[1] —

Dry Matter.

	Average Yield per Acre.	Per Cent. digested.	Pounds per Acre digested.
Mature,	7,686	74	5,688
Medium mature,	8,344	71	5,924
Immature,	6,394	71	4,540
Very immature,	7,858	67	5,265

It would appear from the above that the larger growing varieties, such as Leaming, Red Cob, Early Mastodon and White Cap, will produce rather more dry and digestible matter than do the medium dent or flints as typified in the Longfellow or Rustler, and the former varieties, on the whole, are to be given the preference for silage purposes. It is questionable, however, if they furnish any more final nutritive effect (net available energy) than do the varieties that will thoroughly mature by the middle of September. The percentage of dry matter digested, on the other hand, is in favor of the mature varieties. The extremely late varieties, such as the Eureka and Klondike, are not at all suited to New England conditions.

Experiments were made with a sample of Pride of the North and a sample of Eureka corn stover during the year of 1904, the two lots proving to be equally digestible. The former variety of stover contained 18.13 per cent. of water when sampled (December 27), and the latter contained 59.92 per cent. (February 29). Both samples had been stored in the barn since late autumn. When drawn from the field the former contained 37.84 per cent. and the latter 68.92 per cent. of water. The Eureka stover, because of its coarse, immature condition, retained the moisture to a much greater extent than did the fully matured corn.

[1] Omitting coefficients for Rustler Dent from the mature varieties.

Proportions and Composition of Parts.

(a) Proportions at Time of Cutting (100 Pounds).

Year.	Variety.	Stalks.	Leaves.	Husks.	Ears.
1909	Twitchell's,	27	26	10	37
1908	Sanford White,	45	20	11	24
1908	Longfellow,	48	21	10	21
1910	Longfellow,	38	25	9	28
1904	Pride of the North,	47	20	11	22
1906	Pride of the North,	40	17	12	31
1907	Pride of the North,	52	16	14	18
1908	Rustler,	46	19	7	28
1909	Rustler,	41	14	15	30
1910	Rustler,	40	19	9	32
1906	Leaming,	48	19	11	22
1907	Leaming,	52	17	12	19
1909	Brewer's,	51	17	13	19
1910	Brewer's,	53	17	10	20
1908	Early Mastodon,	52	19	9	20
1909	Early Mastodon,	50	18	12	20
1908	Klondike,	62	19	9	10
1908	Red Cob Silage,	53	17	12	18
1908	White Cap Yellow,	46	19	11	24
1909	White Cap Yellow,	50	16	12	22
1909	Wing's Improved White Cap,	52	19	10	19
1904	Eureka,	64	22	7	7
1910	Eureka,	62	21	7	10

(b) Proportions in Dry Matter (100 Pounds).

Year.	Variety.	Stalks.	Leaves.	Husks.	Ears.
1909	Twitchell's,	15	21	9	55
1908	Sanford White,	35	20	10	35
1908	Longfellow,	34	18	9	39
1910	Longfellow,	23	21	7	49
1904	Pride of the North,	37	18	9	36
1906	Pride of the North,	28	14	9	49
1907	Pride of the North,	50	19	11	20
1908	Rustler,	33	19	7	41
1909	Rustler,	32	13	12	43
1910	Rustler,	30	17	8	45
1906	Leaming,	41	19	9	31

(*b*) *Proportions in Dry Matter* (*100 Pounds*) — Concluded.

Year.	Variety.	Stalks.	Leaves.	Husks.	Ears.
1907	Leaming,	48	20	10	22
1909	Brewer's,	51	20	12	17
1910	Brewer's,	47	20	10	23
1908	Early Mastodon,	44	19	9	28
1909	Early Mastodon,	47	21	11	21
1908	Klondike,	59	22	7	12
1908	Red Cob Silage,	50	19	11	20
1908	White Cap Yellow,	38	19	10	33
1909	White Cap Yellow,	47	19	11	23
1909	Wing's Improved White Cap,	52	23	9	16
1904	Eureka,	63	25	6	6
1910	Eureka,	59	28	6	6
	Average,	42	20	9	29

Condition of Crop when cut and Character of Season.

1904. *Poor Corn Year.* — Varieties grown: Pride of the North and Eureka. In spite of the unfavorable season, Pride of the North was fairly ripe when cut and contained a fair proportion of ear. The Eureka was quite immature, with ears just forming.

1906. *An Exceptionally Favorable Corn Year.* — Varieties grown: Pride of the North and Leaming. Both matured, gave a large total yield and showed a noticeably large proportion of ears.

1907. *Poor Corn Year.* — Varieties grown: Pride of the North and Leaming. Neither variety did as well as in 1906 and the proportion of ear was much less.

1908. *Satisfactory Corn Year.* — Varieties grown: Sanford White, Longfellow, Rustler, Early Mastodon, Klondike, Red Cob Silage and White Cap Yellow. Of these the first three were fully developed when cut, and showed a larger development of ear than did the last four, which were in the milk-to-denting stage. White Cap Yellow was the best developed of the last-named varieties, and showed a fair proportion of ear.

1909. *Poor Corn Year.* — Varieties grown: Twitchell's, Rustler, Brewer's, Early Mastodon, White Cap Yellow, Wing's Improved White Cap. The first two varieties matured. The Twitchell, a very small variety, has a short stalk with a long ear setting low on the stalk. It showed the largest proportion of ear of any variety raised. The last three varieties were in milk when cut.

1910. *Favorable Corn Year.* — Varieties: Longfellow, Rustler, Brewer's, Eureka. The first two varieties were mature when cut. Brewer's was in milk and the ears just forming on the Eureka.

It will be observed that in many cases the proportion of the several parts differ in the green stage and on the dry-matter basis. Thus Twitchell's shows 27 per cent. of stalk when cut and only 15 per cent. when all of the water is eliminated. Sanford White shows 24 per cent. of ears when cut and 35 per cent. in dry matter.

The remarks which follow refer to the proportions of the parts on the basis of dry material. In general it may be said that there is a wide difference between the proportion of stalks and ears; the difference between the leaves and husks is less marked.

A decided difference is noted between the *same variety* grown *in different* years. This variation is evidently due, to some extent, to the stage of maturity of the plant when cut and also to unfavorable conditions, which checked the development of the ear. *The stalks and ears form practically 70 per cent. of the dry matter of the plant. The leaves and husks 30 per cent.* From the data at hand the inference can be drawn that this is an inherent characteristic of the maize plant. While other investigators [1] have determined the relative proportions of the plant, it is believed that this fact has not before been noticed.

Those coarse varieties maturing late naturally have less ear and a correspondingly larger proportion of stalk. Note the mature varieties, including the Longfellow with an average of 28 per cent. of stalk and 44 per cent. of ears; the Pride of the North with an average of 38 per cent. of stalk and 35 per cent. of ears; the Rustler with 32 per cent. of stalk and 35 per cent. of ears, against the later maturing varieties, such as the Brewer's with 49 per cent. of stalk and 19 per cent. of ears; the Leaming with 44 per cent. of stalk and 26 per cent. of ears; and finally the Eureka with 61 per cent. of stalk and 6 per cent. of ears. On the whole, the proportion of leaves and husks does not vary widely in any of the varieties, averaging 20 per cent. for the leaves and 9 per cent. for the husks. The Eureka shows rather

[1] Schweitzer, Bul. No. 9, Mo. Exp. Sta., Caldwell, Bul. Nos. 7-11; Rept. of 1890, pp. 30-43, Pa. Exp. Sta.; Bul. No. 21, Iowa Exp. Sta.

more leaf and correspondingly less husk than the other varieties; in fact, this variety as cut was largely stalk and leaf.

The following general conclusions can be drawn: —

1. The stalks and ears form substantially 70 per cent. of the entire maize plant.

2. The small, early maturing varieties of which the Twitchell is a type show an exceptionally large proportion of ears.

3. The mature medium varieties average 33 per cent. of stalk and 37 per cent. of ears.

4. The coarser, less mature varieties show 45 per cent. of stalk and 26 per cent. of ears.

5. The very coarse, immature varieties (excepting Eureka) show 52 per cent. of stalks and 17 per cent. of ears.

6. Most of the varieties have in the vicinity of 20 per cent. of leaves and 10 per cent. of husks.

The above conclusions are for corn grown in Massachusetts and cut about September 15. These conclusions might not hold, especially for the larger immature varieties, had they been ripe at the time of cutting.

Average Composition of Parts (Per Cent.).

Number of Analyses.	Variety.	Water.	Dry Matter.				
			Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
	Stalks.						
2	Pride of the North,	79.84	4.04	.89	56.52	32.91	5.64
2	Leaming,	80.97	3.91	.94	58.94	31.56	4.65
1	Eureka,	83.08	4.80	1.07	52.94	35.77	5.42
	Leaves.						
2	Pride of the North,	76.28	13.99	3.39	48.89	24.06	9.67
2	Leaming,	76.53	13.65	3.03	48.89	25.16	9.27
1	Eureka,	81.17	14.53	2.43	45.63	28.43	8.98
	Husks.						
2	Pride of the North,	77.49	5.14	1.36	62.23	27.98	3.29
2	Leaming,	81.87	6.77	1.50	61.69	26.74	3.30
1	Eureka,	85.35	8.66	1.46	62.22	24.64	3.02
	Ears.						
2	Pride of the North,	56.54	9.53	3.73	75.50	9.46	1.78
2	Leaming,	71.77	9.56	2.90	71.48	13.82	2.24
1	Eureka,	86.91	12.00	1.44	63.84	19.47	3.25

While the analyses are not sufficient in number to enable one to draw any positive conclusions, attention may be called to a few of the more striking facts.

Stalks. — A comparatively low percentage of both protein and fat is noted in the stalks of all the several kinds. The proportion of extract matter is lowest in the Eureka and the fiber percentage the highest.

Leaves. — The protein percentage is highest in the leaves. Naturally, the fiber percentage is less in the leaves than in the stalks, while the percentage of ash is noticeably high and quite constant for the three types. The leaves of the three varieties analyzed resemble each other quite closely in the proportion of all of the several groups of constituents.

Husks. — The one noticeable difference in the case of the husks of the several varieties consists in the low protein content in the Pride of the North and the high protein content of the Eureka. This is, of course, due to the fact that the ears of the latter were in the formative stage, while those of the former had matured and the protein had entered into the kernel. The fiber content of the Pride of the North was somewhat higher than that contained in the Eureka, which is explained on similar grounds.

Ears. — The composition of the ears of the three varieties indicate a very immature condition on the part of the Eureka, — high protein and fiber and low carbohydrates and fat, — and a reasonably mature condition of the ears yielded by the Pride of the North and Leaming.

Relative Proportions of Grain and Cob.

Ten representative ears of corn were selected at the time of husking from the crops of 1908 and 1909 and preserved for analysis. The corn and cob were weighed separately at the time of shelling, dry-matter determinations made, and percentage of cob and kernel determined.

Weights of Ten Average Ears with Proportion of Kernel and Cob in Dry Matter.

Variety.	Condition when cut.	Dry Matter (Pounds).			Dry Matter (Per Cent.).	
		10 Ears.	Kernel.	Cob.	Kernel.	Cob.
Twitchell's,	Mature.	3.37	2.93	.44	86.9	13.1
Sanford White,	Mature.	3.37	2.65	.72	78.6	21.4
Longfellow,	Mature.	3.53	2.95	.58	83.6	16.4
Rustler,	Mature.	4.71	4.08	.63	86.6	13.4
Rustler,	Mature.	4.87	4.23	.64	86.9	13.1
Average,	. .	3.97	3.37	.60	84.5	15.5
Brewer's,	In milk.	4.29	3.57	.72	83.2	16.8
Early Mastodon,	In milk.	4.05	3.37	.68	83.2	16.8
Early Mastodon,	In milk.	5.48	4.55	.93	83.0	17.0
Klondike,	In milk.	3.60	2.66	.94	73.9	26.1
Red Cob Silage,	In milk.	4.37	3.59	.78	82.2	17.8
White Cap Yellow,	In milk.	3.70	3.12	.58	84.3	15.7
White Cap Yellow,	In milk.	3.71	3.11	.60	83.8	16.2
Wing's Improved White Cap,	In milk.	4.14	3.39	.75	81.9	18.1
Average,	. .	4.17	3.42	.75	81.9	18.1

Wide variations were noted depending upon stage of ripeness. The Twitchell, a long eared and early maturing flint, showed the smallest percentage of cob (13.1), and the Klondike, a quite immature dent, the largest amount of cob (26.1). The average of the several mature types was 15.5 per cent. cob, and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 for cob and 81.9 for kernel. If the less mature varieties had been grown in a climate favorable to their complete maturity, it is probable that they would have shown equally as favorable a proportion of cob and kernel.

The weight of the Massachusetts legal bushel in case of shelled corn is 56 pounds, and for a bushel of ears 70 pounds. This allows 14 pounds, or 20 per cent., for the cob. With but two exceptions the samples tested contained less than 20 per cent. cob in dry matter. Assuming that the standard of 70 pounds per bushel for corn was based upon the average of a large number of trials, is it not possible that the corn crop has been improved since the time that such a standard was adopted, and that corn is now being grown that contains relatively less cob and more kernel than formerly?

The results of these trials are substantiated by work done by the author in connection with corn grown for the Bowker prize in 1910. The proportions of corn and cob in dry matter in 10 representative ears of 9 varieties were determined with the following results: —

	Grain (Per Cent.).	Cob (Per Cent.).
1. Flint,	83.7	16.3
2. Flint,	84.8	15.2
3. Flint,	85.8	14.2
4. Flint,	78.7	21.3
5. Flint,	83.6	16.4
6. Flint,	84.6	15.4
Average,	83.5	16.5
7. Dent,	85.0	15.0
8. Dent,	80.7	19.3
9. Dent,	83.9	16.1
Average,	83.2	16.8

Composition of Grain and Cob.

During the seasons of 1908 and 1909 samples of corn kernels were analyzed with the following results: —

Analyses of Grain (Per Cent.).

[Dry Matter.]

Year.	Variety.	Condition.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.	Starch.
1909	Twitchell's,	Mature.	11.30	5.12	80.49	1.58	1.51	67.54
1908	Sanford White,	Mature.	10.92	5.22	80.83	1.53	1.50	71.35
1908	Longfellow,	Mature.	10.80	5.46	80.72	1.43	1.59	70.86
1908	Rustler,	Mature.	9.55	4.44	82.79	1.77	1.45	72.84
1909	Rustler,	Mature.	9.56	4.55	82.33	1.41	1.52	70.00
1909	Brewer's,	In milk.	9.64	3.97	81.99	2.70	1.70	67.27
1908	Early Mastodon,	In milk.	9.22	4.62	82.29	2.33	1.54	72.98
1909	Early Mastodon,	In milk.	9.69	4.36	82.06	2.21	1.68	68.39
1908	Klondike,	In milk.	10.81	4.40	80.73	2.27	1.79	71.48
1908	Red Cob Silage,	In milk.	10.69	3.61	81.80	2.33	1.57	72.70
1908	White Cap Yellow,	In milk.	10.30	3.93	82.13	2.09	1.55	73.13
1909	White Cap Yellow,	In milk.	9.06	4.42	82.77	2.24	1.51	69.16
1909	Wing's Improved White Cap,	In milk.	10.21	4.35	81.18	2.52	1.74	67.90

A study of the analytical results shows very slight variations in composition. The protein of the first varieties is rather in excess of the Rustler Dent. The protein of the coarse, less mature dents would probably have been somewhat less had they been more completely matured. The fiber percentage is noticeably less in the mature lots, 1.54 as against 2.34 for the immature types. A high fiber is believed to be characteristic of immature corn. The percentages of starch are remarkably uniform.

While corn has been bred in an experimental way which bore decidedly different chemical characteristics (namely, high protein, high starch and high fat), such corn has not come into general use; when, therefore, the grain is grown primarily as a food for stock it is believed that the farmer can do no better than to grow the variety that will in his experience produce the largest number of bushels of mature corn per acre. This fact is borne out not only by the analyses herein reported, but also by others made by the author. Chemical composition cannot, at the present time, be considered a factor in the selection of seed corn where the crop is used for the sustenance of live stock.

An evident effect of the season upon the starch content is shown in the case of Rustler, Early Mastodon and White Cap Yellow, all grown in two successive years. In each case the starch content was slightly lower for 1909, an unfavorable year.

Analysis of Corn Cob (Per Cent.).
[Dry Matter.]

Year.	Variety.	Condition.	Protein.	Fat.	Nitrogen-free Extract.	Fiber.	Ash.
1908	Sanford White, . .	Mature.	1.97	.27	58.21	38.01	1.54
1908	Longfellow, . . .	Mature.	1.98	.30	59.11	36.91	1.70
1908	Rustler, ...	Mature.	1.70	.44	62.15	34.12	1.59
1908	Early Mastodon, . .	In milk.	1.84	.32	60.79	35.49	1.56
1908	Klondike, . . .	In milk.	2.21	.38	61.80	33.86	1.75
1908	Red Cob Silage, . .	In milk.	2.09	.38	60.07	35.75	1.75
1908	White Cap Yellow Dent,	In milk.	2.17	.34	60.08	35.98	1.49
	Average, . . .	–	1.99	.33	60.32	35.73	1.63

The above analyses represent the product of several varieties of cob produced during the season of 1908. One notes comparatively little variation in the composition. The cob is characterized by its very low protein and fat content and its high extract matter and fiber. It is doubtful if the cob from any number of different varieties would show substantial variations from the figures reported above. Lindsey and Holland [1] have shown the cob to contain over 30 per cent. of pentosans which have a digestibility of 63 per cent., and, further,[2] that the total dry matter of the cob has a digestibility of 59 per cent. So far as known, further studies of the chemical character of the extract matter have not been made. It is evident that the chief feeding value of the cob is to be found in its 59 per cent. of digestible carbohydrates.

On the basis of the work done by Kellner,[3] the net available energy in 100 pounds of cob containing 11 per cent. water is 40.2 therms, as against 85.5 therms in a like amount of corn meal; or 100 pounds of corn cob has 47 per cent. of the energy value of corn meal.

The practical feeder, therefore, cannot afford to pay grain prices for the cob when used as an adulterant of wheat-mixed feed, hominy meal or the like. Its use, however, is warranted when produced upon the farm and ground together with the kernel as a food for farm animals.

Summary.

Yield. — The small, early maturing types of corn are not economical for Massachusetts conditions; the medium dent and flint varieties that will mature in the average season are quite well suited for grain, and also serve fairly well for silage. The larger medium dent varieties that in an average season bring their ears to the milk stage are, all conditions considered, rather preferable for silage purposes, while the coarse, late maturing varieties, which never ripen seed in this locality, are not satisfactory because of the less net available energy produced (actual food value).

The season has a marked influence upon the yield of the corn crop, the same variety of corn under otherwise identical

[1] Fifteenth Rept. of the Hatch Exp. Sta., pp. 78–79.

[2] Eighteenth Rept. of the Hatch Exp. Sta., p. 243.

[3] Die Ernährung die Landw. Nützthiere, fünfte Auflage, pp. 159–169, also p. 601.

conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

Composition of the Corn Plant. — The general conclusion can be drawn that the changes in chemical composition which the plant undergoes in its development are such that its maximum feeding value exists at its maturity.

Digestibility of the Corn Plant. — Digestion experiments conducted with the entire corn plant showed no wide variation in the digestibility of the several varieties, the range being from 67 to 77 per cent. With one exception the digestibility appeared to depend upon the percentage of nitrogen-free extract. The higher the percentage of extract or starchy matter present, the higher the digestibility.

Proportion and Composition of Parts. — The stalks and ears form practically 70 per cent. of the dry matter of the plant, the leaves and husks 30 per cent.

Relative Proportion of Grain to Cob. — The percentage of grain to cob varies widely, depending to some extent upon the maturity of the plant when cut. The average for the several mature types was 15.5 per cent. cob and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 per cent. cob and 81.9 per cent. kernel. In either case the percentage of cob was less than that of the Massachusetts legal bushel, which in the case of shelled corn is 56 pounds, and for ear corn 70 pounds, thus allowing 14 pounds, or 20 per cent., for cob.

Composition of Grain and Cob. — The grain analyzed showed only slight variations in composition. Chemical composition cannot at the present time be considered a factor in the selection of seed corn where the crop is used for the sustenance of live stock.

There appears to be very little variation in the composition of the corn cob. The net available energy in 100 pounds of cob, after the method of calculation suggested by Kellner, is 40.2 therms as against 85.5 therms in a like amount of corn meal; hence on this basis ground corn cob would have 47 per cent. of the energy value of corn meal.[1]

[1] The Kellner method of calculation is the best we have for making comparative estimates of relative values.

THE DIGESTIBILITY OF CATTLE FOODS.

BY J. B. LINDSEY AND P. H. SMITH.

The digestion experiments herein reported were made during the autumn, winter and early spring of 1906–07, 1908–09 and 1909–10, and form part of what are known as Series XII., XIV. and XV. The experiments made in these series and not here included have been published in previous reports.

The usual method was employed and has been fully described elsewhere.[1] The full data are here presented, with the exception of the daily production of manure and the daily water consumption, in which cases, to economize space, averages only are given. The periods extended over fourteen days, the first seven of which were preliminary, collection of feces being made during the last seven. Ten grams of salt were given each sheep daily with water *ad libitum*.

Series XII.

Three lots of Southdown wethers were employed and were known as Old Sheep, Young Sheep and Paige Sheep. The former were fully seven years of age, and the latter two lots four to five years old.

The hay used in connection with the several experiments consisted of fine-mixed grasses, and contained a large proportion of June grass. The digestion coefficients of this hay as applied to the experiments in this series were obtained in 1905, and were as follows: —

[1] Eleventh report of the Mass. State Agr. Exp. Sta., pp. 146–149; also the 22d report of the Mass. Agr. Exp. Sta., p. 84.

Digestion Coefficients used in these Experiments.[1]

[English Hay.]

	Old Sheep II. and III.	Young Sheep I., II. and III.	Paige Sheep IV. and V.
Dry matter,	67.87	65.92	65.48
Ash,	49.17	51.95	44.60
Protein,	62.31	61.98	61.53
Fiber,	76.30	72.87	73.81
Nitrogen-free extract,	66.39	64.66	64.46
Fat,	52.37	54.23	50.20

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Pride of the North corn fodder (entire plant),	4.07	7.69	17.96	67.62	2.66
Leaming corn fodder (entire plant),	4.69	7.89	22.42	62.94	2.06
English hay,	6.75	12.23	33.45	44.67	2.90
Biles Union grains,	6.67	27.11	10.55	47.45	8.22
Schumacher's stock feed,	4.44	11.73	11.70	67.31	4.82
Protena dairy feed,	7.28	19.56	20.16	49.92	3.08
Buffalo Creamery feed,	4.68	21.87	13.58	55.32	4.55
Waste, Paige Sheep, IV., Period I.,	3.77	8.70	14.28	69.92	3.33

Composition of Feces (Per Cent.).

[Dry Matter.]

Old Sheep II.

Period.	FEEDS.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
I.	Pride of the North corn fodder,	10.21	11.74	27.77	48.65	1.63
VI.	Biles Union grains,	13.30	17.90	21.39	43.81	3.60

Old Sheep III.

II.	Leaming corn fodder,	9.67	10.90	28.21	49.49	1.73

[1] Made in 1905.

Composition of Feces (Per Cent.) — Concluded.

[Dry Matter.]

Young Sheep I.

Period.	Feeds.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
VIII.	Schumacher's stock feed, . .	11.58	13.62	24.06	47.40	3.34
XIII.	Buffalo Creamery feed, . .	10.07	13.59	25.17	47.61	3.56
	Young Sheep II.					
IX.	Biles Union grains, . . .	11.32	17.33	22.28	45.71	3.36
	Young Sheep III.					
VIII.	Schumacher's stock feed, . .	11.63	12.95	25.14	46.91	3.37
XIII.	Buffalo Creamery feed, . .	10.03	13.62	25.14	47.87	3.34
	Paige Sheep IV.					
I.	Pride of the North corn fodder,.	12.89	12.75	24.61	47.65	2.10
XII.	Protena dairy feed, . . .	11.72	14.49	27.15	43.42	3.22
	Paige Sheep V.					
II.	Leaming corn fodder, . .	10.23	10.30	29.40	48.50	1.57
XII.	Protena dairy feed, . . .	11.24	13.77	28.24	43.67	3.08

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Old Sheep II.

Period.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protena Dairy Feed.	Waste.	Feces.
I.	–	29.50	–	–	–	–	–	–	89.78
VI.	88.20	–	–	–	–	90.91	–	–	92.15
				Old Sheep III.					
II.	–	–	24.52	–	–	–	–	–	89.92
				Young Sheep I.					
VIII.	89.82	–	–	90.78	–	–	–	–	92.79
XIII.	90.65	–	–	–	90.55	–	–	–	94.48

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.) — Concluded.

Young Sheep II.

Period.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protena Dairy Feed.	Waste.	Feces.
IX.	89.82	-	-	-	-	92.57	-	-	92.34

Young Sheep III.

Period.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protena Dairy Feed.	Waste.	Feces.
VIII.	89.82	-	-	90.78	-	-	-	-	92.97
XIII.	90.65	-	-	-	90.55	-	-	-	94.26

Paige Sheep IV.

Period.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protena Dairy Feed.	Waste.	Feces.
I.	-	29.50	-	-	-	-	-	36.26	90.19
XII.	90.45	-	-	-	-	-	91.36	-	94.55

Paige Sheep V.

Period.	English Hay.	Pride of the North Corn Fodder.	Leaming Corn Fodder.	Schumacher's Stock Feed.	Buffalo Creamery Feed.	Biles Union Grains.	Protena Dairy Feed.	Waste.	Feces.
II.	-	-	24.52	-	-	-	-	-	90.76
XII.	90.45	-	-	-	-	-	91.36	-	94.42

Average Daily Amount of Manure excreted and Water drunk (Grams).

Old Sheep II.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Pride of the North corn fodder, ...	1,008	31.84	937
VI.	Biles Union grains, ...	751	25.68	1,899

Old Sheep III.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Leaming corn fodder, ...	795	28.64	893

Young Sheep I.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
VIII.	Schumacher's stock feed, ...	540	24.96	1,936
XIII.	Buffalo Creamery feed, ...	545	25.68	2,286

Young Sheep II.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
IX.	Biles Union grains, ...	770	25.41	2,271

Average Daily Amount of Manure excreted and Water drunk (Grams) — Concluded.

Young Sheep III.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
VIII.	Schumacher's stock feed,	528	25.32	2,185
XIII.	Buffalo Creamery feed,	551	25.32	2,179

Paige Sheep IV.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Pride of the North corn fodder,	613	20.03	1,101
XII.	Protena dairy feed,	823	26.36	1,364

Paige Sheep V.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Leaming corn fodder,	1,143	29.91	1,050
XII.	Protena dairy feed,	769	27.03	1,764

Weights of Animals at Beginning and End of Period (Pounds).[1]

Old Sheep II.

Period.	Character of Food or Ration.	Beginning.	End.
I.	Pride of the North corn fodder,	110.0	111.0
VI.	Biles Union grains,	108.5	103.5

Old Sheep III.

Period.	Character of Food or Ration.	Beginning.	End.
II.	Leaming corn fodder,	113.5	125.5

Young Sheep I.

Period.	Character of Food or Ration.	Beginning.	End.
VIII.	Schumacher's stock feed,	102.0	101.5
XIII.	Buffalo Creamery feed,	102.0	100.0

Young Sheep II.

Period.	Character of Food or Ration.	Beginning.	End.
IX.	Biles Union grains,	93.5	89.0

Young Sheep III.

Period.	Character of Food or Ration.	Beginning.	End.
VIII.	Schumacher's stock feed,	94.5	92.5
XIII.	Buffalo Creamery feed,	92.0	93.0

[1] The weights of the sheep in several cases vary much more widely than would be expected, and it is possible that errors were made in recording them. In order to guard against this, weights for two consecutive days are now made at the beginning and end of each trial.

Weights of Animals at Beginning and End of Period (Pounds) — Concluded.

Paige Sheep IV.

Period.	Character of Food or Ration.	Beginning.	End.
I.	Pride of the North corn fodder,	121.5	116.5
XII.	Protena dairy feed,	124.5	122.5

Paige Sheep V.

II.	Leaming corn fodder,	108.0	110.0
XII.	Protena dairy feed,	119.0	112.0

Pride of the North Corn Fodder, Period I.

Old Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3,600 grams Pride of the North corn fodder fed daily.	1,062.00	43.22	81.67	190.74	718.12	28.25
318.41 grams manure excreted,	285.87	29.19	33.56	79.39	139.08	4.66
Grams digested,	776.13	14.03	48.11	111.35	579.04	23.59
Per cent. digested,	73.08	32.46	58.91	58.38	80.63	83.50

Paige Sheep IV.

3,600 grams Pride of the North corn fodder fed daily.	1,062.00	43.22	81.67	190.74	718.12	28.25
335.4 grams waste,	121.62	4.59	10.58	17.37	85.04	4.05
Amount consumed,	940.38	38.63	71.09	173.37	633.08	24.20
200.26 grams manure excreted,	180.61	23.28	23.03	44.45	86.06	3.79
Grams digested,	759.77	15.35	48.06	128.92	547.02	20.41
Per cent. digested,	80.79	39.74	67.60	74.36	86.41	84.34
Average per cent. for both sheep,	76.94	36.10	63.26	66.37	83.52	83.92

Leaming Corn Fodder, Period II.

Old Sheep III.

3,600 grams Leaming corn fodder fed,	882.72	41.40	69.65	197.91	555.58	18.18
286.43 grams manure excreted,	257.56	24.91	28.07	72.66	127.47	4.46
Grams digested,	625.16	16.49	41.58	125.25	428.11	13.72
Per cent. digested,	70.82	39.83	59.70	63.29	77.06	75.47

Leaming Corn Fodder, Period II — Concluded.

Paige Sheep V.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
3,600 grams Leaming corn fodder fed,	882.72	41.40	69.65	197.91	555.58	18.18
299.08 grams manure excreted,	271.45	27.77	27.96	79.81	131.65	4.26
Grams digested,	611.27	13.63	41.69	118.10	423.93	13.92
Per cent. digested,	69.25	32.92	59.86	59.67	76.30	76.57
Average per cent. for both sheep,	70.04	36.38	59.78	61.48	76.68	76.02

Biles Union Grains, Period VI.

Old Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
650 grams English hay fed,	573.30	38.70	70.11	191.77	256.09	16.63
250 grams Biles Union grains fed,	227.28	15.16	61.62	23.98	107.84	18.68
Amount consumed,	800.58	53.86	131.73	215.75	363.93	35.31
256.76 grams manure excreted,	236.60	31.47	42.35	50.61	103.65	8.52
Grams digested,	563.98	22.39	89.38	165.14	260.28	26.79
Minus hay digested,	389.10	19.03	43.69	146.32	170.02	8.71
Biles Union grains digested,	174.88	3.36	45.69	18.82	90.26	18.08
Per cent. digested,	76.94	22.16	74.15	78.48	83.70	96.79

Biles Union Grains, Period IX.

Young Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
600 grams English hay fed,	538.92	36.38	65.91	180.27	240.74	15.63
200 grams Biles Union grains fed,	185.14	12.35	50.19	19.53	87.85	15.22
Amount consumed,	724.06	48.73	116.10	199.80	328.59	30.85
254.10 grams manure excreted,	234.86	26.59	40.70	52.33	107.35	7.89
Grams digested,	489.20	22.14	75.40	147.47	221.24	22.96
Minus hay digested,	355.26	18.90	40.85	131.36	155.66	8.48
Biles Union grains digested,	133.94	3.24	34.55	16.11	65.58	14.48
Per cent. digested,	72.35	26.23	68.84	82.49	74.65	95.14

Schumacher's Stock Feed, Period VIII.

Young Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
550 grams English hay fed,	494.01	33.35	60.42	165.25	220.67	14.33
250 grams Schumacher's stock feed fed,	226.95	10.08	26.62	26.55	152.76	10.94
Amount consumed,	720.96	43.43	87.04	191.80	373.43	25.27
249.64 grams manure excreted,	231.64	26.82	31.55	55.73	109.80	7.74
Grams digested,	489.32	16.61	55.49	136.07	263.63	17.53
Minus hay digested,	325.65	17.33	37.45	120.42	142.69	7.77
Schumacher's stock feed digested,	163.67	–	18.04	15.65	120.94	9.76
Per cent. digested,	72.12	–	67.77	58.95	79.17	89.21

Young Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Amount consumed as above,	720.96	43.43	87.04	191.80	373.43	25.27
253.20 grams manure excreted,	235.40	27.38	30.48	59.18	110.43	7.93
Grams digested,	485.56	16.05	56.56	132.62	263.00	17.34
Minus hay digested,	325.65	17.33	37.45	120.42	142.69	7.77
Schumacher's stock feed digested,	159.91	–	19.11	12.20	120.31	9.57
Per cent. digested,	70.46	–	71.79	45.95	78.76	87.48
Average per cent. for both sheep,	71.29	–	69.78	52.45	78.97	88.35

Protena Dairy Feed, Period XII.

Paige Sheep IV.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
600 grams English hay fed,	542.70	36.63	66.37	181.53	242.42	15.74
200 grams Protena dairy feed fed,	182.72	13.30	35.74	36.84	91.21	5.63
Amount consumed,	725.42	49.93	102.11	218.37	333.63	21.37
263.57 grams manure excreted,	249.21	29.21	36.11	67.66	108.21	8.02
Grams digested,	476.21	20.72	66.00	150.71	225.42	13.35
Minus hay digested,	355.36	16.34	40.84	133.99	156.26	7.90
Protena dairy feed digested,	120.85	4.38	25.16	16.72	69.16	5.45
Per cent. digested,	66.14	32.93	70.40	45.39	75.83	96.80

Protena Dairy Feed, Period XII — Concluded.

Paige Sheep V.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Amount consumed as above,	725.42	49.93	102.11	218.37	333.63	21.37
270.27 grams manure excreted,	255.19	28.68	35.14	72.07	111.44	7.86
Grams digested,	470.23	21.25	66.97	146.30	222.19	13.51
Minus hay digested,	355.36	16.34	40.84	133.99	156.26	7.90
Protena dairy feed digested,	114.87	4.91	26.13	12.31	65.93	5.61
Per cent. digested,	62.87	36.92	73.11	33.41	72.29	99.64
Average per cent. for both sheep,	64.51	34.93	71.76	39.40	74.06	98.22

Buffalo Creamery Feed, Period XIII.

Young Sheep I.

600 grams English hay fed,	543.90	36.71	66.52	181.93	242.96	15.77
200 grams Buffalo Creamery feed fed,	181.10	8.48	39.61	24.59	100.18	8.24
Amount consumed,	725.00	45.19	106.13	206.52	343.14	24.01
256.84 grams manure excreted,	242.66	24.44	32.98	61.08	115.53	8.64
Grams digested,	482.34	20.75	73.15	145.44	227.61	15.37
Minus hay digested,	358.54	19.07	41.23	132.57	157.10	8.55
Buffalo Creamery feed digested,	123.80	1.68	31.92	12.87	70.51	6.82
Per cent. digested,	68.36	19.81	80.59	52.34	70.38	82.77

Young Sheep III.

Amount consumed as above,	725.00	45.19	106.13	206.52	343.14	24.01
253.23 grams manure excreted,	238.69	23.94	32.51	60.01	114.26	7.97
Grams digested,	486.31	21.25	73.62	146.51	228.88	16.04
Minus hay digested,	358.54	19.07	41.23	132.57	157.10	8.55
Buffalo Creamery feed digested,	127.70	2.18	32.39	13.94	71.78	7.49
Per cent. digested,	70.55	25.71	81.77	56.69	71.65	90.90
Average per cent. for both sheep,	69.46	22.76	81.18	54.52	71.02	86.84

Summary of Coefficients (Per Cent.).

Food.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Pride of the North corn fodder,	Old Sheep II.,	73.08	32.46	58.91	58.38	80.63	83.50
	Paige Sheep IV.,	80.79	39.74	67.60	74.36	86.41	84.34
Average,	–	76.94	36.10	63.26	66.37	83.52	83.92
Leaming corn fodder,	Old Sheep III.,	70.82	39.83	59.70	63.29	77.06	75.47
	Paige Sheep V.,	69.25	32.92	59.86	59.67	76.30	76.57
Average,	–	70.04	36.38	59.78	61.48	76.68	76.02
Biles Union grains,	Old Sheep II.,	76.94	22.16	74.15	78.48	83.70	96.79
	Young Sheep II.,	72.35	26.23	68.84	82.49	74.65	95.14
Average,	–	74.65	24.20	71.50	80.49	79.18	95.97
Schumacher's stock feed,	Young Sheep I.,	72.12	–	67.77	58.95	79.17	89.21
	Young Sheep III.,	70.46	–	71.79	45.95	78.76	87.48
Average,	–	71.29	–	69.78	52.45	78.97	88.35
Protena dairy feed,	Paige Sheep IV.,	66.14	32.93	70.40	45.39	75.83	96.80
	Paige Sheep V.,	62.87	36.92	73.11	33.41	72.29	99.64
Average,	–	64.51	34.93	71.76	39.40	74.06	98.22
Buffalo Creamery feed,	Young Sheep I.,	68.36	19.81	80.59	52.34	70.38	82.77
	Young Sheep III.,	70.55	25.71	81.77	56.69	71.65	90.90
Average,	–	69.46	22.76	81.18	54.52	71.02	86.84

Discussion of the Results.

The most important results obtained from the experiments reported in the previous pages are discussed under the following headings: —

Pride of the North Corn Fodder. — The fodder used was of excellent quality and exceptionally well eared. The one-twentieth acre plot on which it was grown yielded at the rate of slightly over 21 tons to the acre and contained 49 per cent. of ears in dry matter. The unusually high percentage of ears naturally increased the digestibility of the fodder. The corn was cut from the field every two days, the first cutting being September 5, and the last September 19. The entire plant was finely cut before being fed, dry matter determinations being made of each single cutting.

Summary of Coefficients, Period I. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep II.,	1	1	73.08	32.46	58.91	58.38	80.63	83.50
Paige Sheep IV.,	1	1	80.79	39.74	67.60	74.36	86.41	84.34
Average,	1	2	76.94	36.10	63.26	66.37	83.52	83.92
Average of all experiments, mature dent corn fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

Paige Sheep IV. gave higher results than did Old Sheep II., probably due in part to the fact that the former left a portion of the tougher and less digestible part. The present experiment shows in a fairly satisfactory manner the digestibility of a variety of dent corn that will mature in Massachusetts, and also emphasizes the fact that a fodder containing a higher percentage of ears is noticeably more digestible than one containing relatively fewer ears and a larger percentage of stalk.

Leaming Corn Fodder. — The fodder used was fed at the same time and handled in the same manner as was the preceding variety. The one-twentieth acre plot yielded at the rate of 25½ tons per acre. The crop contained 31 per cent. of ears in dry matter. The stalks are rather larger than the Pride of the North, and in the average season the Leaming matures a little later.

Summary of Coefficients, Period II. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep III.,	1	1	70.82	39.83	59.70	63.29	77.06	75.47
Paige Sheep V.,	1	1	69.25	32.92	59.86	59.67	76.30	76.57
Average,	1	2	70.04	36.38	59.78	61.48	76.68	76.02
Average all experiments, mature dent corn fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

The sheep consumed the entire ration fed. The coefficients for both sheep agreed closely, not only with each other, but also with the average of all experiments with dent fodder. The Leaming is shown to be rather less digestible than the Pride of the North, due to its rather coarser stalks and to its relatively less ear production. It is believed, however, that this variety of dent fodder is quite well suited for silage in Massachusetts.

Biles Union Grains. — Biles Union Grains is a proprietary feed consisting principally of a mixture of distillers' dried grains and malt sprouts, together with some corn and wheat products, cottonseed meal and salt. The amount of its several components is likely to vary more or less from time to time, depending upon the feeding stuffs available and their cost. This variation in composition varies its digestibility within narrow limits. It is intended, when fed with home-grown roughage, to constitute a balanced ration for dairy stock.

Summary of Coefficients, Periods VI. and IX. (Per Cent.).

SHEEP.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Old Sheep II.,	1	1	76.94	22.16	74.15	78.48	83.70	96.79
Young Sheep II.,	1	1	72.35	26.23	68.84	82.49	74.56	95.14
Average,	1	2	74.65	24.20	71.50	80.49	79.18	95.97

The coefficients agree fairly well, although the Young Sheep II. did not appear to digest the nitrogen-free extract as well as did Old Sheep II. The feed can be considered fairly digestible.

Schumacher's Stock Feed. — This material consists of a mixture of corn, oat and barley residues resulting from the manufacture of human foods from these cereals. It contains about 10 per cent. protein, 3.50 per cent. fat and 9 per cent. fiber. It is extensively advertised as a food for horses and dairy stock.

Summary of Coefficients, Period VIII. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Young Sheep I.,	1	1	72.12	–	67.77	58.95	79.17	89.21
Young Sheep II.,	1	1	70.46	–	71.79	45.95	78.76	87.48
Average,	1	2	71.29	–	69.78	52.45	78.97	88.35
Oats, unground, for comparison,	2	6	70.00	–	77.00	31.00	77.00	89.00

The coefficients obtained for both sheep with the exception of that for fiber agree satisfactorily. The digestibility as well as the composition of this feed resembles that of oats, for which it is often substituted in feeding horses. When used for this purpose it would be advisable to moisten it because of its fine and dry condition.

Protena Dairy Feed. — This material is no longer found in the Massachusetts market. It was composed of ground alfalfa as a basis, together with cottonseed meal, wheat by-products and salt.

Summary of Coefficients, Period XII. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Paige Sheep IV.,	1	1	66.14	32.93	70.40	45.39	75.83	96.80
Paige Sheep V.,	1	1	62.87	36.92	73.11	33.41	72.29	99.64
Average,	1	2	64.51	34.93	71.76	39.40	74.06	98.22

The presence of so much alfalfa gave it a relatively high fiber content, and a low fiber digestibility. The digestibility of the entire foodstuff is decidedly below the minimum desired for a high-grade concentrate, due also to the large amount of alfalfa used.

Buffalo Creamery Feed. — This is a proprietary mixture containing about 20 per cent. protein, 5 per cent. fat and 9 per cent. fiber. According to the manufacturer's guarantee it contains corn, wheat middlings, oat hulls, hominy feed, cottonseed meal and gluten feed.

Summary of Coefficients, Period XIII. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Young Sheep I.,	1	1	68.36	19.81	80.59	52.34	70.38	82.77
Young Sheep III.,	1	1	70.55	25.71	81.77	56.69	71.65	90.90
Average,	1	2	69.46	22.76	81.18	54.52	71.02	86.84

The coefficients agree closely, and the feed approaches the minimum degree of digestibility (70 per cent.) for a concentrate. Its protein digestibility is fairly satisfactory. Its economy as a dairy feed would naturally depend upon its cost. Feeds of this character are likely to cost more than the ingredients of which they are composed.

Series XIV.

Eleven experiments were made in this series, all of which, with the exception of the 4 that follow, were carried out with Porto Rico molasses and are published elsewhere. The digestion coefficients for the hay used in periods VIII. and X. were those obtained in period XI. The 4 sheep used in this experiment were yearling Shropshires of substantially uniform weight.

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

Feeds.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
English hay,	6.82	7.67	30.35	52.79	2.37
Early Mastodon Dent corn fodder.	4.31	7.38	19.40	66.74	2.17
Rustler White Dent corn fodder,	4.38	6.87	19.46	66.96	2.33
Unicorn dairy ration,	3.60	29.61	9.76	50.11	6.92
Waste, Sheep IV., period II.,	2.85	3.37	29.12	63.58	1.08

Composition of Feces (Per Cent.).

[Dry Matter.]

Sheep I.

Period.	Feeds.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
I.	Early Mastodon Dent corn fodder,	9.52	11.12	27.34	50.57	1.45
VIII.	Unicorn dairy ration, . . .	10.55	15.61	24.37	46.56	2.91
X.	Unicorn dairy ration, . . .	11.64	13.63	25.18	46.47	3.08
XI.	English hay, ...	11.16	10.65	27.78	46.91	3.50

Sheep II.

I.	Early Mastodon Dent corn fodder,	10.16	11.41	27.70	49.17	1.56
VIII.	Unicorn dairy ration, . . .	11.01	14.66	25.32	46.14	2.87
XI.	English hay, ...	10.45	10.17	29.55	46.65	3.18

Sheep III.

II.	Rustler White Dent corn fodder, .	9.77	12.07	26.62	49.87	1.67

Sheep IV.

II.	Rustler White Dent corn fodder, .	11.17	14.11	25.11	47.61	1.99

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Sheep I.

Period.	English Hay.	Early Mastodon Dent Corn Fodder.	Rustler White Dent Corn Fodder.	Unicorn Dairy Ration.	Waste.	Feces.
I., ...	–	24.80	–	–	–	89.08
VIII., ...	89.45	–	–	91.11	–	93.36
X., ...	90.22	–	–	92.46	–	93.52
XI., ...	90.05	–	–	–	–	93.41

Sheep II.

I., ...	–	24.80	–	–	–	88.92
VIII., ...	89.45	–	–	91.11	–	93.27
XI., ...	90.05	–	–	–	–	93.49

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.) — Concluded.

Sheep III.

Period.	English Hay.	Early Mastodon Dent Corn Fodder.	Rustler White Dent Corn Fodder.	Unicorn Dairy Ration.	Waste.	Feces.
II.,	–	–	31.46	–	–	88.51

Sheep IV.

Period.	English Hay.	Early Mastodon Dent Corn Fodder.	Rustler White Dent Corn Fodder.	Unicorn Dairy Ration.	Waste.	Feces.
II.,	–	–	31.46	–	94.05	88.64

Average Daily Amount of Manure excreted and Water Drunk (Grams).

Sheep I.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Early Mastodon Dent corn fodder,	594	18.62	404
VIII.	Unicorn dairy ration,	1,000	21.97	2,325
X.	Unicorn dairy ration,	751	23.97	2,493
XI.	English hay,	633	24.55	2,292

Sheep II.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Early Mastodon Dent corn fodder,	733	18.99	416
VIII.	Unicorn dairy ration,	891	21.85	2,500
XI.	English hay,	722	26.62	2,251

Sheep III.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Rustler White Dent corn fodder,	929	26.67	1,889

Sheep IV.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Rustler White Dent corn fodder,	1,184	24.15	904

Weights of Animals at Beginning and End of Period (Pounds).

Sheep I.

Period.	Character of Food or Ration.	Beginning.	End.
I.	Early Mastodon Dent corn fodder,	89.0	89.0
VIII.	Unicorn dairy ration,	86.5	87.5
X.	Unicorn dairy ration,	86.0	88.0
XI.	English hay,	90.0	88.5

Sheep II.

I.	Early Mastodon Dent corn fodder,	86.5	86.0
VIII.	Unicorn dairy ration,	87.5	87.0
XI.	English hay,	90.5	88.5

Sheep III.

II.	Rustler White Dent corn fodder,	85.5	90.0

Sheep IV.

II.	Rustler White Dent corn fodder,	97.0	95.0

Early Mastodon Dent Corn Fodder, Period I.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,400 grams Mastodon corn fodder fed,	595.20	25.67	43.93	115.47	397.21	12.92
186.21 grams manure excreted (air-dry),	165.88	15.79	18.45	45.35	83.88	2.41
Grams digested,	429.32	9.88	25.48	70.12	313.33	10.51
Per cent. digested,	72.13	38.49	58.00	60.73	78.88	81.35

Sheep II.

2,400 grams Mastodon corn fodder fed,	595.20	25.67	43.93	115.47	397.21	12.92
189.90 grams manure excreted (air-dry),	168.86	17.16	19.27	46.77	83.03	2.63
Grams digested,	426.34	8.51	24.66	68.70	314.18	10.29
Per cent. digested,	71.63	33.15	56.13	59.50	79.10	79.64
Average per cent. for both sheep,	71.88	35.82	57.07	60.12	78.99	80.50

Rustler White Dent Corn Fodder, Period II.

Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,400 grams Rustler corn fodder fed,	755.04	33.07	51.87	146.93	505.56	17.59
266.74 grams manure excreted (air-dry),	236.09	23.07	28.50	62.85	117.72	3.93
Grams digested,	518.95	10.00	23.37	84.08	387.84	13.66
Per cent. digested,	68.73	30.24	45.05	57.22	76.71	77.66

Sheep IV.

2,400 grams Rustler corn fodder fed,	755.04	33.07	51.87	146.93	505.56	17.59
37.86 grams waste,	35.61	1.01	1.20	10.37	22.65	.38
Amount consumed,	719.43	32.06	50.67	136.56	482.91	17.21
241.53 grams manure excreted,	214.09	23.91	30.21	53.76	101.95	4.26
Grams digested,	505.34	8.15	20.46	82.80	380.96	12.95
Per cent. digested,	70.24	25.42	40.38	60.63	78.89	75.25
Average per cent. for both sheep,	69.49	27.83	42.72	58.93	77.80	76.46

Unicorn Dairy Ration, Period VIII.

Sheep I.

500 grams English hay fed,	447.35	30.51	34.31	135.77	236.21	10.55
200 grams Unicorn dairy ration fed,	182.22	6.56	53.96	17.78	91.31	12.61
Amount consumed,	629.57	37.07	88.27	153.55	327.52	23.16
219.65 grams manure excreted (air-dry),	205.07	21.63	32.01	49.98	95.48	5.97
Grams digested,	424.50	15.44	56.26	103.57	232.04	17.19
Minus hay digested,	277.36	12.81	16.81	90.97	153.54	5.17
Unicorn dairy ration digested,	147.14	2.63	39.45	12.60	78.50	12.02
Per cent. digested,	80.74	40.09	73.11	70.87	85.97	95.32

Sheep II.

Amount consumed as above,	629.57	37.07	88.27	153.55	327.52	23.16
218.50 grams manure excreted (air-dry),	203.79	22.44	29.87	51.60	94.03	5.85
Grams digested,	425.78	14.63	58.40	101.95	233.49	17.31
Minus hay digested,	277.36	12.81	16.81	90.97	153.54	5.17
Unicorn dairy ration digested,	148.42	1.82	41.59	10.98	79.95	12.14
Per cent. digested,	81.45	27.74	77.07	61.75	87.55	96.27
Average per cent. for both sheep,	81.10	33.92	75.09	66.31	86.76	95.80

Unicorn Dairy Ration, Period X.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
600 grams English hay fed, ...	541.32	36.92	41.52	164.29	285.73	12.86
150 grams Unicorn dairy ration fed, . .	138.69	4.98	41.07	13.54	69.50	9.60
Amount consumed, ...	680.01	41.90	82.59	177.83	355.23	22.46
239.67 grams manure excreted (air-dry), .	224.14	26.09	30.55	56.44	104.16	6.90
Grams digested, ...	455.87	15.81	52.04	121.49	251.07	15.56
Minus hay digested, ...	335.62	15.51	20.34	110.07	185.72	6.30
Unicorn dairy ration digested, . . .	120.25	.30	31.70	11.42	65.35	9.26
Per cent. digested, ...	86.70	6.02	77.19	84.34	94.03	96.46

English Hay, Period XI.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
700 grams English hay fed, ...	630.35	44.82	48.85	205.74	315.24	15.70
245.46 grams manure excreted (air-dry), .	229.28	25.59	24.42	63.69	107.56	8.02
Grams digested, ...	401.07	19.23	24.43	142.05	207.68	7.68
Per cent. digested, ...	63.63	42.91	50.01	69.04	65.88	48.92

Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
700 grams English hay fed, ...	630.35	44.82	48.85	205.74	315.24	15.70
266.16 grams manure excreted (air-dry), .	248.83	26.00	25.31	73.53	116.08	7.91
Grams digested, ...	381.52	18.82	23.54	132.21	199.16	7.79
Per cent. digested, ...	60.53	41.99	48.19	64.27	63.18	49.62
Average per cent. for both sheep, . .	62.08	42.45	49.10	66.66	64.53	49.27

Summary of Coefficients (Per Cent.).

Food.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Early Mastodon Dent corn fodder,	Sheep I.,	72.13	38.49	58.00	60.73	78.88	81.35
	Sheep II.,	71.63	33.15	56.13	59.50	79.10	79.64
Average,	. . .	71.88	35.82	57.07	60.12	78.99	80.50
Rustler White Dent corn fodder,	Sheep III.,	68.73	30.24	45.05	57.22	76.71	77.66
	Sheep IV.,	70.24	25.42	40.38	60.63	78.89	75.25
Average,	. . .	69.49	27.83	42.72	58.93	77.80	76.46
Unicorn dairy ration,	Sheep I.,	80.74	40.09	73.11	70.87	85.97	95.32
	Sheep I.,	86.70	6.02	77.19	84.34	94.03	96.46
	Sheep II.,	81.45	27.74	77.07	61.75	87.55	96.27
Average,	. . .	82.96	24.62	75.79	72.32	89.18	96.02
English hay,	Sheep I.,	63.63	42.91	50.01	69.04	65.88	48.92
	Sheep II.,	60.53	41.99	48.19	64.27	63.18	49.62
Average,	. . .	62.08	42.45	49.10	66.66	64.53	49.27

Discussion of the Results.

Early Mastodon Dent Corn Fodder. — This is a large growing yellow dent variety bred by C. S. Clark of Ohio. It is evidently rather too late for the average Massachusetts season. At the time of cutting (September 5–19) it was in the milk-to-denting stage, and could not be considered ripe enough to be cut for the grain. It yielded about 20 tons to the acre of green fodder which contained 28 per cent. of ears in dry matter.

Summary of Coefficients, Period I. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	72.13	38.49	58.00	60.73	78.88	81.35
Sheep II.,	1	1	71.63	33.15	56.13	59.50	79.10	79.64
Average,	1	2	71.88	35.82	57.07	60.12	78.99	80.50
Average of all experiments, dent fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

The results obtained in this trial were very satisfactory. They also agreed quite closely with the average for all trials for dent corn.

Rustler White Dent Corn Fodder. — So far as known this variety of corn originated in Minnesota; it was first grown at the Massachusetts Agricultural Experiment Station, where it has given excellent satisfaction. At the time of cutting (September 5–19) it was dented and glazing and ready to harvest. It yielded about 12 tons of green fodder which contained 41 per cent. of ears in dry matter. The yield was not so large as on other fields nearby. The tendency of this variety is to mature in our latitude and yield a fair amount of stalk with a relatively high grain percentage.

Summary of Coefficients, Period II. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep III.,	1	1	68.73	30.24	45.05	57.22	76.71	77.66
Sheep IV.,	1	1	70.24	25.42	40.38	60.63	78.89	75.25
Average,	1	2	69.49	27.83	42.72	58.93	77.80	76.46
Average of all experiments, dent fodder for comparison.	12	23	69.00	34.00	54.00	59.00	75.00	75.00

While the coefficients obtained in this experiment agreed closely, the digestibility was not as great as would naturally be expected, considering the percentage of ears and degree of maturity. This may be due, in part at least, to the fact that this corn was comparatively dry when cut, and the animals were fed rather more dry matter than was intended; in fact, more than they could readily care for. Sheep IV. left a part of the daily ration. With a smaller amount of dry matter in the ration, the coefficients might have been somewhat higher.

Unicorn Dairy Ration. — This is a proprietary mixture consisting of corn, distillers' grains, cottonseed meal, hominy feed, barley feed and sprouts and wheat bran. It contained on a natural moisture basis about 26 per cent. protein, 6 per cent. fat and 9 per cent. fiber.

Summary of Coefficients, Periods VIII. and X. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	80.74	40.09	73.11	70.87	85.97	95.32
Sheep II.,	1	1	81.45	27.74	77.07	61.75	87.55	96.27
Sheep I.,	1	1	86.07	6.02	77.19	84.34	94.03	96.46
Average,	1	2	81.10	33.92	75.09	66.31	86.76	95.80

The results secured in case of Sheep I. in period X. are noticeably above those for the other two trials, and it is thought best not to include them in the average. The reason for this variation cannot be explained. The coefficients for Sheep I. and II. in period VIII. agree fairly well, and show this proprietary feed to have a high digestibility. These results, together with its high protein and a low fiber content, indicate a high-grade protein dairy feed.

English Hay. — The hay used in this period consisted of mixed grasses with June grass predominating. It was cut while in blossom, well cured and in good condition. Before feeding it was cut fine by running it through a feed cutter, and thoroughly mixed to insure uniformity through the entire lot.

Summary of Coefficients, Period XI. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	63.63	42.91	50.01	69.04	65.88	48.92
Sheep II.,	1	1	60.53	41.99	48.19	64.24	63.18	49.62
Average,	1	2	62.08	42.45	49.10	66.66	64.53	49.27
Average of all trials, similar hay for comparison.	21	73	61.00	47.00	57.00	62.00	62.00	50.00

The coefficients obtained in this trial agree closely. With the exception of the coefficient obtained for protein they also agree closely with the average of all results obtained with similar hay.

Series XV.

This series of experiments was conducted during the fall and winter of 1909–10. Those not reported concerned the effect of lactic acid and calcium lactate upon digestibility, and will be published at a later date. The sheep used were the same as for the preceding year.

Composition of Feedstuffs (Per Cent.).

[Dry Matter.]

Period.	Feeds.	Ash.	Protein.	Fiber.	Nitrogen-free Extract Matter.	Fat.
I.	Brewer's Dent corn fodder,	5.32	9.84	23.94	59.40	1.50
II.	Wing's Improved White Dent corn fodder,	4.85	9.36	22.58	61.64	1.57
III.	Alfalfa hay, first cutting, third-year growth,	7.55	16.62	30.16	43.78	1.89
IV.	Alfalfa hay, second cutting, third-year growth.	6.70	15.31	38.03	38.67	1.29
V.	Alfalfa hay, first cutting, first-year growth,	7.63	16.49	35.28	39.10	1.50
VI.	Clover, second cutting,	8.96	15.28	29.76	44.12	1.88
VII.	Clover, first cutting,	11.22	17.82	28.30	40.70	1.96

Composition of Feces (Per Cent.).

Sheep I.

I.	Brewer's Dent corn fodder,	10.00	11.27	25.93	51.17	1.63
III.	Alfalfa hay, first cutting, third-year growth,	10.13	11.35	43.90	31.33	3.29
V.	Alfalfa hay, first cutting, first-year growth,	10.41	11.01	45.14	30.87	2.57
VII.	Clover hay, first cutting,	12.26	18.09	30.28	36.75	2.62

Sheep II.

I.	Brewer's Dent corn fodder,	10.50	10.87	27.75	49.08	1.80
III.	Alfalfa hay, first cutting, third-year growth,	10.70	10.74	44.82	30.74	3.00
V.	Alfalfa hay, first cutting, first-year growth,	10.34	11.04	44.99	30.86	2.77
VII.	Clover hay, first cutting,	12.14	17.23	32.45	35.68	2.50

Sheep III.

II.	Wing's Improved White Cap corn fodder,	9.96	11.66	28.33	48.54	1.51
IV.	Alfalfa hay, second cutting, third-year growth.	9.47	10.23	48.09	29.78	2.43
VI.	Clover hay, second cutting,	9.87	14.78	40.15	33.19	2.01

Composition of Feces (Per Cent.) — Concluded.

Sheep IV.

Period.	Feeds.	Ash.	Protein.	Fiber.	Nitrogen-free Extract Matter.	Fat.
II.	Wing's Improved White Cap corn fodder, .	9.99	11.73	25.08	51.55	1.65
IV.	Alfalfa hay, second cutting, third-year growth.	9.50	9.68	48.46	29.79	2.57
VI.	Clover hay, second cutting, . . .	9.73	15.56	38.93	33.63	2.15

Dry Matter Determinations made at the Time of weighing out the Different Foods, and Dry Matter in Air-dry Feces (Per Cent.).

Sheep I.

Period.	Brewer's Dent Corn Fodder.	Wing's Improved Dent Corn Fodder.	Alfalfa Hay, First Cutting, Third-year Growth.	Alfalfa Hay, First Cutting, First-year Growth.	Alfalfa Hay, Second Cutting, Third-year Growth.	Clover Hay, First Cutting.	Clover Hay, Second Cutting.	Feces.
I., . .	19.39	-	-	-	-	-	-	89.59
III., . .	-	-	85.42	-	-	-	-	91.53
V., . .	-	-	-	86.97	-	-	-	93.88
VII., . .	-	-	-	-	-	88.65	-	93.12

Sheep II.

Period.	Brewer's Dent Corn Fodder.	Wing's Improved Dent Corn Fodder.	Alfalfa Hay, First Cutting, Third-year Growth.	Alfalfa Hay, First Cutting, First-year Growth.	Alfalfa Hay, Second Cutting, Third-year Growth.	Clover Hay, First Cutting.	Clover Hay, Second Cutting.	Feces.
I., . .	19.39	-	-	-	-	-	-	89.71
III., . .	-	-	85.42	-	-	-	-	91.62
V., . .	-	-	-	86.97	-	-	-	93.87
VII., . .	-	-	-	-	-	88.65	-	93.22

Sheep III.

Period.	Brewer's Dent Corn Fodder.	Wing's Improved Dent Corn Fodder.	Alfalfa Hay, First Cutting, Third-year Growth.	Alfalfa Hay, First Cutting, First-year Growth.	Alfalfa Hay, Second Cutting, Third-year Growth.	Clover Hay, First Cutting.	Clover Hay, Second Cutting.	Feces.
II., . .	-	19.18	-	-	-	-	-	89.17
IV., . .	-	-	-	-	86.75	-	-	93.51
VI., . .	-	-	-	-	-	-	88.10	93.05

Sheep IV.

Period.	Brewer's Dent Corn Fodder.	Wing's Improved Dent Corn Fodder.	Alfalfa Hay, First Cutting, Third-year Growth.	Alfalfa Hay, First Cutting, First-year Growth.	Alfalfa Hay, Second Cutting, Third-year Growth.	Clover Hay, First Cutting.	Clover Hay, Second Cutting.	Feces.
II., . .	-	19.18	-	-	-	-	-	89.72
IV., . .	-	-	-	-	87.90	-	-	93.37
VI., . .	-	-	-	-	-	-	88.10	93.21

Average Daily Amount of Manure excreted and Water drunk (Grams).

Sheep I.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Brewer's Dent corn fodder, ...	403	29.21[1]	262
III.	Alfalfa hay, first cutting, third-year growth, .	563	22.21	1,737
V.	Alfalfa hay, first cutting, first-year growth, .	906	33.06	2,451
VII.	Clover hay, first cutting, ...	807	27.05	2,646

Sheep II.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
I.	Brewer's Dent corn fodder, ...	407	30.91[1]	224
III.	Alfalfa hay, first cutting, third-year growth, .	749	26.03	1,969
V.	Alfalfa hay, first cutting, first-year growth, .	724	29.83	2,475
VII.	Clover hay, first cutting, ...	721	28.48	2,656

Sheep III.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Wing's Improved White Cap fodder, . .	560	32.42[1]	157
IV.	Alfalfa hay, second cutting, third-year growth.	944	31.80	2,261
VI.	Clover hay, second cutting, ...	972	31.85	2,562

Sheep IV.

Period.	Character of Food or Ration.	Manure excreted Daily.	One-tenth Manure Air-dry.	Water drunk Daily.
II.	Wing's Improved White Cap fodder, . .	372	31.11[1]	95
IV.	Alfalfa hay, second cutting, third-year growth.	779	28.60	1,841
VI.	Clover hay, second cutting, . . .	675	29.26	2,453

Weighis of Animals at Beginning and End of Periods (Pounds).

Sheep I.

Period.	Character of Food or Ration.	Beginning.	End.
I.	Brewer's Dent corn fodder, ...	94.50	93.25
III.	Alfalfa hay, first cutting, third-year growth, . .	99.50	97.25
V.	Alfalfa hay, first cutting, first-year growth, . .	101.25	100.00
VII.	Clover hay, first cutting, ...	97.25	100.00

[1] One-fifth of daily amount excreted.

Weights of Animals at Beginning and End of Periods (Pounds) — Concluded.

Sheep II.

Period.	Character of Food or Ration.	Beginning.	End.
I.	Brewer's Dent corn fodder,	95.25	93.00
III.	Alfalfa hay, first cutting, third-year growth,	101.75	96.25
V.	Alfalfa hay, first cutting, first-year growth,	97.75	98.75
VII.	Clover hay, first cutting,	102.50	96.50

Sheep III.

II.	Wing's Improved White Cap fodder,	78.50	77.75
IV.	Alfalfa hay, second cutting, third-year growth,	93.25	89.50
VI.	Clover hay, second cutting,	93.75	91.75

Sheep IV.

II.	Wing's Improved White Cap fodder,	107.75	106.75
IV.	Alfalfa hay, second cutting, third-year growth,	112.75	110.50
VI.	Clover hay, second cutting,	113.75	111.50

Brewer's Dent Corn Fodder, Period I.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,500 grams Brewer's Dent corn fodder fed,	484.75	25.79	47.70	116.05	287.94	7.27
146.04 grams manure excreted,	130.84	13.08	14.75	33.93	66.95	2.13
Grams digested,	353.91	12.71	32.95	82.12	220.99	5.14
Per cent. digested,	73.01	49.28	69.08	70.76	76.75	70.70

Sheep II.

2,500 grams Brewer's Dent corn fodder fed,	484.75	25.79	47.70	116.05	287.94	7.27
154.56 grams manure excreted,	138.66	14.56	15.07	38.48	68.05	2.50
Grams digested,	346.09	11.23	32.63	77.57	219.89	4.77
Per cent. digested,	71.40	43.54	68.41	66.84	76.37	65.61
Average per cent. for both sheep,	72.21	46.41	68.75	68.80	76.56	68.16

Wing's Improved White Cap Dent Corn Fodder, Period II.

Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
2,500 grams White Cap Dent corn fodder fed,	479.50	23.26	44.88	108.28	295.56	7.52
162.08 grams manure excreted, . . .	144.53	14.40	16.85	40.95	70.15	2.18
Grams digested, ...	334.97	8.86	28.03	67.33	225.41	5.34
Per cent. digested, ...	69.86	38.09	62.46	62.18	76.27	71.01

Sheep IV.

2,500 grams White Cap Dent corn fodder fed,	479.50	23.26	44.88	108.28	295.56	7.52
155.55 grams manure excreted, . . .	139.56	13.94	16.37	35.00	71.95	2.30
Grams digested, ...	339.94	9.32	28.51	73.28	223.61	5.22
Per cent. digested, ...	70.89	40.07	63.52	67.68	75.66	69.41
Average per cent. for both sheep, . .	70.38	39.08	62.99	64.93	75.97	70.21

Alfalfa Hay, First Cutting, Third-year Growth, Period III.

Sheep I.

750 grams alfalfa hay fed, ...	640.65	48.37	106.46	193.22	280.49	12.11
222.06 grams manure excreted, . . .	203.25	20.59	23.07	89.22	63.68	6.69
Grams digested, ...	437.40	27.78	83.39	104.00	216.81	5.42
Per cent. digested, ...	68.27	57.43	78.33	53.82	77.30	44.76

Sheep II.

750 grams alfalfa hay fed, ...	640.65	48.37	106.46	193.22	280.49	12.11
260.33 grams manure excreted, . . .	238.51	25.52	25.62	106.89	73.32	7.16
Grams digested, ...	402.14	22.85	80.84	86.33	207.17	4.95
Per cent. digested, ...	62.77	47.24	75.93	44.68	73.86	40.88
Average per cent. for both sheep, . .	65.52	52.34	77.13	49.25	75.58	42.82

Alfalfa Hay, Second Cutting, Third-year Growth, Period IV.

Sheep III.

750 grams alfalfa hay fed, ...	650.63	43.59	99.61	247.43	251.61	8.39
318.04 grams manure excreted, . . .	297.40	28.16	30.42	143.02	88.57	7.23
Grams digested, ...	353.23	15.43	69.19	104.41	163.04	1.16
Per cent. digested, ...	54.29	35.40	69.46	42.20	64.79	13.83

Alfalfa Hay, Second Cutting, Third-year Growth, Period IV — Concluded.

Sheep IV.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
750 grams alfalfa hay fed,	659.25	44.17	100.93	250.71	254.94	8.50
285.99 grams manure excreted,	267.03	25.37	25.85	129.40	79.55	6.86
Grams digested,	392.22	18.80	75.08	121.31	175.39	1.64
Per cent. digested,	59.49	42.56	74.39	48.39	68.80	19.29
Average per cent. for both sheep,	56.89	38.98	71.93	45.30	66.80	16.56

Alfalfa Hay, First Cutting, First-year Growth, Period V.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams alfalfa hay fed,	695.76	53.09	114.73	245.46	272.04	10.44
330.56 grams manure excreted,	310.33	32.31	34.17	140.07	95.80	7.98
Grams digested,	385.43	20.78	80.56	105.39	176.24	2.46
Per cent. digested,	55.40	39.14	70.22	42.94	64.78	23.56

Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams alfalfa hay fed,	695.76	53.09	114.73	245.46	272.04	10.44
298.29 grams manure excreted,	280.00	28.95	30.91	125.97	86.41	7.76
Grams digested,	415.76	24.14	83.82	119.49	185.63	2.68
Per cent. digested,	59.76	45.47	73.06	48.68	68.24	25.67
Average per cent. for both sheep,	57.58	42.31	71.64	45.81	66.51	24.62

Clover Hay, Second Cutting, Period VI.

Sheep III.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams clover hay fed,	704.80	63.15	107.69	209.75	310.96	13.25
318.54 grams manure excreted,	296.40	29.25	43.81	119.00	98.38	5.96
Grams digested,	408.40	33.90	63.88	90.75	212.58	7.29
Per cent. digested,	57.94	53.68	59.32	43.27	68.36	55.02

Sheep IV.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams clover hay fed,	704.80	63.15	107.69	209.75	310.96	13.25
292.57 grams manure excreted,	272.70	26.53	42.43	106.17	91.71	5.86
Grams digested,	432.10	36.62	65.26	103.58	219.25	7.39
Per cent. digested,	61.31	57.99	60.60	49.38	70.51	55.77
Average per cent. for both sheep,	59.63	55.84	59.96	46.33	69.44	55.40

Clover Hay, First Cutting, Period VII.

Sheep I.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams clover hay fed,	709.20	79.57	126.38	200.70	288.65	13.90
270.50 grams manure excreted,	251.89	30.88	45.57	76.27	92.57	6.60
Grams digested,	457.31	48.69	80.81	124.43	196.08	7.30
Per cent. digested,	64.48	61.19	63.94	62.00	67.93	52.52

Sheep II.

	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
800 grams clover hay fed,	709.20	79.57	126.38	200.70	288.65	13.90
284.76 grams manure excreted,	265.45	32.23	45.74	86.14	94.70	6.64
Grams digested,	443.75	47.34	80.64	114.56	193.95	7.26
Per cent. digested,	62.57	59.49	63.81	57.08	67.19	52.23
Average per cent. for both sheep,	63.53	60.34	63.88	59.54	67.56	52.38

Summary of Coefficients (Per Cent.).

Food.	Sheep Number.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Brewer's Dent corn fodder,	Sheep I.,	73.01	49.28	69.08	70.76	76.75	70.70
	Sheep II.,	71.40	43.54	68.41	66.84	76.37	65.61
Average,	. . .	72.21	46.41	68.75	68.80	76.56	68.16
Wing's Improved White Cap Dent corn fodder.	Sheep III.,	69.86	38.09	62.46	62.18	76.27	71.01
	Sheep IV.,	70.89	40.07	63.52	67.68	75.66	69.41
Average,	. . .	70.38	39.08	62.99	64.93	75.97	70.21
Alfalfa hay,	Sheep I.,	68.27	57.43	78.33	53.82	77.30	44.76
	Sheep I.,	55.40	39.14	70.22	42.94	64.78	23.56
	Sheep II.,	65.52	52.34	77.13	49.25	75.58	42.82
	Sheep II.,	59.76	45.47	73.06	48.68	68.24	25.67
	Sheep III.,	54.29	35.40	69.46	42.20	64.79	13.83
	Sheep IV.,	59.49	42.56	74.39	48.39	68.80	19.29
Average,	. . .	60.46	45.39	73.77	47.55	69.92	28.32
Clover hay,	Sheep I.,	64.48	61.19	63.94	62.00	67.93	52.52
	Sheep II.,	62.57	59.49	63.81	57.08	67.19	52.23
	Sheep III.,	57.94	53.68	59.32	43.27	68.36	55.02
	Sheep IV.,	61.31	57.99	60.60	49.38	70.51	55.77
Average,	. . .	61.58	58.09	61.92	52.93	68.50	53.89

Discussion of the Results.

Brewer's Dent Corn Fodder. — This is a yellow dent corn believed to have been first bred in the middle west and improved by N. H. Brewer of Connecticut, who has raised enormous crops by following an intensive system of fertilization and cultivation. We have not been successful in ripening it on the station farm. At the time of cutting (September 5–19) the ears were hardly in milk, and consequently not suitable to harvest for grain. It evidently needs a somewhat longer growing season than is usually experienced in the vicinity of Amherst. It produced at the rate of about 18 tons of green fodder per acre, and yielded about 17 per cent. of ears in dry matter.

Summary of Coefficients, Period I. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	73.01	49.28	69.08	70.76	76.75	70.70
Sheep II.,	1	1	71.40	43.54	68.41	66.84	76.37	65.61
Average,	1	2	72.21	46.41	68.75	68.80	76.56	68.16
Average of all trials, immature dents for comparison.	5	14	68.00	42.00	66.00	65.00	71.00	68.00

The coefficients obtained in this trial are somewhat higher than the average for immature corn. While the percentage of ears was low, the high digestibility can probably be accounted for by the soft, incompletely developed stalks, the fiber showing a relatively high digestibility.

Wing's Improved White Cap Dent Corn Fodder. — This variety of corn was originated by J. E. Wing of Ohio. It would probably form a very satisfactory variety in the middle west, but the season is not sufficiently long to enable it to reach maturity in New England. Two partially developed ears were frequently noticed on a stalk. When cut (September 5–19) it was in milk and still green. It yielded at the rate of about 14 tons of green fodder per acre, and contained 16 per cent. of ears in its dry matter.

Summary of Coefficients, Period II. (Per Cent.).

Sheep.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep III.,	1	1	69.86	38.09	62.46	62.18	76.27	71.01
Sheep IV.,	1	1	70.89	40.07	63.52	67.68	75.66	69.41
Average,	1	2	70.38	39.08	62.99	64.93	75.97	70.21
Average of all trials, immature dents for comparison.	5	14	68.00	42.00	66.00	65.00	71.00	68.00

This corn is of substantially the same type as the one immediately preceding. It appeared to be slightly less digestible, although the difference may have been partly due to the individuality of the two lots of sheep.

Alfalfa Hay. — The alfalfa hay used in these experiments was grown on the college farm. It was cut while in early blossom, and was quite free from weeds and grass. Period III. represented the first cutting of the third-year growth, period IV. the second cutting of the third-year growth, and period V. the first cutting of the first-year growth. Owing to different weather conditions which prevailed at the time of cutting, and which necessitated different methods of handling, the amount of leaves lost in curing was not uniform; hence a strictly fair comparison could not be made between the different cuttings. The results are therefore reported together, and the average given for the several lots. In order to draw accurate conclusions between cuttings, the crop should either be fed green or cured under uniform conditions. Owing to frequent weather changes this is often not possible in New England.

Summary of Coefficients, Periods III., IV. and V. (Per Cent.).

Sheep.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1[1]	1	1	68.27	57.43	78.33	53.82	77.30	44.76
Sheep I.,	1[2]	1	1	55.40	39.14	70.22	42.94	64.78	23.56
Sheep II.,	1[1]	1	1	62.77	47.24	75.93	44.68	73.86	40.88
Sheep II.,	1[2]	1	1	59.76	45.47	73.06	48.68	68.24	25.67
Sheep III.,	2[1]	1	1	54.29	35.40	69.46	42.20	64.79	13.83
Sheep IV.,	2[1]	1	1	59.49	42.56	74.39	48.39	68.80	19.29
Average,	–	3	6	60.00	44.54	73.57	46.79	69.63	28.00
Average of all trials, alfalfa hay for comparison.	–	42	80	62.00	50.00	74.00	46.00	72.00	40.00
Average of all trials, red clover for comparison.	–	12	25	58.00	36.00	58.00	54.00	65.00	56.00

Unfortunately an exact record of the conditions during the curing process of the several lots was not kept. It would appear that the first cutting of the *third-year growth* was cured without the loss of a great deal of leafy matter. This is shown by the relatively low fiber percentage and the high digestibility. The second cutting of the *third-year growth* evidently lost a considerable portion of its leaves, as indicated by its high fiber percentage and lessened digestibility. The first cutting of the *first-year growth* also must have lost an excess of leaves, as it also shows excessive fiber and low digestion coefficients. It is possible that the tags of the first cutting, third-year growth and the first cutting first-year growth, were reversed, although we have not the slightest evidence to that effect.

While the coefficients obtained vary considerably the average is about the same as the average for all trials, except that the coefficient for fat is somewhat lower. It is believed that the average coefficients obtained in our several trials show fairly the digestibility of eastern grown alfalfa under the adverse conditions due to the loss of leaves in the process of curing.

Red Clover Hay. — The clover was seeded in early August the year previous. It yielded well, was in early blossom when

[1] Third-year growth. [2] First-year growth.

cut, and was cured in cocks. The first cutting did not cure out well, owing to a rainy spell during the curing process. It had a black appearance when taken to the barn, and later had to be spread in the sun for further drying. It did not lose its leaves to any extent. The lot was lacking in a satisfactory odor and was slightly musty. The conditions during the curing of the second cutting were more favorable. Both lots were rich in protein (15.28 and 17.82 per cent. in dry matter) and comparatively low in fiber (29.76 and 28.30 per cent. in dry matter).

Summary of Coefficients, Periods VI. and VII. (Per Cent.).

SHEEP.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I.,	1	1	1	64.48	61.19	63.94	62.00	67.93	52.52
Sheep II.,	1	1	1	62.57	59.49	63.81	57.08	67.19	52.23
Sheep III.,	2	1	1	57.94	53.68	59.32	43.27	68.36	55.02
Sheep IV.,	2	1	1	61.31	57.99	60.60	49.38	70.51	55.77
Average,	–	2	4	61.58	58.09	61.92	52.93	68.50	53.89
Average alfalfa hay (our trials).	–	3	6	60.46	45.39	73.77	47.55	69.92	28.32
Average of all trials, clover hay for comparison.	–	12	25	58.00	36.00	58.00	54.00	65.00	56.00
Average of all trials, alfalfa hay for comparison.	–	42	80	62.00	50.00	74.00	46.00	72.00	40.00

The most noticeable difference in the four single trials with clover hay consists in the variation in the digestion coefficients obtained for the fiber (43–62). This is evidently due, in part at least, to the individuality of the several animals. The fiber in the second cutting was apparently not as digestible as in the first cutting. The other coefficients — excepting the ash, which is found to vary widely in most all experiments — may be considered fairly uniform. The coefficients secured by us are higher than the average for all experiments, probably due to the early cuttings of the crop. When the clover coefficients are compared with our reported experiments for alfalfa, it is noted that in case of the total dry matter, the former shows to advantage, although the reverse is true in a comparison of the experiments reported for all trials. The protein in the clover is shown to be substantially 12 per cent. less digestible than in the alfalfa; the coefficients vary 16 per cent. in case of the average for all trials. In case of the fiber the conditions are reversed, differences of from 5 to 8 points being noted in favor of the clover. The comparative digestibility of the extract matter is about the same, although the average figures show 7 points in favor of the alfalfa. In making a comparison of the two plants from the standpoint of digestibility, two important differences are noted: (1) the protein in the alfalfa is noticeably more digestible than in the clover (12 to 16 points), and (2) the fiber from 5 to 8 points less so. In total digested the two plants approach each other, showing an average of about 60 per cent. as against 55 per cent. for timothy, 60 per cent. for early cut fine hay, 65 per cent. for rowen, 70 per cent. for the entire corn plant, and 85 per cent. for corn meal.

It is evident that the relative value of the two crops cannot be determined from their digestibility alone; other important factors to be considered are cost of production, yield and adaptability to Massachusetts conditions. Taking all the evidence into consideration, it would appear that although the cost of seed and preparation of land is somewhat against the alfalfa, yet its much greater length of life, its larger average annual yield, and its rather superior nutritive value are all in its favor. The conditions governing its successful cultivation must be carefully studied by all interested in its production. To the lack of attention to these conditions by the average farmer is due in no small measure the failures reported.

INDEX.

INDEX.

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TWENTY-FOURTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

PART II.,

BEING PART IV. OF THE FORTY-NINTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

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GENERAL REPORT OF THE EXPERIMENT STATION.

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CONTENTS.

Part II.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

OF THE

MASSACHUSETTS AGRICULTURAL COLLEGE,

AMHERST, MASS.

TWENTY-FOURTH ANNUAL REPORT.

PART II.

SUMMARY OF LEADING CONCLUSIONS.

WM. P. BROOKS, DIRECTOR.

A number of the papers included in this part of the annual report are themselves summaries of articles which will be found in Part I. of the report. It is impossible, therefore, to summarize them further. All the articles are brief and concise and should be read in full by those interested in the subjects discussed. Especial attention is called to the following conclusions: —

1. A majority of those who have tried co-operative experiments with alfalfa have attained either complete or partial success, and the results indicate that the crop can be grown profitably in many parts of the State.

2. The most profitable varieties of corn for ensilage are those which bring their ears to the milk stage in an average season.

3. The total yield of grain affects the value of a variety of field corn in greater degree than variation in chemical com-

position, and a large proportion of kernel to cob is a character of much importance.

4. Great improvement in yield of crops can be made by careful selection, and in the case of self-fertilized plants by pollinating from superior individuals.

5. Laboratory experiments indicate that the loss of nitrogen from manure cannot economically be prevented by use of chemicals. The best method of preservation appears to be to keep the manure moist and well packed.

6. Among the different chemicals tested sulfate of magnesia appears to be one of the best nitrogen absorbents, while gypsum (sulfate of lime), although most commonly used in farm practice, is one of the least active absorbents.

7. Tobacco injury, due to malnutrition or overfertilization, usually occurs on land that is underlaid with an impervious subsoil and poorly drained, as increased evaporation brings such an excess of plant food to the surface that normal growth is checked. Deficiency in rainfall may also have some influence. The remedy consists in breaking up the subsoil or in underdrainage, and also planting the land for a year or two to corn or grass.

8. Alfalfa has been shown to be rather superior in nutritive value to clover hay, and while it is a more costly crop to establish, its much greater length of life and larger annual yield render it preferable to clover wherever it can be grown.

9. The bronzing of maple leaves is not caused by pathogenic organisms. It occurs on very hot, dry days in periods of severe drouth, and is purely functional in nature.

10. From the standpoint of cost and efficiency the high-pressure coarse nozzle is superior to the low-pressure mist nozzle, especially for work on large trees. The nozzles at present in use can undoubtedly be greatly improved.

11. The soil best adapted to roses is one which contains from 8–12 per cent. of clay, and is well supplied with silt and the finest grades of sand. The proportion of these three classes of material should exceed 75 per cent.

12. The elm is greatly affected by the texture of the soil in which it grows. If this is right it is usually free from disease and attains enormous size and great beauty.

13. Elms thrive better in pastures and lawns than in mowings, and they are usually benefited by application of fertilizers and by cultivation.

14. The reasons why a seed law framed upon existing models would be unsatisfactory in Massachusetts are presented; the difficulties which must be met are discussed and the conclusion is reached that, for the present at least, while reasonable guarantees as to germination and purity should be required, it seems best to depend chiefly upon inspection and publicity.

ALFALFA CO-OPERATIVE EXPERIMENTS.

WM. P. BROOKS AND H. J. BAKER.

In the late summer of 1910 a number of farmers agreed to co-operate with the experiment station in determining the possible success of growing alfalfa in this State. The experiments have been made in 10 different counties. Northern grown seed treated with " Farmogerm " for inoculation with nitrogen-fixing bacteria was used. The following directions, which are believed to give a satisfactory method of preparing for the crop, were sent to all those taking part in the experiment: —

1. Plow in spring just as soon as possible after the ground can be worked.
2. Apply lime at the rate of about 1½ tons to the acre and disk in at once.
3. About ten days later apply the following mixture per acre: basic slag meal, 1,500 pounds, high-grade sulfate of potash, 400 to 500 pounds, and disk in.
4. Thereafter harrow about once in ten to twelve days, until you are ready to sow the seed, which should not be later than about July 27.
5. When ready to sow the seed, apply per acre: nitrate of soda, 100 pounds, basic slag meal, 300 pounds, mixing them and harrowing in lightly.
6. Sow 30 pounds of seed per acre, in showery weather if possible, and cover as you would grass seed.

The fall months were exceedingly dry and, therefore, somewhat unfavorable; but in most cases the crop made an excellent start and was in good condition before winter began, having made sufficient growth to afford the needed protection. The winter was a rather hard one for alfalfa. In the spring circular letters were sent to the growers asking for information relative to the condition of the crop. Most of the growers sent in a very favorable report. The crop had winter killed to some extent, though in most cases this occurred on poorly drained portions of the field, and in some instances it was due to standing water and ice. Under such conditions it would naturally be expected to winter kill, since it is a crop which demands good drainage. Standing water and ice during the winter are fatal to it. Most of the growers reported about the middle of May. At that time the crop was from 8 to 12 inches in height.

The experiments have been classified under three headings: successful, partially successful and failures. The number under each heading follows: —

Successful,	13
Partially successful,	9
Failures,	7
Total,	29

Causes for Failures. — From the reports of the 7 experiments which failed entirely, one or more of the following conditions are given as the cause of failure: —

1. Winter killing.
   (*a*) Due in most cases to poor drainage, standing water and ice.
   (*b*) Planted too late so that there was not sufficient growth for winter protection.
2. Excessively dry weather so that the crop did not get a good start the first season before winter set in.
3. Weeds and grasses have come in. (This occurred mainly on fields that did not get a good start in the beginning and in places that winter killed.)

Condition as affected by Drouth. — The growing seasons of 1910 and 1911 are noted as excessively dry. The crop in many instances was affected by this long-continued drouth. Alfalfa, however, stood this excessive drouth well, and in several instances better than other farm crops. During this extremely dry time a grower on Nantucket wrote: "It is practically the only green thing on my farm." Another grower said: "It has stood the drouth fully as well as timothy, redtop and clover."

Condition as affected by Frost. — Some of the growers reported that it had heaved to some extent, but in practically all cases this appears to have occurred on land that was not thoroughly drained. Several growers reported that the crop did not heave.

Yield. — The range of yields on the successful experiments, as reported by the growers, is from 1½ to 6 tons per acre. The average yield per acre of 14 growers who reported definite yields is 2½ tons. In most cases the crop was cut three times and had sufficient growth for winter protection. The dates of cutting appear to have been about as follows: —

1. June 1 to June 30.
2. August 3 to August 20.
3. September 1 to October 1.

Opinions of Growers. — Following is a list of farmers who are co-operating in this work and their opinion as to the value of this crop for the section of the State in which they live: —

C. M. Cudworth (Cummington). — If land well prepared and planted on the dryest land it should be a good crop for two years at least.

John H. Bartlett (Nantucket). — Don't see any reason why it can't be raised with success. Have put in 2½ acres more.

Lovett Brothers (Oxford). — Believe it to be a valuable crop.

C. W. Prescott (Concord). — Results very encouraging. Fed green to horses, hogs, cattle and hens with great profit.

F. E. Tatreau (Framingham). — Not promising, which is partly due to extremely dry season.

Frank S. Walker (Dudley). — I feel sure crop will be very valuable.

Edward Kirkham (Holliston). — So far I am not discouraged. Its value depends upon length of time it will remain in sod.

Lyman P. Thomas (Rock). — Can form better estimate next fall. Made a mistake in pasturing too late.

Charles L. Clay (North Dana). — My land is sandy and it was so dry in June and July that it did better than I expected. It seems to be just the grass for this sandy valley.

Paul Cunningham (Bolton). — From results obtained do not think crop will be valuable.

H. A. Parsons (North Amherst). — Results indicate crop to be valuable.

Cyrus S. Bardwell (Shelburne). — Will be valuable if blight can be controlled, otherwise, clover more valuable.

G. B. Trowbridge (South Weymouth). — From results obtained believe it to be a valuable crop.

J. B. Sawyer (Bradford). — Highly satisfactory. Have planted 1½ acres more. Neighbors are planting it.

In conclusion I would say that the results of these experiments up to the present time indicate that alfalfa can be grown profitably when planted on land that has thorough surface and under-drainage, has been well prepared, and properly fertilized.

If the leaves show much "spot" or blight the crop should be cut at once. The reports of growers make it apparent that many failed to act on this plan.

In not a few instances the first and second crops were cut too late. The best time for cutting is indicated by the formation of buds at the base of the stems. These usually appear about the time blooming begins.

TYPES OF CORN BEST SUITED TO MASSACHUSETTS.[1]

P. H. SMITH AND J. B. LINDSEY.

Since 1903 experiments have been in progress with corn to determine those types best suited to Massachusetts conditions. The total yield of dry matter per acre, digestibility, relative proportions, in some cases the composition of the various parts of the plant (stalk, leaf, ear and husk), and the relation of stage of development to the relative proportion of different parts as affecting the food value, have been carefully studied. The following varieties have been tested: Twitchell's Early Flint, Sanford White, Longfellow, Pride of the North, Rustler Dent, Leaming, Brewer's, Early Mastodon, Klondike, Red Cob Silage, White Cap Yellow, Wing's Improved White Cap, and Eureka.

The results of the study may be summarized under the following headings: —

1. The stalks and ears form substantially 70 per cent. of the entire maize plant; most varieties showed about 20 per cent. leaves and 10 per cent. husks.

2. The Twitchell, a small early maturing variety, showed an exceptionally large proportion of ears (55 per cent.), but it is not economical for Massachusetts conditions. The medium dent and flint varieties (Pride of the North, Rustler, Longfellow, Sanford White) averaged 33 per cent. of stalk and 37 per cent. of ears, and are quite well suited for grain, and serve fairly well for silage. The larger medium dent varieties that in an average season bring their ears to the milk stage, yield about 45 per cent. stalk and 26 per cent. ears, and are rather preferable for silage purposes (Leaming,

[1] The entire article with full data is to be found in Part I. of this report.

White Cap Yellow, Brewer's,[1] Early Mastodon[1]). The very coarse late-maturing varieties which never ripen seed in this locality are not satisfactory for silage purposes.

3. As is well known, the season has a marked influence on the yield of the corn plant, the same variety under otherwise identical conditions yielding from 50 to 100 per cent. more in a year particularly favorable to its growth.

4. The changes in chemical composition which the corn plant undergoes in its development are such that its maximum feeding value exists at its maturity.

5. Numerous digestion experiments have shown no wide variations in the digestibility of the several varieties, the range being from 67 to 77 per cent. with an average of approximately 70 per cent. The general statement can be made that the higher the percentage of extract or starchy matter present (the larger the percentage of ears) the higher the digestibility and resulting feeding value.

6. The percentage of grain to cob varies widely, depending, to some extent, upon the maturity of the plant when cut. The average for the several mature types was 15.5 per cent. cob and 84.5 per cent. kernel, while the average for the less mature varieties was 18.1 per cent. cob and 81.9 per cent. kernel. In either case the percentage of cob was less than that of the legal Massachusetts bushel, which in case of shelled corn is 56 pounds and in case of ear corn 70 pounds, thus allowing 14 pounds or 20 per cent. for cob.

7. The grain showed only slight variations in composition. It is believed that chemical composition cannot be considered an important factor in the selection of seed corn when the crop is to be used for the sustenance of live stock.

8. But little variation was noted in the composition of the corn cob. The net available energy in 100 pounds of cob is 40.2 therms, as against 85.5 therms in a like amount of corn meal; hence the cob has 47 per cent. of the value of the meal for feeding purposes.[2]

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[1] Do better in southern New England.

[2] This is calculated on the basis of the method suggested by Kellner, and is the most satisfactory method available for the estimation of relative energy values.

COMPLETE ANALYSES OF CORN GROWN IN COMPETITION FOR THE BOWKER PRIZE.

BY P. H. SMITH.

The analyses which follow were made from samples grown in competition for the Bowker corn contest for the year 1910.[1] In this contest the production values of the several food ingredients as well as the total yield were considered, which necessitated a complete fodder analysis of the corn. Of the 27 samples sent to the station to be tested 22 were flint and 5 dent varieties. The analyses are figured to a uniform water content of 12 per cent., which is considered a fair average for crib-dried corn.

So far as we have been able to ascertain, all of the flint varieties were fully matured when harvested. Information is not at hand in regard to the stage of maturity of the dent varieties grown by John P. Bowditch and Butler Bros. Silver King, grown by the Middlebrook farm, and Brewer's dent, grown by E. W. Capen, were not fully matured when cut. Early Huron, grown by M. H. Williams, was ripe when harvested.

[1] For complete data see Book of the Bowker Contest, issued by the Bowker Fertilizer Company, 43 Chatham Street, Boston, Mass.

Table of Analyses.

[12 per cent. water basis.]

Grower.	Variety.	Protein (Per Cent.).	Fat (Per Cent.).	Nitrogen-free Extract (Per Cent.).	Fiber (Per Cent.).	Ash (Per Cent.).
Flints.						
John P. Bowditch, Framingham, Mass.,	Stickney,	10.03	4.88	70.42	1.23	1.44
Nathaniel I. Bowditch, Framingham, Mass.	Stickney,	10.09	4.66	70.79	1.17	1.29
Samuel Carr, Northborough, Mass.,	Stickney,	10.58	4.85	70.01	1.26	1.30
Martin A. Carey, Brockton, Mass.,	Dibble,	8.97	4.71	72.10	1.14	1.08
Paul Cunningham, Bolton, Mass.,	Stickney,	11.59	4.95	68.83	1.17	1.46
Perley E. Davis, Granby, Mass.,	Davis Improved,	10.32	4.51	70.51	1.28	1.38
Arthur S. Felton, Bolton, Mass.,	Stickney,	10.72	4.89	69.78	1.18	1.43
George H. Fish, North Appleton, Me.,	Yellow Flint,	9.50	4.11	71.12	1.67	1.60
W. C. Ford, Whitefield, Me.,	Yellow Flint,	9.55	4.45	70.31	2.44	1.25
A. J. Guptil & Sons, Berwick, Me.,	Ordway,	10.21	4.77	70.52	1.22	1.28
Arthur T. Hathaway, Monmouth, Me.,	Early Canada,	9.74	4.73	71.08	1.17	1.28
Joseph Howland, Taunton, Mass.,	Yellow Flint,	10.33	4.55	70.48	1.27	1.37
Hathorn J. Libby, Charleston, Me.,	Yellow Flint,	10.09	4.29	70.39	1.69	1.54
L. W. Peet, Middlebury, Vt.,	White Australian,	10.30	4.65	70.49	1.17	1.39
Burton L. Robinson, Monmouth, Me.,	Yellow Flint,	9.21	4.80	71.50	1.20	1.29
William E. Sarle, Shawomet, R. I.,	Longfellow,	10.67	4.73	69.94	1.30	1.36
George E. Stickney, Newburyport, Mass.,	Stickney,	9.30	4.64	71.68	1.13	1.25
Edward P. West, Hadley, Mass.,	Yellow Flint,	10.42	4.61	70.53	1.14	1.30
L. S. White, Collinsville, Conn.,	White Flint,	9.65	4.58	71.06	1.36	1.35
James E. Phelps, Millbury, Mass.,	Yellow Flint,	10.91	4.78	69.73	1.17	1.41
John G. Francis, Bridgewater, Mass.,	Early Canada,	10.33	4.88	70.29	1.11	1.39
J. E. Hamilton, Garland, Me.,	Yellow Flint,	11.20	4.81	68.65	1.70	1.64
Average,	. . . .	10.17	4.67	70.46	1.33	1.37
Dents.						
John P. Bowditch, Framingham, Mass.,	Funk Bros.,	9.07	3.73	71.84	2.12	1.24
Middlebrook farm, Dover, N. H.,	Silver King,	9.55	4.29	71.10	1.75	1.31
M. H. Williams, Sunderland, Mass.,	Early Huron,	9.44	4.30	71.23	1.65	1.38
E. W. Capen, Monson, Mass.,	Brewer's,	8.84	3.47	72.48	2.01	1.20
Butler Bros., Montello, Mass.,	Diamond Joe,	9.77	3.33	71.63	1.94	1.33
Average,	. . . .	9.33	3.82	71.67	1.89	1.29

The corn showed the following ranges in analysis: —

Flint.

	High (Per Cent.).	Low (Per Cent.).
Protein,	11.59	8.97
Fat,	4.95	4.11
Nitrogen-free extract,	72.10	68.65
Fiber,	2.44	1.11
Ash,	1.64	1.08

Dent.

	High (Per Cent.).	Low (Per Cent.).
Protein,	9.77	8.84
Fat,	4.30	3.33
Nitrogen-free extract,	72.48	71.10
Fiber,	2.12	1.65
Ash,	1.38	1.20

From the data obtained it is evident that chemical composition cannot be considered an important factor in the selection of seed corn where the crop is used for the sustenance of live stock. For such a purpose that variety should be selected which is suited to the locality where it is grown and which will produce the largest amount of shelled corn to the acre.

The variation in the analyses of the different samples is evidently due largely to the relative size of the several parts of the kernel (hull, gluten layer, starch and germ).

Additional Data.

[Relative proportions of kernels and cob.]

Grower.	Variety.	Weight of Ten Ears (Ounces).		Average Weight per Ear (Ounces).		Weight of Kernels from Ten Ears. Water Free (Ounces).	Weight of Cob from Ten Ears. Water Free (Ounces).	Per Cent. Kernel and Cob in Dry Matter.	
		Air Dry.	Water Free.	Air Dry.	Water Free.			Kernel.	Cob.
Flints.									
Samuel Carr, Northborough, Mass.,	Stickney,	83.4	77.9	8.3	7.8	65.2	12.7	83.6	16.4
Perley E. Davis, Granby, Mass.,	Yellow Flint,	78.5	73.0	7.9	7.3	61.9	11.1	84.8	15.2
W. C. Ford, Whitefield, Me.,	Yellow Flint,	89.6	83.6	9.0	8.4	65.8	17.8	78.7	21.3
A. J. Guptil & Sons, Berwick, Me.,	Ordway,	68.9	64.0	6.9	6.4	53.6	10.4	83.8	16.2
Arthur T. Hathaway, Monmouth, Me.,	Early Canada,	61.0	57.0	6.1	5.7	48.9	8.1	85.8	14.2
L. S. White, Collinsville, Conn.,	White Flint,	53.7	50.1	5.4	5.0	42.4	7.7	84.6	15.4
Average,		72.5	67.6	7.3	6.8	56.3	11.3	83.6	16.4
Dents.									
Middlebrook farm, Dover, N. H.,	Silver King,	84.0	78.3	8.4	7.8	65.7	12.6	83.9	16.1
M. H. Williams, Sunderland, Mass.,	Early Huron,	93.8	87.2	9.4	8.7	74.1	13.1	85.0	15.0
E. W. Capen, Monson, Mass.,	Brewer's,	86.5	79.9	8.7	8.0	64.5	15.4	80.7	19.3
Average,		88.1	81.8	8.8	8.2	68.1	13.7	83.2	16.8

Ten representative ears of 6 of the flint and 3 of the dent varieties were secured from the growers, and the relative proportion of corn to cob determined. With but two exceptions the differences were not marked. The yellow flint corn grown by W. C. Ford consisted of 21.3 per cent. of cob and 78.7 per cent. kernel. This corn had an exceptionally large ear with a bulging butt, and the kernels were quite shallow, a condition which would affect adversely the total yield of grain. Brewer's dent corn, grown by E. W. Capen of Monson, consisted of 80.7 per cent. kernel and 19.3 per cent. cob. This corn was quite immature when cut and would have shown a larger percentage of kernel had it reached maturity.

In the selection of seed corn the relative proportion of kernel to cob should be carefully considered. If seed corn is purchased rather than home grown, it is advisable to obtain ear corn, test its vitality by approved germination tests, and finally determine the proportion of kernels and cob. This is easily done by weighing separately the kernels and cob and calculating the percentage of each. The ear should not contain over 17 per cent. of cob. It is a significant fact that the prize corn in this contest contained only 15.2 per cent. of cob.

METHODS OF SELECTION FOR PLANT IMPROVEMENT.

BY J. K. SHAW.

The fact that plants are unlike lies at the foundation of all plant improvement. Sometimes it is first attempted to bring about increased unlikeness by hybridization or otherwise, but the great part of the work is the choice of desirable plants and by repeated selection securing and maintaining the desired standard. Selection of desirable plants is generally followed by more or less positive results, but not uniformly so; sometimes the results seem to be negative, or at any rate not as satisfactory as might be desired.

The plant is much the subject of its environment; variation in the nature and amount of the available food supply, and the varying conditions of weather and climate, affect it strongly, and selection of plants whose desirable qualities are thus brought about must obviously be less effective than selection of differences that arise from causes within the plant, and which persist from generation to generation. In a collection of varying plant individuals some of the differences are environmental and are inherited in small degrees if at all, while others are innate with the plant and persist from generation to generation. The task of the man who would improve his stock of beans or corn is to distinguish between these two sorts of variation, and select and hold to that which is not due to environment but is inherited by succeeding generations.

Certain investigations that have been carried on by the department of horticulture during the past four years with garden peas bear directly on this. This work is fully reported in Part I. of this report (p. 82), to which the reader may refer for detailed information. It is the purpose of this article to set forth the application of results there indicated to practical methods of plant improvement. The methods used have served to distinguish between those differences that are due to soil and weather conditions and those peculiar to the plant which are inherited and therefore of greatest interest to the practical plant grower. The results which are in harmony with those of other investigations indicate that our common varieties of garden peas are composed of subvarieties or, more properly, strains, which differ from each other in varying degrees, this difference, however, being relatively fixed and permanent.

A planting of Excelsior peas proved to contain two strains, one of which exceeded the other in productiveness by about 15 per cent. in an average of four years crops. While this difference is a pronounced one, it would have been totally hidden by differences in yield due to environment had the two strains not been planted separately and in large numbers. The separation of this more prolific strain should prove advantageous to the gardener.

According to the generally accepted belief, the selection of superior individuals within this strain should result in further improvement. This is doubtful. It is probable that if any real progress can be made by this method it will be small and of doubtful permanency. We do not regard this as a proven fact, but only as a strong probability. The efforts of the gardener should then be directed to the isolation of their superior strains where they exist in our common varieties.

We may now outline a simple method of accomplishing this.

The first step is to secure the best available stock of a variety suited to the purpose of the grower. This should be planted and cared for in the best possible manner. The most uniform plot of ground available should be selected. The grower should study the plants carefully and select those which appear the most desirable, particularly as regards yield. The seed from each plant should be gathered separately and given a number. All shrunken or otherwise imperfect seeds should be thrown out.

The next spring the seeds from the several plants should be planted, each in a row by itself, under the most uniform conditions possible as to space for the plants and soil, and given good care as before. The grower should study them carefully during the growing period and make a note of the rows showing desirable characters. As yield is a most important character, it may be well to provide for a careful record of the yield of equal length of row of the different selections. In the fall the seed from the most successful rows should be saved as before. If one cares to take the trouble to select from the better plants within the row it will do no harm, but it seems doubtful if it will do any good, and it will delay the increase of the stock to a point when it is sufficient for the general crop. The superior rows chosen will each yield seed enough, after rejecting the imperfect seeds by sifting or other convenient method, to plant a longer row or a small plot, thus providing for the growing of the selected strains in greater quantity and enabling one to judge their comparative value better. This operation may be repeated a third time, and this should result in the final selection of the best that the original selection contained.

Fig. 1 will serve to make this method of selection perfectly clear. Twelve plants are chosen from a field plot and sown the

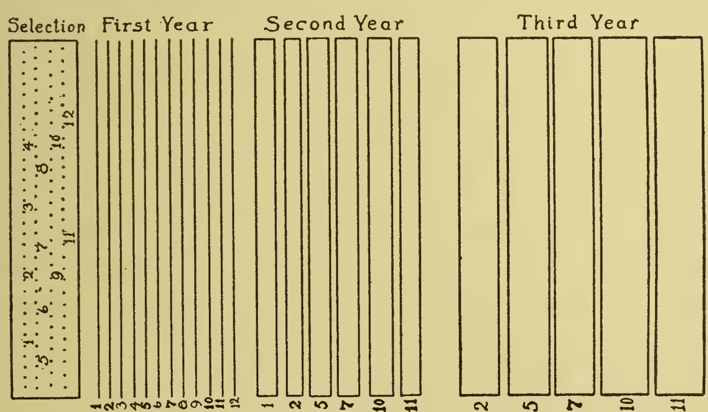

Fig. 1.

first year in 12 rows. The ones with the heavy-faced figures prove the better and are sown the second year in small plots. One of these is rejected and 5 are retained for a third year. Of these number 7 proves the most desirable and is retained for field sowing. If possible a larger number of plants than indicated should be chosen at the start, thus increasing the chances of securing the very best that the variety affords. Experience has shown most conclusively that the character of an individual plant is small indication of the value of its progeny, and the selection that proves finally to be the best may very likely come from one of the less promising plants of the original selection.

The foregoing has been written as applicable to the garden peas alone, for our own investigations along this line have been confined to that plant. The question now arises whether the same methods may be applied to other plants as well.

Our common garden peas are almost invariably self-pollinated, and there is reason to believe that the same general method will succeed equally well with all self-pollinated plants; with naturally cross-pollinated plants some modification will be necessary. Among our common garden and field crops the following are believed to be almost always self-pollinated; peas, beans, tobacco, wheat, oats, barley. Most others are often or generally crossed in the field, and for such the method must be modified to make sure that the pollen for the improved races comes from the best possible plant.

Assuming that naturally cross-fertilizing plants are made up of slightly differing strains, as seems to be the case with peas, a field of plants will be made up largely of individuals that are crosses between the several strains; consequently the task of separating superior strains becomes a complicated one. Furthermore, it is probable that with some, and perhaps many, naturally crossed fertilized plants, crossing between distinct strains or varieties results in the first generation, in greater vigor and more productive plants. Thus is the problem of securing the very best still further complicated.

Nevertheless, great improvement can be made by following substantially the scheme outlined for self-fertilized plants, but taking into consideration the pollen parent, and pollinating from superior individuals either by hand or planting individuals which are desired as parents together in an isolated location. The latter method is often used with corn and other wind-pollinated plants. In any event it is always of the utmost importance to judge the value of any strains by the average of the largest possible number of individuals belonging to it, and if the test can be extended over a period of several years, three or four at least, the estimate of value will be more dependable.

With cross-fertilized plants it may prove best to use for field seeding the first generation hybrid between certain strains which are known to give desirable progeny when so crossed, and repeating the same cross for succeeding years, growing only the first generation of the cross as the benefits derived from crossing tend to disappear in succeeding generations.

We are only beginning to realize the improvement, especially in yield, that may be realized by proper methods of breeding, and great progress is being made in working out these methods. Their general application by practical plant growers will effect most substantial increase in the value of crops. It is, perhaps, not too much to say that the general application in this Commonwealth of our present knowledge of breeding would result in an increase of 20 per cent. in the value of its crops.

It is hoped that the farmers and gardeners of Massachusetts may become more interested in plant improvement, and the department of horticulture of the experiment station will be glad to co-operate with any one desiring further information or specific suggestions.

EXPERIMENTS TO DETERMINE THE NITROGEN ABSORPTION CAPACITY OF SEVERAL WELL-KNOWN CHEMICALS.

BY HENRI D. HASKINS.

Some years since a series of tests was instituted to show the nitrogen-absorbing capacity of several of the better known chemicals, more commonly used as fixers or absorbers of nitrogen in the form of ammonia, resulting from the decomposition of barnyard manure. Four hundred and fifty grams of manure were employed in each test, and 100 grams of each of the following chemicals were used: —

1. Sulfate of magnesia.
2. Sulfate of lime (gypsum).
3. Sulfate of potash-magnesia.
4. Kainit.
5. High-grade sulfate of potash.

The chemicals were all tested for nitrogen with negative results. An analysis of the several manures which are represented by the numbers from 1 to 5, as in case of the chemicals, showed the following percentages of moisture and nitrogen.

Table 1.

Number.	Moisture.	Nitrogen.	Number.	Moisture.	Nitrogen.
1, ...	70.37	.62	4, ...	71.77	.61
2, ...	73.75	.58	5, ...	72.86	.59
3, ...	73.29	.61	Average, . .	72.40	.602

The tests were conducted in the following manner: 450 grams of manure were placed in like-sized crystallization dishes, and a large pipestem triangle was placed across the top of each dish upon which was set a smaller crystallization dish containing, in each case, 100 grams of one of the absorbents. Each crystallization dish thus arranged was set on a ground-glass plate and enclosed within a bell glass, which was made air-tight by the use of tallow and sealed with melted paraffine. The tests were conducted side by side in a room of ordinary temperature (70° to 75° F.) and covered a period of six weeks. At the close of the experiment all of the chemicals were subjected to a chemical analysis, and showed the following content of nitrogen: —

Table 2. — Weight of Nitrogen in Manure and Nitrogen absorbed by Each Chemical.

	Grams Nitrogen in 450 Grams Manure.	Grams Nitrogen absorbed.	Per Cent. Nitrogen absorbed.
Sulfate of magnesia,	2.79	.018409	.66
Kainit,	2.61	.016553	.63
Sulfate of potash-magnesia,	2.75	.006884	.25
High-grade sulfate of potash,	2.75	.003483	.13
Sulfate of lime (gypsum),	2.66	.000851	.03

From the above table of comparative results it will be seen that magnesium sulfate absorbed the greatest amount of nitrogen, and that gypsum, the absorbent more commonly used in general farm practice, had the lowest nitrogen absorption power of any of the chemicals under trial. The percentage of nitrogen absorbed, however, in proportion to the amount contained in the manure was so small (less than 1 per cent.) as to indicate that but little decomposition took place. This is not to be wondered at when it is recalled that the manure was placed in an air-tight dish.

To obtain further data as to the nitrogen-absorbing capacity of the different chemicals during the process of decomposition of barnyard manure, another test was instituted, beginning on the same date as the above-described experiments and continuing through a period of six weeks. Four hundred and fifty grams of manure (analyzing .65 per cent. of nitrogen and 68.57 per cent. of moisture) were placed in a glass vessel and enclosed within a bell glass similar to the ones used in the above tests, with the exception that the bell jar was provided with glass tubes for the ingress and egress of air. The air passing into the bell jar was made to pass through a solution of sulfuric acid to remove any traces of ammonia which might be present in the atmosphere. Upon leaving the bell jar the air was made to pass through a standard solution of half normal hydrochloric acid, which was to absorb any ammonia which might be given off in the process of decomposition of the manure. The exit tube from the flask of standard hydrochloric acid was attached to an aspirator to provide a steady current of air through the apparatus. The apparatus was made perfectly air-tight by sealing, so that no air could enter the bell jar except by first passing through the sulfuric acid arranged to remove all traces of ammonia. An analysis of the standard solution of hydrochloric acid at the end of the experiment showed the following amount of nitrogen, expressed in fractions of a gram .001709. The infinitesimal amount of nitrogen liberated may be due to the fact that the steady current of dry air which was constantly passing through the bell jar removed the greater part of the moisture from the manure, thus retarding and preventing its natural decomposition.

For the purpose of verifying the results of the foregoing experiments a series of tests was instituted similar to those previously described, with the exception that 50 grams of each fixer were used and the experiment covered a much longer period of time, beginning March 21, 1901, and continuing through the spring and summer, concluding Feb. 1, 1902.

In the following table the first column shows the amount of nitrogen contained in 450 grams of the manure. The second column shows the nitrogen given off during the experiment, both in grams and percentage, as determined by a chemical analysis of the manure samples before and after the experiment. The third column shows the nitrogen absorbed as determined by a chemical analysis of each fixer at the conclusion of the experiment.

Table 3.

Absorbent.	Nitrogen Present in Manure.	Nitrogen given off.		Nitrogen absorbed (Basis of Grams in Manure).	
	Grams.	Grams.	Per Cent.	Grams.	Per Cent.
Sulfate of magnesia,	2.30	.13449	5.85	.05229	2.27
Kainit,	2.28	.16811	7.37	.04653	2.04
Sulfate of potash-magnesia,	2.39	.11768	4.92	.04031	1.69
High-grade sulfate of potash,	2.46	.31961	12.99	.03660	1.49
Sulfate of lime,	2.35	.26217	11.16	.00179	.08

Table 4. — *Showing the Order of Excellence of the Different Chemicals used as Fixers and the Percentage of Liberated Nitrogen which each Fixer absorbed.*

Order of Excellence of the Absorbents.	Per Cent. of Liberated Nitrogen absorbed.
1. Sulfate of magnesia,	38.88
2. Sulfate of potash-magnesia,	34.25
3. Kainit,	27.67
4. High-grade sulfate of potash,	11.45
5. Sulfate of lime (gypsum),	.68

The above tables show that the 5 different samples of manure, of 450 grams each, contained from 2.28 to 2.46 grams of nitrogen, and of these amounts from 5.85 per cent. to 12.99 per cent. were liberated. Of the relatively small amounts liberated the sulfate of magnesia absorbed 38.88 per cent., and was followed by the other chemicals as indicated in Table 4. How much more nitrogen as ammonia would have been absorbed by the different chemicals had the manure undergone a more normal fermentation it is impossible to state. The above tests strongly indicate sulfate of magnesia and sulfate of potash-magnesia to be decidedly preferable to gypsum as ammonia absorbents.

If the above, however, were typical of actual farm conditions we should have the following results: nitrogen in 1 ton of barnyard manure, 37.2 pounds; per cent. absorbed by sulfate of magnesia (being, of course, a part of the nitrogen set free as ammonia), 1.87, which is equal to .67 pound of nitrogen. In other words, less than 1 pound of nitrogen would be actually saved from a ton of manure, which, of course, is of no practical account. It is probable, however, that much more nitrogen in different forms would be liberated than the amounts secured in the above experiment, and that probably somewhat more would be absorbed.

Extensive investigations by German authorities indicate that the value of the nitrogen saved by chemical absorbents is quite out of proportion to the cost of the chemicals and the labor involved. See the results of their investigations in the paper following, entitled, " Chemical Methods for the Preservation of Manure."

CHEMICAL METHODS FOR THE PRESERVATION OF MANURE.

BY J. B. LINDSEY.

Barnyard manure is composed (*a*) of the undigested part of the food, represented by the solid matter or feces; (*b*) the end products of the protein digestion largely diluted with water, namely, the urine; and (*c*) such materials as straw, sawdust and the like, which are used for bedding. The solid part, or feces, is mixed with more or less of the digestive fluids, such as the bile of the liver, the intestinal juices and minute pieces of the skin or lining of the intestines. The nitrogen-containing matter of the urine of herbivorous or plant-eating animals is composed chiefly of urea, together with such mineral matter as is no longer of use in the blood (potash, soda, phosphates, etc.). A considerable portion of the soluble nitrogenous part of the manure is likely to be lost, both by volatilization and leaching. The loss through volatilization, and in part through leaching, is brought about by the action of bacteria, of which manure contains an innumerable number and a great variety of species.

Briefly stated there are four groups of bacteria which act upon the nitrogenous matter of the manure: —

1. *Putrefactive bacteria,* which attack both the insoluble part of the nitrogenous matter and also the urea or soluble part, and convert them into carbonate of ammonia, which is volatile.

2. *Nitrifying bacteria*, which act upon the ammonia compounds and convert them into nitrites and nitrates. In order to be active they must have plenty of oxygen, and hence act near the surface of the manure pile.

3. *Denitrifying bacteria*, which have the power to take the oxygen from the nitrates, thus decomposing it and setting the

unbound nitrogen free. These bacteria act when the air is excluded, deriving their supply of oxygen both from the nitrates and from the protein and carbohydrates of the manure.

4. *Protein-forming bacteria.* In order for bacteria to live and multiply they must have as a food a certain amount of nitrogen-containing matter. This they take from the ammonia and nitrates (soluble compounds), and convert it again into the insoluble proteid matter, which naturally does not become again available, and then only gradually, until the bacteria cease to live. Certain molds also act in a similar way.

Bacteria, therefore, destroy the nitrogenous matter of the manure by converting it into the volatile ammonia compounds and nitrates, and then reconvert a small portion of the ammonia and nitrates back into protein; they also destroy the nitrates and set the elementary nitrogen free.

If manure is allowed to remain in loose piles exposed to the air for months, about 35 per cent. of its total nitrogen is likely to be lost. The extremes are said to be from 20 to 50 per cent. Fully one-third of the total nitrogen lost has been ascertained to be in the elementary form, *i.e.*, uncombined. No method is known for preventing the loss of the uncombined nitrogen.

Various chemical methods have been tried to catch that portion of the nitrogen which escapes in the form of ammonia. The results of the numerous experiments may be summarized as follows: [1]

Gypsum or Land Plaster.

As early as 1860 ordinary land plaster or calcium sulfate was recommended, particularly by the German investigator, Grouven, as a substance suitable to catch and hold the volatile ammonia. Later the French investigators, Müntz and Girard, by means of carefully conducted experiments, demonstrated that such material was of no particular value for such a purpose. The reports of other investigators confirmed this and showed that the plaster actually hastened the decomposition of the manure.

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[1] After A. Stutzer, Behandlung und Anwendung der Stalldüngers.

Precipitated Gypsum.

About 1870 the manufacture of double superphosphate was undertaken. The method consisted of extracting the raw phosphate with dilute sulfuric acid, and this solution was used again for extracting another portion of the phosphoric acid. This method left behind a large amount of gypsum which contained about 1 per cent. of citrate soluble phosphoric acid. This residue was sold to farmers at a low price, and was used to check the escape of the ammonia from the manure. Experiments by several investigators, particularly by Hansen, showed it to be of no particular value for such a purpose.

Gypsum-superphosphate and Superphosphate.

In Germany low-grade raw phosphates were treated with sulfuric acid, and a product was secured containing 4–6–8 per cent. of soluble phosphoric acid, and this was called gypsum-superphosphate. It was found that this material, if used in sufficient amount, held fast the ammonium carbonate present in the manure and checked the further action of the bacteria. This was due to the action of the free phosphoric acid. Sulfuric acid and ordinary superphosphate had a similar effect. Because of the cost of such materials, however, their use was not advised.

Sulfuric Acid.

After the use oı superphosphate had been discontinued numerous experiments were made with quite dilute sulfuric acid. A 2 per cent. solution of the sulfuric acid was sprinkled over the manure before throwing it out, and also in the gutters after its removal. The dilute acid was also mixed with peat and sand before distributing it. Experiments by Maercker and Pfeiffer showed that such treatment made the manure sour, checked the loss of ammonia, and better results were secured temporarily in the field due to the conserved nitrogen. It was found, however, that one had to be very careful, otherwise the feet and udder of the animal would be injured; and, furthermore, that the resulting manure had a bad effect upon the physical character of heavy soils which required the addition of lime to correct. These disadvantages, together with the cost of the acid, rendered the use of the sulfuric acid inadvisable.

Kainit.

As early as 1860 kainit was recommended as a desirable material for the preservation of manure; it was supposed that the sulfate of magnesia in this salt would act even better than the gypsum. Holderfleiss recommended 5 pounds, and later 2 pounds, of kainit to every 100 pounds of manure. Numerous other investigators experimented with the kainit and came to the conclusion that it was of no particular value for the purpose.

German workers, therefore, have come to the conclusion that there is no economy in attempting to check the loss of nitrogen in manures by chemicals, and advise in their place the following simple method of treatment: —

Halt ihn feucht und tritt ihn feste,
Das ist für den Mist das beste.

Keep the manure moist and well packed,
That is the best method of preservation.

TOBACCO INJURY DUE TO MALNUTRITION OR OVERFERTILIZATION.

BY H. D. HASKINS.

During the past four or five years the experiment station has received occasional inquiries from tobacco growers concerning certain peculiar conditions which affect the young tobacco plant, and which usually manifest themselves soon after transplanting. The young plants may make a small growth in the field during the first week, after which differences in growth are observed. The plants growing on low places or hollows, which receive drainage from the surrounding soil, seem to be more affected and show a more stunted growth than do those on the more elevated portions of the field. It was thought at first that the trouble was due to some fungus disease, but a careful microscopical examination failed to reveal the presence of fungi which could be held accountable for the trouble. An examination of the roots showed that the tap root had been destroyed; that the plant, in its endeavor to recover from the injury, had thrown new secondary roots, which in turn had become injured or destroyed so that it was unable to make any appreciable growth. It was the opinion of Dr. G. E. Stone, the vegetable pathologist, that the trouble was due to overfertilization, the roots having all of the characteristic symptoms of fertilizer burning. The absence of fungi also indicated that some abnormal soil condition was responsible for the trouble.

Samples of the surface soil were, therefore, carefully taken from a field where the trouble was noticed. Numbers 1, 2 and 3 were taken from portions of the field where the trouble was most conspicuous, number 4 from an elevated portion of the field, showing practically a fairly normal growth, and number

5 from the tobacco bed which furnished the plants for setting the field. Exact quantitative determinations of nitrogen, potash, phosphoric acid and lime were made, using 1.115 specific gravity hydrochloric acid as a solvent. For the sake of comparison the results have been calculated to a normal moisture soil condition, namely, 20 per cent. The results have also been expressed in pounds per acre, it being assumed that an acre of the average tobacco soil 1 foot deep would weigh about 3,000,000 pounds.

Table 1. — *Showing Constituents soluble in Hydrochloric Acid Solution.*

	Soil No. 1, Abnormal.		Soil No. 2, Abnormal.		Soil No. 3, Abnormal.		Soil No. 4, Normal.		Soil No. 5, Tobacco Bed.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.000	-	20.000	-	20.000	-	20.000	-	20.000	-
Organic matter,	6.456	193,680	6.576	197,280	6.304	189,120	7.304	219,120	5.144	154,320
Nitrogen,	.182	5,472	.221	6,624	.210	6,312	.246	7,380	.092	2,760
Phosphoric acid,	.164	4,920	.110	3,312	.165	4,944	.196	5,880	.478	14,328
Potassium oxide,	.182	5,472	.156	4,680	.110	3,288	.127	3,816	.211	6,336
Calcium oxide,	.640	19,200	.506	15,168	.769	23,064	.568	17,040	1.096	32,880

As may be seen from the table of analysis, it was not possible to account for the trouble from a chemical analysis showing the total amount of the several elements of plant food present, soluble in the acid solution. The soil producing a normal plant showed a *larger amount* of nitrogen and phosphoric acid than the three abnormal soils producing a stunted growth; also in one instance a *larger amount* of potash and lime.

It seemed at least possible that any injurious effect to the growing plant might be due to the *water soluble portion* of the various fertilizer constituents contained in the soil. A given weight (200 grams) of each soil was, therefore, successively washed with the same volume of hot water (1,000 cubic centimeters), the water being allowed to percolate through the soil contained within a separatory funnel, cylindrical in shape. The water solution was evaporated to dryness, carefully weighed, and a chemical analysis was made of the saline residue. The results have been calculated on the basis of 20 per cent. moisture in the soil, and have also been computed to show the pounds of the various constituents per acre.

TABLE 2. — *Showing Constituents soluble in Hot Water, Results figured to Parts in 100 Parts of Soil, the Latter showing a Moisture Content of 20 Per Cent.*

	Soil No. 1, Abnormal.		Soil No. 2, Abnormal.		Soil No. 3, Abnormal.		Soil No. 4, Normal.		Soil No. 5, Tobacco Bed.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids (largely saline residue),	.2000	6,000.0	.2096	6,288.0	.1384	4,152.0	.1072	3,216.0	.0800	2,400.0
Water soluble nitrogen,	.0210	631.0	.0229	868.0	.0108	324.0	.0099	298.0	.0068	204.0
Water soluble potash,	.0238	715.0	.0219	658.0	.0199	598.0	.0069	206.0	.0073	218.0
Water soluble phosphoric acid,	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Water soluble calcium oxide,	.0344	1,032.0	.0275	825.0	.0271	814.0	.0144	431.0	.0202	605.0
Water soluble sodium oxide,	.0146	438.0	.0148	444.0	.0188	564.0	.0144	431.0	.0159	478.0
Water soluble magnesium oxide,	.0094	282.0	.0180	540.0	.0073	219.0	.0144	431.0	.0046	137.0
Water soluble iron and aluminum,	None.	None.	None.	None.	None.	None.	None.	None.	None.	None.
Water soluble sulfates calculated as SO_3,	.0272	816.0	.0210	639.0	.0147	442.0	.0158	475.0	.0082	247.0
Water soluble chlorine,	Trace.	.3	Trace.	.7	Trace.	.3	Trace.	.2	Trace.	.1
Acidity,	Trace.	.4	Trace.	.4	Trace.	.4	Trace.	.4	Trace.	.4

The results shown by this table tell quite a different story than do the analyses in the first table. Note the comparatively small amount of total solids, nitrogen, potash and, in fact, of most all of the water soluble constituents in soil No. 4, which showed a normal growth of tobacco, and No. 5, taken from tobacco bed. The soils giving abnormal results showed an increase of over 70 per cent. in total soluble solids, over 85 per cent. in water soluble nitrogen, and over 219 per cent. in water soluble potash. To have supplied the water soluble nitrogen found in soil No. 2, it would have required an application of 3,445 pounds of nitrate of soda per acre; to have supplied the water soluble potash found in soil No. 1 it would have required an application of 1,112 pounds of high-grade sulfate of potash per acre.

It was subsequently discovered that the field was underlaid with a hard impervious subsoil furnishing very poor drainage facilities, the soil had been used for the cultivation of tobacco continuously for more than thirty years. These facts, taken in connection with the very large amount of soluble plant food present, seemed to indicate strongly that the trouble was due to the accumulation of soluble saline constituents, probably originating in the fertilizers which had been applied in very liberal quantities for many years. It is a reasonable assumption that, had the soil been underlaid by an open porous subsoil, the condition would never have occurred, as the soluble salines would have passed out in the drainage water. This is borne out by the fact that all of the soils which have given this trouble have had imperfect drainage. In this connection it seemed of interest to procure several typical, well-drained tobacco soils which had been used continuously for thirty or forty years for tobacco culture. Three samples of soil and subsoil were, therefore, carefully taken from the farms of well known tobacco growers in various parts of the Connecticut valley. The soil was taken to a depth of 1 foot, the subsoil to a depth of 1 foot below the surface soil.

The following table shows the composition of the several soils and subsoils. Hydrochloric acid, specific gravity 1.115, was used as a solvent. The results are expressed on a 20 per cent. moisture basis, also in pounds per acre.

Table 3. — *Averages of Normal Surface Soils used for Over Thirty Successive Years for the Cultivation of Tobacco.*

	Soil No. 1.		Soil No. 2.		Soil No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.0000	–	20.0000	–	20.0000	–
Nitrogen,	.0970	2,910	.0810	2,430	.0604	1,812
Phosphoric acid,	.2341	7,023	.1535	4,605	.0810	2,430
Potassium oxide,	.1940	5,820	.2020	6,060	.1691	5,073
Calcium oxide,	.2131	6,393	.3300	9,900	.3450	10,350
Sodium oxide,	.1291	3,873	.2340	7,020	.1192	3,576
Magnesium oxide,	.0440	1,320	.0291	873	.0880	2,640

Table 4. — *Analyses of Subsoils taken from Field used for Over Thirty Successive Years for the Cultivation of Tobacco.*

	Soil No. 1.		Soil No. 2.		Soil No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Moisture,	20.0000	–	20.0000	–	20.0000	–
Nitrogen,	.0251	753	.0183	549	.0220	660
Phosphoric acid,	.0880	2,640	.0482	1,446	.0810	2,430
Potassium oxide,	.1530	4,590	.1690	5,070	.1370	4,110
Calcium oxide,	.3770	11,310	.3610	10,830	.2790	11,370
Sodium oxide,	.1280	3,840	.1610	4,830	.1630	4,890
Magnesium oxide,	.0723	2,169	.0580	1,740	.0733	2,199

Two hundred grams of each soil and subsoil were also washed with 1,000 cubic centimeters of hot water. The solution was evaporated to dryness and a chemical analysis was made of the soluble residue. The results are computed on the basis of 20 per cent. moisture in the soils; they are also expressed in terms of pounds per acre of the various ingredients.

TABLE 5. — *Water Soluble Constituents contained in Normal Surface Soils used for Over Thirty Successive Years for the Cultivation of Tobacco. Underlying Subsoil Open and Porous, furnishing Good Facilities for Drainage.*

	Soil No. 1.		Soil No. 2.		Soil No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids,	.0881	2,643	.0937	2,811	.0509	1,527
Water soluble nitrogen,	.0092	276	.0079	237	.0093	279
Water soluble potash,	.0150	450	.0153	459	.0054	162
Water soluble phosphoric acid,	.0029	87	.0030	90	Trace.	Trace.
Water soluble calcium oxide,	.0091	273	.0107	321	.0098	294
Water soluble sodium oxide,	.0087	261	.0105	315	.0074	222
Water soluble magnesium oxide,	.0046	138	.0034	102	.0030	90
Water soluble sulfuric acid (SO_3),	.0088	264	.0108	324	.0117	351

TABLE 6. — *Water Soluble Constituents contained in Subsoils. Samples taken from Field used for Over Thirty Successive Years for the Cultivation of Tobacco. Subsoils of a Sandy Character, Open and Porous, insuring Good Drainage.*

	Soil No. 1.		Soil No. 2.		Soil No. 3.	
	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.	Per Cent.	Pounds per Acre.
Total solids,	.0321	963	.0286	858	.0289	867
Water soluble nitrogen,	.0092	276	.0043	129	.0033	99
Water soluble potash,	.0062	186	.0072	216	.0025	75
Water soluble phosphoric acid,	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Water soluble calcium oxide,	.0055	165	.0041	123	.0038	114
Water soluble sodium oxide,	.0051	153	.0064	192	.0066	198
Water soluble magnesium oxide,	.0018	54	.0010	30	.0006	18
Water soluble sulfuric acid (SO_3),	.0109	327	.0092	276	.0092	276

For the sake of comparison a table has been prepared giving the average composition of the three normal soils including both the active hydrochloric acid and water solutions, and likewise the average of the several abnormal soils which have shown strong indication of overfertilization. Results calculated to 20 per cent. moisture basis on soils.

TABLE 7. — *Amounts dissolved by Hydrochloric Acid (Specific Gravity 1.115).*

	Average Analysis of 4 Normal Tobacco Soils.		Average Analysis of 3 Abnormal Tobacco Soils.	
	Parts per 100 Parts of Soil.	Pounds per Acre.	Parts per 100 Parts of Soil.	Pounds per Acre.
Moisture,	20.0000	–	20.000	–
Nitrogen,	.1211	3,633	.204	6,120
Phosphoric acid,	.1661	4,983	.146	4,380
Potassium oxide,	.1731	5,193	.149	4,470
Calcium oxide,	.3640	10,920	.638	19,140
Sodium oxide,	.1608	4,824	–	–
Magnesium oxide,	.0537	1,611	–	–

TABLE 8. — *Water Soluble Constituents in Average Normal and Abnormal Tobacco Soils.*

	Average Analysis of 5 Normal Tobacco Soils.		Average Analysis of 4 Abnormal Tobacco Soils.	
	Parts per 100 Parts of Soil.	Pounds per Acre.	Parts per 100 Parts of Soil.	Pounds per Acre.
Total solids,	.1043	3,129	.1981	5,943
Nitrogen,	.0109	327	.0193	579
Potassium oxide,	.0122	366	.0205	615
Phosphoric acid,	.0013	39	.0002	6
Calcium oxide,	.0148	444	.0326	978
Sodium oxide,	.0102	306	.0161	483
Magnesium oxide,	.0063	189	.0116	348
Sulfuric acid (SO_3),	.0118	354	.0209	627
Total salines,	–	1,698	–	3,057

The results of analysis of the different soils indicate that the injurious effect upon the growing plants, if due to the accumulation of plant food elements, must have resulted from the water soluble salines present. The soluble matter in the three normal soils was very much less than in the soils which had given trouble, although the normal soils had been used for the continuous growing of tobacco for as long a term of years, and had been as liberally fertilized, as the soils giving poor results.

It is impossible to say just how large an accumulation of soluble constituents may take place before the plants will be injuriously affected. The data at hand, however, would indicate that a relatively wide latitude may be allowed on at least some of the constituents. It is believed that the combined effect of the total *soluble mineral constituents* in the soil is responsible for the injurious effect on the growing plants rather than an accumulation of any *one* of the soluble elements. It is probable, also, that the rainfall has an important influence in this connection, plenty of rain having a tendency to keep the soluble matter well below the surface, while the absence of a normal rainfall would tend to draw the soluble salts to the surface.

It will be seen from Table 8, giving the average composition of the two types of soil, that nearly twice the amount of soluble salines was found in the abnormal solids as was present in the normal ones. A tobacco soil examined but not reported here has shown as high as .18 per cent. water soluble salines (equivalent to 5,448 pounds per acre), and yet has produced a fair crop of tobacco. On the other hand, serious injury to the crop has been noted on soil which tested only .14 per cent. soluble salines (equivalent to 4,152 pounds per acre). Another fact should not be lost sight of, namely, that the abnormal soils in all cases were underlaid with an impervious or hardpan subsoil which prevented the free circulation of the soil water. It seems probable, therefore, that the trouble is due to, or is most likely to occur on, soils underlaid with hardpan and in the absence of a normal rainfall, the accumulated soluble saline matter being brought to the surface.

The investigation brings out one fact of unusual interest, namely, the large amount of water soluble potash as compared with the total potash content of the abnormal soil. The average total acid soluble potash present in the three abnormal soils was .149 per cent., of which .0205 per cent. (or nearly 14 per cent. of the total amount) was present in water soluble form. The writer is aware that these facts are not in accordance with the usual teachings, it being generally held that potash does not remain in solution for any great length of time, but is soon fixed as basic compounds in the soil, only to be liberated gradually by chemical action. It does not seem improbable that the concentration of the soluble salines may in a measure be responsible for the large proportion of soluble potash present, and possibly even tends to dissolve greater quantities of the fixed potash. The proportion of water soluble potash in the normal tobacco soils bears out this theory, as out of a total of .1731 per cent., only .0122 per cent. (about 7 per cent. of the total amount) was present in water soluble form.

The results in Table 8 are of interest in connection with the question of the proper concentration of soil solutions most favorable to plant development. Numerous investigators have demonstrated that one part of mineral matter in 1,000 parts of water furnishes the best conditions.[1] The average analysis of the five normal soils shows the presence of 1.04 parts per 1,000, whereas in the abnormal soils nearly twice this amount was present. It is well known that some plants stand a greater concentration of soil solutions than others; for instance, corn and grass showed a wonderful development on soils which were so unfavorable for tobacco. Onions, on the other hand, seem to be quite as susceptible to injury as is tobacco. The same difference has been noticed in connection with the accumulation of soluble mineral constituents in greenhouse soils. Soil solutions too concentrated for cucumbers seem to be quite favorable for tomatoes. Little data is available in connection with this whole subject of the concentration of soil solutions, and further study with different plants is needed before any sweeping conclusions can be drawn. It is not improbable that if the amounts of the various soluble constituents in the soil are present in certain proportions the plant may be able to with-

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[1] Pfeffer, Vol. 1, p. 420; Stockbridge, Rocks and Soils, p. 206.

stand a more concentrated soil solution. Pfeffer, in speaking of the concentration of cultural solutions, says, "The concentration of the cultural fluid is always important, for when its osmotic concentration passes a certain limit growth becomes impossible, though no poisonous effect is exercised, while when the fluid is too dilute, *or when a single essential salt is present in insufficient amount, the development of the plant is retarded.*"

As a remedy for the trouble under consideration the rotation of crops is advised. Corn seems to be a good hoed crop to be grown on soils in this condition. It requires a liberal amount of potash and other plant food constituents, and it appears to withstand the effect of the concentrated soil solution. The writer has known of some tremendous yields of corn, grown on tobacco soils evidently suffering from overfertilization, without the addition of any fertilizer whatever. Grass can follow corn with satisfactory results, and after three or four years of such treatment the soil can be used again for tobacco.

It is needless to say that if possible such land as has been described would be greatly benefited by underdraining, and it is strongly advised.

DIGESTION EXPERIMENTS WITH CATTLE FEEDS.

BY J. B. LINDSEY.

The term "digestibility" refers to that portion of food that an animal can actually make use of for nutritive purposes; the undigested portion is represented by the solid manure (feces) which is excreted by the animal as so much worthless material.

The unit of measurement is termed "digestion coefficient." Thus, experiments have shown that out of 100 pounds of bran 62 pounds, or 62 per cent., are digestible, and this figure is termed the digestion coefficient for bran. Again, experiments have shown that 77 per cent. of the protein and only 39 per cent. of the fiber in bran are digestible, and these two figures represent, respectively, the digestion coefficients for the protein and fiber in bran. Coefficients are used in figuring out balanced rations and in determining the relative nutritive values of different feedstuffs. A single illustration as to the method employed in calculating the actual digestible material in a foodstuff may suffice: —

One Hundred Pounds Timothy Hay.

	Contains (Per Cent.).	Per Cent. Digestible (Coefficient).	Pounds Digestible.
Water,	15.00	–	–
Ash,	4.30	–	–
Protein,	6.30	48	3.0
Fiber,	28.40	58	16.5
Starchy matter,	43.60	63	27.5
Fat,	2.40	61	1.5
Total,	100.00	–	48.5

It thus appears that 100 pounds of hay contain 48.5 pounds of material available for the purposes of nutrition. In case of corn meal 76.2 pounds are available, so that a definite amount of the latter food is more valuable than a like amount of the former.

In Part I. of this report detailed data of numerous digestion experiments with a variety of cattle foods are presented. In this article a résumé only is given of the results secured.

1. Corn Fodders (Varieties).

(*a*) Pride of the North, a medium dent that will mature its ears in Massachusetts.

(*b*) Rustler white dent, a corn of medium growth that will mature its ears in this State.

(*c*) Leaming, a dent that usually is not quite mature by September 15, in many sections of Massachusetts.

(*d*) Early Mastodon, a large growing dent that brings its ears to the milk stage by September 15.

(*e*) Brewer's dent, a large growing dent that may mature its ears in southern and southeastern Massachusetts in a favorable corn year.

(*f*) Wing's improved white dent, a large growing variety that is spoken of highly in Ohio, but will not mature with us.

Results secured.

	Coefficients.					
	Dry Matter.	Ash.	Protein.	Fiber.	Extract or Starchy Matter.	Fat.
Pride of the North,	77	36	63	66	84	84
Rustler Dent,	69	27	43	59	78	76
Leaming,	70	36	60	61	77	76
Early Mastodon,	72	36	57	60	79	80
Brewer's Dent,	72	46	69	69	77	68
Wing's Improved,	70	39	63	65	76	70
Average,	72	37	59	63	78	76
Average all trials, mature dents,	69	34	54	59	75	75
Average all trials, immature dents,	68	42	66	65	71	68

The results of the several experiments as expressed in the above coefficients when studied by themselves, without taking into consideration the chemical composition of the plant, would not reveal much of interest.

In general it may be said that those varieties that will bring their ears to maturity will have a higher degree of digestibility than those coarser, less mature varieties. This is due to the relatively larger proportion of grain to stalk. The Pride of the North shows a total digestibility of 77 as against 72 for the average of the others. It is not entirely clear why the Rustler dent did not show approximately as high a degree of digestibility as the Pride of the North. This may be due to the fact that the animals were fed rather more than they could eat, and probably did not digest quite as thoroughly as though they had received a less amount. The last four — Leaming, Mastodon, Brewer's and Wing's — representing the less mature dent varieties, show about the same degree of digestibility.

Mature dents (whole plant) will have a digestibility of from 70 to 75 per cent., while in case of the less mature dents the digestion coefficient will fall somewhat below that figure.

2. Proprietary Grain Mixtures.

The highest grades of unmixed concentrates have the following digestion coefficients: —

	Dry Matter.	Ash.	Protein.	Fiber.	Extract or Starchy Matter.	Fat.
Corn meal,	88	-	67	-	92	90
Gluten feed,	88	-	85	87	90	81
Cottonseed meal,	79	-	84	35	78	94

In experiments conducted with a number of proprietary mixtures the following coefficients were secured: —

	Dry Matter.	Ash.	Protein.	Fiber.	Starchy or Extract Matter.	Fat.
Schumacher's stock food, . . .	71	–	70	52	79	88
Biles union grains, ...	75	24	71	80	79	96
Buffalo creamery feed, . . .	69	23	81	55	71	87
Unicorn dairy ration, ...	83	25	76	72	89	96

It will be seen that the sample of Unicorn dairy ration had a relatively high total digestibility. Biles union grains were also well digested, while Schumacher's stock food and Buffalo creamery feed were fairly well utilized. None of these feeds had what would be termed a relatively low degree of digestibility. From a nutritive standpoint, therefore, the feeder could safely purchase these mixtures and feel that he was not buying inferior articles, provided, of course, that the manufacturers continued to maintain the standards represented by those samples. The questions of cost and suitability for definite purposes would also have to be considered before purchasing. These items are discussed in our annual feed bulletins.

3. Alfalfa Hay.

The alfalfa hay used in these experiments was grown on the college farm. It was cut while in early blossom and was quite free from weeds and grass. Owing to different weather conditions which prevailed at the time of cutting, and which necessitated different methods of handling, the amount of leaves lost in curing was not uniform; hence a strictly fair comparison could not be made between the different cuttings. The results of the several trials are therefore reported, and the average given for the several lots. In order to draw accurate conclusions between cuttings, the crop should either be fed green or cured under uniform conditions. Owing to frequent weather changes this is often not possible in New England.

Summary of Coefficients (Per Cent.), Periods III., IV. and V.

Sheep.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I., ...	1[1]	1	1	63.27	57.43	78.33	53.82	77.30	44.76
Sheep I., ...	1[2]	1	1	55.40	39.14	70.22	42.94	64.78	23.56
Sheep II., ...	1[1]	1	1	62.77	47.24	75.93	44.68	73.86	40.88
Sheep II., ...	1[2]	1	1	59.76	45.47	73.06	48.68	68.24	25.67
Sheep III., ...	2[1]	1	1	54.29	35.40	69.46	42.20	64.79	13.83
Sheep IV., ...	2[1]	1	1	59.49	42.56	74.39	48.39	68.80	19.29
Average, ...	–	3	6	60.00	44.54	73.57	46.79	69.63	28.00
Average of all trials, alfalfa hay for comparison, .	–	42	80	62.00	50.00	74.00	46.00	72.00	40.00
Average of all trials, red clover for comparison, .	–	12	25	58.00	36.00	58.00	54.00	65.00	56.00

[1] Third-year growth. [2] First-year growth.

Unfortunately an exact record of the weather conditions during the curing process of the several lots was not kept. It would appear that the first cutting of the *third year growth* was cured without the loss of a great deal of leafy matter. This is shown by the relatively low fiber percentage and the high digestibility. The second cutting of the *third year growth* evidently lost a considerable portion of its leaves, as indicated by its high fiber percentage and lessened digestibility. The first cutting of the *first year growth* also must have lost an excess of leaves, as it also shows excessive fiber and low digestion coefficients. It is possible that the markings of the first cutting third-year growth and the first cutting first-year growth were reversed, although we have not the slightest evidence to that effect.

While the coefficients obtained vary considerably the average is about the same as the average for all trials, except that the coefficient for fat is somewhat lower. It is believed that the average coefficients obtained in our several trials show fairly the digestibility of eastern-grown alfalfa under the adverse conditions due to the loss of leaves in the process of curing.

4. Red Clover Hay.

The clover was seeded in early August. It yielded well, was in early blossom when cut, and was cured in cocks. The first cutting did not cure out well, owing to a rainy spell during the curing process. It had a black appearance when taken to the barn, and later had to be spread in the sun for further drying. It did not lose its leaves to any extent; the lot was lacking in a satisfactory odor and was slightly musty. The conditions during the curing of the second cutting were more favorable. Both lots were rich in protein (15.28 and 17.82 per cent. in dry matter), and comparatively low in fiber (29.76 and 28.30 per cent. in dry matter).

Summary of Coefficients (Per Cent.), Periods VI. and VII.

Sheep.	Cutting.	Number of Different Lots.	Single Trials.	Dry Matter.	Ash.	Protein.	Fiber.	Nitrogen-free Extract.	Fat.
Sheep I., ...	1	1	1	64.48	61.19	63.94	62.00	67.93	52.52
Sheep II., ...	1	1	1	62.57	59.49	63.81	57.08	67.19	52.23
Sheep III., ...	2	1	1	57.94	53.68	59.32	43.27	68.36	55.02
Sheep IV., ...	2	1	1	61.31	57.99	60.60	49.38	70.51	55.77
Average, ...	–	2	4	61.58	58.09	61.92	52.93	68.50	53.89
Average alfalfa hay (our trials), ...	–	3	6	60.46	45.39	73.77	47.55	69.92	28.32
Average of all trials, clover hay for comparison, .	–	12	25	58.00	36.00	58.00	54.00	65.00	56.00
Average of all trials, alfalfa hay for comparison, .	–	42	80	62.00	50.00	74.00	46.00	72.00	40.00

The most noticeable difference in the four single trials with clover hay consists in the variation in the digestion coefficients obtained for the fiber (43 to 62). This is evidently due in part, at least, to the individuality of the several animals. The fiber in the second cutting was apparently not as digestible as in the first cutting. The other coefficients — excepting the ash, which is found to vary widely in most all experiments —

may be considered fairly uniform. The coefficients secured by us are higher than the average for all other experiments, probably due to the early cutting of the crop.

When the average of the clover coefficients is compared with the average of our reported coefficients for alfalfa, it is noted that in case of the total dry matter the former shows to advantage, although the reverse is true in a comparison of the experiments reported for all trials. The protein in the clover is shown to be substantially 12 per cent. less digestible than in the alfalfa; in case of the average for all trials the difference is 16 per cent. In case of the fiber the conditions are reversed, — differences of from 5 to 8 points being noted in favor of the clover. The comparative digestibility of the extract matter is about the same, although the average figures show 7 points in favor of the alfalfa. In making a comparison of the two plants from the standpoint of digestibility, two important differences are noted: (1) the protein in the alfalfa is noticeably more digestible than in the clover (12 to 16 points), and (2) the fiber from 5 to 8 points less so. In total digestibility the two plants approach each other, showing an average of about 60 per cent. as against 55 per cent. for timothy, 60 per cent. for early cut fine hay, 65 per cent. for rowen, 70 per cent. for the entire corn plant, and 85 per cent. for corn meal.

It is evident that the relative value of the two crops cannot be determined from their digestibility alone; other important factors to be considered are cost of production and yield and adaptability to Massachusetts conditions. Taking all the evidence into consideration it would appear that although the cost of seed and preparation of land is somewhat against the alfalfa, yet its much greater length of life, its larger average yearly yield, and its rather superior nutritive value are all in its favor. The conditions governing its successful cultivation must be carefully studied by all interested in its production. To the lack of attention to these conditions by the average farmer is due, in no small measure, the failures reported.

BRONZING OF MAPLE LEAVES.

G. E. STONE.

A somewhat common and peculiar effect on rock maple leaves, especially noticeable in very hot and dry summers, was brought to our attention this past summer. We have noticed this trouble many times before, particularly on rock maples growing in certain characteristic soils or habitats. It is most commonly seen on maples growing in dry soil where there is insufficient soil-moisture during periods of extreme drought.

The trouble is characterized by an absence of the typical maple leaf green. The leaves are more or less rigid, and in color are light, with a reddish brown tinge. An examination of the surface of the leaf with a hand lens, or even with the naked eye plainly shows that many of the cells of the leaf blade or lamina are dead and reddish brown in color. These dead cells are confined to certain areas of the laminæ, mainly between the minute veinlets, whereas those cells near the veinlets are green and alive.

Repeated examination of the leaves has demonstrated that the trouble is caused by no pathogenic organism, but is purely functional in nature. On the other hand, it is quite distinct from the so-called sun scorch so commonly affecting the rock maple, although both are induced by similar conditions. The typical sun scorch is characterized by more or less irregular blotches of dead tissue more often on the edges of the leaves, which are usually more susceptible to the scorching and are often lacerated severely. This sun scorch, like the "bronzing," also affects maples growing in very dry soil, on dry, windy days, when the roots cannot supply the foliage with sufficient water. Since transpiration under such conditions is very active and root absorption limited, wilting and death of the leaf tissues result.

Sun scorch is common to many plants, and is referred to under different names such as "topburn" in lettuce, "tipburn" of potatoes, "leaf burn," "wilt," etc. It may result from the presence of certain chemical substances in the soil, or from some individual peculiarity in the root-absorptive capacity of the organism. The peculiar drying and reddening of the cells of the maple leaves which we have previously referred to as "bronzing" is not necessarily caused by wind; the principal factors necessary being a soil deficient in moisture, and excessive transpiration.

As already stated, "bronzing" occurs on very hot, dry days, in periods of severe drought, and this last summer we have succeeded in producing many excellent examples of it in the greenhouse. The trouble was very common this season, our attention often being called to it, and we have been observing very severe cases of it in certain maple trees for many years.

COARSE NOZZLE VERSUS MIST NOZZLE SPRAYING.

G. E. STONE.

At the present time much thought is being given to the general technique of spraying. The subject is an important one and is by no means settled, either as regards equipment or methods. Our own State has done its share in this respect since the important economic problems involved in handling the gypsy and brown-tail moths have made it necessary to originate and utilize the most modern and efficient spraying machinery.

For the perfection of modern spraying on a large scale great credit should be given to Mr. A. H. Kirkland, a graduate of this college and former superintendent of the Gypsy Moth Commission, whose handling of economic problems of this nature has been unexcelled, and particularly to Mr. L. H. Worthley, the present superintendent. The former methods of spraying advocated and used by the old commission were considered revolutionary in those days, and great credit should be given to Mr. E. C. Ware, the mechanic associated with the former commission, for developing an improved outfit and for originating the best fine mist nozzle as yet devised. The old method, however, has been practically discarded, since the modern method is much cheaper and about as effective.

This makes use of the powerful high pressure machine and coarse nozzle, which is capable of throwing a stream to a great height, this breaking up into a more or less fine mist. The first attempt to use engines in spraying dates back some years.[1] Most of the devices were very crude in construction. Mr. J.

[1] L. O. Howard, Year Book, Department of Agriculture, 1895, pp. 361–394, and 1896, pp. 69–88.

W. Pettigrew, superintendent of the Boston park system, was one of the first to construct a really effective spraying equipment provided with high-pressure gasoline engines and modern coarse spray nozzles. This was used with much satisfaction some years ago in spraying woodlands for the gypsy moth and for park work, and on this model were constructed the later and more improved types of machines. In 1896 he employed a more or less cumbersome outfit for spraying in the public parks of Brooklyn, N. Y., consisting of an ordinary road sprinkler and a 10-horse power portable steam boiler fitted to a large pump. He made use of a ¾-inch hose provided with 3/16 or ¼ inch nozzle.

About the same time Mr. Christopher Clark, the veteran city forester of Northampton, Mass., made use of a similar machine for spraying elm trees. Mr. Clark's equipment consisted of a small steam boiler which used coal for fuel, and a Duplex pump mounted on a truck. The pressure he obtained from this equipment was something over 100 pounds. He used an ordinary garden hose nozzle of ⅛-inch aperture and obtained a coarse spray, not in any way comparable, however, with that obtained from the use of modern equipment. Other makeshifts, which used steam for power, were employed here and there about the same time, but these were all crude affairs compared with the modern outfit.

Those who have had opportunity to make extensive comparisons of the high-pressure, coarse-nozzle spraying and the fine mist spray under low pressure are generally convinced that, considering the cost and efficiency, the former method is far superior to the latter for certain work. The question therefore arises to-day whether or not high-pressure coarse-nozzle spraying cannot be applied to orchards with the same results that have followed its use in other ways. Recent experiments made in Virginia [1] have shown that for the control of the codling moth the high-pressure, coarse-nozzle spray has proved superior to the low-pressure mist spray. The best high-power sprayers in use at the present time have reached a high degree of perfection, especially the machines manufactured for and

[1] Spraying for the Codling Moth, West Vir. Agr. Exp. Sta., Bul. No. 127.

used by the Gypsy Moth Commission. But there are many others, of both high and low power, which are thrown together in an altogether haphazard fashion. A machine which is to develop and maintain 250 pounds pressure with a 1-inch hose and 1.8 and 3.16 inch nozzle should be provided with an engine which will develop 5 or 6 horse power at the least. A machine of this type would be suitable for small towns where it is necessary to spray only 500 or 1,000 trees each year, or it would be suitable for large orchardists. When the spraying to be done is extensive, however, the larger machines, at least 10 or 15 horse power, are the more economical in the end, even if the first cost is greater, since some allowance should be made for deterioration and loss of power in any machine.

It is a question whether we are using the best methods in some of our spraying work. A 5 or 6 horse power pressure machine can be depended upon to handle a stream of from 40 to 60 feet high, and this is sufficient if a ladder is used; but if it is necessary to throw the spray 100 feet, or to the tops of the trees, larger machines must be used.

At the present time less attention is being given to nozzles than to machines, and in our opinion there is ample room for improvement on the nozzles in use to-day. The various mist-spray nozzles are good for short distances, and those in use at the present time are an improvement over the old spray nozzles. But we need wide-angled spray nozzles that will give a spray of uniform density which will throw a relatively fine mist at least 20 or 30 feet. To obtain such a spray high pressure is one of the necessities, and a new type of nozzle another. By the use of nozzles adapted to high-pressure machines which can be adjusted to different distances we are of the opinion that the spraying of orchards can be done as effectively and more cheaply than at present. Instead of employing 70 pounds pressure and forcing the spray through ½-inch hose provided with a mist nozzle with a limited carrying capacity, we shall come to the use of high pressure and larger hose provided with nozzles of great carrying capacity. In our opinion spraying will be developed along these lines in the future, since the process will be rendered cheaper and practically as effective as at the present time by the use of high pressures and nozzles of better carrying power.

The writer has devised a number of spray nozzles adapted to high-pressure machines, some of which have been constructed and tested. The aim has been in constructing the nozzles to get a good carrying power, and still to maintain a fairly fine mist.

EXPERIMENTS WITH ROSE SOILS.

G. E. STONE.

Although requiring exceptional skill, the management of green-houses has reached such a high degree of perfection in the United States that it seems somewhat presumptuous for an amateur to attempt serious experimentation with the idea of its being of value to the remarkably trained men who make a profession of growing roses and carnations under glass. Nevertheless, for two years we experimented with roses, and during this time freely consulted the best experts in the line. The experiments were undertaken largely to determine the effects of different soil textures on the growth of roses, to study their diseases, and in general to ascertain the limitations of the plant under different methods of treatment. Such crops as lettuce, tobacco, roses and others are quite susceptible to differences in soil texture, which often produce quite different types of tissues and of growth. Tobacco, for example, will bring $0.30 a pound when grown in certain soils, while the same plants, when grown in other soils even by the same grower, will often not be worth $0.10 a pound. Likewise lettuce grown in the light, porous soils about Boston is quite different from that grown in the heavy, inland soils.

For the best growth of roses it is essential that the soil have a more or less definite texture, and in these experiments it was our purpose to observe the effect of different soils on the development of roses. We selected the American Beauty rose for the experiments, as it is considered the most susceptible to soil texture. It has even been maintained that a soil suitable for its growth is rare in this State, whereas in Pennsylvania the soils appear to be ideal for this variety.

Mechanical analyses of some of the best rose soils in this country demonstrate that they contain a large percentage of finer particles, clay, etc., than is generally found here in our soils. In our experiments we selected soils which resembled as much as possible the best types. Some of the soils in the Connecticut valley seemed to be excellent substitutes for the real rose soils, and these were tested in order to obtain some idea of their relative value. Most of the Connecticut valley soils run low in coarser materials and high in the finer materials such as very fine sand, and occasionally silts predominate. These fine sands and silts give a compact character to the soil, with a large water retaining capacity. Very fine sand predominates in many of these soils, as high as 75 per cent. being found in some samples, but nearer the river we often find samples in which the coarser silt predominates.

These experiments were continued for two years in a greenhouse provided with 5 beds, one-half of each bed containing a typical Amherst loam which had been used for some years in growing cucumbers, tomatoes and melons, and to which no commercial fertilizer had been added, although horse manure had been applied freely. The other half of each bed was filled with specially selected soil of different textures for the purpose of comparison. These benches were 1 foot deep and the bottoms were filled with brick placed on end, leaving about 7 inches depth of soil in each bed. Seventeen plants were used in each section, or in the whole house a total of 170 plants. Since five of these sections contained soil of the same types, only five were used for other types, and these were all different.

TABLE 1. — *Showing Mechanical Analysis of Soils used in Rose Experiments.*

Number.	Section.	Bed.	Per Cent. of Organic Matter, Gravel, Sand, Silt, and Clay in 20 Grams of Soil.								
			Organic Matter.	Gravel (2-1 mm.).	Coarse Sand (1-.5 mm.).	Medium Sand (.5-.25 mm.)	Fine Sand (.25-.1 mm.).	Very Fine Sand (.1-.05 mm.).	Silt (.05-.01 mm.).	Fine Silt (.01-.005 mm.).	Clay. (.005-.0001 mm.).
20, ...	I.	A	8.22	0.10	9.45	1.44	4.35	40.01	29.67	0.46	5.65
69, ...	I.	B	18.21	1.45	4.40	3.85	12.93	38.13	1.50	0.51	12.26
68, ...	I.	C	6.58	0.99	1.48	1.53	12.51	28.02	14.51	14.11	10.41
67, ...	I.	D	8.96	3.51	3.25	3.87	9.75	45.42	14.49	0.99	3.86
66, ...	I.	E	9.80	0.69	3.86	3.63	6.51	36.53	14.27	12.25	9.43
71, ...	II.	A-E	7.54	1.24	3.62	3.48	11.64	49.01	10.85	1.55	1.71

The mechanical analysis of the soils used in our experiments with roses is shown in the preceding table. Five of the beds in section II., beds A to E, contained soils represented by No. 71, which is a fairly typical Amherst loam, the analysis being made from a composite sample taken from each of the five beds, and contains 1.71 per cent. of clay. The remaining five beds, section I., were filled with selected soil of different textures. These were all obtained from the vicinity of the experiment station, but were different in texture and appearance from our typical loams. All were thoroughly mixed with about one-third cow manure. The character of the soils in beds A to E, section I., was as follows: —

Soil No. 70, bed A, was obtained from near the banks of the Connecticut River, and was higher in clay than No. 71. Silt and very fine sand, however, predominated in this type.

Soil No. 69, bed B, was obtained from a forest near by and was rich in vegetable matter as a result of many years' accumulation of decayed roots, leaves and twigs, and was very dark in appearance. It was characterized by considerable amounts of clay and very fine sand, which was the result of wash from higher elevations.

Soil No. 68, bed C, procured 6 feet below the surface, was very compact, containing little organic matter, and would be designated as hardpan. Very fine sand predominated in this soil, which also contained 10 per cent. of clay.

Soil No. 67, bed C, was a modified local soil obtained from what was originally a muck meadow which at one time was overflowed with water, but later reclaimed. It had received some wash in times past, was dark in appearance, and more or less compact. For some years it had been growing excellent crops of grass, but the year before we obtained it had been ploughed up and reseeded. Our sample was taken from the surface and contained the old and new seeded soil, well decomposed. Fine sand and silt predominated and the soil contained a little more clay than No. 71.

Soil No. 66, bed E, was the same as No. 68, except that besides the one-third cow manure, one-third finely pulverized sod was added.

All of the soils in section I. contained more clay than our regular greenhouse soils shown in section II., the clay ranging from 3.86 per cent. to 12.26 per cent. The plants were set out in October and removed the following June. Besides the above treatment all of the beds were freely supplied every week or two with liquid cow manure. The steam pipes were painted with sulphur and oil, and there was little or no mildew or black spot. The plants were quite free from diseases caused by pathogenic organisms, although much variation occurred in the vigor and growth of the plants in the different soils, as was anticipated from the dissimilar conditions. In most cases they were not what would be called vigorous. The following table gives the height of the plants at two different periods in their growth; viz., at March 17 and June 19.

TABLE 2. — *Showing the Average Height in Inches of Rose Plants grown in Different Soils, in Beds A to E, Section I.*

	Beds.				
	A.	B.	C.	D.	E.
Soil number,	70	69	68	67	66
Average height of plants March 17 (inches),	37	38	22	46	36
Average height of plants June 19 (inches),	50	68	39	72	66

The average height of plants in section I., beds A to E, which contained a variety of new soils, was 36 inches for March 17, and 29 inches for corresponding plants in section II., beds A to E. At the second period of measurement, June 19, the average height of the plants in beds A to E, section I., was 59 inches, while that for beds A to E, section II. was only 34 inches, showing that the new soils produced plants of greater average height than the old greenhouse soil. If we take the averages of the final measurements made on June 19 of the plants grown in new soils, that is, in beds A to E, section I., we find that the highest average growth in height is shown by soil No. 67, or in bed D. (See Table 2.) Soil No. 67 contained nearly 4 per cent. of clay and considerable fine sand and silt, and constituted one of the best soils for roses in the house. Soil No. 69, bed B, produced the next highest average of plants, but they were abnormal, developing small leaves and a spindling growth. The soil in this case was very dark colored and rich in organic matter.

The plants in soil No. 66, bed E, closely resembled in height those in the preceding one. The soil in this case was heavy and compact, but contained besides the cow manure considerable pulverized sod. Soil No. 70 in bed A and No. 68 in bed C gave the lowest average growth in height. The latter soil was the same as No. 66, bed E, except that it contained no pulverized sod. This soil contained the least organic matter of any, was heavy and compact, and contained 10 per cent. of clay. When pulverized sod was added, as in No. 66, far better results were obtained. No. 70 was also lacking in organic matter. The heavier, more compact soil developed better leaves and blossoms than the lighter soil. Soil No. 67 produced the best developed plants, while the most slender canes were produced by soil No. 69.

The largest number of flowers developed on the plants which made the best growth, but the quality was the best in No. 67. The most normally developed plants were grown in soils No. 67 and No. 66, the latter being the only soil to which was added pulverized sod, and the former contained a fairly good supply of well decomposed sod incorporated with the soil when brought from the field into the greenhouse. The addition of sod to some of the other soils would no doubt have given better results. The superior plants produced by soil No. 67 were undoubtedly due to the large amount of well decomposed sod it contained; in other words, the humus was in a condition to make it more available, whereas in soil No. 66 this was not so, as the sod was applied fresh and was not in the least decomposed, and in Nos. 70 and 68 there was too little humus. Soil No. 69, obtained from the woods and containing large amounts of decomposed roots, leaves and branches of shrubs and other plants, was not suitable for growing stocky plants, although rich in humus.

The soil in the different beds remained undisturbed during the summer, and a second crop of roses was set out the following fall. However, before setting out the plants each bed in both sections received a fairly good application of cow manure, this being thoroughly incorporated in the soil. The new plants during the second year started very poorly, became sickly, and in the course of three months half of them died. This experiment was conducted purposely along this line, although we knew we were violating the customs of the best growers. Nevertheless, we wished to learn what the result would be. The sickly plants showed no indications of being affected by pathogenic fungi or eel worms, but the roots were abnormal, indicating that the trouble was in the soil. We therefore flooded each bed while the plants were "in situ" for a period of two hours, washing out the soil very thoroughly. The first water that came through the soil was exceptionally turbid, but that which came through later was very clear. The percolated water was collected at intervals and chemical tests made of it for acidity, etc. These tests gave surprising results, as they showed that the soil was in very abnormal condition for root growth. These soils had been given, the year before, the customary treatment, consisting of a liberal supply of cow manure, both in the solid and liquid form, but this had so filled up the soils with injurious chemical compounds as to prevent root development. Rose growers have found by experience that good results can be obtained only by changing their soils each year, and this experiment verifies the wisdom of the practice.[1] On the other hand, lettuce growers seldom if ever change their soil, experience showing that for lettuce the older the soil the better. In the former case cow manure is used, and in the latter, horse manure, mixed with a large percentage of straw, is used exclusively, the effects on the soil being quite different.

Carnation soils are treated in the same way as rose soils, the soil being changed each year. Roses and carnations, therefore, require a new soil each year, while most market garden crops are grown year after year in the same soil enriched with horse manure and straw. Repeated applications of horse manure improve such soils, and there is little danger of over manuring; whereas cow manure has a quite different effect and cannot be used in the same way, as there is danger of root injury and malnutrition.

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[1] At the present time rose growers use Manetti stock for grafting and do not change the soil more than once in two or three years. This stock is said to be more immune to eel worms.

Most of the lettuce soils in the greenhouses in this State have never been changed, and some of them are very old. The older such soils are the better for lettuce and market-garden crops in general although tomatoes do the best when the soil is changed occasionally.

After the rose soils were washed out no further dying of the plants occurred; on the other hand, they developed quite rapidly and the crop matured. The trouble was with the roots and was caused by an abnormal chemical condition of the soil. When this occurs, as it does quite commonly in greenhouses, washing out the soil is a corrective. Sometimes the trouble can be remedied by placing a new layer of soil on top of the bed, in which case new roots will form in the top layer of soil.

The development of the plants in the second crop was not as good as in the first, but the same characteristic growth in the different beds was noticeable. The washing out of the soil improved the condition of the plants to quite a remarkable degree, especially in soil No. 69, which appeared to be more acid than that in the other beds. The plants in soil No. 67, however, as in the preceding experiments, showed the best development.

At this point it might be well to compare the texture of other rose soils with that of those with which we experimented. The following table gives the results of the analyses of some of the best and most typical rose soils found in the eastern States.

TABLE 3. — *Showing Mechanical Analysis of some of the Best Rose Soils obtainable from the Rose Houses of the Eastern United States*

STATES.	Number.	PER CENT. OF ORGANIC MATTER, GRAVEL, SAND, SILT, AND CLAY IN 20 GRAMS OF SOIL.								
		Organic Matter.	Gravel (2–1 mm.).	Coarse Sand (1–.5 mm.).	Medium Sand (.5–.25 mm.).	Fine Sand (.25–.1 mm.).	Very Fine Sand (.1–.05 mm.).	Silt (.05–.01 mm.).	Fine Silt (.01–.005 mm.).	Clay (.005–.0001 mm.).
New Hampshire,	109	4.58	0.13	0.16	0.25	6.62	36.80	16.34	12.74	9.11
	110	7.90	1.35	1.25	2.22	3.72	13.18	32.25	23.59	13.73
	105	4.69	0.41	0.13	0.49	0.89	14.05	29.46	15.36	29.28
New York,	106	4.69	0.74	0.73	2.09	8.57	32.25	26.84	12.76	8.53
	108	3.15	0.21	0.13	0.56	2.82	43.15	14.56	19.40	10.15
Pennsylvania,	107	7.28	2.87	1.73	3.33	9.55	39.44	20.09	3.37	6.73
	118	5.12	5.10	2.62	4.52	12.09	26.20	31.04	3.52	6.42
	111	4.60	0.62	0.60	2.04	3.98	23.15	25.52	19.10	11.01
	112	5.19	0.35	0.42	1.34	2.48	32.26	5.15	36.10	11.80

TABLE 4. — *Showing the Percentage of Coarse and Fine Material in Rose Soils.*

Bed.	Number of Soil.	Percentage of Soil Constituents in— Gravel through Fine Sand.	Very Fine Sand through Clay.
A,	70	15.34	75.70
B,	69	22.63	52.40
C,	68	16.51	67.05
D,	67	20.38	64.76
E,	66	14.69	72.48
A-E,	71	19.98	63.12
	109	71.17	74.98
	110	8.54	82.75
	105	1.92	88.15
	106	12.13	80.38
	108	3.72	87.26
	107	17.48	69.63
	118	24.33	67.18
	111	7.24	78.78
	112	4.59	85.31
Average,	70-66	17.91	66.49
Average,	109-112	9.68	79.36

All the soils shown in this table are from locations where roses are grown to perfection. A casual glance, however, at the mechanical analyses of these soils given in Tables 3 and 4 shows that they are somewhat higher in the finer particles than most of the Massachusetts soils. The clay runs from 6 to 29 per cent. in the soils shown in Table 3, while the very fine sand, silt and clay run from 67.18 to 88.15 per cent. The gravel, coarse and medium and fine sand run from 1.92 to 24.33 per cent. (See Table 4.) In our experiment soil the very fine sand, silt and clays run from 52.40 to 75.79 per cent., while the coarse particles, namely the gravel, coarse, medium and fine sand, run from 14.69 to 22.63 per cent. In most of the types the silts run higher than in our typical Massachusetts soils, although in some cases the very fine sand and silt are less than those found in some Connecticut valley soils.

The average percentage of coarse particles is 19.98 in our experiment soils, and 9.68 in typical rose soils, while the average for the finer particles is 66.49 in our soils and 79.36 for the typical rose soils; in other words, the percentage of coarse material averages highest in the soils with which we experimented, and the percentage of finer particles averaged less than in the typical rose soils. The average percentage for silt is 14.88, and for fine silt 5.66 in our experiment soils, while the typical rose soils give 22.36 for the silt and 16.21 for the fine silt, the typical rose soils showing a larger percentage of silts than our experiment soils. This also holds true for the clays. We are of the opinion that the larger percentage of silt and very fine sand makes a compact soil of good water-retaining capacity. Our experiments were not carried on extensively enough to determine, except in a general way, the textural effect on roses, and it would require considerable experimenting to determine the specific effects of each group of soil particles on the development of this plant. Numerous mechanical analyses of a large number of our best rose soils which have been made for many years throw some light on the problem of soil texture, but the problem, like many others, is complicated by the undoubted presence of other factors which may play a part here in the development of a crop.

The best rose soils appear to be those which possess from 8 to 12 per cent. or more of clay, and which are well supplied with other grades of the finer particles. The percentage of very fine sand, silt and clay should exceed 75 per cent.

Our experiments with roses were not continued as long as we should have liked, and the results have a limited value. Neither were our soils treated with fresh pulverized sod, as is customary, except in one case, where the addition of sod proved a great benefit. The presence of organic matter is important, and our best soil was the one in which the organic matter was well incorporated and decomposed. The soils which produced the most normal growth were those of a compact nature, and the freshly prepared soils gave better results than the old ones which had been used for growing various crops.

A NOTABLE ELM TREE.

G. E. STONE.

The American elm, as found growing in New England, is a tree unsurpassed in grace and beauty. It reaches its highest state of perfection in the river valleys where the soil conditions are well suited to its growth, and especially in the Connecticut valley, where the soil is largely composed of very fine sand and silt, and has considerable water-retaining capacity. The elm, however, will grow in very moist soil, although requiring for its best development a well-drained surface soil. While it makes good growth in almost any type of Connecticut valley soil, it reaches its best development in a soil in which coarse silt predominates rather than very fine sand. Our many years' observations on the elm have convinced us that it is quite susceptible to soil texture, and its freedom from various troubles is equally marked when growing under ideal conditions.

A somewhat notable elm growing near the college was recently cut down, and the opportunity was taken advantage of to make careful observations in regard to its age and growth. This tree is illustrated in the third edition of Emerson's "Trees and Shrubs of Massachusetts," published in 1878, and was at that time considered an exceptionally large and symmetrical tree. At the time of its removal, in 1911, it had lost none of its beauty and symmetry.

Measurements of the tree after it was cut down showed it to be 19 feet in circumference 1 foot above the ground; 17 feet 4 feet from the ground, and 8 feet above the ground, at a point just below the larger branches, it measured 21 feet 7 inches. Fourteen feet from the ground it measured 25 feet 5 inches.

The age of the tree, obtained by counting the annual rings, was found to be one hundred and thirty-one years, and the height, which was estimated after the tree was felled, was between 115 and 125 feet. The south and east radii showed the greatest development. This is not surprising, since the light conditions are 10 or 15 per cent. more favorable in the morning than in the afternoon, and there naturally occurs more photosynthetic activity and therefore more growth on the southeast side of the tree than on any other side. Careful measurements were made of the annual rings in decades by Sumner C. Brooks, and the results of these measurements, showing the grand period of growth, are shown in Fig. 1. By studying the

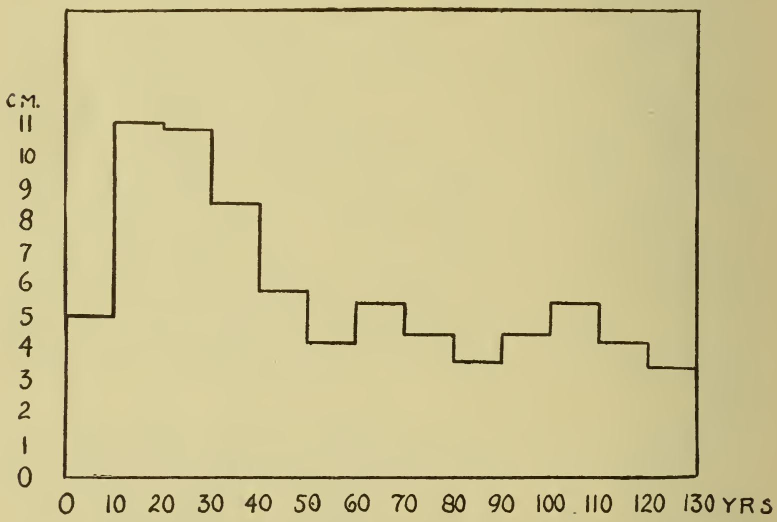

FIG. 1. — Showing grand period of growth of elm tree, *Ulmus Americana*, L. The figures on the ordinates represent centimeters, and those in the abscissæ, years.

curve it will be seen that the maximum period of growth occurred between the tenth and thirtieth years, following which there is a gradual decline in the decade growth, as might be expected. Even between the one hundred and twentieth and one hundred and thirtieth year the growth in thickness of the trunk indicated considerable vigor and was about two-thirds that which occurred between the first and tenth year.

There were a few small, dead branches on the tree, and a small split in one of the crotches of the larger branches. One of the largest branches also showed a more or less decayed interior resulting from lack of proper treatment, which should have been given years before; but the tree was practically intact at the time of its removal, and providing its root system was normal it was certainly capable of growth for many years to come, as was shown by its vigor at the time it was cut down. By the aid of modern tree surgery what few defects the tree possessed could easily have been remedied.

Table showing the Growth in Thickness of an Elm Tree, Ulmus Americana, L. Measurements represent the Growth of the Annual Rings in Decades.

Decades.	Growth in Centimeters.	Decades.	Growth in Centimeters.
0-10,	5.0	70-80,	4.4
10-20,	11.0	80-90,	3.6
20-30,	10.8	90-100,	4.4
30-40,	8.5	100-110,	5.4
40-50,	5.8	110-120,	4.2
50-60,	4.2	120-130,	3.4
60-70,	5.4		76.1

SOME OBSERVATIONS ON THE GROWTH OF ELM TREES.

G. E. STONE.

Trees like most plants, make different growths in soils of different natures, and many of them respond noticeably to cultivation. While no extensive experiments have been made to determine the effects of specific fertilizers on shade trees, it is well known that many varieties respond to such treatment. The elm is especially susceptible to variations in soil texture, requiring certain conditions for its best development. Dry, gravelly soil causes a spindling growth, and it is very often difficult to make young trees live in soils of this nature. Mowings are not at all favorable locations for elm trees, as the grass robs them of considerable moisture; and here young trees often succumb in the struggle for existence.

There are many elm trees on the college grounds which have been for the most part set out by the different classes, and in this immediate vicinity we have for some years had opportunity to carefully observe the growth these elms have made. For some time we have been making series of measurements at frequent intervals to determine the rate of growth under various conditions, and the results of some of these observations are presented here.

In two rows of elm trees running north and south and growing in soils of similar texture we find quite marked differences in the rate of growth. On one side of the road the trees have been in mowing land ever since they were set out, about thirty-two years ago, and on the other side they have been growing in lawn conditions for the same length of time. As the road was not very wide the roots of both rows of trees extended into the roadway, giving some of the roots similar conditions.

The rate of growth in circumference 4 feet from the ground of the trees growing on the lawn side of the road was 9 per cent. greater than of those on the mowing side for the same period, thirty-two years.

In another case, where the roadway was wider and the trees smaller, the difference was 36 per cent. in favor of the trees on the lawn for a period of twenty-two years. Here the soil was much drier than in the preceding instance, and the trees showed the effects of occasional applications of fertilizer to the lawn. However, there was a marked difference not only in the growth, but in the color and amount of foliage in the two groups of elms. The difference between lawn and mowing conditions is more prominent in dry than in moist soil, although it is possible for elms to receive too much water, as is proved by the following instance: —

Two rows of elms running north and south on either side of a wider highway were under practically the same conditions, except that one row was in a good soil underdrained and the other in a wet soil where the drainage was very insufficient. The difference in the growth in circumference of these 4 feet from the ground for a period of thirty years was 10 per cent. It should also be noted that the soil with the poor drainage had been cultivated a few times, while the other had not, but the drainage in the former soil was so poor that the trees made little growth and were stunted in appearance.

Elms growing in wet soils are invariably poorly formed, and seldom develop into good ornamental or street trees.

Exposure to light, as might be expected, materially affects the growth of trees. A row of trees located in mowing soil on either side of a narrow roadway running southeast, in thirty-two years showed a difference of 11 per cent. in their circumference 4 feet from the ground, in favor of the south or sunny side of the radii. No differences would occur with small trees when first set out, but when they grow large enough to shade each other there are differences in the rate of growth. Since these trees were planted close together and the roadbed is narrow, they shade each other at the present time, and have for some years past.

Trees grow in proportion to the amount of foliage they develop, as well as to the amount of light they receive. Those growing on the east side of mountains develop most on the east side, and those on the west side will develop most on that side of the trunk. We found 28 per cent. difference in favor of the east radii of some stumps growing on the east side of a mountain, and 8 per cent. difference between the east and west radii of trees growing on the west side of mountains. The growth of trees differs greatly according to the exposure; as, for example, on the edge of forests the growth is greater than in the middle of the forest, proving that light affects growth materially.

In the case of the trees on the east and west sides of mountains, they will receive sunlight during only part of the day, and their development will coincide with the amount of light they receive, as well as depending also on the side of the tree exposed. Since morning light is more intense than afternoon light, the east side of a tree will show the greatest growth, and a great many measurements of trees and of light intensity at different times during the day have shown us that the growth of the tree in one direction or another is directly in proportion to the light they receive.

In conclusion we might repeat that elms thrive better in pastures where the grass is likely to be scant, than in mowings, and lawn conditions are more or less favorable. They also respond to cultivation and treatment with fertilizers like any other crop.

DO WE NEED A SEED LAW IN MASSACHUSETTS?

G. E. STONE.

There has been considerable agitation during the past two or three years over a seed law for the State, interest in which has been shown by farmers and citizens in general. Some States have passed laws relating to seeds and have established standards for seed germination and purity, while others are seriously considering the matter of purity of seeds, and are attempting to establish laws to this end. The standards for purity and germination adopted by our different States are similar, but are so high that it is impossible for any seed dealer or extensive importer to live up to the law under the present system of handling seeds. The presence of laws on our statute books which no one can live up to is conducive to the best interests of no one; nor is it wise to bring seed dealers before the courts for selling as good quality seeds as can be obtained, and brand them as criminals or law-breakers. A law which cannot be enforced is worse than none, since it has a tendency to breed contempt for all law. A seed law which cannot be conformed to is bound to be broken, as certain crops have to be grown whether the seed complies with some arbitrary standard or not.

It is most unfortunate that the majority of the laws are drawn up from the seed analyst's point of view and not from that of the dealer or retailer. Too rigid seed laws are bound to prove very unsatisfactory in the end to seed importers and dealers, and if strictly enforced will prove of great disadvantage to the farmer. The best process of cleaning seed is not known, and it is also a difficult matter to grow clean seed.

The germination of seeds is greatly influenced by climatic conditions, and the percentage is by no means a constant factor from year to year. It is often impossible to obtain seeds anywhere in the world that will come up to the standard required for germination by these arbitrary laws, and the question is, "What are the farmer and seedsman going to do in such cases?" We are strongly of the opinion that the time is not ripe for a severe seed law, at least in this section, and we question whether it would not be better at present to restrain by publicity the dealer who persists in selling poor seeds rather than hold him to a standard impossible to comply with.

The seed situation in a nutshell is this: the purchaser has a right to know what he is buying, therefore the seedsman should give some guarantee of what he is selling. The sale of adulterated seeds should be prohibited by law, and if all packages of the more important varieties of seeds containing over 5 pounds were to have a guarantee label, and if samples were tested each year and the results made public through some official publication, the moral effect would be good.

Many of the State seed laws which have been adopted at the present time appear to us to be failures. A glance at the results of official analyses of seeds of various States which have these laws shows that a very large percentage do not come up to the standard, many being far from it, and prosecutions in these States are so rare that it is difficult to find them. We question very much whether the purity of seeds or the standard of germination have been very much improved in those States where these laws have been passed. If some of these laws were strictly enforced it would drive most of the seed dealers out of business, and many of them are of course very reliable and honest men. A great many, as we know from personal experience, take the greatest pains in selecting the best and highest grade seeds on the market, although of course there are many dealers who care little about the grade of seed they sell. They buy the poorest seed obtainable, catering to the farmer who wants to get seed as cheaply as possible, regardless of its quality. Here the farmer is largely to blame.

The seed laws passed up to this time expressly emphasize seed purity and germination. It is well known that these are by no means the most essential factors, and cannot be compared with such important considerations as strain, etc. The seed of a certain strain, even if it contains 10 per cent. impurities, is better than one that is pure and of an inferior variety.

The writer has studied the seed question from various points of view, — from that of the seed importer, the seed dealer and the farmer, — and is well aware that there are a great many difficulties associated with the seed problem which cannot be overcome by legislation. The importer, retailer and farmer are interested in the seed question, and the reliable dealer is anxious to put on the market as good seed as possible. We are of the opinion, however, that the matter is a delicate one, and whatever is accomplished in the line of legislation must be done cautiously and in a spirit of co-operation.

As already stated, the collecting of seed samples in the open market or from dealers each year would greatly improve conditions if these samples were analyzed and tested for purity and germination and the results published. A law requiring an approximate guarantee concerning the germination and purity of certain seeds, especially those sold in packages of over 5 pounds, would also have a salutary effect. We repeat that we do not consider it wise to load our statute books, however, with impractical laws; any restrictions relating to the sale of seed should conform to common sense. We cannot compel nature, by any form of legislation, to produce a definite quality of seeds each year; neither have we the right to ask dealers to accomplish what is impossible. Publicity, in our opinion, would constitute the best corrective for abuses.

DISEASES MORE OR LESS COMMON DURING THE YEAR.

G. E. STONE.

Like the preceding one the past summer has been exceptionally dry, and the heat has been intense at times. This drought, coming as it did after three or four previous dry seasons has affected vegetation to a considerable extent, and will result in later injury, especially to trees.

Some of the diseases which have been more or less common during the summer are as follows: black rot of cabbage and cauliflower (Pseudomonas), asparagus rust (Puccinia), bean Anthracnose (Colletotrichum) and celery rot. The cucumber Fusarium wilt described in our last report has caused much damage to greenhouse cucumbers, in many cases destroying the whole crop, and is serious at the present time. Experiments relating to the control of this disease are now being carried on, but the nature of the trouble makes considerable study necessary. A similar disease of tomatoes is also becoming troublesome, but it does not cause so much damage to the tomato as to cucumbers.

A new disease of tomatoes characterized by bacterial infection of the leaves has recently been brought to our attention, but at present we have found only one variety of tomatoes affected.

Many dahlias made a stunted growth this summer, and others were deficient in flower production. From our observations we should say that this condition was not associated with attacks of either fungi or insects, but was due to some abnormal feature causing a slow and stunted growth.

A peculiar instance of malnutrition was observed on corn. This was caused either by too heavy applications of fertilizer or wrong methods of applying it; or it may possibly have occurred from lack of rain needed to dilute or wash out the fertilizer; at any rate, the plants were yellow and sickly and the tissues were abnormally gorged with nitrates.

The epidemic of rust which has prevailed generally over the country during the past few years and which has affected plants usually immune in this region was not so severe this year. However, beans were affected to some extent, as were quinces and Vinca. The apple, ash and some other species were practically free from the trouble.

Some apple troubles have been somewhat common, while others have been less common than usual. The Baldwin fruit spot, which has been with us for so many years, and which has never been associated with pathogenic organisms, has apparently been superseded by a similar but more prominent and disastrous spot termed the "fruit spot." This has been very common not only on Baldwins but on Greenings and other varieties. The latter is characterized by much more conspicuous spots than the former, and a fungus termed Cylindrosporium is usually found associated with it. In one of the best orchards in the State we were able to find only two or three apples on a tree affected with this spot. In some other cases, however, it was much more common. On the whole, this trouble has proved rather serious this year, and as it appears to be controlled by spraying it may become necessary to resort to this in order to control it. Both spots seem to be associated with drought.

Many cases of sun scald were observed on apple trees during the year, both large and small trees being affected. Much of the scalding noticed was on the trunk near the ground. In some orchards which have been severely pruned, and the trees ploughed around and fertilized, more or less sun scalding occurred. This was noticed on unusually vigorous young shoots which are characteristic of trees handled in this way, and was due to the nonripening of the wood.

Potatoes were affected by the drought and to some extent by early blight. The severe fall rains caused attacks from late blight, and in some cases potato stem rot was reported.

Trees in general were affected to an unusual extent by a series of troubles.

Burning of conifers, including our native white pine, and various evergreens such as rhododendrons, arbor vitæs and others was the worst experienced in years. The loss to nurserymen and others from this cause was large, and it was very difficult to meet the demand for nursery stock of this class. Sun scorch was also common on the rock maple, and the young growth was generally affected by winter killing.

The chestnut disease, which has been with us now for four or five years, is spreading in some localities, but it should be borne in mind that every chestnut tree which appears sickly or dying is not necessarily affected with the so-called "blight." There are, in fact, many sickly chestnut trees as well as others which are showing no indications of blight, a feature which Dr. G. P. Clinton, of New Haven, has noted in Connecticut. The chestnut disease is the worst at present in the Connecticut valley so far as we can observe, and the question of preventive measures seems wellnigh hopeless, although not less so than the possibility of extermination in other ways. There is, however, some reason to believe that it will not prove as severe as further south.

Other trees, such as the elm, maple, some oaks and ashes, are at present in bad condition throughout the State. The large number of dying trees, particularly elms, which may be seen here and there is surprising even to a casual observer. The elm, to be sure, has many enemies, such as the leopard moth and elm-leaf beetle, but there are other causes responsible for their present condition. It is questionable whether it is advisable at the present time to plant elms as shade trees, and a number of other varieties are doubtful, but after many years of close observation on trees we have found one species which has stood the effects of drought, winter killing and other troubles better than all others, and that is the red oak. Prof. C. S. Sargent of the Arnold Arboretum has recommended this for many years as a shade tree, and although little used there are a great many reasons why it should be used more than it is. Under good conditions the red oak will grow as rapidly as the elm and maple, and its habit of retaining its leaves, which it shares with other oaks, gives it a rugged and picturesque appearance in winter.

In conclusion we might repeat that the past few years have been very hard on vegetation. The summers have been dry and the falls wet. Vegetation needs water the most during the growing season, and a superabundance in the fall is a menace rather than a benefit, as it has a tendency to develop tender shoots and prevent the ripening of the tissue. When the wood of trees does not ripen properly and is subjected to even ordinary cold, it sun scalds or winter kills, with disastrous results. The exceptionally dry summer and rather wet fall which we have just experienced have furnished ideal conditions for winter injury this coming winter.

INSECTS OF THE YEAR 1911, IN MASSACHUSETTS.

H. T. FERNALD.

No unusual destruction by insects has been observed in Massachusetts during the year which has just closed. On the other hand, many different kinds have contributed toward the loss which has been experienced, and several not usually met with have been in evidence.

The unusually hot, dry summer was of course favorable to the rapid increase of plant lice and the San José scale. Cutworms were also very abundant and did much damage, and the elm-leaf beetle was unusually destructive, though in most towns this pest is now quite well kept in check by spraying. It was first found in Nantucket this summer in small numbers, on five or six elms, near the center of the town, not, as perhaps might have been expected, on the trees nearest the wharves.

The leopard moth, *Zeuzera pyrina* L., is now present almost everywhere in eastern Massachusetts near the coast, and has even reached Nantucket. It does not seem to have worked its way far inland, however, and, as in other States, its injuries are most pronounced in the cities and larger towns.

The 12-spotted asparagus beetle, *Crioceris 12-punctata* L., which has been working its way northward, was taken at Concord and Roslindale near Boston in 1909. It was not observed at Amherst until last summer, which might indicate a more rapid dispersal along the coast than inward.

The cottony maple scale, *Pulvinaria innumerabilis* Rathv., has been unusually abundant in the Connecticut valley this year, many of the soft maples being so thoroughly covered with it as to have made little or no growth. This is the first time for several years that this insect has attracted any attention in the State.

In 1910 the white birches throughout New England were attacked by the birch-leaf skeletonizer, *Bucculatrix canadensisella* Chamb., and almost without exception the leaf tissues were entirely consumed. As scrub birch is so abundant everywhere in this part of the country much attention was directed to this insect, and many inquiries as to the likelihood of the destruction of the trees were received. During the past fall the insect was again in evidence, but to a less degree, only a small portion of the foliage being destroyed, and as a whole the greatest injury appears to have been in localities where the pest was least abundant last year.

The cut-leaved birches, so much favored as ornamental trees, have had a different experience. They have suffered equally with the native varieties, but in addition, for the last three years in the Connecticut valley at least, they have also been attacked by the bronze birch borer, *Agrilus anxius* Gory, and in nearly every case where this insect has entered a tree the death of the latter has followed, while the native birches have thus far appeared to be exempt.

The latter part of May some large chestnut trees in Amherst were reported as dying. An examination showed that they had been nearly girdled close to the ground, and full grown larvæ, pupæ, and adults of *Leptura zebra* Oliv. were found in the burrows.

For several years the elm-leaf miner, *Kaliosyphinga ulmi* Sund., has been present in considerable abundance. Last year this insect was less noticeable than in 1909, but during the past summer its work on Camperdown and European elms has been very noticeable. In many cases the parenchyma of all the leaves of the trees has been almost entirely consumed, and the trees have made little or no growth. Some facts which have been noted would seem to indicate that there are two generations a year of this sawfly in Massachusetts.

The work of the maple-leaf stem sawfly, *Priophorus acericaulis* MacGill., was quite noticeable in some parts of the State last spring. It had previously been noticed, but has evidently become much more abundant during the last year or two.

A specimen of the roach *Panchlora hyalina* Sauss. was taken near Amherst in a field at least half a mile from the nearest store. It is of course to be presumed that it came in on some tropical fruit, but it is evidently liable to fly some distance, and may therefore be met with almost anywhere.

During June the members of an elementary class in entomology at the college, interested in collecting insects, obtained a trolley car headlight with the requisite apparatus, and took it to a point where the local car line passes through a densely wooded area. There they established connections with the feed wire of the line and used the headlight to attract insects. The resulting catch included about twenty *lunas,* several *polyphemus* and *io* moths, besides a large number of smaller Lepidoptera, in a little over an hour. Several trials of this method gave extremely good results, and suggest the possibility of using electricity at places where moths are most abundant when trolley lines are properly located for this purpose.

On the 5th, 10th and 23d of June blister beetles were received from correspondents in Stockbridge and Williamstown which were evidently of the genus *Pomphopœa,* and which were kindly identified by Mr. Charles Schaeffer of the Brooklyn Museum as *Pomphopœa sayi Lec.* This insect has never before been received by the experiment station, and the data sent with the insects were of such interest as to be worthy of record. The Williamstown correspondent, under date of June 5, writes: "On the mountain ash tree where they were found there were about a quart." One of the Stockbridge correspondents wrote, June 10: —

Yesterday morning on entering my garden I found that these beetles had taken possession of the place. Every flower stalk had been eaten down and the iris and roses were fast being devoured. Lupins seemed to be the favorite and not one was left. The beetles seem to be drunk with the nectar, for they stuck to the flowers and we could easily cut the stalk and drop it in a pail of kerosene. We caught hundreds in this way. Later, in the afternoon, they seemed to have taken flight. There was a flight of about 300 on June 12, eating lupin, roses, syringas, iris, etc., eating the flowers and not the foliage. They appeared suddenly, over night. There was no special wind or other climatic conditions noticed. They were exterminated by hand, and after a heavy rain at night none appeared next day.

The other Stockbridge correspondent, on June 23, wrote: —

Three days ago I found these beetles eating the roses in the garden. They lighted, half a dozen or so, on one rose and devoured it rapidly. They were either so sluggish or so hungry that they were easily caught and the gardener drowned several hundred in an hour. Since then I have seen only a few scattered individuals. They seem tenacious of life, as specimens have lived three days in a box.

INDEX.

INDEX.

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TWENTY-FOURTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION.

PART II.,

BEING PART IV. OF THE FORTY-NINTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL COLLEGE.

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