A Study, by the Crop Survey Method, of Factors Influencing the Yield of Potatoes

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL OF CORNELL UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

EARLE VOLCART HARDENBURG

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Published as Memoir 57
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A STUDY, BY THE CROP SURVEY METHOD, OF FACTORS INFLUENCING THE YIELD OF POTATOES [1]

Earle V. Hardenburg

Almost from the date of their establishment, practically all state and federal experiment stations in this country, as well as many foreign stations, have tested, by diverse methods, the relative influences of factors affecting the yield of potatoes. A review of the abundant literature of the subject shows that a majority of these tests concern the influence of seed and fertilizers on yield. This fact, further substantiated by the results of the study herein reported, indicates that, with the exception of climate and soil, seed and fertilizers are the most vital factors affecting yield. Because of the widely differing environmental conditions under which the tests have been conducted, it is possible in only a limited degree to draw definite conclusions from a summary of the results. Furthermore, a large part of the literature fails to supply much detailed information as to the methods used in the experiments, and gives little if any consideration to factors affecting yield other than the one principally concerned in the respective tests. This means that most of the evidence available to date is of only limited application.

A comparison of the conclusions reached and the recommendations made by experiment stations, with those warranted by actual practice as found on farms in a potato-growing region, is therefore of considerable value. Such a comparison is, to some extent, made possible by the use of the survey method of collecting and studying data on the influences affecting the yield of potatoes. The survey method has accordingly been applied to the study of such factors in several potato sections of New York, and the results are herein compared with those obtained experimentally. As an additional check on the conclusions drawn, the biometrical method as applied by Rietz and Smith (1910)[2] has also been used in studying those factors which, according to the survey method, appear to affect the yield to the greatest extent. The survey method of studying crop production, wholly aside from the agricultural methods involved, has proved to be a most valuable means of determining the actual practice thruout the State, and has aided in correcting many false ideas of long standing concerning cultural methods used with this crop.

The collection of data was begun in the summer of 1913 and continued thru the summer of 1914. In 1913, 330 records of the 1912 potato crop were taken from as many potato farms on Long Island, and 360 records

[1] Also presented to the Faculty of the Graduate School of Cornell University, February, 1919, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

[2] Dates in parenthesis refer to *Bibliography*, page 1274.

of the same year's crop were obtained from that number of farms in northern Steuben County. In 1914, 300 records were similarly taken for the 1913 crop in Monroe County, and 300 in Franklin and Clinton Counties combined. This gives a total of 1290 records for the crops of 1912 and 1913. Each record was in the form of a filled-out survey blank, a sample of which is included at the end of this paper, and was as complete as possible in the details listed. Because of the similarity of regional conditions and of cultural practices, the counties surveyed were studied

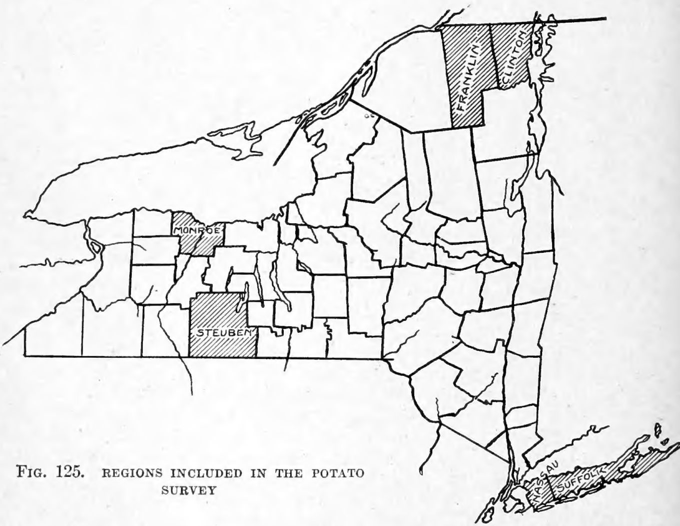

FIG. 125. REGIONS INCLUDED IN THE POTATO SURVEY

as four distinct sections, as follows: (1) Long Island, including the potato-growing areas of Suffolk and Nassau Counties; (2) Steuben County; (3) Monroe County; (4) Franklin and Clinton Counties. The location of these areas is shown in figure 125. These regions were selected, not because they include the counties of highest total production, but because they represent typical and distinct centers of potato production in the State.

The importance of potato production in a region is probably best indicated by figures showing the percentage of total crop acres devoted to this crop and the average potato acreage per farm. A summary of the scope of the survey and the status of the industry during the years 1912 and 1913 is given in table 1. Of the four regions surveyed, the potato crop is regarded as of most importance on Long Island and of least importance in Franklin and Clinton Counties.

TABLE 1. Summary of the Four Regions Surveyed

Region	Year	Number of records	Acreage surveyed	Average size of farm surveyed (acres)	Per cent of total acreage in potatoes, for farms surveyed	Per cent of crop acreage in potatoes, for farms surveyed	Per cent of crop acreage in potatoes, for the county (1909 census)	Average potato acreage per farm surveyed	Average yield per acre for farms surveyed (bushels)
Long Island, including parts of Suffolk and Nassau Counties	1912	330	8,188.16	65.0	37	44	23.0	24.8	175.5
Steuben County	1912	360	5,301.10	145.8	10	18	8.3	14.7	136.4
Monroe County	1913	300	3,728.25	112.1	11	15	8.0	12.4	126.2
Franklin and Clinton Counties	1913	300	2,160.00	169.5	4	10	5.7	7.2	179.3

THE CROP SURVEY AS A METHOD OF RESEARCH

From its inception in this country, agricultural teaching has depended largely on textbooks, collateral references, and the published results of experiments. There is still a considerable lack of practical information which can be supplied only by protracted experimentation or by the study of large numbers of survey records in the regions concerned. Frequently problems arise which local experiments fail to solve because of the impossibility of handling the work on a sufficiently extensive scale. Large numbers of records might very often be the means of discovering the common causal factor prevailing thruout a region, thus furnishing the solution of the problem or at least a working basis for its solution. A typical illustration of this is furnished in the investigations on pecan rosette by McMurran (1919). Pathologists had previously been unable to account for the cause or to recommend measures for the control of this disease, which was so prevalent thruout the pecan orchards of the Southern States. McMurran, by taking records of many orchards in the various pecan regions of the South, discovered that the disease was almost entirely absent in the orchards of the rich river bottom-ands, and from this observation he deduced that the cause of the disease lay in certain soil deficiencies.

The farm-crops survey aims first of all to search out the actual facts concerned in the production of a given crop in a given area. This information, obtained in sufficient quantity, may then be regarded as statistics from which to determine the most beneficial influences and practices. The survey idea was first launched in New York by Dr. L. H. Bailey, under whose direction horticultural studies were made thruout the State. In 1903 Professor John Craig started an orchard survey campaign in western New York. Such of these surveys as were completed have been published as Cornell bulletins (Warren, 1905, a and b; Cummings, 1909; Martin, 1911). Under the direction of Dr. G. F. Warren, the survey idea was extended to include the farm as a whole, with the result that whole farming areas, with the farm as a unit, have been studied in what are called *farm-management surveys*. The results of such studies have also been published as Cornell bulletins (Warren and Livermore, 1911; Thompson, 1915). Montgomery (1913), in discussing crop surveys, states that their primary function is to determine *how* to grow the crop, while farm-management surveys aim to determine *when* to grow the crop. Warren (1914) attests the value of agricultural surveys by saying that there are many kinds of agricultural information that can be found only by survey methods, since the conditions in question exist only on the farms. He states further that agricultural knowledge, to be of most value, should be the result of both survey studies and experimental tests.

The accuracy of survey methods depends very largely on such factors as the personality of the man procuring the records, the manner in which questions are asked, the number of records obtained for each region studied, the unit used as a basis in the study of a factor, accuracy in tabulation, and the final interpretation of results. The more extensive the record to be obtained, the greater is the number of records necessary for final accuracy. The principal faults in much of the survey work to date lie in the attempt to include too much detail and in the use of too few records. Warren (1914) is of the opinion that ordinarily 1000 records should be used, tho 500 may be enough in some cases. However, the necessity of such large numbers depends somewhat upon the scope of the survey. By the law of averages, large numbers tend to eliminate individual errors. Spillman (1917) has said that the accuracy of any average depends on three things: first, on freedom from bias; secondly, on the number of items from which an average is obtained; and thirdly, on the accuracy of the individual items averaged. Considering the limitations of much of the experimental evidence to date, large numbers of survey records are undoubtedly productive of as nearly accurate results as are obtained by experimental work. As emphasized by Warren (1914), the region surveyed should be an agricultural, not a political, unit. Furthermore, the records should be taken only during a normal year unless records are to be obtained for consecutive years. Unfortunately for this study, the year 1912 was at first drier than normal, but the abundant rain which fell late in the growing season caused some blight rot; 1913, however, was a more nearly normal year.

BIOMETRY AS APPLIED TO CROP-SURVEY DATA

Biometry as a science is beginning to have wide application, wherever sufficient data make its application possible, in the solution of problems involving the study of the interrelation of factors or the study of cause and effect. Until the present time, biometry has been used mainly only in the study of inheritance and in the correlation of characters in large populations of plants and animals. Its use has been thus limited because only in such studies have conditions been so controlled that none but the factor or factors under observation could affect the results, and because it has been possible to use large numbers of individuals for such investigations. Biometry should have a place in the study of crop-survey data wherever large numbers of records are involved, in order that the coefficient of correlation may serve as a check on the conclusions otherwise drawn and that it may furnish, thru its frequency table, a description of the prevailing practice in the region in question.

Tolley (1917) states that the coefficient of net correlation affords a good means of determining the net effect of each of several factors bearing on a result, or of eliminating the effect of other factors when it is desired to find the true relationship between any two. Applying biometrical methods to farm-survey data on fattening baby beef, Tolley has shown how the gross apparent correlation between any two or more factors may be substituted in a derived formula and the net correlation of any two factors thereby deduced.

A biometrical analysis of some of the more influential factors involved in this study has been made, altho, owing to the relatively large numbers of records used in each study, only the gross correlation has been computed. Aside from the actual significance of the coefficients obtained, much information of descriptive value relative to the frequency of a given practice may be found in the frequency distribution tables. One of the chief functions of biometry is description. It affords a means of classifying a group of individuals not possible by any other means.

THE TAKING OF RECORDS

Five men constituted the party employed in the taking of records in 1913. This made it possible for four of the party to travel thru the potato regions in pairs while the fifth man copied and checked each day's records. In this way, any discrepancies in the records could be checked up by a return visit to the grower or by discussion within the party. The data on the 1913 crop were taken in 1914 by two men.

As previously noted (Spillman, 1917), the value and accuracy of survey data depend largely on freedom from bias. This may well apply to the selection of farms to be observed. Therefore it was decided that for these surveys the only limitation in the selection of a farm was to be in the acreage of the crop produced the previous year. This limitation was set at a minimum of 5 acres, tho a very few records were taken on farms having a production area of only 4 acres. The reason for the establishment of this minimum limit lies in the assumption that growers of acreages smaller than 5 are probably not growing potatoes in a manner comparable to the average of the region. The data on cost of production, tho obtained at the same time and indicated on the survey blank, are not a part of this study. The subject of cost has been studied by Fox (1919), formerly of the Department of Farm Management at Cornell University.

DESCRIPTION OF REGIONS SURVEYED

For a better understanding of the environmental conditions under which the potato crop was produced, a brief description of climate, soil, topography, elevation, length of growing season, market facilities, type of farming, land values, and status of potato production, is given for each of the four regions surveyed. Unfortunately, of the regions concerned, only Monroe and Clinton Counties have been soil-surveyed by the United States Department of Agriculture. More detailed knowledge as to these environmental influences may be obtained from figures 126 to 129.

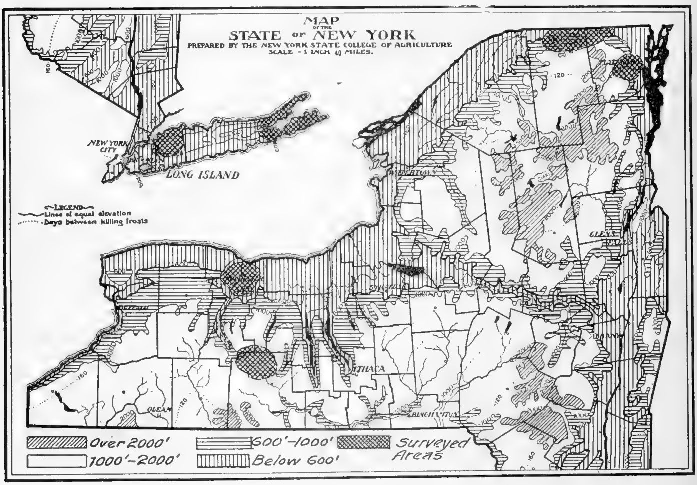

FIG. 126. ELEVATIONS OF THE REGIONS SURVEYED

LONG ISLAND

Most of the potato crop in Suffolk County is grown east of Riverhead on both the north and the south shores of Long Island. The Long Island Railroad furnishes the transportation facilities for practically all of the surplus crop of this region. Most of the roads are improved to a high degree. Thus the time required for shipments to reach New York City need not be over one day and no delay is necessitated by transfers to other railroads.

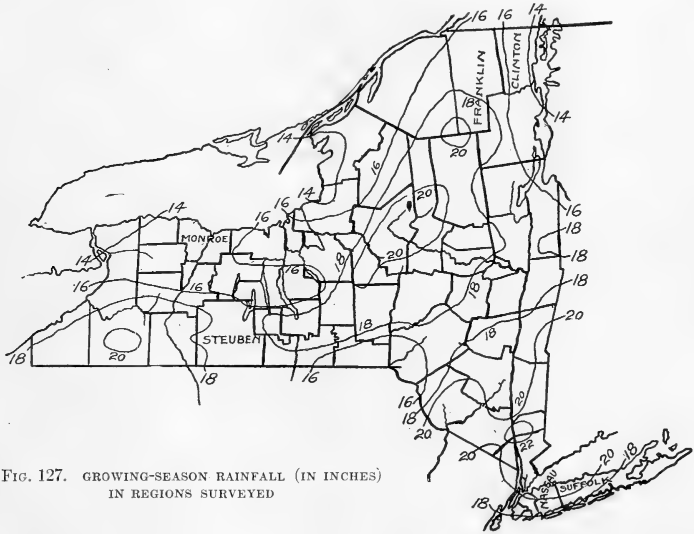

FIG. 127. GROWING-SEASON RAINFALL (IN INCHES) IN REGIONS SURVEYED

Nearly all of the crop in Nassau County is grown north of a line drawn east and west thru the central part of the county. Most of the surplus crop of this county is transported directly, in heavy wagons and motor trucks, to the Wallabout and Harlem Markets in Brooklyn.

The greater part of Long Island is of marine deposit formation, the elevation ranging from a point at about sea level, in the Hampton section, to an altitude of nearly 300 feet in some places on the north shore. The average elevation of the potato fields surveyed was 65.5 feet. Due to the low elevation of the south shore, the crop is exposed to heavy sea fogs which make conditions favorable to the development of late blight. The topography is in general fairly level, tho the slightly rolling lands along the north shore gradually rise until they merge into prominent hills along the Sound.

The potato sections of Long Island show an average growing-season rainfall of from 16 to 20 inches, which is somewhat higher than that of most of the potato sections of New York. Rainfall seldom limits production here. The tempering influence of the Atlantic Ocean affords a growing season of approximately 200 days between killing frosts, which is greater than that

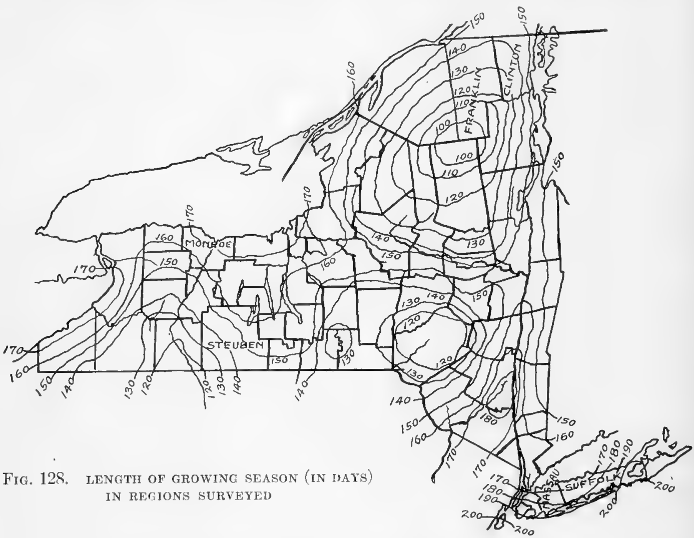

FIG. 128. LENGTH OF GROWING SEASON (IN DAYS) IN REGIONS SURVEYED

of any other section of New York. The growing season on Long Island is fully a month earlier than that in the other three regions under discussion.

The soil of most of the potato-growing areas of Long Island is of a sandy texture, topped by silty loam in layers of varying thickness. This is counter to a rather common impression that the Long Island crop is produced in sandy soil. The greater part of the central section of the island does consist of sand, and this supports little vegetation aside from scrub oak and pine. That the potatoes are grown mainly on the Sassafras series of soil is shown in figure 129.

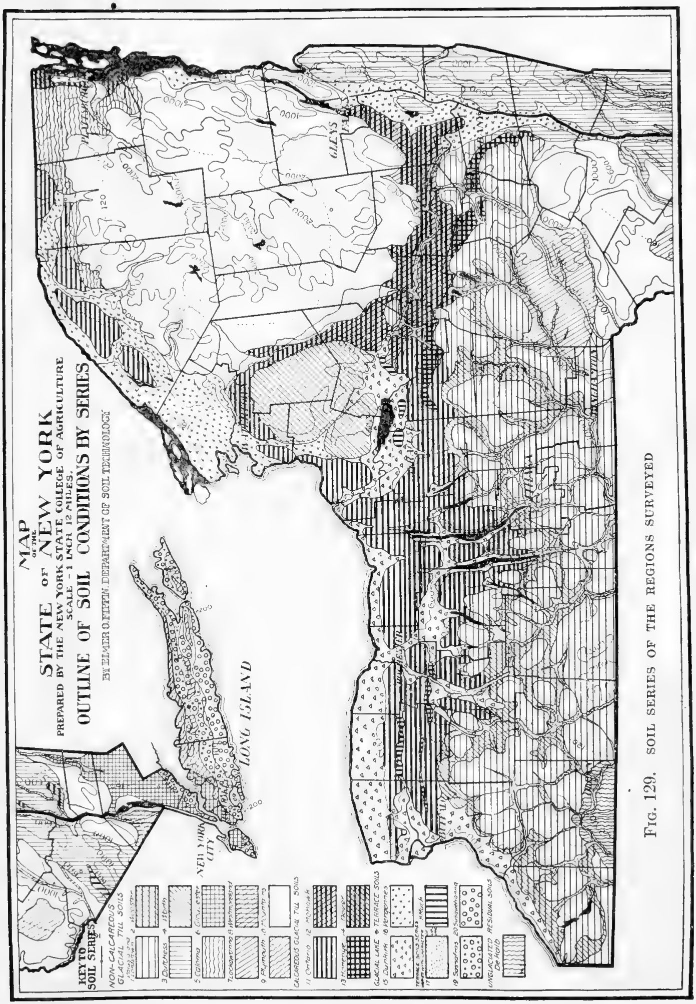

Fig. 129. Soil series of the regions surveyed

The importance of the crop on Long Island is shown by the fact that no regular system of crop rotation is practiced, potatoes being grown for several successive years on the same land. In order to maintain the humus content, cover crops of rye are turned under each spring. The commonest practice is two to four years of potatoes, the land being cover-cropped to rye over winter. Along the north shore, where a rotation is sometimes used, wheat seeded to clover and timothy follows potatoes, the hay being grown from one to two years before the sod is plowed for corn, cabbage, and cauliflower. Potatoes then follow these cultivated

FIG. 130. HARVESTING IRISH COBBLERS IN NASSAU COUNTY IN JULY

The large immature vines should be noted

crops. Wheat and hay are the principal rotation crops on the southern shore.

Much double-cropping is practiced in Nassau County, the early potatoes being harvested in July and the second crop in late August and early September. Land producing a first crop of potatoes is commonly planted to turnips, beets, carrots, or other root crops, or is set to cabbage for the fall market. Rye is used here also as a cover crop. A field in which Cobblers were harvested one day and turnips were planted the next day, is shown in figure 130.

Land values are higher on Long Island than in the other potato sections, partly because much of the land in Nassau County is held for real-estate purposes and partly because of its geographical advantages and adaptability for potato production. The values range from $100 an acre in Suffolk County, to $1000 an acre, real-estate value, in Nassau County.

The average size of the farms surveyed was 65 acres, of which 37 per cent was in potatoes. On the average, 44 per cent of the total crop acreage was in potatoes, while the average potato acreage per farm was 24.8. The potato crop is relatively more important in the farming system here than elsewhere among the regions surveyed.

The number of records taken on Long Island was 330, representing a total of 8188.16 acres planted to potatoes in 1912. The average yield per acre, on the farms surveyed, was 175.5 bushels.

STEUBEN COUNTY

The area of most intensive production in Steuben County lies in its northeastern part, along the Cohocton River valley and in the hill sections on each side. The Delaware, Lackawanna & Western and the Erie Railroad handle the potato shipments. Local buyers take most of the crop from the grower, buying it either at harvest time or on contract. They store it in temporary warehouses along the railroads or ship it direct. Because of the unevenness of topography and the heavy nature of the soil in this county, the highways are often so poor that the movement of the crop from field or cellar to the shipping point is seriously handicapped. For this reason, most of the crop is moved at the times when the roads are in the best condition. Much of it is shipped to New York and Philadelphia, but the variety Spalding's Rose 4 is sent to Florida as seed.

The elevation of the surveyed fields ranged from 1200 to 2100 feet, the average being 1659.2 feet. This wide range in elevation has considerable influence on the development of the potato crop, as is indicated by this study. A large part of the total crop is produced on hillsides of varying slope, the incline often being so steep as to limit the use of heavy machinery; on the other hand, many of the best potato fields are found on the level table-lands at the highest elevations.

Northern Steuben County has an average growing-season rainfall of from 16 to 18 inches, which is sufficient for maximum crops. Because of the heavy nature of the soil, years of abnormally large rainfall often cause much loss from blight rot. The growing season between killing frosts averages 150 days, and is usually sufficient to mature the crop. Because of better air drainage and cooler average temperatures, the crop is often later and the yields are larger on the farms at the higher elevations. This was not the case in 1912, however, as is shown later in the discussion of the influence of elevation.

Five soil series are principally concerned in the area studied in Steuben County, as shown by figure 129. Nearly half of the crop of 1912 was grown on Lordstown silt loam, which gave a higher average yield than any other series. In elevation this soil series is next to the Volusia series, which is found only at the highest elevations. Tho both of these soil series are naturally low in fertility, the highest average yield was obtained on the Lordstown series, while the lowest average yield was produced on the Volusia series. The soils on the hilltops are largely derived from shale and sandstone; the valley soils, altho naturally higher in fertility, contain more stone and gravel.

Relatively long and fixed rotations are used in Steuben County, the commonest being potatoes, oats, hay two years. Frequently the sod is left until long past its profitable stage for hay, with the result that the humus content remaining for the potato crop to follow is seriously depleted. Farms on which the sod was left down for the shortest period of years showed the highest yield, and vice versa. Sometimes wheat followed oats in the rotation, giving two successive years of grain. The wheat was used as the nurse crop. These farms showed a higher average yield of potatoes than did the farms using only one year of grain. This may have been due to the additional residual fertilizer left from the second year of grain, or possibly to production on better soil than is ordinarily devoted to potatoes. Buckwheat, in which Steuben County ranks second according to the United States census of 1909, is commonly used to follow old sod land that is being broken for potatoes or to break virgin land recently cleared. On the smaller potato farms, corn for grain or silage is grown in the rotation with potatoes.

Land values are as low in Steuben County as anywhere in New York, for much of the land is infertile and rough, and little of it has been sold or rented in recent years. The estimated values ranged from $25 to $80 and more an acre, the average being about $50. The average size of the farms surveyed was 145.8 acres, 10 per cent of this being in potatoes. The per cent of total crop acres per farm in potatoes was 18. The average yield per acre on the 360 farms surveyed, which represented a total of 5301.1 acres of potatoes, was 136.4 bushels.

MONROE COUNTY

The potato section of Monroe County covers most of the region east, west, and south of Rochester. Potatoes are an important crop on most of the farms south of the fruit belt that extends across the northern border of the county abutting on Lake Ontario. Excellent railroad facilities provide transportation for the marketing of the crop, loading stations being located on the New York Central, the Lehigh Valley, the Delaware, Lackawanna & Western, the Erie, and the Buffalo, Rochester, & Pittsburg Railroad.

Elevation is not an influential factor in this region, since its variation is only between 400 and 1000 feet, the average being 592.5 feet. In general the topography is gently rolling, and in only a very few places is it sufficiently uneven to affect production or the usual cultural practices.

The growing-season rainfall is somewhat less than that of the other regions, ranging normally from 14 to 16 inches. However, it is seldom insufficient for maximum production. Due to the tempering influence of Lake Ontario, the average growing season is 165 days, which is somewhat longer than that of the other regions except Long Island.

The soils on which the potato crop is produced are principally of the Dunkirk and Ontario series, as shown in figure 129. Altho both of these soils are naturally fairly fertile, a study of comparative yields shows that, other things being equal, the Dunkirk soils gave the higher production. The soil map of Monroe County shows an especially wide range in soil types within each of these series.

The cropping system of this region is usually a four-years rotation of potatoes and grain or another crop, oats, wheat, hay. Corn is most commonly chosen as the additional cultivated crop to be raised with potatoes, tho beans and cabbage are sometimes used. The value of potato land ranged from $50 to $250 an acre, the average acre value being $150. The farms surveyed averaged 112.07 acres in size, 11 per cent of the total acreage being in potatoes; and the importance of the crop is emphasized by the fact that 15 per cent of the crop acreage is in potatoes. The average yield per acre of the 1913 crop, for the 3728.25 acres of potatoes on the 300 farms, was 126.2 bushels.

FRANKLIN AND CLINTON COUNTIES

The areas of production in Franklin and Clinton Counties are two: one consists of a broad, level stretch of fertile valley land along the St. Lawrence River, extending across the northern end of Franklin County and over into Clinton County; the other consists of hill and valley farms on each side of the Saranac River, in central Clinton County. In both these areas the potato lands extend back into the foothills of the Adirondack Mountains. Most of the production centers in Franklin County are located along the Rutland Railroad, while the Delaware and Hudson Railroad handles most of the crop of Clinton County. The greater part of the surplus is marketed in the eastern seaboard markets after the early crops of Long Island, New Jersey, and the South have been sold. A thriving trade in seed potatoes has been developed with Long Island, New Jersey, and southern points.

Being in close proximity to the Adirondack Mountains, this region has a wide range in elevation. It varies from 300 to 1850 feet, the average for the farms surveyed being 1038.2 feet. The excellent yields obtained at the higher altitudes are due largely to the cool climate there afforded.

In spite of the range in elevation, very little of the crop is produced on anything but level land. The farms along the St. Lawrence River valley are generally level or gently sloping toward the river, and most of the crop in Clinton County is also grown on fairly level fields, either in the Saranac River valley or on top of the foothills of the Adirondacks.

Due to the northerly latitude of this region the growing season is relatively short, the average period between killing frosts being 150 days. Elevation and latitude are jointly contributing factors for an ideal potato climate conducive to late maturity of the crop. As a rule the growth is stopped by frost, resulting in a crop more or less immature at harvest time. This gives a product of excellent seed value and keeping qualities. The growing-season rainfall averages from 14 to 18 inches, the mountain areas receiving the greater precipitation. The rainfall is uniform thruout the growing season, each month averaging 3 or more inches.

Most of the soils of this region are a fine sandy loam and are included in the Ontario, Caloma, and Terrace soil series. The Ontario series comprises the area along the St. Lawrence River, and the Caloma and Terrace soils comprise most of the area in central Clinton County (fig. 129). The Ontario series is largely of sedimentary origin and its fertility is rather higher than the average; while the Caloma and Terrace soils are mainly of glacial drift formation and are of only mediocre fertility.

The commonest system of cropping is a five-years rotation of potatoes and corn, oats, hay three years. The corn is used mainly for silage. Hops have been regarded as a relatively important cultivated crop in the Franklin County area until recently, when low prices, disease, and competition with the western crop caused a decided decrease in acreage. At present, potatoes are the chief source of cash income in this district. Land values here are similar to those in Steuben County, the range being from $10 to $100 an acre, with the average at about $50.

The average size of the farms surveyed was 169.5 acres. Only 4 per cent of the total acreage, and 10 per cent of the crop acreage, was in potatoes. The average yield per acre on the 300 farms surveyed, representing 2160 acres, was 179.3 bushels.

METHOD OF STUDYING SURVEY DATA

As previously pointed out, one of the handicaps in any effort to determine, by an analysis of survey data, the absolute influence of a single factor on yield, lies in the difficulty of separating the influence of other factors from that of the one in question. This is a necessary step, however, in insuring accuracy and a correct interpretation of results. A preliminary study of factors influencing potato yield in Steuben County in 1912 (Hardenburg, 1915 b) indicated that the most important factors were the amount of seed used per acre, the value of manure and fertilizer employed per acre, and the frequency of bordeaux spraying. The results of the present study have borne out that conclusion. Therefore, in considering the influence of a given factor on yield, an effort has been made to eliminate as far as possible, or at least to give due credit to, other contributing factors.

Since the study of each region concerns but a single year, too definite conclusions must not be drawn in interpreting the data presented. Depending upon the normality of the season in which the crop was grown, the degree of influence of a given factor may or may not be maintained under average conditions. Tho cultural practices are not usually varied radically from one year to another, differences in the length of the growing season, in the average growing-season temperature, and in rainfall, tend to affect the influence of those practices. Therefore it will not be possible to answer, in any appreciable degree, many of the questions that will be raised. The consideration of experimental results is therefore of value in furnishing background for the study of each factor. As stated by Warren (1914), there are questions that can be answered only by a study of the results obtained on farms, and other questions that can be answered only by the results of experiments.

Little attempt has been made to discuss any potato literature except that pertaining to seed, fertilizers, and planting, these being obviously the most influential factors under the grower's control. In reviewing the literature, one is impressed by the large quantity available and by the meagerness and unreliability of the data given to substantiate the statements.

THE STUDY OF FACTORS

CLIMATE

A brief review of climatic conditions in each of the surveyed areas has been given, not because of any definite influence on the crop under consideration, but to make clearer the normal conditions to which the crop is subject. Facilities for taking weather data in each of these regions are not yet sufficient to allow of any attempt at the correlation of rainfall and temperature with yield for a given year.

In general, the average growing-season temperature to which the crop is subject has a marked influence on the vitality of that crop as used for seed. Briefly, high temperatures tend to produce devitalization. Long Island growers obtain average yields ranging from 150 to 250 bushels per acre from new Maine seed, but the use of the same stock for seed a second year results in greatly inferior yields, as is indicated in figure 131. The same principle is demonstrated in the rather common practice of introducing seed from northerly latitudes, a practice which is justified on the basis of better yields, as is shown in the tests cited under the caption *Source of seed.*

FIG. 131. GROWTH VARIATION BETWEEN NEW AND ONE-YEAR-OLD MAINE SEED STOCK ON LONG ISLAND

The photograph shows also the characteristic topography of potato lands in Suffolk County

Valuable studies of the influence of weather on the yield of potatoes in Ohio for a period of fifty-five years have been made by Smith (1915), and a similar study for a period of twenty-six years has been made in New York by Fox (1916). The relationship of both growing-season rainfall and temperature, in both States, is expressed in terms of the coefficient of correlation (r). A comparison of these coefficients shows that July is by far the most critical month with respect to these factors, in both Ohio and New York. The coefficient of correlation between temperature and yield is in most cases negative for both States, indicating that yield is inversely proportional to increase in temperature. So far as rainfall is concerned, the correlation for Ohio is positive and fairly large, indicating that rainfall is ordinarily a limiting factor in yield. The correlation of rainfall and yield in New York, on the other hand, is negative, showing that years of high rainfall are years of low yield. The average growing-season rainfall for the potato sections of New York, previously given as ranging from 14 to 20 inches, is evidently sufficient for this crop. The negative coefficient of correlation is probably a reflection of the fact that years of highest rainfall in New York have been years of severe loss from blight rot.

ELEVATION

Elevation as a factor influencing production has been determined from the figures shown on the topographic sheets of the surveyed areas published by the United States Geological Survey. As far as possible, the location of the potato fields for which data were taken was indicated on these topographic sheets at the time of taking the data. The chief difficulty in determining the absolute influence of elevation lies in the fact that increase or decrease in elevation is usually accompanied by a difference in soil type. A study of elevation, therefore, really involved also the consideration of both climate and soil. The writer is not aware that any test has ever been made in which either one or the other of these factors was studied with the other factor eliminated.

Progressive increases in altitude and in latitude are similar in that each is accompanied by a reduction in temperature. The United States Weather Bureau, in computing temperature equivalents, makes use of the principle that every 300 feet rise in altitude is accompanied by a reduction in temperature of one Fahrenheit degree.

Influence of elevation on Long Island

Elevation cannot be considered a potent factor in the Long Island area, for its highest point does not greatly exceed 200 feet. Many farms along the south shore of Suffolk County are below sea level, the sand dunes alone keeping out the sea. A typical Long Island potato field is shown in figure 131. The relation of elevation to yield in 1912 is shown in table 2:

TABLE 2. Relation of Elevation to Yield on 327 Long Island Farms in 1912

Elevation (feet)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer per acre	Average elevation (feet)
1 – 50	157	178.3	12.9	$35.31	26.4
50 – 100	87	157.5	12.0	27.71	64.8
100 – 150	53	184.3	12.4	32.20	117.2
150 – 200	22	188.8	12.2	33.01	167.7
200 and over	8	196.3	13.4	31.65	218.1
Total	327	....	....	....	....
Average	....	175.3	12.5	$32.39	65.5

Altho there is no proof in table 2 that the yield increases with an increase in elevation, there is a slight indication that this may be true. The farms located at 50 to 100 feet elevation had a lower yield than those at the lowest elevation, partly because they received less seed and fertilizer than any other group. Furthermore, the farms at the lowest elevation received slightly more than the average amount of seed and fertilizer per acre. It is improbable, however, that the wide difference in yield between the two groups at the lowest elevations was due entirely to differences in amount of seed and fertilizer. There may have been some basic reason why the 87 growers at the 50-to-100-feet elevation used the least seed and the least fertilizer, which would account in part for the lower yield. No such reason is apparent, however, from the data at hand.

Influence of elevation in Steuben County

The average elevation of the farms visited in Steuben County is greater than in any other of the regions concerned in this survey, it being 1659.2 feet. The elevation varies from 1200 to 2100 feet, a range of 900 feet, and within this range there is a considerable variation in the soil types, as is shown later in table 13 (page 1770). A summary of the average yields obtained at various elevations is given in table 3:

TABLE 3. RELATION OF ELEVATION TO YIELD ON 355 STEUBEN COUNTY FARMS IN 1912

Elevation (feet)	Number of farms	Average yield per acre (bushels)	Average unharvested yield per acre (bushels)	Average elevation (feet)
1200 – 1300	9	148.8	24.6	1,243.6
1300 – 1400	36	156.6	13.1	1,336.0
1400 – 1500	39	129.7	20.5	1,426.2
1500 – 1600	46	136.4	20.0	1,530.4
1600 – 1700	46	133.9	24.1	1,630.2
1700 – 1800	63	131.6	29.0	1,732.1
1800 – 1900	61	138.3	30.7	1,829.7
1900 – 2000	34	134.6	27.9	1,920.4
2000 – 2100	21	124.7	17.0	2,033.4
Total	355	....	....	....
Average	....	136.4	24.2	1,659.2

A general tendency for yields to decrease as elevation increases is ndicated by table 3. This is counter to the expected influence of altitude, and may be explained by the fact that the soil at the higher altitudes of this region is heavier and of lower natural fertility. Further evidence of this condition is found in the figures showing a greater percentage of unharvested yield due to blight rot, which is so common in these heavier soils, at the higher elevations.

The Green Mountain, or white-sprout, type of potato withstands less heat than does the Rural, or blue-sprout, type. Where the growing-season temperature is relatively cool, as in Franklin and Clinton Counties and on Long Island, the white-sprout type is therefore more common. In Steuben County, of 94 farms growing the white-sprout potatoes, 61 per cent were located above 1660 feet elevation and only 39 per cent were located below this level. Of 239 farms growing the blue-sprout type, 50 per cent were above and 50 per cent were below 1660 feet elevation. There is some tendency, therefore, to grow more of the white-sprout type at the cooler altitudes.

Influence of elevation in Monroe County

The range of elevation in Monroe County is between 400 and slightly over 800 feet. Little opportunity is therefore afforded to study the influence of this factor in this region. The figures in table 4, interpreted in the light of average seed and fertilizer used, show that elevation has some tendency to increase yield.

TABLE 4. RELATION OF ELEVATION TO YIELD ON 296 MONROE COUNTY FARMS IN 1913

Elevation (feet)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
400 – 500	30	130.5	12.6	$14.03
500 – 600	107	122.8	12.5	11.20
600 – 700	129	116.0	12.4	10.86
700 – 800	23	165.2	12.5	11.56
800 and over	7	225.4	14.7	11.39
Total	296	....	....	....
Average	....	127.1	12.5	$11.34

Influence of elevation in Franklin and Clinton Counties

A variation of over 1500 feet elevation in the farms in Franklin and Clinton Counties affords excellent opportunity for the study of the influence of elevation on yield. The summary given in table 5 shows a rather marked

TABLE 5. RELATION OF ELEVATION TO YIELD ON 290 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Elevation (feet)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer	Average elevation (feet)
300 – 600	33	154.8	11.6	$12.90	437.7
600 – 800	19	154.9	10.9	11.12	697.1
800 – 1000	31	185.1	11.5	13.09	895.5
1000 – 1200	47	184.0	12.1	13.10	1,094.4
1200 – 1400	101	179.1	12.2	12.72	1,296.9
1400 – 1600	42	191.0	12.5	13.22	1,468.6
1600 – 1850	17	193.4	11.8	14.13	1,709.7
Total	290	....	....	....	....
Average	....	177.3	11.9	$12.91	1,038.2

influence of this factor. With the amounts of seed and the value of manure and fertilizer used approximately equal, the best yields were produced at the higher mountain elevations.

Since the increase in elevation for this region is accompanied by a considerable variation in soil type, a part of the increase in yield at the higher levels may be due to the latter factor. However, since Franklin County has not been soil-surveyed, it is impossible here to measure accurately the influence of the soil. Very little difference in soil type was evident between the Dover fine sandy loam of the lower elevations and the Caloma fine sandy loam of the higher elevations in Clinton County.

CROP ROTATION

The benefits of crop rotation to a heavy-feeding cultivated crop such as potatoes have long been recognized. The crop survey as a means of comparing various rotations in a given region, however, has very limited possibilities, for in the older farming regions the same general type of rotation is followed thruout. Very few tests have thus far been made by the experiment stations to determine the most suitable place in the rotation and the best length of rotation for potatoes in a given region. Probably the most valuable work has been done by Hartwell and Damon (1916) in their twenty-years comparison of different rotations of corn, potatoes, rye, and grass, at the Rhode Island Station. The principal feature of this work lies in a comparison of four-, five-, and six-years rotations of potatoes, rye and rowen, grass, corn, the grass being left down for from one to three years. No stable manure was used, but complete commercial fertilizers were added to the sod each year. In the matter of fertilizers, Hartwell and Damon's experiment is not comparable to farm practice in New York, where little or no commercial fertilizer is ever used, stable manure being generally applied, instead, as a top dressing, during the last year of sod or perhaps just before plowing for corn or potatoes. The average yields per acre of potatoes obtained by Hartwell and Damon, in the rotations including grass for one, two, and three years, were 200, 199, and 223 bushels, respectively. It appears that their commercial-fertilizer treatments were sufficient to maintain a maximum condition of sod thruout the three years.

A test on the influence of various fertilizers on potatoes, conducted at the Rothamsted station, is reported by Hall (1905). In this test the crop was grown for twenty-six consecutive years on the same land, and under each treatment the yields declined during the later as compared to the earlier years of the test. Long Island is the only section in New York in which the crop is grown without rotation, and it is only the increased use of fertilizers that has maintained yields there. Not only is it difficult to get sufficient stable manure for the potato crop on Long Island, but many growers do not find it economical to haul fertilizer in this form so great a distance as would often be necessary. Consequently, each year more than a third of the growers sow a cover crop of rye after potatoes. Some use the cover crop every year, while others use it only every second or third year, and some not at all. In the consideration of the influence of cover crops on yield, only those fields are included on which a cover crop was grown in the fall and winter preceding the potato crop. In table 6 the average yields that are obtained directly after cover crops, are compared with those obtained when no previous cover crop had been used.

TABLE 6. Relation of Cover Crop to Yield on 313 Long Island Farms in 1912

Treatment	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer per acre
Cover crop	131	174.1	12.6	$32.61
No cover crop	182	177.3	12.5	32.25
Total	313	....	....	....
Average	....	175.5	12.5	$32.40

The figures given in table 6 should not be construed to mean that cover crops are not beneficial to the potato crop on Long Island, because the yields obtained in the group listed as not using a cover crop may have been produced on farms which used a cover crop two or three years previously or on farms whose soil was naturally higher in organic content. Granting this, the data on cover crops for Long Island are not sufficient to indicate either advantage or disadvantage accruing from its use. It is true that in 1912 growers who had not sown a cover crop the previous fall did not attempt to supplement the soil fertility by using more fertilizer. This in itself may indicate that, in the main, only those growers who actually needed the cover crop to maintain yields were the ones who used it.

The rotations followed in Steuben County, consisting usually of potatoes, grain, and hay, vary principally in the number of successive years that the hay and the grain are left on the same ground. Commercial fertilizer is applied lightly at the time of planting potatoes, and, altho what stable manure is available is put on the sod to be plowed for potatoes, there is seldom enough to cover the entire potato acreage. The yields of hay are largely dependent on the residual fertilizer left from that applied directly to the grain crops. Thus in the longer rotations, in which sod is left down for three or more years, only a poor supply of root and stubble residue is left to supply humus to the potato crop. A comparison of the influence on the yield of various types of rotations in this region is shown in table 7:

TABLE 7. RELATION OF ROTATION TO YIELD ON 240 STEUBEN COUNTY FARMS IN 1912

Rotation	Manure or fertilizer on part of acreage			Manure or fertilizer on entire acreage			No manure nor fertilizer used		
	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Number of farms	Average yield per acre (bushels)	Average cost of manure and fertilizer	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)
Potatoes, grain, hay..	13	177.0	10.9	8	189.1	$10.51	1	150.0	7.5
Potatoes, grain, hay, hay..............	117	134.9	10.3	58	150.1	13.98	7	106.2	9.6
Potatoes, grain, hay, hay, hay.........	62	122.7	10.0	26	135.0	11.95	3	103.6	10.5
Potatoes, grain, grain, hay, hay.........	25	150.1	9.2	12	160.9	13.34	.....	......	....
Potatoes, grain, grain, hay, hay, hay.....	11	143.0	8.8	5	160.2	20.34	1	50.0	8.8

Eliminating the factors of seed and fertilizer as given in table 7, the yield consistently decreased with each successive year that the sod remained in rotation. This shows the tendency of the seeding to become thinner and of less value as a source of humus for the potato crop, the older it becomes. The figures for the last two rotations in the table — which differ from the first three in that they contain two years of grain instead of one, and from each other only in the number of years of successive hay crops — show a higher average yield of potatoes with them than with the first three. This may be due to the additional residual fertilizer left from that applied to the extra year of grain, or to the factor of naturally better soil as indicated by the tendency to produce more grain.

The type of rotation commonest in each region is indicated by the figures in table 8 on the percentage of total crop acres occupied by each crop listed. No fixed rotation is indicated for Long Island, where potatoes are grown for a varying number of successive years on the same land. The

TABLE 8. Relative Importance of Crops on Farms Surveyed

Crop	Per cent of crop acres				
	Long Island	Steuben County	Monroe County	Franklin and Clinton Counties	Average
Hay	12	42	24	59	34.25
Potatoes	43	18	15	10	21.50
Oats	2	21	17	19	14.75
Corn for grain	15	1	6	1	5.75
Wheat	5	3	14	0	5.50
Orchard	0	1	8	2	2.75
Rye	1	4	4	1	2.50
Corn for silage	1	0	2	4	1.75
Cabbage	4	0	3	0	1.75
Sweet corn	5	0	1	0	1.50
Beans	1	0	4	0	1.25
Buckwheat	0	4	0	1	1.25
Cauliflower	5	0	0	0	1.25
Barley	0	2	1	1	1.00
Garden truck	4	0	0	0	1.00
Brussels sprouts	2	0	0	0	0.50
Corn for fodder	0	1	0	1	0.50
Alfalfa	0	1	1	0	0.50
Peas	0	1	0	0	0.25
Oats and barley	0	1	0	0	0.25
Sugar bush	0	0	0	1	0.25

figures for Steuben County indicate a rotation of potatoes, oats, hay two years; those for Monroe County, a rotation of potatoes with corn or beans or cabbage, oats, wheat, hay one to two years; and those for Franklin and Clinton Counties, a rotation of potatoes with corn, oats, hay three years.

A review of the experimental literature on the influence of crop rotation in potato production shows a striking preference for either grass, or a legume productive of considerable vegetative growth, as a crop to precede potatoes. This is evidence of the efficient use which the potato crop is able to make of this form of organic material. Such legumes as cowpeas, soybeans, and crimson clover commonly precede potatoes in the Southern and the South Atlantic States, while timothy, in combination with red or alsike clover, is used generally thruout the principal potato States. Alfalfa is considered the ideal legume to precede potatoes in the alfalfa belt of the West. The root and stubble residue from these crops not only contributes to the food requirements of the potato, but also improves the aeration, the temperature, and the moisture-holding ability of the soil.

Generally speaking, the rotations of the three regions aside from Long Island are long enough not to serve as factors limiting yield except as the type of rotation may affect fertilizing practices. Inasmuch as the available stable manure is not usually applied for the benefit of the hay crops, and the residual organic fertility is not thereby maintained or improved, the sod residue commonly turned under before potato planting is usually less valuable after a three-years stand than after a stand of shorter duration.

VALUE OF LAND

The farmer's estimate of farm land values is very often not based on productive value, altho this factor, together with the distance from railroad and city and the salability of the farm, usually enters into the appraisement. A correlation of estimated value with average yields will show, in a measure, the extent to which productive ability of potato land enters into its evaluation. App (1916), studying the factors that influence farm profits on potato farms in Monmouth County, New Jersey, found a consistent tendency for farm acre values to decrease as distance from the railroad increased. His similar conclusions with respect to crop acre values and labor income, however, do not seem warranted from the data given.

The figures obtained on land values in the regions surveyed represent the estimated selling value of potato land only. A more important factor than the distance from the post office, which was ascertained and used in making this estimate, would have been that of the distance from the nearest city, village, or railroad.

Apparently, on Long Island, land valued up to $550 an acre is yielding an increased crop with the increase in value (table 9). However, it is true also that the increase in land values is accompanied by the use of more seed and more fertilizer, and by more spraying for blight. These combined factors would easily account for the consistent increase in yield. The farms showing a land value of over $550 an acre are located principally in Nassau County, at a considerable distance from the post office, and are appraised at their real-estate value. In fact, much of the land has been sold at fabulous prices for real-estate purposes and is now rented

TABLE 9. RELATION OF VALUE OF LAND TO YIELD ON 330 LONG ISLAND FARMS IN 1912

Value	Number of farms	Average yield per acre (bushels)	Average distance from post office (miles)	Amount of seed used per acre (bushels)	Value of manure and fertilizer per acre	Per cent of farms using bordeaux
Less than $250	118	147.0	2.7	12.1	$30.24	24
$250–$400	132	184.7	2.3	12.6	33.50	45
$400–$550	27	196.7	2.8	13.0	35.24	52
$550 and over	53	191.9	5.6	12.7	32.73	11
Total	330	....	....	....	....	....
Average	.....	175.5	3.0	12.5	$32.40	32

back to the original owner who is again growing potatoes on it. Somewhat less seed and fertilizer are used on these farms, and less spraying is done on them.

In Steuben County, potato land valued up to $80 an acre gives increased yields with the increase in value (table 10). Tho the amount of seed used

TABLE 10. RELATION OF VALUE OF LAND TO YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Value	Number of farms	Average yield per acre (bushels)	Average distance from post office (miles)	Amount of seed used per acre (bushels)	Value of manure and fertilizer per acre	Per cent of farms using bordeaux
$25–$40	46	110.2	5.3	9.6	$ 7.93	4
$40–$50	111	134.1	4.2	10.4	9.01	6
$50–$60	76	139.4	3.6	10.1	10.86	8
$60–$70	44	144.4	3.6	10.4	11.80	0
$70–$80	42	148.2	2.9	10.3	12.29	0
$80 and over	41	145.1	2.5	9.5	10.31	5
Total	360	....	....	....	....	....
Average	.....	136.4	3.8	10.1	$10.14	5

per acre is about the same thruout, there is a tendency to spend more in manure and fertilizer for the higher-priced land. The real reason for this is doubtless the relative cheapness with which manure and fertilizer can be handled by the growers nearest the villages. The increased yield of the higher-priced land may be due in part to this increase in the value of manure and fertilizer used. Land values decrease as the distance from the post office increases, in Steuben County. Distance, in fact, may largely determine the valuation of potato land.

In Monroe County, as in Steuben County, the yields increased with the increase in land values (table 11), the yield increase being accompanied by,

TABLE 11. RELATION OF VALUE OF LAND TO YIELD ON 297 MONROE COUNTY FARMS IN 1913

Value	Number of farms	Average yield per acre (bushels)	Average distance from post office (miles)	Amount of seed used per acre (bushels)	Value of manure and fertilizer per acre	Per cent of farms using bordeaux
$ 50 – $100	27	103.4	4.3	11.1	$10.86	19
$100 – $150	145	128.3	2.6	12.5	10.09	23
$150 – $200	69	130.6	2.3	12.7	12.02	35
$200 – $250	56	129.3	2.3	13.0	14.10	18
Total	297	....	....	....	....	....
Average	.....	127.0	2.6	12.5	$11.33	24

TABLE 12. RELATION OF VALUE OF LAND TO YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Value	Number of farms	Average yield per acre (bushels)	Average distance from post office (miles)	Amount of seed used per acre (bushels)	Value of manure and fertilizer per acre	Per cent of farms using bordeaux
$ 10 – $ 25	29	160.2	4.2	10.2	$12.35	0
$ 25 – $ 50	105	173.4	3.5	11.3	13.73	0
$ 50 – $ 75	114	189.0	3.7	12.9	12.79	2
$ 75 – $100	42	178.2	2.5	12.3	11.83	0
$100 and over	10	176.9	1.6	13.0	15.02	10
Total	300	....	....	....	....	....
Average	.....	179.3	3.4	12.0	$13.01	1

and doubtless largely due to, an increase in the amount of seed and in the value of manure and fertilizer used. Here also the land values tend to decrease as the distance from the post office increases.

In Franklin and Clinton Counties there is a tendency to spend more for seed, fertilizer, and spraying, on the farms having the higher-valued potato land (table 12). This expenditure is apparently justified on land valued up to $75 an acre. Above that point, the average yield did not increase even with increased expenditure. This may be taken as an indication that such land was valued at more than its productive ability would justify. These more valuable farms are situated near Peru, in Clinton County, and are thus highly valued because of their location in the apple section of northern New York rather than on the basis of their adaptability to potato culture.

SOIL

It has not been possible to study the influence of soil on yield on Long Island and in Franklin and Clinton Counties. Altho Clinton County has been soil-surveyed, it is included in the tabulations with Franklin County, and the records taken were insufficient to justify the making of such a study on Clinton County alone. The Monroe County soils map, published by the United States Bureau of Soils, has been used in correlating yield and other factors with the soils of that region.

Professor E. O. Fippin, formerly of the Department of Soil Technology at Cornell University, accompanied by the writer, made a reconnaissance soil survey of the surveyed area in Steuben County in the summer of 1916. Professor Fippin's familiarity with soil mapping in New York enabled him therefor to sketch the boundaries of the various soil types and series on the topographic sheets previously used in locating the surveyed potato fields.

Nearly half of the crop in Steuben County is grown on the Lordstown soil series at an average elevation of 1718.2 feet. As indicated in table 13, the highest average yield was obtained on this soil series in spite of the fact that only an average amount of seed was used and somewhat less than the average value of manure and fertilizer. In contrast to this, the Volusia soil series, located on the hilltops at an average elevation of 1785.5 feet, yielded the lowest average yield of any series in spite of the fact that about the average amount of seed was used and more than the average value of manure and fertilizer. The principal difference between these two soil series lies in the somewhat darker color and the better oxidized condition of the Lordstown series. It is true that the soils of this region become lighter in texture and of higher gravel and stone content as the valleys are approached. This condition is probably blamable, at least in part, for the higher percentage of blight rot on the heavier soils at the higher elevations, as indicated in table 13. Altho very little spraying for blight was done in 1912, it was noted that the fields which were sprayed returned a higher average yield than those which were not sprayed, irrespective of the soil type. Apparently, depth of planting and date of planting are not influenced by soil type.

TABLE 13. RELATION OF SOIL TYPE TO YIELD ON 293 STEUBEN COUNTY FARMS IN 1912

Soil type	Number of farms	Average yield per acre (bushels)	Average unharvested yield per acre (bushels)	Average value of manure and fertilizer	Average amount of seed used per acre (bushels)	Per cent of farms using bordeaux	Average depth of planting (inches)	Average date of planting	Average elevation (feet)
Volusia silt loam and loam........	36	115.9	32.7	$10.79	10.2	0	3.4	May 17	1,785.5
Lordstown silt loam	151	144.8	25.2	9.35	10.9	6	3.1	May 19	1,718.2
Wooster gravelly loam...........	19	126.9	16.0	11.22	9.2	0	3.2	May 17	1,637.9
Rodman gravelly loam...........	59	142.1	24.0	11.76	10.1	2	3.0	May 22	1,496.5
Chenango gravelly loam...........	28	140.4	23.7	9.25	11.0	7	3.1	May 18	1,364.6
Total............	293	......	......	......	......	......	......	.....	....
Average..........	.....	139.6	25.1	$10.08	10.6	4	3.1	May 19	1,642.8

In the area surveyed in Monroe County, four soil series are concerned—Ontario, Dunkirk, Clyde, and Genesee. In all, fourteen soil types are involved, but because of the small number of farms on some of these types, only those shown in table 14 are used in correlating soil with yield and other factors. On the basis of seed used, of value of manure and fertilizer, and of percentage of farms using bordeaux, the Dunkirk fine sandy loam and the Dunkirk fine sand are naturally the best for potatoes from the standpoint of yield, among the types considered. Altho in 1913 nearly half of the crop in the surveyed area was grown on Ontario fine sandy loam, under at least average cultural treatment, it gave the lowest average yield per acre of any series studied. As indicated in the summary of table 14, the soil types of the Dunkirk series seem to give higher yields than those of the Ontario series. The average amount of seed, fertilizer, and spraying was about the same in both series. Here, as in Steuben County, depth and date of planting do not seem to be influenced by any difference in soil type. The average elevation of the two soil series summarized is almost identical. In brief, with more seed, more fertilizer, and a higher percentage of area sprayed with bordeaux, the Ontario soils yielded 20 bushels per acre less than did the Dunkirk soils.

TABLE 14. RELATION OF SOIL TYPE TO YIELD ON 253 MONROE COUNTY FARMS IN 1913

Soil type	Number of farms	Average yield per acre (bushels)	Average value of manure and fertilizer	Average amount of seed used per acre (bushels)	Per cent of farms using bordeaux	Average depth of planting (inches)	Average date of planting	Average elevation (feet)
Dunkirk fine sandy loam	20	186.6	$11.45	12.4	15	2.9	June 14	659.3
Ontario fine sandy loam	124	122.0	11.09	12.6	19	2.9	June 3	595.2
Dunkirk gravelly loam	32	123.1	9.83	12.0	25	3.1	June 7	586.2
Ontario loam	52	124.2	12.99	13.0	6	3.3	June 6	582.0
Dunkirk gravelly sandy loam	11	123.7	9.01	11.0	27	3.3	June 8	573.6
Dunkirk fine sand	14	137.2	11.24	12.4	21	3.7	June 7	515.0
Total	253	....	....	....	....	....	....	....
Average	.....	128.3	$11.31	12.5	17	3.1	June 6	591.0
Summary								
Ontario series	176	122.7	$11.65	12.7	27	3.0	June 5	591.3
Dunkirk series	77	142.6	$10.42	12.0	17	3.2	June 10	590.5

PLOWING

The study of plowing as to its bearing on yield is treated under two headings — time of plowing and depth of plowing. The average date of plowing was obtained by averaging the actual dates of plowing for each region. It is recognized, of course, that this date will vary from year to year, depending on seasonal conditions. The only region in the State in which fall plowing was done to any appreciable extent was Franklin and Clinton Counties. To determine the depth of plowing, the grower was in each case asked to give his estimate of the actual depth, in inches, which he plowed for potatoes.

Time of plowing

For many years, such advantages as increased liberation of plant food, elimination of injurious insects, and improved soil texture, have been pointed out in favor of fall plowing. Very little experimental evidence has been presented, however. Dickens (1914) has furnished data covering two years of work at five substations in Kansas, all showing a decided increase in yield on fall-plowed as compared to spring-plowed land for potatoes. A summary of the data on the season at which potato land was plowed in each of the surveyed regions in this study is given in table 15:

TABLE 15. PER CENT OF POTATO LAND FALL- OR SPRING-PLOWED IN THE AREAS SURVEYED

Time of plowing	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Fall	1.5	1.7	0.33	57.0
Part fall and part spring	2.1	8.0	0.00	16.0
Spring	96.4	90.3	99.67	27.0

The average dates of spring plowing in 1912 for Long Island and for Steuben County were April 3 and April 29, respectively. The average dates of spring plowing in 1913 for Monroe County and for Franklin and Clinton Counties were May 15 and May 12, respectively. No speculation as to the reason for the greater proportion of fall plowing in Franklin and Clinton Counties is offered, but it is presumed to be due as much to weather conditions for the year as to labor competition with work on other crops. The comparative yields on land plowed at the different seasons in Franklin and Clinton Counties are shown in table 16:

TABLE 16. RELATION OF TIME OF PLOWING TO YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Time of plowing	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer	Average acreage of potatoes
Fall	171	183.7	12.4	$12.81	7.2
Part fall and part spring	48	173.9	11.6	14.47	7.2
Spring	81	173.2	11.5	12.46	7.2
Total	300	....	....	....	....
Average	......	179.3	12.0	$13.01	7.2

In view of the fact that about a bushel more of seed and a slightly higher value of manure and fertilizer were used on the fall-plowed land, the difference in yield of 10.5 bushels per acre in favor of fall plowing may not be entirely due to a difference in the time of plowing. There is no indication that fall plowing is commoner on the larger potato acreages, since the average acreage was the same in all three groups.

Depth of plowing

It might be expected that a crop such as the potato, which develops underground and is subject to varying conditions of soil moisture and soil texture, would be influenced by the factor of depth of plowing. However, no actual experiments with this problem have come to the writer's attention. Dickens (1914) states that shallow plowing has given the best results on loamy soil at the Kansas station. Stone (1905) states that at the Cornell station, deep plowing on the Dunkirk gravelly soil gave the best results. Generally speaking, shallow plowing has been recommended for heavy soils and deep plowing for light soils.

The possibility of drawing definite conclusions from a study of a factor depending so much on the grower's estimate and on only one year's results, is necessarily limited. This is one of the factors that for its ultimate solution must depend upon carefully controlled experiments on a given soil type in each region concerned. From the following discussion of the regions herein considered, it would appear that depth of plowing is an important factor only on soils of either extreme of texture — deep planting increasing the area for tuber development in heavy soils, and providing for planting at the moisture-table depth in light soils.

Depth of plowing on Long Island

Altho the soils of Long Island are noticeably lighter than those of any other potato region in the State, a marked correlation of depth of plowing with yield is evident in table 17. An increase in the depth of plowing was accompanied by the use of more seed and fertilizer per acre and a greater

TABLE 17. Relation of Depth of Plowing to Yield on 328 Long Island Farms in 1912

Depth of plowing (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer	Average number of times sprayed with bordeaux
Less than 5	26	163.7	11.4	$30.01	2.5
5–6	60	162.9	11.6	30.53	3.0
6–7	119	173.8	12.8	32.15	3.0
7–8	65	174.1	12.9	33.65	3.3
8–9	36	188.6	12.7	35.26	3.4
9 and over	22	202.1	12.9	32.13	3.6
Total	328	....	....	....	....
Average, 6.3 inches	......	175.6	12.5	$32.42	3.1

frequency of spraying. These factors contributed in some degree to the greater yield apparently resulting from the deeper plowing. In answer to the question whether the deeper plowing was accompanied by deeper planting, it may be stated here that, whereas the Long Island fields were plowed at about the same average depth as those of the similarly light soils of Franklin and Clinton Counties, the average depth of planting was deepest on Long Island, and shallowest in Franklin and Clinton Counties, of the four regions. Apparently, deeper plowing on Long Island is to be advised.

By virtue of its descriptive value as well as its value as a means for measuring correlation, the biometrical method has been applied to this factor of depth of plowing for Long Island, as also for the other regions, and the result is shown in figure 132. The correlation coefficient, r, here

Yield per acre, in bushels

Depth of plowing, in inches	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	
3			1	1	2		1						5
4			4	1	9	5			2				21
5		2	5	15	12	6	10	5	2		1	2	60
6	1	2	5	11	33	16	19	11	8	8	5		119
7		2	5	4	16	11	12	5	7	3			65
8			5	5	7	3	8	4	1	1	1	1	36
9			1		1	1	8	1	2		1		15
10			1				2	1	1	1			6
11													0
12					1								1
	1	6	27	37	81	42	60	27	23	13	8	3	328

$r = 0.159 \pm 0.036$

FIG. 132. CORRELATION OF DEPTH OF PLOWING AND YIELD ON 328 LONG ISLAND FARMS IN 1912

has the value 0.159 ± 0.036. Inasmuch as the coefficient is positive and is more than three times its probable error, it shows a significant degree of correlation between depth of plowing and yield. Present-day biometricians are now well agreed that the significance of a coefficient is measured not alone by its absolute value, but in the light of its consistency with coefficients of other series or other years and its probable error.

Depth of plowing in Steuben County

In contrast to soil conditions on Long Island, the soils of Steuben County are the heaviest of any of the four regions. Nevertheless, a rather marked positive correlation between depth of plowing and yield is shown in table 18. In this region, as on Long Island, the growers who plowed deeper

TABLE 18. RELATION OF DEPTH OF PLOWING TO YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Depth of plowing (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
4– 6	52	125.8	9.9	$ 8.59
6– 8	258	136.2	10.1	10.39
8–10	50	149.4	10.4	10.54
Total	360	....	....	....
Average, 6.6 inches	......	136.4	10.1	$10.06

for potatoes were inclined to plant more seed and to use a greater value of manure and fertilizer. The difference in yield of nearly 24 bushels per acre resulting from a difference of 4 inches in depth of plowing is evidently due, in part at least, to the increase in depth of plowing. The coefficient of correlation shown in figure 133 is 0.190 ± 0.034, a value expressing

Yield per acre, in bushels

Depth of plowing, in inches	1– 25	26– 50	51– 75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	
4				2	1	2	2									7
5		1	4	7	11	14	5	2								44
6		2	13	31	32	23	13	12	4	3						133
7	1	2	7	18	19	26	26	18	4	4		1				126
8	1		2	5	10	12	6	6	1	3					1	47
9				1		1						1				3
	2	5	26	64	73	78	52	38	9	10	0	2	0	0	1	360

$r = 0.190 \pm 0.034$

FIG. 133. CORRELATION OF DEPTH OF PLOWING AND YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

significant correlation. Most of the crop in this region is grown on soils underlain at rather shallow depths with more or less impervious strata. Deeper plowing under these conditions would tend to enlarge the area adapted to maximum tuber development.

Depth of plowing in Monroe County

The soils of Monroe County may be considered intermediate in texture between those of Long Island and those of Steuben County. As a rule, they are deeper than those of the latter region. A study of table 19 shows no

TABLE 19. RELATION OF DEPTH OF PLOWING TO YIELD ON 261 MONROE COUNTY FARMS IN 1913

Depth of plowing (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
4–7	47	136.4	11.7	$11.95
7–8	93	134.2	12.2	10.97
8–9	90	132.5	12.7	12.05
9 and over	31	145.0	14.5	11.42
Total	261	....	....	....
Average, 6.6 inches	....	135.6	12.6	$11.57

apparent relation between depth of plowing and yield. With approximately the same fertilization for each depth of plowing, the slight tendency for increased yields at the deeper plowing may easily be attributed to the larger amount of seed planted.

The coefficient of correlation shown in figure 134 is 0.006 ± 0.039. Both

Yield per acre, in bushels

Depth of plowing, in inches	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	
4				1											1
5					1					1					2
6		2	7	12	8	12	5	4	2						52
7		2	10	19	24	18	13	10	2	1				1	100
8	1	1	16	30	11	20	13	10	3			1			106
9		2	4	8	6	9	1		1	2					33
10			1			1	2						1		5
	1	7	38	70	50	60	34	24	8	4	0	1	1	1	299

$r = 0.006 \pm 0.039$

FIG. 134. CORRELATION OF DEPTH OF PLOWING AND YIELD ON 299 MONROE COUNTY FARMS IN 1913

the coefficient and its probable error indicate a lack of relationship between depth of plowing and yield for this region. Apparently the minimum depth of plowing was sufficient for maximum production in Monroe County soils.

Depth of plowing in Franklin and Clinton Counties

The figures shown in table 20 indicate that depth of plowing does not influence yields in Franklin and Clinton Counties. Tho the amount of seed

TABLE 20. RELATION OF DEPTH OF PLOWING TO YIELD ON 299 FARMS IN FRANKLIN AND CLINTON COUNTIES IN 1913

Depth of plowing (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
4– 5	23	175.5	11.3	$14.51
5– 6	70	180.3	11.4	12.37
6– 7	118	179.2	12.3	13.33
7– 8	52	180.4	11.9	13.38
8–10	36	179.6	12.7	12.07
Total	299	....	....	....
Average, 6.2 inches	......	179.3	12.0	$13.01

planted was increased slightly as the depth of the plowing was increased, the amount of fertilizer used was not increased. Consequently there would be ample opportunity for any influence of depth of plowing to be reflected in the yields under this method of study. The coefficient shown in figure 135 is 0.028 ± 0.039, and indicates no relationship between the depth of plowing and the yield.

Depth of plowing, in inches	Yield per acre, in bushels: 76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	
4	1	1	3	6	8	1	2	1		23
5	5	3	11	16	19	6	3	5	2	70
6	2	13	23	17	32	16	8	5	2	118
7	2	5	8	8	10	10	8	1		52
8	1	4	4	5	6	5	4	2	1	32
9	1		1		1		1			4
	12	26	50	52	76	38	26	14	5	299

r = 0.028 ± 0.039

FIG. 135. CORRELATION OF DEPTH OF PLOWING AND YIELD ON 299 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

MANURE AND FERTILIZER

The commercial-fertilizer industry, as a country-wide enterprise, began in the Eastern States and dates from about 1860. Previous to that time, the potato crop depended for its plant food largely upon the natural available supply of the soil, supplemented by applications of barnyard manure. Manure has been recommended by many experiment stations as perhaps the best source of nitrogenous plant food for this crop. However, as the acreage increased in the East and the soils became more impoverished, the need for a commercial source of plant food became imperative. Today there are few crops which require more and respond better to fertilizer than do potatoes, tho even yet commercial fertilizer is used very little on the newer potato lands of Michigan, Wisconsin, and Minnesota. From the beginning of the fertilizer industry, hundreds of tests have been conducted by the eastern state experiment stations to determine the influence on the yield of potatoes of such factors as the amount of fertilizer used, its analysis, and the time and method of its application. According to Whitney (1910), 1769 such tests were conducted between 1868 and 1908, a period of forty years. Of all the tests made up to 1908, nearly 72 per cent fall within the ten-years period from 1890 to 1900. Twenty-three States contributed to these tests, and about 57 per cent of the total were made in New York, Ohio, and New Jersey. Whitney states that it is impossible to draw conclusions even from an average of similar experiments among those listed, since the variation in the yields of check plots of individual experiments sometimes ranges as high as 900 per cent.

The crop survey has been found to have its limitations in the study of such questions as best analysis, best amount, or best source of ingredients, of a fertilizer to be used for potatoes. It is generally impossible to get information from the grower as to the analysis or the source of the elements of the fertilizer he has used. Many growers who were questioned had been more impressed by the brand name or by the price paid for the fertilizer than by its analysis. An attempt to correlate the amount of fertilizer per acre with the yield resulting was found impracticable without knowledge of its analysis, owing to the fact that large applications of a cheap fertilizer might be no more than equivalent to small applications of a high-grade fertilizer. Furthermore, many growers used manure in place of fertilizer, or vice versa, while many others used both on the same acreage. The study of the influence of manure and fertilizer on yield in the surveyed regions has therefore been made on the basis of the combined value per acre of manure and fertilizer. Estimates of the value of the manure used, made by the grower, and the prices he paid for fertilizer, have been used. In determining the proportion of the total value of the manure received by the potato crop, depending on the time and place of its application, 50 per cent of its value was charged if it was applied directly to the potato crop, 30 per cent if it was applied to the crop just preceding the potatoes, and 20 per cent if it had been applied two years before potatoes. This evaluation of residual manure is not based on exact experimental knowledge, but is presumed to represent the approximate availability of stable manure for successive crops. The Department of Agricultural Economics and Farm Management at Cornell University estimates that, on the heavier soils, 40, 30, 20, and 10 per cent of the value of manure is received by the first, the second, the third, and the fourth crop after its application, respectively. On lighter soils, which are more subject to leaching, probably a charge of 50 per cent to the first crop would be more nearly correct. A uniform basis of evaluation has been applied in this study.

Home-mixed fertilizers

Potato growers have never adopted the practice of mixing their own fertilizer, even in the regions where potatoes are raised on a very extensive scale. The advantage of using home-mixed fertilizers has usually been considered to lie in a saving in cost rather than in an increase in yield. Woods and Bartlett (1909) compared several home-mixed fertilizers with a common ready-mixed commercial fertilizer of the same analysis. They found only a very slight advantage, on the average, in favor of the home-mixed fertilizers.

In table 21 is shown the relative extent to which home mixing is practiced in the regions surveyed. These figures indicate that an average of about

TABLE 21. Per Cent of Growers Using Home-mixed Fertilizer on Potatoes

Long Island	Steuben County	Monroe County	Franklin and Clinton Counties
6	5	10	1

5.5 per cent of the potato growers in New York mix their own fertilizer for potatoes. A comparison of the various ingredients which constitute the home-mixed fertilizers used in these four regions is given in table 22:

TABLE 22. Per Cent of Growers Using Various Ingredients in Home-mixed Fertilizers

Ingredient	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Nitrate of soda	95	26	3	100
Acid phosphate	90	84	100	75
Muriate of potash	95	62	87	100
Tankage	95	0	10	0
Blood and tankage	5	0	13	0
Dried blood	10	0	10	0
Bone meal	10	5	0	25
Nitrate of soda and dried blood	0	60	10	0
Sulfate of potash	5	21	13	0
Raw rock phosphate	10	5	0	0
Fish scrap	55	0	0	0

The percentages shown in table 22 indicate that on Long Island, nitrate of soda and tankage are used almost universally as the sources of nitrogen in home-mixed fertilizers. As is typical of coast regions, much fish scrap also is used for its nitrogen content. Acid phosphate is the principal source of phosphoric acid, altho ten per cent of the growers who mix their own fertilizers on Long Island use bone meal, and an equal number use raw rock phosphate, for the phosphoric acid supply. Of the potash supply 95 per cent comes from muriate of potash, and the remaining 5 per cent comes in the sulfate form.

In Steuben County, nitrate of soda and dried blood used together was the main source of nitrogen, no tankage being used by the five per cent of growers who mixed their own fertilizer. Phosphoric acid was obtained by eighty-four per cent of these growers from acid phosphate, and five per cent obtained it from bone meal. More sulfate of potash was used in this region than in any of the other regions surveyed, altho 62 per cent of all the potash was obtained in the muriate form.

One-tenth of the growers visited in Monroe County mix their own fertilizer. About an equal number of these growers obtained their nitrogen supply from dried blood and from tankage. A few used nitrate of soda. All of these growers obtained their phosphoric acid from acid phosphate. Muriate of potash was used by eighty-seven per cent of the growers, while thirteen per cent used the sulfate form for potash.

Only one per cent of the growers in Franklin and Clinton Counties practiced home mixing. These men used only nitrate of soda for nitrogen and muriate of potash for potash. Acid phosphate was the principal source of phosphoric acid, altho a little bone meal was used.

Summarizing for the four regions, it is seen that nitrate of soda is the commonest source of nitrogen. Generally, however, there is a tendency to mix nitrate of soda with either dried blood or tankage to furnish nitrogen in both a quickly and a slowly available form. Acid phosphate and muriate of potash are the principal sources of phosphoric acid and potash, respectively.

Quantity and value of fertilizer

The optimum amount of fertilizer for any crop necessarily depends on three principal factors: the available supply of plant food in the soil, the feeding requirements of the crop, and the net return per unit invested in fertilizer. Of these, the first two are usually measured by the yield per acre, regardless of cost, while the last is too often neglected. Macoun (1905) has shown, by a large number of analyses, that a 200-bushel yield of potatoes (exclusive of the tops) removes an average of 40 pounds of nitrogen, 20 pounds of phosphoric acid, and 70 pounds of potash, per acre of soil. This is about the same amount of nitrogen and phosphoric acid, but twice as much potash, as is removed by comparable yields of wheat and corn.

Whitney (1910) summarized the many fertilizer experiments on potatoes in this country as to the influence of increasing the amount of fertilizer. So far as nitrate of soda, acid phosphate, and muriate of potash, used singly, are concerned, no consistent increase in yield has resulted from increasing the amount up to 500 pounds per acre. Increasing the amount of complete commercial fertilizer up to a ton and more per acre has, on the contrary, consistently increased the yields. The figures shown, however, would indicate that the increase in yield caused by amounts exceeding a ton has not been profitable. The same conclusions can be drawn regarding the use of manure in these experiments up to an amount not exceeding 20 tons per acre.

One of the oldest and best series of fertilizer experiments on potatoes, covering many years, was begun on Long Island in 1895, by the New York Agricultural Experiment Station at Geneva (Van Slyke, 1895). Comparison of the yields from the use of 500, 1000, 1500, and 2000 pounds of fertilizer, up to 1898, showed that it was not profitable to use more than 1000 pounds per acre. The tests in 1898 showed 1500 pounds to be the most profitable amount. The curve of relation between the cost of fertilizer and the yield of potatoes, altho irregular, shows a positive correlation. Jordan (1900), reporting on a continuation of these Long Island tests in 1900, showed that whereas the highest yields were obtained with 2000 pounds of fertilizer per acre, the greatest net gain from the crop resulted when only 1000 pounds was used. Rane and Hall (1904), at the New Hampshire station, found that 1500 pounds of commercial fertilizer was the most profitable amount to use, whether or not normal applications of manure were used. Greater amounts of fertilizer, either with or without manure, were not profitable. Kohler (1910), in a triplicate series of plots conducted at the Minnesota station in 1910, showed that under Minnesota conditions it would not pay to use more than 800 pounds of fertilizer per acre, and in most of his tests 650 pounds gave the highest gain. The gain in yield from the elements used singly was almost negligible, their efficiency showing only when in combination. Kohler recommended the use of commercial fertilizer only when the supply of stable manure became insufficient in quantity. The experiments of Zavitz (1916) at the Ontario station, covering cooperative and station tests for five and three years, respectively, show a gain in yield, in most cases, resulting from an increase in either the amount or the value of the fertilizer used. Manure and fertilizer in combination, and manure alone, gave the greatest yields per acre and formed the cheapest fertilizer in both sets of experiments, not counting the cost of freight and application. So far as profit is concerned, therefore, the results of the Ontario experiments must be discounted. General experience has shown that the high cost of handling stable manure for potatoes on a large scale is often prohibitive.

Manure and fertilizer used in the four regions

There is considerable variation in the amount of manure and fertilizer used in the four regions surveyed. On Long Island, where the crop is grown successively on the same land, it is necessary to use large amounts of fertilizer in order to maintain the yields. In table 23 are given data concerning the use of manure and fertilizer in the four areas surveyed. It is obvious from this table that the use of manure on potatoes is closely associated with, and largely dependent upon, the dairy industry.

TABLE 23. SUMMARY OF MANURE AND FERTILIZER USED IN THE FOUR REGIONS SURVEYED

Region	Per cent of growers using manure or fertilizer or both	Average value per acre of manure and fertilizer on farms using them	Per cent of growers using fertilizer on potatoes	Average amount of fertilizer per acre (pounds)	Per cent of growers using manure on potatoes	Average amount of manure per acre (tons)
Long Island	100	$32.42	100	1,922	21	5.2
Steuben County	95	11.00	39	270	93	12.2
Monroe County	100	14.84	65	406	98	12.0
Franklin and Clinton Counties	99	13.14	76	516	79	11.0

The first column of percentages in table 23 includes not only the growers who applied manure or fertilizer directly to potatoes, but also those who applied manure or fertilizer to the crop preceding potatoes, the potatoes receiving a certain percentage of value from the residue. On this basis, the average value of manure and fertilizer used on Long Island was more than twice that for the Monroe and the Franklin and Clinton County areas, and nearly three times that for the Steuben County region. The second and third columns of percentages in the table represent the growers who applied fertilizer and those who applied manure, respectively, directly to the potato crop. (The reader is referred to page 1178 for the method used in evaluating manure.) It may be noted that manure is used directly for the potato crop by almost every grower in Steuben and Monroe Counties, while on Long Island only one grower in five uses it in this way. Growers on Long Island do not find it so practicable because of the expense of handling it for large acreages, the danger of scab infection, and the insufficiency of the supply for their fertilizer needs. In Steuben and Monroe Counties, manure is almost invariably applied to the sod land previous to plowing for potatoes. It is so applied also, but to a lesser extent, in Franklin and Clinton Counties, altho here much manure is applied to new seeding and some is applied to oats.

It is evident from table 23 that the region in which only a small proportion of the growers use fertilizer on potatoes is also the region in which the least fertilizer is applied to an acre. The average application of manure per acre in each region shown in the table, is reckoned not on the basis of those acres alone which received manure, but on the basis of the total potato acreage of those farms where manure was applied. Thus, on Long Island, manure is applied to only a small proportion of the total potato acreage per farm, while in the other regions most of the acreage is covered. The amount per acre averages nearly 10 tons, tho the rate varies from 10 to 20 tons.

The extent to which fertilizer and manure are used in Monroe County and in Franklin and Clinton Counties is fairly similar. The least fertilizer is used in Steuben County. Whether more could be used profitably in any of these regions is discussed in the subsequent studies.

Value of manure and fertilizer on Long Island

Inasmuch as the amount of seed used has been found to be a very influential factor in determining yield, this factor is eliminated as far as possible in the studies of other factors. Therefore, in studying the influence of the value of manure and fertilizer on yield, the records were first sorted into groups, according to the value of manure and fertilizer, and were then resorted according to the amount of seed used, as shown in table 24:

TABLE 24. RELATION OF VALUE OF MANURE AND FERTILIZER TO YIELD ON 330 LONG ISLAND FARMS IN 1912

Value of manure and fertilizer per acre	Less than 12 bushels of seed per acre		From 12 to 14 bushels of seed per acre		14 bushels and more of seed per acre		Average of totals	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than $30	67	155.5	43	157.1	13	176.4	123	158.9
$30–$40	58	172.1	60	174.0	38	196.2	156	180.1
$40 and over	14	182.7	23	187.5	14	222.1	51	198.0
Total	139	......	126	......	65	......	330	....
Average	.....	166.0	.....	170.2	.....	197.8	.....	175.5

With the amount of seed used remaining constant, the yield was increased in every instance by an increase in the value of manure and fertilizer used. Furthermore, the yields were apparently sufficiently increased by the use of fertilizer to the value of at least \$40 an acre, to make such applications profitable. It is evident that the maximum limit of fertilization in 1912 did not exceed the point of optimum profit.

The correlation between value of manure and fertilizer, and yield per acre, for this region is significantly expressed by the positive coefficient 0.244 ± 0.035 shown in figure 136.

Cost of manure and fertilizer per acre	Yield per acre, in bushels: 26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	
\$11–\$15				1									1
\$16–\$20			1	3	2								6
\$21–\$25			9	12	21	9	13	2	3	1			70
\$26–\$30		3	6	9	16	10	16	6	1	2		2	71
\$31–\$35	1	3	7	6	23	14	14	11	14	4			97
\$36–\$40			3	1	12	5	10	4	4	3	2		44
\$41–\$45			1	3	3	2	5	3		2	4		23
\$46–\$50					3	2		1	1		1		8
\$51–\$55				1		1	1				1	1	5
\$56–\$60				1						1			2
\$61–\$65				1			1						2
\$66–\$70													0
\$71–\$75													0
\$76–\$80					1								1
	1	6	27	38	81	43	60	27	23	13	8	3	330

$r = 0.244 \pm 0.035$

FIG. 136. CORRELATION OF VALUE OF MANURE AND FERTILIZER, AND YIELD, ON 330 LONG ISLAND FARMS IN 1912

Value of manure and fertilizer in Steuben County

In Steuben County the value of manure and fertilizer has been studied in a similar way. As appears in table 25, however, little manure and fertilizer is used here. Altho the average results indicate an increase in yield from the use of as much as \$50 worth of manure and fertilizer per acre, the increased yield from applications of more than \$20 worth per acre was not sufficient to cover the extra cost of the fertilizer. Therefore, in spite of the relatively small amount of fertilizer applied in this region, there may be other factors that limit the profit possible from larger applications. The coefficient of correlation between this factor and yield, for this region, is 0.289 ± 0.033, as shown in figure 137.

TABLE 25. Relation of Value of Manure and Fertilizer to Yield on 155 Farms in Steuben County in 1912

Value of manure and fertilizer per acre	From 6 to 10 bushels of seed per acre		From 10 to 14 bushels of seed per acre		From 14 to 18 bushels of seed per acre		Average of totals	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
$ 4–$12	25	127.8	41	148.0	5	182.8	71	144.4
$12–$20	21	141.3	27	162.4	3	287.1	51	160.0
$20–$50	11	134.9	17	162.8	5	217.0	33	166.4
Total	57	......	85	......	13	......	155	....
Average	.....	133.9	.....	155.2	.....	213.7	.....	153.7

Yield per acre, in bushels

Cost of manure and fertilizer per acre	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	
$ 0–$ 1					1											1
$ 1–$ 5	1	2	8	20	25	15	13	5	1							90
$ 6–$10		1	11	22	23	29	18	12	1	2						119
$11–$15			3	13	8	14	8	11	2	4		1			1	65
$16–$20			1	1	5	7	8	4	2	2						30
$21–$25			1	4	4	6	1	5	1	1						23
$26–$30					2	1	4					1				8
$31–$35				1	2			1								4
$36–$40									1							1
$41–$45																0
$46–$50									1	1						2
	1	3	24	61	70	72	52	38	9	10	0	2	0	0	1	343

$r = 0.289 \pm 0.033$

Fig. 137. Correlation of value of manure and fertilizer, and yield, on 343 Steuben County farms in 1912

Value of manure and fertilizer in Monroe County

The influence of manure and fertilizer in Monroe County is marked, and, except in a few cases where too few records were available, the results are consistent under constant amounts of seed used. It is evident from table 26 that not enough manure and fertilizer was used in this region so that the

TABLE 26. RELATION OF VALUE OF MANURE AND FERTILIZER TO YIELD ON 300 MONROE COUNTY FARMS IN 1913

Value of manure and fertilizer per acre	Less than 10 bushels of seed per acre		From 10 to 12 bushels of seed per acre		From 12 to 14 bushels of seed per acre		From 14 to 16 bushels of seed per acre		16 bushels and more of seed per acre		Average of totals	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
$ 1–$10	27	99.4	41	109.2	59	114.7	28	125.1	10	176.9	165	118.2
$11–$20	9	130.9	19	138.2	46	123.0	36	144.1	9	142.4	119	133.9
$21 and over	1	120.9	3	156.2	6	161.7	5	162.2	1	150.0	16	158.5
Total	37	......	63	......	111	......	69	......	20	......	300	....
Average	....	106.9	....	120.0	....	120.1	....	137.5	....	163.2	....	126.2

point of diminishing returns was reached. The yields increased sufficiently, up to the highest value of manure and fertilizer used, to warrant the cost. Evidently it would be safe to recommend the use of larger amounts on potatoes in this region. The positive coefficient of correlation shown in figure 138 is 0.258 ± 0.036, a value significant and consistent with the coefficients for the other regions.

Cost of manure and fertilizer per acre	Yield per acre, in bushels: 1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	
$ 1–$ 5		1	7	17	9	7	3								44
$ 6–$10	1	3	18	28	20	25	14	7	3	1			1		121
$11–$15		2	10	14	11	14	8	10	4	2				1	76
$16–$20			3	9	8	11	6	6							43
$21–$25		1		1	1	3	3			1					10
$26–$30				1	1	1		1	1						5
$31–$35															0
$36–$40															0
$41–$45												1			1
	1	7	38	70	50	61	34	24	8	4	0	1	1	1	300

r = 0.258 ± 0.036

Fig. 138. Correlation of value of manure and fertilizer, and yield, on 300 Monroe county farms in 1913

Value of manure and fertilizer in Franklin and Clinton Counties

A constant increase in yield for each increase in value of manure and fertilizer used, is shown in table 27 for the Franklin and Clinton County

TABLE 27. Relation of Value of Manure and Fertilizer to Yield on 290 Franklin and Clinton County Farms in 1913

Value of manure and fertilizer per acre	Less than 12 bushels of seed per acre		From 12 to 14 bushels of seed per acre		14 bushels and more of seed per acre		Average of totals	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than $10	40	149.2	35	182.1	19	174.8	94	167.1
$10–$15	40	164.2	39	187.3	26	199.9	105	181.4
$15 and over	43	170.4	27	190.0	21	221.7	91	188.2
Total	123	......	101	......	66	......	290	....
Average	.....	161.6	.....	186.2	.....	198.0	.....	178.8

region. The increase in yield obtained by growers using $15 worth or more of manure and fertilizer, over that obtained by growers using less, was sufficient to warrant the extra cost. Only twelve growers in this region used more than $25 worth of manure and fertilizer per acre. In view of the decreasing rate of increase in yield between the last two groups, it is doubtful whether a larger expenditure than $25 an acre would have shown a profitable increase. The correlation coefficient for this factor and yield, as shown in figure 139, is 0.169 ± 0.038. This indicates a significant relation, but one not so strongly marked as that for the other three regions.

Cost of manure and fertilizer per acre	Yield per acre, in bushels: 76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	
$ 1–$ 5	2	7	3	4	2	1		1		20
$ 6–$10	2	9	13	21	23	13	6	3		90
$11–$15	5	3	21	15	38	14	8	5	2	111
$16–$20	1	6	8	10	6	7	9	3	2	52
$21–$25	1	1	2	1	3	2	1	1	1	13
$26–$30		1	1	1	2	1	1	1		8
$31–$35			1							1
$36–$40					2					2
$41–$45							1			1
	11	27	49	52	76	38	26	14	5	298

r = 0.169 ± 0.038

FIG. 139. CORRELATION OF VALUE OF MANURE AND FERTILIZER, AND YIELD, ON 298 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Analysis of fertilizer

The average potato grower of New York is even yet none too familiar with the significance of fertilizer analyses. As previously stated, it was difficult to get information as to the analyses of the brands used, many of the growers having been more impressed by the price paid or the brand name. Most of the fertilizer experiments for some years have justified the practice, as found in the surveyed regions, of using fertilizers in complete form for potatoes.

Aside from the more fundamental physiological processes stimulated by each of the essential plant-food elements in plant growth, nitrogen functions principally in producing foliage, phosphorus in hastening maturity, and potash in increasing starch production. These elements in combination naturally maintain a balance of value in successful potato production.

Whitney (1910), in summarizing fertilizer tests on potatoes up to 1908, showed that: (1) there has been a consistent increase in the average yield of potatoes with the increase in the number of minerals used in mineral fertilizers; (2) there has been a similar increase in the average yield from an increase in the number of minerals used in combination with organic fertilizers; (3) the use of organic fertilizers in combination with minerals resulted in higher average yields than resulted from mineral fertilizers alone; and (4) manure and commercial fertilizers produced higher average yields than any other type of fertilizer. Ballou (1910) and Gourley (1910) substantiate these general conclusions in reporting the results of a fifteen-years comparison of nitrate of soda, acid phosphate, and muriate of potash, used both alone and in combination on potatoes. These tests have shown that, altho the cheapest cost of increase per bushel was obtained from the use of acid phosphate alone, the greatest profit per acre resulted from the use of the complete fertilizer. The Rothamsted station, in England (Hall, 1905), experimenting for twenty-six years and using five varieties of potatoes on a series of ten plots, compared the yields from plots receiving ammonium salts alone, nitrate of soda alone, superphosphate alone, and mixed mineral fertilizer. The average yields resulting from these treatments varied in the order listed, ranging from the lowest yields with ammonium salts to the highest yields with mixed mineral fertilizer. Since these plots grew potatoes successively for twenty-six years, and since potatoes yielded less with nitrogenous fertilizers than with mineral salts alone, it was concluded that "the potato finds a difficulty in obtaining ash constituents rather than nitrogen from an impoverished soil." Balentine (1894) conducted greenhouse experiments to compare the foraging power of the potato plant for phosphoric acid, with that of other crop plants. He used identical amounts and forms of nitrate and potash fertilizer, but varied the phosphatic form. He compared the results from equivalent amounts of phosphoric acid in mostly insoluble forms with those from the soluble form and with the check in each crop series. The results showed that the potato plant is not able to make use of this element in the insoluble form nearly so well as do wheat, corn, peas, and turnips.

Because of its importance in stimulating the vigor and yield in the crop and in satisfying the feeding requirements of the plant, potash had occupied the most important place in potato fertilizers up to the time when this survey was made. Rane and Hall (1904) compared the yields from plots containing 5, 10, and 15 per cent of potash, respectively, and those from plots containing no potash at all. They found that at the New Hampshire station, altho the yield was increased up to 15 per cent of potash, the most profitable results came from the 10 per cent of potash in a complete fertilizer. Several years later T. C. Johnson (1916) compared complete fertilizers differing only in that they contained 3, 5, and 7 per cent, respectively, of potash. He obtained the best results from the 5-per cent fertilizer, since that containing 7 per cent of potash seemed to retard maturity and decrease the yield. Conner (1906), at the Florida station, compared complete fertilizers containing 7, 8, 9, and 10 per cent of potash, respectively. Tho this was but a one-year test, the check plots averaged nearly as high yields as did the plots receiving potash, which indicates that probably potash is not a limiting factor in the soil at the Florida station.

Under the recent war conditions, growers in the Eastern States were forced to do without potash or to use less. Woods (1918), at the Maine station, has attempted to determine the possibility of obtaining satisfactory yields without this element. His average results for the three years 1915, 1916, and 1917 show that, whereas fairly good yields have been obtained with no potash, the yield has been increased 26 bushels an acre by the addition of 3 per cent of potash. The additions of 5 and 8 per cent of potash have given practically no increase above that from 3 per cent. The high percentage of potash previously used in Maine was evidently not needed, or else the soil had become temporarily stocked with a surplus. Chemical analyses have shown that the sandier soils of the coastal plain are more deficient in potash than the heavier soils farther inland. This fact and the more intensive cultivation of potatoes probably account for the larger amounts of potash previously used in these regions. It might be supposed, therefore, that yields of potatoes cannot long be maintained without this constituent. The recent studies of Dr. Oswald Schreiner, of the United States Department of Agriculture, on potash hunger in the Aroostook potato region in Maine and in the Norfolk potato truck areas, bear out this conclusion. The writer has recently observed marked examples of potash hunger in the potato fields of Long Island. Evidently the shortage of potash is beginning to be felt.

Of the two principal forms of potash — muriate, or the chloride form, and sulfate — the muriate has always been the more commonly used on this crop. The reasons for this are the greater cost and the lesser supply of the sulfate form. It is occasionally stated, tho the point does not seem to be borne out by much experimental evidence, that the chlorine in muriate of potash is detrimental to quality in the potato. There has generally been little difference between the two forms as to the yield resulting. Rane and Hunt (1897), in a one-year test, used 87 varieties of potatoes and obtained a very slight advantage in favor of muriate of potash. Many years later, Brooks (1914) obtained an increase in yield of 11 bushels per acre in favor of the sulfate form, with an additional improvement in quality.

The experiments of Conner (1906) show results from the use of various amounts of ammonia and of phosphoric acid in complete fertilizer, which not only are inconsistent but also show average yields not essentially different from those from the check plots. T. C. Johnson (1916), comparing the results from 2, 4, and 8 per cent, respectively, of phosphoric acid in complete fertilizer, found the best results from the 8-per-cent analysis. His results with varying amounts of nitrogen were inconclusive. Woods (1918), in a test to compare nitrogenous fertilizers in combinations of nitrate of soda, ammonium sulfate, and organic forms, thru the years 1914 to 1917, inclusive, found practically no advantage for any one form over another.

Altho many different analyses of fertilizers were used in 1912 and 1913 in the surveyed regions, the majority of growers in each region were buying fertilizers of the same analysis. In table 28 are shown the analyses of the fertilizers in commonest use at that time, in the four regions:

TABLE 28. Commonest Analyses of Fertilizers Used in the Four Regions Surveyed

Rank	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Used by majority	3–8–7	2–8–10	2–8–10	2–8–10
Second in amount used	4–8–7	0–10–8	0–10–8	0–10–8
Third in amount used	5–8–5	0–8–10	0–8–10	0–8–10

Because of the higher percentage of nitrogen in the fertilizer used on Long Island, this region has used a higher grade of fertilizer than any of the other regions. The extra nitrogen has been used to maintain this element in view of the heavy draft on it caused by the continuous potato culture. The greater use of manure and sod residue in the other regions has furnished the nitrogen lacking in the additional fertilizer used. Aside from the nitrogen content, the fertilizers used in the four regions have been similar in analysis.

Method of applying fertilizer

The method of applying fertilizer to potatoes is a question not well worked out because it is complicated by, and dependent on, such factors as soil type, amount of fertilizer used, and method of planting the crop. The question as treated here relates to (1) the depth of applying the fertilizer relative to the seed pieces, (2) broadcasting as compared with drilling, and (3) time of application relative to time of planting the crop. Obviously, fertilizer should be applied at that depth which will afford it a constant supply of moisture to make it available to the root system of the potato plant. As this depth is less in heavy soils than in light soils, both fertilizer and seed are generally applied less deeply in heavy than in light soils. Since the root system of the potato plant normally develops laterally to a radius of from 18 to 24 inches, the question of depth of application would seem more important than that of whether the application should be by drill or broadcast. The question of time of application must depend on the availability of the fertilizer used and the seasonal distribution of rainfall.

Taft (1892) reported the comparative yields obtained by placing fertilizer above and below the seed piece in a year of light rainfall. All plots gave a gain of from 14 to 34 bushels per acre in favor of the applications below the seed piece. Taft and Coryell (1894) reported on the same test covering three years and using complete fertilizer on three varieties. The results were all in favor of the application of fertilizer below the seed piece, the gain being from 25 to 40 bushels per acre. Munson (1894) compared the relative efficiency of applying fertilizer by the Rural-New-Yorker trench system, in which the fertilizer is placed in mellow earth two inches above the seed, with the method of applying it to the surface and harrowing in. Not enough difference in yield was obtained to pay for the extra labor of making the trench required in the former method.

Rane and Hall (1904), replicating plots three times, compared yields from fertilizer applied above and below the seed, both with and without the use of stable manure. They obtained in all cases an average difference of 18 bushels per acre in favor of the shallow applications. No mention was made of the rainfall available that year.

Van Slyke (1895), at the New York station, compared potato yields grown under 1000, 1500, and 2000 pounds of fertilizer per acre, respectively, applied both broadcast and in the drill row. In all cases in which 1500 pounds or less was used, the drill-row applications gave the better yield by about 10 bushels per acre. When 2000 pounds was applied, there was a difference of 17.5 bushels per acre in favor of broadcasting. This difference was probably due to a slight injury to the seed pieces caused by contact with the fertilizer applied in the drill row, for the stand in the latter case was rather uneven. Rane and Hall (1904), using 1500 pounds of fertilizer per acre, compared the yields obtained by applying all in the hill with those from applying half in the hill and half broadcast. No check plots, and only three plots altogether, were used, but a small yield favoring the half-and-half method was obtained. The gain, however, was due to a larger yield of culls under this method. Hall (1905), in reporting the experience of the Rothamsted station, stated that phosphoric acid and potash should generally be applied in drills, but that kainit should be applied broadcast. Jordan and Sirrine (1910) compared these two methods of application at three points on Long Island during the years 1905 to 1908, inclusive. Altho the differences were small in all cases, there was an average gain of 3 bushels per acre in favor of the drill method. Applications of 500, 1000, and 1500 pounds, respectively, were compared under each method. Woods (1917), using 1000 pounds and 1500 pounds of fertilizer, respectively, all broadcast, all drilled, and a part used either way with the remainder applied after the crop was up, found differences favoring the drill method but no greater than might be expected as within experimental error. The greatest average difference between the two methods, thru the years 1914 to 1916, inclusive, was 6 barrels in favor of drilling. Woods concluded that nothing is to be gained by the practice commonly followed in Maine, of applying some fertilizer along the row at the first cultivation, for this method is less convenient and apparently no more efficient than applying all the fertilizer in the row at planting time.

Much variation in the method of applying fertilizer has been observed in the surveyed areas. Wherever machine planters were used, the fertilizer was generally applied with these. On Long Island, however, where 98 per cent of the crop was planted by machine, nearly forty per cent of the growers applied the fertilizer broadcast, using a grain drill or a lime sower before planting. Tables included in the study of this factor show that most of the fertilizer not applied thru the planter was applied broadcast before planting. Generally this means an application only a few days prior to planting the crop.

Without exception, on Long Island a higher average yield resulted from the broadcasting of fertilizer before planting (table 29). This difference in favor of broadcasting is in part due to the greater quantity of seed usually planted when this method is used. But the difference is sufficient to be significant. Furthermore, the growers in the first fertilizer group who broadcast the fertilizer, used less seed than did those who applied the fertilizer in the drill row. Apparently the average of nearly a ton of fertilizer per acre used in this region in 1912, was more efficient when broadcast than when drilled.

There are rather too few farms included in each of the groups for Steuben County (table 30) to allow any definite conclusions to be drawn. The differences in yield apparently due to difference in the method of fertilizer application, are all probably due mainly to the indicated difference in the amount of seed planted. This leads to the conclusion that for Steuben County, when as little as the average of 270 pounds of fertilizer per acre is used, it is fully as efficient to apply it all in the drill row as to broadcast it either just before or just after planting.

Altho the differences in yield between the two methods employed in Monroe County were small, they are consistent thruout (table 31). Usually, less seed was planted per acre by those broadcasting fertilizer before planting than was used by those in the other group, yet the yields favor the method of broadcasting. The writer is unable to reconcile this conclusion with that for Steuben County. Whether the exception here favoring broadcasting when an average of only 406 pounds of fertilizer per acre was used, is due to seasonal rainfall conditions, is purely conjecture which can be settled only by controlled experiments over a protracted period.

A study of table 32, weighing the influence of the amount of seed and the value of the fertilizer used in Franklin and Clinton Counties, indicates that here, as in Monroe County, the broadcasting of the fertilizer proved more efficient in 1913 than the application of it in the drill row. It is of

TABLE 29. RELATION OF METHOD OF APPLYING FERTILIZER, TO YIELD, ON 319 LONG ISLAND FARMS IN 1912

Method	Value of fertilizer per acre									Average		
	From $15 to $25			From $26 to $35			$36 and over					
	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)
Broadcast before planting	18	153.9	10.8	66	187.5	13.0	47	211.9	14.0	131	191.8	13.1
In row at planting	65	148.1	11.8	92	165.9	12.3	31	167.7	12.2	188	161.0	12.1
Total	83	....	....	158	....	....	78	....	......	319	....	....
Average	.....	149.3	11.5	.....	175.8	12.6	.....	194.3	13.2	.....	174.6	12.5

TABLE 30. RELATION OF METHOD OF APPLYING FERTILIZER, TO YIELD, ON 140 STEUBEN COUNTY FARMS IN 1912

Method	Value of fertilizer per acre									Average		
	From $1 to $10			From $11 to $20			$21 and over					
	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)
Broadcast before planting	38	131.6	9.6	28	152.7	10.5	4	178.0	10.2	70	141.9	10.0
In row at planting	27	135.7	10.7	20	168.0	11.8	7	185.2	13.2	54	153.3	11.4
Broadcast after planting	11	148.7	11.3	4	135.2	9.3	1	73.5	8.2	16	141.5	10.7
Total	76	....	....	52	....	....	12	....	....	140	....	....
Average	.....	135.8	10.3	.....	157.8	11.0	.....	172.8	12.0	.....	146.8	10.7

TABLE 31. Relation of Method of Applying Fertilizer, to Yield, on 186 Monroe County Farms in 1913

Method	Value of fertilizer per acre									Average		
	From $1 to $10			From $11 to $20			From $21 to $30					
	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)
Broadcast before planting	50	129.7	13.0	56	139.7	12.5	7	166.7	12.9	113	136.4	12.7
In row at planting	29	121.5	12.9	38	137.0	13.6	6	143.1	13.1	73	131.1	13.3
Total	79	....	....	94	....	....	13	....	....	186	....	....
Average	.....	126.8	12.9	.....	138.6	13.0	.....	156.2	13.0	.....	134.4	12.9

TABLE 32. Relation of Method of Applying Fertilizer, to Yield, on 211 Franklin and Clinton County Farms in 1913

Method	Value of fertilizer per acre									Average		
	From $1 to $10			From $11 to $20			$21 and over					
	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)	Number of farms	Yield per acre (bushels)	Amount of seed used (bushels)
Broadcast before planting	10	192.0	13.3	57	200.1	13.0	41	188.2	12.0	108	194.5	12.6
In row at planting	19	171.6	13.3	19	188.5	13.7	2	164.7	13.3	40	178.6	13.5
In row after planting	14	149.2	9.5	41	169.5	10.3	8	173.0	11.5	63	165.4	10.3
Total	43	....	....	117	....	....	51	....	....	211	....	....
Average	.....	168.3	12.1	.....	177.0	11.5	.....	185.3	12.0	.....	182.2	12.1

interest to note that more than half of the 211 growers listed here applied their fertilizer by the broadcasting method.

The study of the methods of applying fertilizer, as treated in this paper, does not allow any definite conclusions to be drawn. The question is apparently one of local application, probably depending on such factors as seasonal rainfall, amount of fertilizer used, and soil type, as previously suggested.

Use and influence of lime on potato land

Lime has been given little prominence in use either as a plant food or as a soil amendment for potatoes. This is due to the fact that, being an alkaline agent, its use is conducive to the development of common scab (*Actinomyces chromogenus*) on potato tubers whenever the causal organism is present in the soil or introduced on the seed tubers. Therefore lime is usually applied in the rotation as far removed from the potato crop as is possible, while its major benefits to this crop, in the improvement of soil texture and the growth of legumes, are as well accomplished. Wheeler and Adams (1909) reported an increase in the proportion of tubers of merchantable size from the use of lime. There seems to be little or no conclusive evidence available that lime has increased the yield of potatoes except indirectly thru the benefits just mentioned.

In spite of the fact that lime is advised for most potato farms outside of the surveyed areas of Long Island and Monroe County, very few growers reported its use in the rotation which they were using at the time when the survey was made. A summary of the use of lime and its place in the rotation followed in the surveyed regions is given in table 33:

TABLE 33. USE OF LIME, AND ITS PLACE IN THE FOUR AREAS SURVEYED

Region	Per cent of growers using lime in rotation	Average number of years removed from potatoes
Long Island, 1912	6	3.4
Steuben County, 1912	16	3.1
Monroe County, 1913	16	3.0
Franklin and Clinton Counties, 1913	7	3.7

Very few growers apply lime regularly in their rotation. The commoner practice is to use it only when necessity demands it as a means of producing legumes. On Long Island, where potatoes are grown for so many successive seasons on the same land, it is unsafe to use lime at all. The number of years from the potato crop that lime is applied, indicated in table 33, shows the consistent effort of the growers to apply it as far from potatoes as is possible, in order to avoid scab.

ADAPTATION AND YIELD OF VARIETIES

The crop survey offers one of the best means of determining the relative merits of potato varieties for a given locality. Too often the experiment stations have made generalized recommendations solely on the basis of the performance of a few strains tested for only a few years at the station grounds. A correct knowledge of the adaptability of various types and varieties to given soil and climatic conditions can be obtained only by cooperative controlled tests under varying conditions, or by a crop survey of the performance of the varieties growing over a wide area with diverse conditions. Nearly every state experiment station in the United States has at some time conducted a yield test of potato varieties, the results of which are to be found in the published literature. These results are in most cases of very local significance and pertain only to the strains of seed that were available for the test. Because of the wide variation in yield of the different strains of a given variety, no absolute recommendations for any variety should be made on the basis of such tests. A comparison by survey methods of the average yields of strains of the varieties within a region, furnishes the best criterion of the merits of such varieties for that region. Stuart (1915) has classified the standard American varieties into groups containing varieties similar in tuber and foliage characters. It is now well known that the varieties within each group conform fairly closely to one another in their adaptation to specific soil and climatic conditions. This has made it possible to determine the type or group of varieties best adapted to certain regions. It remains, then, only to choose high-yielding strains of standard varieties within this group. The status of varieties within each of the surveyed areas has been studied on this basis. Varieties and types have been tabulated in the order of their extent of production in each region.

Potato varieties on Long Island

Of the four regions surveyed, Long Island presented the greatest varietal standardization by growing the fewest varieties and the fewest types. Growers in this region are convinced that varieties of the Rural group yield less, are poorer in quality, and are less popular in the New York market, than varieties of the Green Mountain, or white-sprout, type. Generally speaking, for the medium late crop, only varieties of the Green Mountain group are raised on Long Island, and the early varieties for this region are chosen from the Cobbler, the Early Ohio, the Rose, and the Triumph groups (table 34).

Altho Green Mountain was only one of several varieties of this group grown in the three years from 1911 to 1913 inclusive, its popularity is shown by the fact that two-thirds of the average total acreage during this period was given to this variety. Irish Cobbler was the leading early variety produced, and most of the acreage of this variety was grown in Nassau

TABLE 34. VARIETIES GROWN ON 330 LONG ISLAND FARMS IN 1911, 1912, AND 1913

Variety	Color of sprout	Average number of farms raising variety in 1911, 1912, and 1913	Average yield per acre in 1911 and 1912 (bushels)	Per cent of total acreage grown in 1911, 1912, and 1913
Green Mountain	White	200.7	180.4	66.0
Irish Cobbler	Pink	119.7	169.7	13.0
Carman No. 1	White	34.0	189.3	10.0
Delaware	White	19.3	210.5	3.0
Mills Pride	White	16.3	164.4	2.0
Uncle Sam	Blue	9.7	220.4	1.6
Early Ohio	Pink	9.7	216.9	1.6
Norcross	White	8.7	212.1	1.0
World's Fair	White	3.7	185.8	0.5
Genesee Seedling	White	5.3	248.1	0.3
Rose	Pink	5.7	172.8	0.3
Bliss Triumph	Pink	13.0	126.9	0.3
Early Rose	Pink	7.0	104.5	0.2
Bagley	White	4.3	126.2	0.2

County. A summary of the varieties belonging to each group, as classified by Stuart (1915), is given in table 35:

TABLE 35. SUMMARY OF TYPES ON 330 LONG ISLAND FARMS IN 1911 AND 1912

Type	Per cent of total acreage in 1911	Per cent of total acreage in 1912	Average yield per acre in 1911 (bushels)	Average yield per acre in 1912 (bushels)	Average amount of seed used in 1912 (bushels)	Average value of manure and fertilizer in 1912
Green Mountain	86	84	186.6	179.7	12.9	$32.74
Cobbler	10	12	189.0	157.2	12.2	32.00
Triumph	0	1	....	128.6	11.4	28.71
Early Ohio	2	1	199.6	231.5	12.3	44.99
Rose	1	1	166.8	123.6	13.4	38.72
Rural	1	1	227.7	216.2	10.1	27.66

Since the Green Mountain group is the only one of importance in this region, no comparison of relative merits is made between the types. Because most of the Early Ohio acreage was produced near or at Orient Point, under high fertilization and with ideal moisture conditions, its high average yield must be discounted when compared to that of the Cobbler group. Owing to its high average yield and its white skin, Cobbler has proved to be the best early variety for this section.

Potato varieties in Steuben County

In contrast to Long Island, Steuben County showed the least standardization of varieties of the four regions. The thirty-five varieties listed in table 36 do not represent all that were found in the region, but only those comprising an average of at least 0.1 per cent of the total acreage for three years.

TABLE 36. VARIETIES ON 360 STEUBEN COUNTY FARMS IN 1911, 1912, and 1913

Variety	Color of sprout	Average number of farms raising variety in 1911, 1912, and 1913	Average yield per acre in 1911 and 1912 (bushels)	Per cent of total acreage grown in 1911, 1912, and 1913
Number 9	Blue	76.7	143.5	22.6
Ruloff	White	41.3	126.5	12.3
Spaldings Rose 4	Pink	66.6	139.0	11.2
White Pearl	Blue	20.7	148.5	6.6
Sir Walter Raleigh	Blue	16.0	156.8	4.7
Gold Coin	White	21.0	135.0	4.7
Dooley	Blue	15.3	148.8	4.5
Carman No. 3	Blue	15.3	149.5	4.2
White Giant	Blue	13.0	135.3	4.2
State of Wisconsin	White	12.0	134.4	3.1
Rural New Yorker No. 2	Blue	7.7	134.4	2.6
Green Mountain	White	7.3	115.8	1.8
McKinley	Blue	8.0	142.9	1.7
Pan American	Blue	4.0	121.3	1.4
White Granger	Blue	6.3	147.2	1.4
Pearline	Blue	4.0	114.9	1.3
German Queen	Pink	4.7	154.0	1.1
Planet	Blue	3.7	126.8	1.0
Million Dollar	Blue	3.0	118.7	1.0
Early Manistee	Pink	5.7	163.7	0.9
Uncle Sam	Blue	3.0	134.0	0.9
Charles Downing	White	3.0	118.2	0.8
American Banner	Blue	2.7	127.6	0.8
Goldstein	Blue	1.7	118.0	0.7
Admiral Dewey	Blue	2.7	167.2	0.7
California	White	1.7	135.6	0.7
White Mammoth	White	3.0	133.8	0.6
Knoxall	Blue	3.7	159.6	0.5
Carlisle	Blue	2.0	156.0	0.5
Norcross	White	3.3	143.0	0.4
Ward's Seedling	Blue	2.7	136.4	0.3
Scotch Mane	Pink	2.3	127.0	0.3
Mix Best	Blue	2.0	168.9	0.2
Early Burpee	Pink	2.0	108.3	0.1
Clustic Beauty	White	0.7	106.2	0.1

It is significant that the three most popular varieties of this region, representing nearly half of the average total acreage during 1911 to 1913 inclusive, are each of a distinct type. Yet each may have its proper place in Steuben County farming. Number 9, representing a high-yielding strain selected from Rural New Yorker No. 2, heads the list in table 36 and is an ideal blue-sprout variety, adapted to the heavy soils and narrow-valley farms of this region. Spaldings Rose 4, a medium early variety of the pink-sprout type, is profitably raised for a special seed trade with the Hastings potato section of Florida. Ruloff is a variety of the Green Mountain type which is well adapted to the lighter soils of the northern part of the county. Altho there may be this apparent justification for diversity of type, there is surely no justification for so many varieties. Among the more popular varieties listed in the table, such standard varieties as Sir Walter Raleigh and Carman No. 3 would, on the basis of yield, appear to justify their more exclusive use in this region. The average yield of the more popular standard white-sprout varieties in this list is considerably inferior to that of the Rural varieties, which apparently indicates that, in general, this type is not so well adapted here as is that represented by Number 9.

A comparison of the types produced in this region is shown in table 37:

TABLE 37. SUMMARY OF TYPES ON 360 STEUBEN COUNTY FARMS IN 1911 AND 1912

Type	Per cent of total acreage in 1911	Per cent of total acreage in 1912	Average yield per acre in 1911 (bushels)	Average yield per acre in 1912 (bushels)	Average amount of seed used in 1912 (bushels)	Average value of manure and fertilizer in 1912
Rural	76	75	138.0	142.4	8.8	$ 8.90
Green Mountain	14	15	126.3	123.1	15.5	13.57
Rose	9	9	113.8	142.2	9.7	8.89
Hebron	1	1	116.7	194.4	9.8	12.82

In both 1911 and 1912, the Rural group of varieties outyielded those of the Green Mountain type by an average difference of 12 and 19 bushels per acre, respectively, in spite of the fact that in both years they were grown with considerably less seed and fertilizer. As is shown later, in table 42, a part of this difference was due to a greater average loss per acre in the unharvested yield, due to late blight rot, in the Green Mountain varieties. It therefore appears certain that the Rural type of potato is better adapted to the prevailing conditions of this region.

Potato varieties in Monroe County

Altho a very large number of varieties were grown in Monroe County during the years 1912 to 1914, inclusive, it is seen in table 38 that the

TABLE 38. Varieties on 300 Monroe County Farms in 1912, 1913, and 1914

Variety	Color of sprout	Average number of farms raising variety in 1912, 1913, and 1914	Average yield per acre in 1912 and 1913 (bushels)	Per cent of total acreage grown in 1912, 1913, and 1914
Sir Walter Raleigh	Blue	59.3	103.9	20.7
Carman No. 3	Blue	37.3	128.2	13.5
Number 9	Blue	45.3	125.6	12.3
Peerless Jr.	Blue	21.0	124.5	8.3
White Giant	Blue	22.3	129.9	6.8
Million Dollar	Blue	21.0	147.0	6.1
Perfection	Blue	17.0	144.1	5.5
World's Wonder	Blue	22.3	138.9	4.5
White Flyers	?	10.0	119.2	2.6
White Grant	Blue	14.0	130.2	2.4
Rural New Yorker No. 2	Blue	7.7	124.1	2.3
Gold Coin	White	3.3	111.0	1.6
American Giant	White	6.3	133.4	1.4
Granger	Blue	5.3	109.2	1.4
Twentieth Century	Blue	6.0	164.9	1.3
Isle of Jersey	Blue	3.0	110.8	1.2
Hundred Fold	?	4.7	141.2	1.2
Irish Cobbler	Pink	11.7	124.6	1.2
Number 6	Blue	4.7	146.5	1.2
Pan American	Blue	4.7	138.5	1.1
McKinley	Blue	4.3	156.5	0.9
Green Mountain	White	3.7	174.9	0.8
Early Michigan	Pink	2.0	115.0	0.5
Livingston	Pink	2.0	90.6	0.5
American Banner	Blue	2.0	153.7	0.4
Number 8	Blue	2.0	150.8	0.3

prevailing type was that of the Rural group. Nearly half of the average total acreage of this region during the years 1912 to 1914, inclusive, was planted to the three standard blue-sprout varieties, Sir Walter Raleigh, Carman No. 3, and Number 9. Altho the three-years average yield for these varieties was slightly less than the average yield for the region in 1913, it would still seem desirable, for the sake of standardization, to select high-yielding strains from, and to retain, these few varieties to the exclusion of most of the other varieties of the Rural type listed in table 38. It is noteworthy that of the twenty-six varieties listed, only three are of the Green

Mountain type. The relatively light seasonal rainfall and the heavy soils of the Dunkirk and Ontario series have resulted in the survival of Rural varieties at the expense of other types. Here, as on Long Island, Irish Cobbler was found to be the leading early variety.

The status of varietal types in this region is summarized in table 39:

TABLE 39. SUMMARY OF TYPES ON 300 MONROE COUNTY FARMS IN 1912 AND 1913

Type	Per cent of total acreage in 1912	Per cent of total acreage in 1913	Average yield per acre in 1912 (bushels)	Average yield per acre in 1913 (bushels)	Average amount of seed used in 1913 (bushels)	Average value of manure and fertilizer in 1913
Rural	94.0	94.0	141.4	125.0	12.8	$11.48
Green Mountain	3.4	3.0	153.3	109.4	14.3	10.97
Cobbler	1.0	1.0	135.9	117.1	11.6	12.75
Hebron	1.0	0.5	121.0	138.8	14.5	9.65
Rose	0.3	0.8	128.6	80.0	10.6	4.40
Early Michigan	0.3	0.7	121.4	100.0	11.1	5.56

The year 1913 was one of low seasonal rainfall in Monroe County, and the crop suffered from the drought. As shown in table 39, varieties of the Green Mountain group yielded, in that year, an average of about 15 bushels per acre less than those of the Rural type, in spite of the use of more seed and about the same amount of fertilizer. This is further evidence that varieties of the Green Mountain group, which set tubers earlier than do those of the Rural group, suffer the effects of reaching their critical growth period during the drought season of midsummer in Monroe County.

Potato varieties in Franklin and Clinton Counties

Altho more varieties are grown in Franklin and Clinton Counties than on Long Island, this region is similar to the Long Island area in that nearly all the varieties were found to be of the Green Mountain type, as is shown in table 40. A notable absence of early varieties was found among those grown from 1912 to 1914, inclusive. This may be explained in general by the fact that the possibilities for profitable yields are much greater in the main crop varieties.

The four Green Mountain varieties listed at the head of table 40 — White Beauty, Selfic Beauty, World's Fair, and Immense — comprised more than half of the average total acreage of this region during the three years concerned. Type has become well standardized here, as the list shows only four varieties of the Rural, or blue-sprout type, the remainder all being of the Green Mountain, or white-sprout, type. While these four Rural varieties are standard varieties, their average yield per acre and extent of

TABLE 40. VARIETIES ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1912, 1913, AND 1914

Variety	Color of sprout	Average number of farms raising variety in 1912, 1913, and 1914	Average yield per acre in 1912 and 1913 (bushels)	Per cent of total acreage grown in 1912, 1913, and 1914
White Beauty	White	47.3	198.1	16.4
Selfic Beauty	White	39.3	200.7	15.0
World's Fair	White	32.3	179.9	12.3
Immense	White	17.7	154.5	7.1
White Mountain	White	20.3	199.1	6.7
Green Mountain	White	18.7	179.5	6.6
Jumbo	White	14.0	176.8	4.7
White Lady	White	8.7	197.9	4.1
Number 9	Blue	11.3	168.9	4.0
Mill's Prize	White	7.7	189.9	3.0
Carman No. 1	White	10.7	204.5	3.0
National	White	6.7	184.8	2.4
Rural New Yorker No. 2	Blue	6.3	135.6	2.0
Lincoln	White	6.3	221.8	1.9
Scott	?	4.7	160.6	1.8
Mountain King	White	5.3	199.7	1.7
Eggswaire	White	5.0	165.6	1.7
Carman No. 2	Blue	5.3	191.9	1.6
Success	?	3.7	169.9	1.2
International	White	3.0	197.3	0.9
Gold Coin	White	2.0	147.7	0.7
Silver Dollar	White	4.7	187.4	0.7
Carman No. 3	Blue	1.7	184.0	0.5

production do not seem to justify their competition with the Green Mountain type. A comparison of these two types for the region in 1912 and 1913 is shown in table 41. The averages for 1912 and 1913 show that with

TABLE 41. SUMMARY OF TYPES ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1912 AND 1913

Type	Per cent of total acreage in 1912	Per cent of total acreage in 1913	Average yield per acre in 1912 (bushels)	Average yield per acre in 1913 (bushels)	Average amount of seed used in 1913 (bushels)	Average value of manure and fertilizer in 1913
Green Mountain	86	92	194.5	183.8	12.0	$13.44
Rural	14	8	168.9	164.9	13.1	14.42

TABLE 42. SUMMARY OF POTATO TYPES PRODUCED IN THE FOUR REGIONS SURVEYED, FROM 1911 TO 1913, INCLUSIVE

Type	Long Island and Steuben County			All four regions					Monroe County, and Franklin and Clinton Counties					Average unharvested yield per acre in Steuben County in 1912 (bushels)
	Total acreage in 1911	Average yield per acre in 1911 (bushels)	Per cent of total acreage in 1911	Total acreage in 1912	Average yield per acre in 1912 (bushels)	Per cent of total acreage in 1912	Average amount of seed used in 1912 (bushels)	Average value of manure and fertilizer in 1912	Total acreage in 1913	Average yield per acre in 1913 (bushels)	Per cent of total acreage in 1913	Average amount of seed used in 1913 (bushels)	Average value of manure and fertilizer in 1913	
Green Mountain	4,323.7	181.7	60	6,856.8	177.2	51	13.8	$32.86	1,383.3	178.0	32	13.6	$14.88	43.4
Rural	2,033.6	139.7	28	5,321.6	143.3	39	8.9	9.39	2,869.8	125.3	66	12.2	12.42	19.5
Cobbler	788.8	189.0	7	819.8	156.4	6	12.2	31.94	39.8	117.1	1	11.6	12.75	....
Rose	264.0	142.9	4	378.3	140.2	3	11.0	14.26	30.0	108.3	1	11.3	6.37	18.9
Early Ohio	70.0	199.6	1	84.0	231.5	1	12.3	44.99	......	....	0	....	....	....

a bushel of seed less and a dollar's worth less of fertilizer per acre, the varieties of the Green Mountain group yielded approximately 26 and 19 bushels per acre more, respectively, than did the Rural varieties. Under the cool climatic and the good soil conditions of this region, therefore, the Green Mountain type of potato is the more profitable.

Summary of varieties in all regions

A comparison of the principal potato groups produced in all four regions during the years for which survey data were obtained, is shown in table 42. It should be understood that no specific recommendations for a given region can be made on the basis of the comparisons drawn in this table. Certain facts of interest, however, are evident. On the average, the Green Mountain type is grown under more favorable climatic and soil conditions than the other types, with more seed and more manure and fertilizer per acre. Therefore, for the State as a whole, the Green Mountain varieties have yielded more than have those of the Rural type. The table shows that in the blight epiphytotic of 1912 in Steuben County, the rotting of the white-sprout varieties in the field exceeded that of the blue-sprout varieties by about 24 bushels per acre. For practically the same reasons the Cobbler type has outyielded the Rose as an early potato. The Early Ohio owes its high average yield in 1912 to the large amount of seed and fertilizer used.

SOURCE OF SEED

In the mind of the average grower, the source of his potato seed is of small concern unless of necessity he is compelled to periodically change his seed stock by obtaining it outside his home county. The only section in New York where this is the case is Long Island. In table 43 are shown the sources from which the seed supply was obtained for each of the surveyed regions in 1912 and 1913.

TABLE 43. Source of Seed in the Four Regions Surveyed, in 1912 and 1913

Region	Farms raising their own seed		Farms raising part and buying part of their seed		Farms buying all their seed	
	Number	Per cent	Number	Per cent	Number	Per cent
Long Island	9	2.7	151	45.8	170	51.5
Steuben County	358	99.4	2	0.6	0	0.0
Monroe County	248	82.7	38	12.6	14	4.7
Franklin and Clinton Counties	215	71.7	50	16.6	35	11.7

For many years, the Long Island growers have been getting most of their seed from Maine. In recent years, the decreasing quality of Maine seed has resulted in the use of some seed from Vermont and New York. Seed for the other three regions is almost entirely used within the county where it is grown. Occasionally there is an exchange of seed between growers within the neighborhood. Long Island growers have learned that it is not profitable to use, as seed, stock that has been grown on Long Island for more than one year. An experimental plot at Southampton is shown in figure 131 (page 1158), which demonstrates the difference in results to be expected between new stock from Maine, and Maine stock grown for one year on Long Island. The 45.8 per cent of growers on Long Island using part home-grown seed and part bought seed, shown in table 43, represent the extent to which one-year Long Island stock originally imported from Maine was used in 1912. Most of the seed stock from Maine is purchased in the fall to be shipped in the very early spring, since storage facilities on Long Island are very meager and the crop is planted late in March or early in April. The seed stock of the other three regions is in most cases stored at home along with the bulk of the harvested crop.

The necessity of a change of seed on Long Island is due to several factors. The abnormally long period between harvest and planting, much of which includes the warm or hot temperatures of late summer and early fall, is not favorable to potato storage. The soil temperature of this region during the later growing season is apparently so high as to seriously reduce the vigor of the stock for seed, in spite of the high average yields obtained. The problem is therefore one of soil, of growing-season and storage temperatures, and of length of storage season as influencing the condition of the seed at planting time.

Emerson (1914) compared yields from seed cultivated for some time in Nebraska, with those from seed raised under straw mulch and from seed recently introduced from the Red River Valley of North Dakota. He found that, whereas the cultivated seed of Nebraska rapidly deteriorated under hot growing-season temperatures, by mulching with straw between planting and blossoming time he was able to so reduce the soil temperature as to maintain vigor and obtain practically as good yields from seed so raised as from seed just introduced. Stuart (1913 a) studied the influence of environment on seed by introducing seed of thirteen English varieties of identical origin from both England and Scotland, and growing it continuously in Vermont for six years. The average increase in yield of the Scotch seed over that of the seed from England varied from 10.9 to 2713.9 per cent. Results similarly striking were obtained by Macoun (1905) in four varieties grown over a period of twenty years at Ottawa. He had practiced seed selection each year for twelve years and had thus been able to maintain the original yield of the stock. Four years of adverse conditions followed, during which the yield of each variety decreased decidedly.

Seed of these same varieties, introduced during the last four unfavorable years from Nappan, Nova Scotia, and subjected to the same unfavorable conditions, maintained its yield much better, showing that the vigor of northern-grown seed enabled it to withstand adversity better than home-grown seed similarly treated. Stone (1905) reported an experiment by Fraser in which tubers that had been stored in a cool cellar until May 1 were taken out and stored for thirty-six days under four different conditions. Yields from seed stored in a dark cellar at from 50° to 60° F., in a coldframe at 80°, at a barn window at out-of-door temperatures, and in a greenhouse at from 70° to 90°, showed about equally good results from the coldframe and the barn-window storage. The seed stored in the dark cellar gave decidedly inferior average yields, showing that moderate light and temperature for from four to six weeks before planting improves production over the usual method of dark-cellar storage up to planting time.

The potato crop of Maine, Vermont, and northern New York is almost invariably harvested before the maturity of the plants. The vines are usually killed by frost. Therefore the use of northern-grown seed for Long Island means the use of immature seed; and, since immature seed is closely associated with the dormancy, or rest period, of the potato tubers, this question also is concerned. According to Appleman (1918), the rest period varies with the variety but is fairly constant within each variety. Appleman (1912) has shown that three processes go on in potato tubers during the rest period: (1) respiration, or the consumption of sugar by reversion to carbon dioxide and water; (2) conversion of starch to sugar by diastase; and (3) change of the sugar back to starch. Since these after-ripening processes are greatly influenced by temperature, it follows that storage conditions have much to do with the condition of the seed tubers when they are removed from storage for planting. The value of seed harvested in an immature condition, which has been shown by the experiments of Macoun (1905), Shepperd and Churchill (1911), Stuart (1913 b), Zavitz (1916), Ballou (1910), and Gourley (1910), is due principally to the fact that, the seed being immature, the after-ripening processes leave it in a less devitalized condition than that of seed that has entered storage fully matured. The symptom of curled skin so common at harvest time on northern-grown potatoes indicates a lesser degree of suberization of the epidermis than occurs in mature tubers. Appleman (1914 and 1918) has shown how the rest period may be shortened or broken, at almost any time, by the use of anaesthetics or of oxidizing agents to facilitate increased oxygen absorption. He further showed (1918) how the rest period of the southern second-crop seed may be shortened by harvesting the seed immature, spreading it on the ground, and covering it with excelsior or burlap to prevent suberization.

SUN-SPROUTING OF SEED

The practice of sun-sprouting seed is one which, tho recommended for many years by experiment stations, has been very little practiced by potato growers. It requires the bringing of the seed stock from dark cellars into a place of moderate light and higher temperatures for a period of from four to six weeks prior to planting. The main objects are to improve the stands and increase the yields by (1) the development of short, thick, green sprouts on which tuber-bearing rhizomes develop close together, (2) the opportunity to rogue diseased and otherwise inferior seed, and (3) increasing the earliness thru the starting of healthy growth before planting. Flagg, Towar, and Tucker (1896), in Rhode Island, using duplicate plots and harvesting at two different dates, obtained increased yields from sprouted seed ranging from 32 to 54 bushels per acre. Fraser (1912) sun-sprouted seed of the varieties Sir Walter Raleigh and Carman No. 3 for thirty-six days prior to planting, and obtained increases in yield ranging from 0.9 to 73.7 per cent. Hutcheson and Wolfe (1917), in a two-years comparison, obtained a difference in marketable yield of about 8 bushels per acre in favor of sun-sprouted seed.

The extent to which sun-sprouting is practiced in the areas surveyed is shown in table 44. Altho earliness is much desired by Long Island growers, no one was found who sun-sprouted seed for the 1912 crop. Much care is used in choosing seed at the time of its purchase in the North. The several days required for cutting the large amount of seed handled by the average grower in this region affords some opportunity for sprout development in the meantime. Furthermore, since nearly all of the Long Island crop is planted by machine, care would be necessary that none of the sprouts so formed would be knocked off in going thru the planter.

TABLE 44. GROWERS WHO SUN-SPROUTED THEIR SEED IN THE FOUR REGIONS SURVEYED

	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Number of growers	0	14	166	40
Per cent of growers	0	4	55	13

The 4 per cent of growers practicing sun-sprouting in Steuben County in 1912 furnishes too small a number to study the influence of sun-sprouting on yield in this region.

The influence of sun-sprouting on yield in Monroe County in 1913 is shown in table 45. The difference of about 8 bushels per acre in favor of

TABLE 45. RELATION OF SUN-SPROUTING TO YIELD ON 166 MONROE COUNTY FARMS IN 1913

Treatment	Number of farms	Yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Not sun-sprouted	134	121.7	12.4	$10.81
Sun-sprouted	166	129.5	12.6	11.64
Total	300	....	....	....
Average	......	126.2	12.5	$11.28

the sprouted seed is probably no more than might be due to the increased amounts of fertilizer and seed used on these same farms. Therefore it cannot be said, on the basis of this difference in yield, that in 1913 sun-sprouting paid for the extra labor involved.

A similar study of this factor for 40 farms in Franklin and Clinton Counties in 1913 is shown in table 46. Here the results of sprouting were

TABLE 46. RELATION OF SUN-SPROUTING TO YIELD ON 40 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Treatment	Number of farms	Yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Not sun-sprouted	260	179.0	11.4	$13.25
Sun-sprouted	40	180.6	12.6	11.65
Total	300	....	....	....
Average	....	179.3	12.0	$13.01

even less marked than in Monroe County. The difference of 1.6 bushels per acre in favor of sun-sprouting, while within experimental error, may easily be due to the increased amount of seed used by growers in this group. The smaller value of fertilizer, however, would partially offset the difference in the amount of seed used.

Tho sun-sprouting apparently is not justified by the results shown for the last two regions in 1913, it must not be concluded that this is not a profitable procedure when it is properly done. It is impossible to determine by survey methods the true merits of this phase of potato growing, because of the difficulty of taking into account the actual methods followed.

CHEMICAL TREATMENT OF SEED

The chemical treatment of seed potatoes to rid their surfaces of the organisms causing common scab (*Actinomyces chromogenus*) and rhizoctonia (*Corticium vaguum*) has been sufficiently tested scientifically to warrant its practice wherever these diseases occur. Tho such treatments as immersion in corrosive sublimate or formaldehyde, or fumigation with formaldehyde gas, are not warranted to insure the crop against either of these diseases in the following crop, yet they have invariably reduced the infection to a profitable extent. Ballou (1910) and Gourley (1910), using duplicate plots of untreated seed, seed treated with formalin, and seed fumigated with formaldehyde gas, reduced the scab infection from an average of 58.5 per cent in untreated seed to 16.7 per cent in formalin-treated seed and to 18.4 per cent in fumigated seed. The writer (Hardenburg, 1917) reported a reduction of rhizoctonia, in the crops of fifty-eight growers in New York who used corrosive sublimate, to 1.8 per cent infection as compared with 12.7 per cent infection of the crops grown by the remaining twenty-two growers considered. He reported a similar reduction of scab infection, thru formalin treatment by sixty-two growers, to 7 per cent as compared with 10.7 per cent in the crops grown from untreated seed.

In spite of these tests and the recommendations based on them, a relatively small proportion of growers in the four surveyed regions treat their seed. The percentage doing this in each region is reported in table 47:

TABLE 47. PER CENT OF GROWERS TREATING SEED CHEMICALLY IN THE FOUR REGIONS SURVEYED

Treatment	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Formalin	1.0	0.003	7.3	0.0
Corrosive sublimate	0.0	0.000	1.7	0.0
Formaldehyde gas	1.0	0.000	0.0	0.0
Sulfur	0.0	0.000	3.7	0.0
Total	2.0	0.003	12.7	0.0

It has not been possible in this study to correlate the apparent need of seed treatment with the actual practice as indicated in this table. This is due partly to incomplete data from the four regions, and partly to a lack of familiarity with diseases on the part of growers. Such treatment, however, is universally recommended because of the attested saving to the crop. For the four regions, an average of 8.3 per cent of the growers reported scab, and an average of 4.6 per cent reported rhizoctonia, in the crop from which these data were taken.

INTERVAL BETWEEN CUTTING AND PLANTING

An interval of from one to ten days sometimes elapses between the time when seed potatoes are cut and the time when they are planted. Weather conditions unsuited to planting after the seed is cut sometimes make this delay necessary, while in some sections the large amount of seed to be cut makes it seem advisable to cut it several days early in order to facilitate the earliest possible planting of the crop. To some extent this is the case on Long Island. In a few cases, growers have cut seed several days in advance of planting because of an assumed benefit from the drying of the cut surface of the seed pieces to be planted. The object of the present discussion is to determine the relation of this interval of time to the yield.

Adams (1887), using two varieties in a single-year test, obtained an average difference of 26 bushels per acre in favor of planting immediately after cutting, between seed cut and planted fresh and seed cut twelve days before planting. Green (1888), on the contrary, using three varieties in a single-year test, reported increased yields for two varieties from a five-days interval, for three varieties from a nine-days interval, and for one variety from a twelve-days interval, over the yields obtained by planting freshly cut seed. These tests, he reported, agreed with those of Goff, of Geneva, who recommended the benefits of drying cut seed for periods not exceeding ten days before planting. T. C. Johnson (1912), tho not reporting yields, published cuts of fields planted from freshly cut seed and from seed held for ten days after cutting. The outstanding feature of Johnson's test of this factor, carried out under carefully controlled conditions, was the strikingly poorer stand grown from the stored cut seed. Zavitz (1916), in a test covering eight years at the Ontario station, obtained an average difference of 8 bushels per acre in favor of planting freshly cut seed rather than seed held for only four or five days. Furthermore, he obtained an increase of 1 per cent of marketable tubers from the unstored seed.

As previously stated, the period between cutting and planting is frequently longer on Long Island than in any of the other three regions surveyed. The relation between this interval and the yield is shown in table 48. Altho the relation is not clearly apparent, it is evident that as the interval is increased, the practice of dusting is also increased. Dusting tends to eliminate any of the deleterious effects caused by the drying out or heating of seed cut and stored over the longer periods of time. The average length of the interval between cutting and planting in this region in 1912 was 5.7 days, and more than half of the growers dusted their cut seed.

The average interval between cutting and planting in Steuben County being only two days, little correlation between this factor and yield would be expected. This is borne out by table 49. Also, here, as on Long Island,

TABLE 48. RELATION OF INTERVAL BETWEEN CUTTING AND PLANTING, TO YIELD, ON 272 LONG ISLAND FARMS IN 1912

Interval (days)	Number of farms	Yield per acre (bushels)	Per cent of growers dusting cut seed	Average amount of seed used (bushels)	Average value of manure and fertilizer
Less than 2	39	161.4	41	12.0	$32.69
2–3	33	185.4	55	12.8	31.73
3–4	52	183.5	46	12.5	33.33
4–5	32	171.1	59	12.0	30.45
5–7	13	195.4	46	12.5	32.39
7	43	178.4	56	12.5	32.41
More than 7	60	177.3	73	12.9	33.53
Total	272	....	....	....	....
Average, 5.7 days	......	180.0	57	12.6	$32.62

TABLE 49. RELATION OF INTERVAL BETWEEN CUTTING AND PLANTING, TO YIELD, ON 354 STEUBEN COUNTY FARMS IN 1912

Interval (days)	Number of farms	Yield per acre (bushels)	Per cent of growers dusting cut seed	Average amount of seed used (bushels)	Average value of manure and fertilizer
Less than 1	103	125.0	6	10.0	$ 8.65
1– 2	84	145.3	14	10.5	10.27
2– 3	82	140.4	11	10.1	11.39
3– 5	55	132.4	25	9.9	10.21
5–15	30	149.6	27	10.2	11.62
Total	354	....	....	....	....
Average, 2 days	......	136.6	14	10.1	$10.17

dusting was commonest where the interval between cutting and planting was the greatest. This being true, the average yields for each group reported in the table appear to vary according to the average amounts of seed and fertilizer used, rather than according to the length of the interval between cutting and planting.

The average interval between cutting and planting in Monroe County was 2.2 days, as shown in table 50. The range in interval was too small to show any marked influence of this factor on yield. In the main, dusting was commonest where the interval was the greatest. As in Steuben

TABLE 50. Relation of Interval between Cutting and Planting, to Yield, on 260 Monroe County Farms in 1913

Interval (days)	Number of farms	Yield per acre (bushels)	Per cent of growers dusting cut seed	Average amount of seed used (bushels)	Average value of manure and fertilizer
Less than 1	58	141.7	7	13.1	$11.68
1–2	66	145.3	21	13.0	13.32
2–3	64	121.8	22	12.6	10.80
3–4	42	132.0	10	12.1	10.79
4 and more	30	135.2	27	11.6	10.87
Total	260	....	....	....	....
Average, 2.2 days	......	135.7	17	12.6	$11.66

County, the amount of seed and fertilizer used was so influential as to obscure any slight influence that the factor of the interval between cutting and planting might have had.

Growers in the Franklin and Clinton County areas, like those of Steuben and Monroe Counties, aim to plant their seed as quickly as possible after cutting. The average interval in 1913 was only two days. Since only about ten per cent of the growers held seed as long as four days after cutting, no significant relation of this factor to yield was found. However, as shown in table 51, the most dusting was done by the growers who held their seed the longest.

TABLE 51. Relation of Interval between Cutting and Planting, to Yield, on 264 Franklin and Clinton County Farms in 1913

Interval (days)	Number of farms	Yield per acre (bushels)	Per cent of growers dusting cut seed	Average amount of seed used (bushels)	Average value of manure and fertilizer
Less than 1	113	174.2	4	12.2	$13.27
1–2	51	193.1	2	12.4	12.42
2–3	37	178.7	5	11.4	13.14
3–4	30	173.6	0	11.6	12.64
4 and more	33	186.5	30	12.6	15.11
Total	264	....	....	....	....
Average, 2 days	......	180.1	6	12.0	$13.32

DUSTING CUT SEED

Dusting of cut seed has for its objects the prevention of drying out by undue bleeding of the cut surfaces, and the prevention of heating which may occur in cut seed stored in large volume under conditions of poor ventilation. Dusting is not commonly practiced except when conditions require the storage of large quantities of cut seed for several days before planting, as on Long Island in 1912. Stone (1905) compared the yields from five varieties cut only one or two days before planting, one lot of each variety being dusted with land plaster and the other lot not being dusted. Four of these varieties gave increased yields from dusting, ranging from 5 to 26 bushels per acre, while the fifth showed a decreased yield of 7 bushels. The writer believes that a greater interval between cutting and planting would have resulted in a greater increase in yield due to dusting. Zavitz (1916) reported on an average of twenty-two tests, covering five years, in which yields from undusted freshly cut seed were compared with yields from seed treated with land plaster and with slaked lime. In all these tests, the seed was planted immediately after cutting and dusting. The average yield from the seed treated with plaster was 23.6 bushels per acre higher than that from the untreated seed, and the average yield from the seed treated with lime was 9.8 bushels per acre more than that from the untreated seed. In another experiment, in which the effects of treating cut seed with road dust, with ground brick, and with land plaster, were compared with the results from no treatment, Zavitz reported yields of 186, 189, 191, and 179 bushels per acre, respectively. Land plaster has been most commonly used as dust because of its cheapness and its adhesive qualities. On the basis of all the comparative tests reported, it has proved the most efficient. Sulfur and air-slaked lime have been used to a lesser extent. The degree to which dusting was practiced in the surveyed regions, as related to the length of time the cut seed was stored, is shown in table 52, and the extent to which various dust materials were used is shown in table 53. Unfortunately, the material used for

TABLE 52. RELATION OF DUSTING TO LENGTH OF STORAGE PERIOD OF CUT SEED IN THE FOUR REGIONS SURVEYED

	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Average number of days seed was stored	5.7	2.0	2.2	2.0
Per cent of growers dusting cut seed	57	14	17	6

TABLE 53. Per Cent of Growers Dusting Seed Who Used Each Material

Material	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Land plaster	49	72	20	11
Sulfur	43	4	16	6
Hydrated lime	1	2	0	6
Air-slaked lime	0	0	0	67
Road dust	0	0	6	0
Ashes	3	0	2	0
Unnamed	4	22	56	10

dusting was not ascertained from all the growers who followed this practice. In the cases in which it was not ascertained, it was listed as *Unnamed.* Land plaster was shown to be the material most commonly used, with sulfur second. About two-thirds of the growers in Franklin and Clinton Counties who dusted, used air-slaked lime, which was not used in any other region. Evidently, because of the likelihood that they cause scab, neither form of lime has been popular, nor have wood ashes.

TYPE OF SEED

Probably no other phases of potato culture have received more experimental attention than those bearing on the relation of type and amount of seed planted, to yield. In attempting to correlate type of seed with yield, however, the all-important factor of amount of seed used has too often been neglected, both in the method of experimentation and in the conclusions. This has led to confusion, false conclusions, and a conglomeration of published data of questionable value. To be of real value, such tests must take into account both the types of seed used and the amount of each planted. The relation of type of seed to yield may be treated under the following headings: (1) large as compared with small tubers for seed, (2) whole as compared with cut seed, (3) large as compared with small seed pieces, and (4) number of eyes. In reviewing the literature on each of these points, it has been difficult to reach conclusions, because of the confusion, in most cases, of one factor with one or more of the others; and very often the amount of seed planted has been entirely neglected.

Large as compared with small tubers for seed

More than thirty years ago, Adams (1889) compared the yields from large, medium, and small whole seed, and found an increase both in total and in marketable yield with each increase in size of tubers used. With an equidistant spacing of 38 inches for each type of seed, more per acre of the large than of the small type was planted. Aicher (1917) compared the yields from three lots of whole seed of a given variety having an average tuber weight of 8, 4, and 3 ounces, respectively. Tho Aicher did not state the amount of seed per acre used for each lot planted, the sets of each lot were planted 16 inches apart in rows 3 feet apart. Aicher reported that as the size of the whole seed was increased, the number of stalks per hill and the total yield per acre were increased. There was little difference in the percentage of marketable yield between the three lots. It must be concluded from this that large whole seed is better than small whole seed, under equidistance of planting, only because of the greater weight of seed used. Welch (1917), in a similar experiment and under similar conditions, duplicated Aicher's results almost exactly, except that he obtained a decrease in the percentage of marketable yield as the size of the whole seed increased. It is clear that the greater yields obtained by Welch from the larger whole seed were due primarily to the almost doubled amount of seed involved in each increase in size of seed used. Harwood and Holden (1893) have brought together the results obtained at the New York, Maryland, Tennessee, Kentucky, Louisiana, Wisconsin, and Utah stations, in all of which it was shown that in many cases not only the gross but also the net yield was greatest from the largest whole seed tubers. However, in all cases this increased yield was obtained from the greatly increased amount of seed used. Zavitz (1916) selected continuously, for eleven years, seed of small unmarketable, small marketable, medium marketable, and large marketable, whole seed tubers, and planted each lot in duplicate plots. With but one slight exception in the eleven years, his average marketable yield from the four types of seed showed an increase with each increase in size of seed used. The average yields per acre from the smallest to the largest seed, for the eleven years, were 105, 145, 181, and 203 bushels, respectively. Zavitz credits these differences in yield to the difference in the weight of the seed tubers, that is, to the difference in the amount of seed planted per acre. Plumb (1890) planted whole seed of Early Rose varying in tuber weight from 14 ounces down to 1 ounce, and concluded from his results that the larger the seed tuber, the greater was the total yield, the earlier the bloom, the taller the plant, and the later the maturity. Plumb obtained a consistent decrease in net yield, however, as the size of the seed tuber increased. He failed to duplicate his test plots.

Whole as compared with cut seed

The advisability of cutting seed potatoes depends on three factors: the cost of labor, the cost of seed, and the relative merit of whole as compared with cut seed in the effect on yield. Literature reporting experimental data on this question considers only the last-named factor. Cutting seed tubers at once facilitates loss of sap by bleeding, and the entrance of rot-producing bacteria and fungi. Appleman (1918) has shown that the transverse cutting of seed tubers permits development in the median and basal eyes which would remain more or less dormant if the tubers were planted whole, due to the exclusive development of the terminal eyes. This would indicate a more economical use of seed than is the case if whole tubers are planted. Aicher (1917) and Welch (1917), in a three-years duplicate experiment on irrigated land in Idaho, compared whole and cut seed as to stand, earliness, and yield. Aicher obtained an earlier growth, a more prolific top growth, a larger total yield, and a smaller marketable yield, from whole than from cut tubers. Welch obtained a better stand from the whole tubers, but one that was not commensurate with the extra amount of seed required. He also obtained a smaller marketable yield from whole than from cut tubers, but he does not agree with Aicher that wholeness has anything to do with earliness. The writer is of the conviction that, so far as the relative merit of whole and of cut seed is concerned, these tests of Aicher and Welch are no true criterion. The much greater rate of planting of whole seed over cut seed invalidates any conclusion that may be drawn relative to differences in yield. Harwood and Holden (1893) reported an interesting experiment attempted by the Tennessee station to test the comparative yields from whole tubers and from an equal weight of halved tubers from the same lot of seed. This eliminated any possible difference in rate of planting, so far as total weight of seed was concerned, but the fact that the half tubers were planted on twice as much area as the whole tubers vitiated the object of the experiment. Nearly two and a half times as much merchantable yield was obtained from the half tubers as from the whole. These same authors report a more nearly accurate test made by the New York station, in which equal-weight seed pieces of whole and cut types were used. The average total yield per acre was the same from the whole and the cut seed, but the marketable yield per acre from the cut seed was nearly double that from the whole seed.

Large as compared with small seed pieces

The question of size of the seed piece in relation to yield has been treated experimentally on the basis of both weight and proportion of tuber. Neither basis can be considered quite separately, and both naturally involve the question of rate of planting, the spacing of the seed remaining constant. The hundreds of experiments recorded for the study of size of seed piece are virtually tests of the most efficient rate of planting, tho the objects of and the conclusions for them have been related to size of piece alone.

Plumb (1890), comparing the yields from whole tubers, halves, quarters, and single-eye pieces, obtained an increased yield with every increase in size of seed, tho the greatest merchantable yield was obtained with the half tuber. As early as 1886, Samuel Johnson (1886) compared the yields from whole and half tubers and from three-, two-, and one-eye pieces, and found that, whereas the whole tuber gave the highest total yield, the three-eye piece gave the highest marketable yield. Two years later, comparing the same types of seed, Johnson (1888) obtained a consistent gain in yield with each increase in size of seed, and a decrease in percentage of stand with each decrease in size of seed. Johnson did not report whether his highest total yields were also the highest net yields.

Taft (1892), in a three-years test, compared the efficiency of various rates of planting, by planting whole, half, quarter, and eighth tubers, and single-eye pieces, equidistant in the row. His net yields increased up to and including the half tuber, altho the highest total yield came from whole seed. Adams (1889), using whole, half, two-eye, and one-eye seed pieces, obtained an increased total yield up to and including whole seed, with the greatest marketable yield from two-eye pieces. He did not report in terms of net yield. Green (1887) reported a two-years average test of the yields from one-eye, two-eye, half, and whole seed pieces as increasing with the size of piece used, but made no mention of the net or the marketable yields or of the rate of planting. Hutcheson and Wolfe (1917) made a three-years comparison of the yields from single-eye, half-ounce, one-ounce, and two-ounce pieces. Whereas both total and marketable yield increased up to and including the two-ounce piece, the increased yield from the two-ounce over that from the one-ounce piece was not sufficient to warrant the use of pieces larger than one ounce in weight. Aicher (1917) and Welch (1917), in their duplicate experiment covering three years, concurred in the results showing the highest total yield to be from whole seed and the highest marketable yield from quartered seed pieces, in a comparison of whole, halved, and quartered seed pieces. These investigators were agreed also that the number of stalks per hill increased with the size of piece planted, a fact which probably accounts for the smaller percentage of marketable tubers from the largest seed.

Appleman (1918) tested the influence of weight of seed piece on yield by varying the weight from 0.08 to 1.75 ounces in the variety McCormick and from 0.61 to 1.46 ounces in the variety Irish Cobbler. To give due consideration to rate of planting in such a test, he showed how this variation in McCormick increased the amount of seed from 1.1 to 24.96 bushels per acre. He obtained, in both varieties, an increased total yield with each increase in weight of the seed piece.

Zavitz (1916) has furnished perhaps the best contribution to the study of this factor. In ten tests, covering five years, he compared one-sixteenth-, one-eighth-, one-quarter-, one-half-, one-, and two-ounce seed pieces, the rate of planting varying from 1.3 to 41.2 bushels per acre and the number of eyes in each set remaining constant. With no seed piece weighing more than two ounces, Zavitz found increased net, marketable, and total yields for each increase in size of seed pieces used. But here he also failed to consider the factor of rate of planting. In another five-years experiment, however, testing the efficiency of various spacings of seed, he has, apparently unconsciously, furnished some much-needed information. This test showed that with the same weight of seed planted per acre, the one-ounce sets, planted twice as close as the two-ounce sets, gave greater total, marketable, and net yields.

Hume, Champlin, and Oakland (1914) compared large, medium, and small seed pieces, eye frequency being constant, and observed an average increase of total yield, in two varieties, of 70.9 per cent in large seed pieces and 55.5 per cent in medium seed pieces, over that from the small seed pieces. Emerson (1907) conducted a very comprehensive and accurate test of the relation of size of seed piece to yield under a constant rate of planting. Planting eighth, quarter, and half tubers, 6, 12, and 24 inches apart, respectively, he used 18 bushels of seed per acre in each plot. This gave him the highest total yield per acre from the quarter-tuber pieces and the lowest total yield from the half tubers. This, together with the test by Zavitz (1916) previously cited, would indicate that with the same rate of planting per acre, smaller pieces, down to one ounce, planted closer, are likely to give larger yields than larger pieces planted farther apart.

Schweitzer (1896), with twelve varieties in a one-year test, compared the total yields and the yields of small tubers from one-eye, two-eye, quarter-tuber, half-tuber, and whole-tuber pieces. This gave a variation in rate of planting of from 4 to 87 bushels. His total yield increased with each increase in size of seed piece and in rate of planting. Also, the percentage of small potatoes increased from 8.9 for one-eye pieces to 26.4 for whole tubers as seed.

Harwood and Holden (1893) brought together a compilation of experiments from thirteen stations designed to test the relation of size of seed and rate of planting, to yield. In summarizing the comparative value of whole and of half tubers as seed, they showed that the results of a substantial majority of these experiments were in favor of the whole tuber, not only for total and marketable yield, but also for net marketable yield and net value of the crop. Similarly, a majority of the comparisons of the half-tuber and the two-eye piece favored the former thruout. In drawing such conclusions, it must be borne in mind that these differences in yield were due to an increase in the amount of seed used because of the larger size of the seed piece. These authors called attention to the conclusions of the Ohio station, that "despite the fact that whole potatoes give more small potatoes than one and two eye cuttings, it is also true that they give more large potatoes."

The foregoing review of the question of large as compared with small seed shows that few tests have actually proved any superior merit of large seed, except as the amount used per acre was increased. The few tests of a more comprehensive nature have indicated that equivalent amounts of smaller seed pieces, down to a minimum weight of one ounce, planted closer, may give even more efficient results. With an expensive and limited seed supply, the latter type of seed and system of planting would seem advisable.

Number of eyes

Many of the older potato growers attach considerable importance to the number of eyes to be left, in cutting seed potatoes. While a few growers cut single-eye pieces, the majority prefer pieces containing two eyes. Whether or not there is any significance in the relation of this factor to yield or to quality of the crop, it is automatically controlled, in practice, by the size of the seed piece, the importance of which has already been discussed. Arthur (1892) showed, in very definite terms, that the yield of large tubers decreases with the use of seed tubers weighing more than four and one-half ounces. His results are in accord with those of many other experiments which show that increasing the number of eyes on the seed piece tends to reduce the average size of the resulting tubers.

Whipple (1915) studied the influence of thinning to one stalk per hill, in a two-years test of nine varieties planted from two-ounce pieces irrespective of the number of eyes. Thinning to one sprout improved the market shape and the uniformity of the crop, but Whipple's results do not justify any conclusion that either total or marketable yield was increased by thinning. The cost of thinning was therefore not warranted.

Ballou (1910) has shown that varieties differ in the number of stalks per hill which will develop from a given size of seed piece. Bovee, having frequent eyes, developed more stalks per hill per unit of seed piece than did Carman No. 3, a variety of few eyes. Ballou obtained an increase in the unmarketable yield from every increase in size of seed piece or number of eyes in both varieties. The most profitable net yield in the Bovee was obtained from two-eye pieces planted at the rate of 15 bushels per acre, and in the Carman No. 3 from half-tuber pieces planted at the rate of 25 bushels per acre.

Again it remained for Zavitz (1916) to contribute the real test of the influence of eye frequency on yield, by eliminating the factor of size of seed piece. Using one-ounce seed pieces thruout a five-years test, he compared the results from seed pieces containing one, two, three, four, and five eyes, respectively, and found that as the number of eyes increased, the average total yield increased and the percentage of marketable yield decreased. The difference in marketable yield, however, was in no case more than 5 per cent. It is therefore evident from Zavitz's work that the yield is proportional to the number of stalks per hill, as well as to the size of the seed piece, and that nothing is to be gained by cutting to a certain minimum number in preparing seed for planting.

Types of seed used in the four regions surveyed

Obviously there are many difficulties in the way of attempting to determine by survey methods the relation of type of seed to yield. Whether or not a grower decides to cut his seed rather than plant it whole, depends principally on the size of the tubers he has for seed, because, in cutting for seed, most growers have a definite size of seed piece in mind. Growers in Steuben County, more than in other regions, showed a tendency to plant seed of low market value. Much cull seed was therefore planted whole in 1912. Since practically all seed used on Long Island is bought and is of a grade higher than the average, growers there find it economical to cut nearly all of it. Good seed is more cheaply produced and more plentiful in Franklin and Clinton Counties, and therefore relatively large seed is used there, and more of it is planted whole than in the other regions. The proportion of whole and of cut seed used in the four surveyed regions is shown in table 54:

TABLE 54. PER CENT OF GROWERS USING WHOLE AND CUT SEED, IN THE FOUR REGIONS SURVEYED

Type of seed	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Whole	0	1	0	10
Whole and cut	0	40	26	39
Cut	100	59	74	51

Evidently there are very few growers who feel that their seed is small enough, cheap enough, or low enough in quality to warrant planting it whole. However, it is not possible to judge from table 54, by the amount of each type of seed used, which region used the best seed in the year for which the data were taken. It has not been possible to study the influence of the size of seed piece on yield, in these regions, because of the impossibility of determining even the average size of the seed used. In studying the influence of the size or the degree of wholeness of the tubers used for seed, definite conclusions cannot be drawn because of the lack of uniformity in the opinions of the growers as to the meaning of the terms *large*, *medium*, and *small*, and furthermore because in many cases more than one type of seed was used. The data are presented here for whatever significance they may have.

On Long Island, as already stated, all the seed used in 1912 was cut. A comparison of the yields from large tubers cut and from medium-sized tubers cut, is given in table 55. The difference of 8.6 bushels per acre in

TABLE 55. Relation of Type of Seed to Yield on 171 Long Island Farms in 1912

Type of seed	Number of farms	Average yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Large cut	99	163.1	12.0	$31.24
Medium-sized cut	72	171.7	13.0	33.18
Total	171	....	....	....
Average	......	167.0	12.4	$31.48

favor of the medium-sized tubers cut is no more, and is probably less, than should be expected from the increased amount of seed and fertilizer used by this group of growers. Apparently there was little choice between the two sizes of tubers used.

The practice of cutting seed of egg size for planting was probably commoner in Steuben County than in the other regions. Some whole seed which might be classed as cull was also used by some of the less progressive growers, as shown in table 56. The yields given in table 56 correlate

TABLE 56. Relation of Type of Seed to Yield on 217 Steuben County Farms in 1912

Type of seed	Number of farms	Average yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Large and medium-sized cut	98	149.7	9.9	$10.94
Large cut	11	139.1	10.1	12.70
Medium-sized cut	102	135.7	10.3	10.83
Small whole	4	95.5	9.4	6.84
Medium-sized whole	2	181.1	11.5	9.53
Total	217	....	....	....
Average	......	146.5	10.4	$10.89

rather closely with the rate of planting and the value of manure and fertilizer used. The four growers who used small whole seed also used the least seed and fertilizer, and, as a result, harvested the lowest average yield. In view of the amount of seed and fertilizer used, the growers who used a combination of both large and medium-sized cut seed obtained a more profitable net yield than did those who used either large or medium-sized cut seed alone.

So far as is possible from the data taken, the relation of type of seed to yield in Monroe County is shown in table 57. More than a third of the

TABLE 57. Relation of Type of Seed to Yield on 257 Monroe County Farms in 1913

Type of seed	Number of farms	Average yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Medium-sized cut	120	143.5	12.0	$11.75
Medium-sized whole and large cut	18	132.5	12.8	13.26
Small whole and medium-sized cut	30	132.1	12.8	9.56
Large cut	52	131.5	13.1	12.56
Large and medium-sized cut	17	129.5	12.3	12.66
Small whole and large cut	2	122.9	11.0	12.28
Medium-sized whole and medium-sized cut	18	120.5	11.4	9.11
Total	257	....	....	....
Average	......	136.2	12.3	$11.63

growers in this region used medium-sized cut seed in 1913. Judging from the average amount of seed and fertilizer used by these same growers, they obtained a more profitable net yield than did the growers who used either large cut seed or large and medium-sized cut seed. The real explanation as to why the group using medium-sized whole and medium-sized cut seed obtained the lowest average yield, lies in the fact that these growers used considerably less than the average amount of seed and fertilizer.

Except that more whole seed was used in Franklin and Clinton Counties, the types of seed used there correspond fairly closely to those reported for Monroe County. The fact that about a third of the growers in this region claimed to have used large cut seed indicates that these growers use seed of larger average size than is used in any of the other regions. The relation of type of seed to yield here is shown in table 58. The comparative yields from large cut and medium-sized cut seed agree very well with the majority of the experiments previously cited, which showed greater yields from the larger seed, due to the greater amount of seed planted. The difference of about 8 bushels per acre of average yield between medium-sized cut and medium-sized whole seed, however, does

TABLE 58. RELATION OF TYPE OF SEED TO YIELD ON 292 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Type of seed	Number of farms	Average yield per acre (bushels)	Average amount of seed used (bushels)	Average value of manure and fertilizer
Large cut	97	189.1	12.9	$13.61
Medium-sized whole and large cut	64	182.7	12.4	12.60
Medium-sized whole and medium-sized cut	21	181.5	11.8	10.49
Medium-sized cut	42	174.6	11.1	12.91
Medium-sized whole	32	166.7	11.0	13.02
Medium-sized and large cut	8	166.1	12.0	14.08
Small whole and large cut	6	157.8	11.1	15.81
Small whole and medium-sized cut	22	157.3	9.9	12.01
Total	292	....	....	....
Average	......	178.5	11.9	$12.96

not agree with the experiments previously cited for the factor of whole as compared with cut seed. The apparent discrepancy cannot be attributed to differences in amount of seed and in value of manure and fertilizer, as these factors average approximately the same for both groups.

A rather striking effect of the rate of planting is shown in table 58, where the types of seed are arranged according to the average yields obtained from each. In fact, thruout these studies of the relation of type of seed to yield, it has been shown that those types which required the highest rate of planting were productive of the highest average yields.

RELATION OF AMOUNT OF SEED TO YIELD

The very marked effect of rate of planting on yield has been shown in the previous discussions of the effect of manure and fertilizer and of size of seed piece. A majority of the very large number of tests which have been conducted to determine the optimum number of bushels per acre to plant, indicate that in this country too little seed is generally planted, under average conditions. In contrast to this, the large yields obtained by European growers, who commonly plant from 30 to 40 bushels of seed per acre, are often cited. It does not follow, however, that similar rates of planting in New York would be productive of such yields. Land, labor, and climatic conditions in northern Europe are such that high rates of planting are not only possible but also profitable. As shown by the majority of experiments testing this factor, the most profitable rate of planting has seldom been exceeded in this country. Rate of planting is increased either by closer planting or by increasing the size of the seed piece.

Harwood and Holden (1893) compiled the results of thirteen experiments conducted at the Michigan station to determine the optimum rate of planting as well as the optimum size of seed piece. The rates of planting varied from 2.7 to 58.9 bushels per acre. The net yields showed that the optimum rates of planting varied from 10.8 to 48 bushels per acre. In only four tests was the best rate of planting higher than 24 bushels. Emerson (1907) tested rates of planting varying from 6 to 36 bushels per acre when eighth, quarter, and half tubers were used. He found that 12, 18, and 36 bushels per acre were the best amounts to use for these respective sizes of seed pieces. Macoun (1905), by varying the spacing of the seed from 10 to 18 inches and thereby varying the rate of planting from 35 to 19 bushels per acre, obtained the highest net yield from 25 bushels of seed. Kohler (1910), using the varieties Early Ohio and Sir Walter Raleigh, varied the rate of planting in each by 3 and by $2\frac{1}{2}$ bushels, respectively, from 6 to 21 bushels in the Early Ohio and from 5 to 20 bushels in the Sir Walter Raleigh. He obtained the highest marketable yield in the Early Ohio from 12 bushels of seed, and in the Sir Walter Raleigh from 17.5 bushels.

Zavitz (1916), using only one-eye pieces, varied the rate of planting from 1.3 to 41.2 bushels by increasing the size of the seed piece. Here both the highest net yield and the highest marketable yield were obtained from using 41.2 bushels of seed. Zavitz's test covered a five-years period, and is therefore more significant in this respect than the other tests just reported.

The wide variation in the optimum rate of planting shown by the experiments here reported, indicates that the available soil moisture and the fertility have much influence in limiting the stand of plants which will develop to maximum productivity. In other words, the potato soils of Steuben County, which are naturally low in fertility, cannot be expected to produce the average yields that are obtained in Monroe, Franklin, and Clinton Counties. From a review of the data available up to this time, it seems a safe assumption that, under at least average conditions, the rate of planting may be profitably increased from its present average to from 15 to 18 bushels per acre. Where weed control is important, labor scarce and expensive, and land relatively cheap, checkrowing is a common system of planting. Tho this system naturally lowers both the rate of planting and the resulting yield, both may be increased by increasing the size of seed piece used.

Rate of planting on Long Island

In spite of the fact that the growers on Long Island pay relatively high prices for nearly all of their seed every year, they have apparently learned that it is not profitable to plant less than the average of 12.5 bushels per acre. The influence of the rate of planting on the yield for this region in 1912 is shown in table 59. It may be seen in this table that there was

TABLE 59. RELATION OF RATE OF PLANTING TO YIELD ON 330 LONG ISLAND FARMS IN 1912

Rate of planting (bushels per acre)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Less than 11	71	148.9	9.9	$28.79
11–12	68	181.4	11.3	32.34
12–13	77	161.7	12.2	31.50
13–14	49	179.5	13.4	33.52
14–15	33	193.0	14.1	33.06
15 and more	32	202.0	15.6	36.63
Total	330	....	....	....
Average	......	175.5	12.5	$32.40

Yield per acre, in bushels

Bushels of seed per acre	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	
7					1								1
8			1	1	1	1		1					5
9			4	3	1	1	1			1			11
10		2	8	8	15	9	7	2	1	2			54
11		2	3	8	20	7	11	6	6	3	1	1	68
12		2	6	12	23	10	11	4	4	1	3	1	77
13			2	5	12	5	11	6	4	2	1	1	49
14	1		1		4	3	13	3	6	2			33
15			2	1	2	3	5	4	1	2	1		21
16						3	1	1					5
17					1				1		1		3
18					1	1					1		3
	1	6	27	38	81	43	60	27	23	13	8	3	330

$r = 0.275 \pm 0.034$

FIG. 140. CORRELATION OF RATE OF PLANTING AND YIELD ON 330 LONG ISLAND FARMS IN 1912

a tendency among the growers who planted the most seed to use also somewhat more than the average value of manure and fertilizer. Also, there was more spraying for blight among these growers. However, the same marked influence on the yield from the rate of planting is shown in table 24, under the discussion of manure and fertilizer, where each of these factors is treated under the various subheads. The single discrepancy in table 59, in the group of growers using from 11 to 12 bushels of seed, is due, at least in part, to the larger value of manure and fertilizer used by this group. Since the average number of eyes per piece gradually increased from the lowest to the highest rate of planting, it may be concluded that the rate of planting varied not so much according to closeness of planting as according to size of seed pieces used. From table 59, it is apparent that the growers in this region who used as high as 15 bushels of seed per acre in 1912, did not use more than was profitable. Applying the biometrical measure of correlation of this factor with yield (fig. 140) shows the significant coefficient 0.275 ± 0.034.

Rate of planting in Steuben County

In the four regions surveyed, Steuben County growers used the least seed, planting an average of only 10.1 bushels per acre in 1912 (table 60). The highest rate reported by any of the 360 growers was 18 bushels, and

TABLE 60. Relation of Rate of Planting to Yield on 360 Steuben County Farms in 1912

Rate of planting (bushels per acre)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
6– 8	19	117.8	6.9	$ 9.17
8–10	138	123.1	8.6	9.27
10–12	126	138.3	10.2	10.17
12–14	57	147.7	12.5	10.96
14–18	20	191.3	15.4	12.63
Total	360	....	....	....
Average	......	136.[illegible]	10.1	$10.06

there was a profitable increase in yield from every increase of 2 bushels per acre planted, up to 18 bushels. Steuben County growers did not exceed the optimum rate of planting in 1912, and it is safe to recommend a considerable increase in the average amount of seed used in that region.

Altho the increased yields were due partly to the increased values of manure and fertilizer used, this factor has been studied in a separate grouping in table 25 under the discussion of the value of manure and fertilizer for the region. The low average rate of planting for this county in 1912 was due partly to the planting of a considerable area in check-rows and partly to the use of small and relatively inferior seed. The data show that the amount of seed used probably did not exceed the maximum which the relatively low soil fertility could support. The coefficient of correlation between rate of planting and yield for this region, 0.374 ± 0.031 (fig. 141), is the highest found for any of the four regions.

Yield per acre, in bushels

Bushels of seed per acre	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	
5						1										1
6			2	2	2	1	1									8
7	1		2	7	4	2	4									20
8		2	11	15	23	15	8	5	1	2						82
9		1	3	11	13	11	7	2								51
10		2	5	18	20	25	15	15	4	1						105
11	1			2	2	6	2	4	1							18
12			3	5	8	7	8	5	1	2		1				40
13						7	4	1		1						13
14				1	1	1	2	1	1							7
15				3		2		1	1	2					1	10
6							1	1								2
17										1						1
18										1		1				2
	2	5	26	64	73	78	52	38	9	10	0	2	0	0	1	360

$r = 0.374 \pm 0.031$

FIG. 141. CORRELATION OF RATE OF PLANTING AND YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Rate of planting in Monroe County

The average amount of seed per acre used in Monroe County in 1913 was 12.5 bushels, which was the same average as was used on Long Island in 1912. The relation of this factor to yield is shown in table 61. Altho there was a tendency among the growers who planted the most seed to use more manure and fertilizer, the influence of seed is nearly as marked in this region as in the others. A few growers used as much as 20 bushels or more per acre, and, without using more fertilizer than was used by growers planting from 14 to 16 bushels per acre, they obtained an average increase in yield of about 25 bushels per acre. It appears, however, that

TABLE 61. RELATION OF RATE OF PLANTING TO YIELD ON 300 MONROE COUNTY FARMS IN 1913

Rate of planting (bushels per acre)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Less than 10	38	108.2	8.2	$ 9.09
10–12	62	119.6	10.3	10.54
12–14	111	120.1	12.4	11.29
14–16	69	137.5	14.5	12.73
16 and more	20	163.2	18.3	12.14
Total	300	....	....	....
Average	......	126.2	12.5	$11.28

even the growers who planted the most seed did not exceed the optimum rate. A coefficient of correlation of 0.247 ± 0.037 between rate of planting and yield for this region in 1913 is shown in figure 142.

Yield per acre, in bushels

Bushels of seed per acre	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	
6				1											1
7			1	1		1	2	1							6
8		1	4	7	2	5	1								20
9		1	1	6	1	1		1							11
10	1	1	8	8	9	11	2	6	1						47
11			4	5	3	2	2	1							17
12		2	10	22	15	9	9	5	3			1		1	77
13		1	2	4	8	12	3	1	1	1					33
14			4	7	6	5	4	3	1	1					31
15		1	3	6	4	9	8	4	1	1					37
16				3	1	3		1	1	1					10
17					1	1									2
18			1				2	1							4
19							1								1
20						1									1
21															0
22						1									1
23													1		1
	1	7	38	70	50	61	34	24	8	4	0	1	1	1	300

r = 0.247 ± 0.037

FIG. 142. CORRELATION OF RATE OF PLANTING AND YIELD ON 300 MONROE COUNTY FARMS IN 1913

Rate of planting in Franklin and Clinton Counties

The growers in Franklin and Clinton counties who were interviewed concerning their 1913 crop planted an average of 12 bushels of seed per acre, the rate varying from less than 10 to more than 18 bushels. The relation of this factor to yield in 1913 is shown in table 62. A study of

TABLE 62. RELATION OF RATE OF PLANTING TO YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Rate of planting (bushels per acre)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Less than 10	38	151.7	8.5	$12.72
10–12	88	167.0	10.4	13.20
12–14	105	188.1	12.3	12.48
14–16	52	185.6	14.6	14.06
16 and more	17	226.1	17.9	12.45
Total	300	....	....	....
Average	......	179.3	12.0	$13.01

Yield per acre, in bushels

Bushels of seed per acre	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	
6			1							1
7		2		1	1					4
8	2	2	3	1	3		1			12
9	2	3	7	1	7			1		21
10	5	8	13	14	9	11	2	1		63
11	2	3	4	1	9	2	2	1		24
12		6	8	18	22	11	6	5	1	77
13	1		6	2	7	4	6	1		27
14		2	4	6	6	1		3	1	23
15		1	3	6	8	6	4	2	1	31
16			1	1	3		1			6
17						2				2
18					1	1	3			5
19										0
20				1			1		2	4
	12	27	50	52	76	38	26	14	5	300

$r = 0.367 \pm 0.034$

FIG. 143. CORRELATION OF RATE OF PLANTING AND YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

this table shows that there was less tendency in this region than in the others for growers using the most seed to use also the most manure and fertilizer. The figures are therefore all the more conclusive in showing the marked influence of rate of planting on yield. More seed than the amount indicated by the highest rate of planting here reported might have been used with profit in raising the 1913 crop. The coefficient of correlation, 0.367 ± 0.034 (fig. 143), is altogether significant and is the second largest value found for any of the four regions surveyed.

DATE OF PLANTING

The average date of planting potatoes in any region is determined primarily by the average date of the last killing frost in the spring, altho elevation, soil type, and the type of potato grown, are also important questions varying with different localities. Thus it is possible to plant earlier on light soils and at lower elevations, than on heavy soils and at higher elevations. However, because of the higher prices which usually obtain early in the harvest season, the earliest possible planting and harvest of early varieties is desirable.

Zavitz (1916) reported results from thirty-six tests which consisted of planting two early, two medium, and two late varieties on four dates, two weeks apart, extending from May 31 to July 12. He carried this experiment thru a period of six years. Without exception, in all six varieties, both marketable and total yield increased directly with the earliness of planting. A continuation of this test the following year, with the plantings made on six dates instead of on four, gave the same general results. These tests were conducted on ordinary clay loam soil at the Guelph station. Champlin and Winright (1917) compared for two years the yields from planting at intervals of fifteen days from April 1 to July 1. For early digging the April 1 planting, and for late digging the May 15 planting, gave the best average yield for the two years. Such results as these are of value, even locally, only when the tests cover a period of several years.

Because of the small variation in date of planting within each region surveyed for the one year, and because of the fact that conclusions on the best time to plant cannot be drawn from the yield of only one season, no attempt has been made to correlate the date of planting and the yield. The average date of planting in 1912 and in 1913, and the average date of the last killing frost in the spring, for the four regions, are shown in table 63. The dates shown in this table indicate that Long Island is the only region in which the crop is planted before the average date of the last killing spring frost. It is evident that the Long Island growers are willing to risk possible damage to the crop from frost in order to enhance the earliness of harvest. The planting season of this region is shown to be at least six weeks earlier than that of the others.

TABLE 63. AVERAGE DATE OF PLANTING, AND AVERAGE DATE OF LAST KILLING FROST IN SPRING, FOR THE FOUR REGIONS SURVEYED

Region	Average date of planting	Average date of last killing frost in spring
Long Island, 1912	April 9	April 25
Steuben County, 1912	May 20	May 10
Monroe County, 1913	May 24	May 1
Franklin and Clinton Counties, 1913	May 30	May 10

HAND AS COMPARED WITH MACHINE PLANTING

The extent to which the potato crop of any region is planted by machine planters is determined principally by the average acreage, the system of spacing hills in the row, and the amount of large stones present in the fields. The writer (Hardenburg, 1915 a) found that in Steuben County, in 1912, when the average acreage of potatoes per farm was at least 5, the saving in labor cost by machine planting more than overbalanced the interest, depreciation, and repair costs of planting by this method. In regions where checkrowing is practiced, machine planting is impossible because potato planters cannot be used to plant in checkrows. As is shown later, much of the acreage in Steuben County was planted in this way in 1912. Some growers in Franklin and Clinton Counties find it impracticable to use planters because there are so many large stones in their fields. Conditions on Long Island, however, are almost ideal for machine planting, and it is done there almost entirely. The extent to which the acreage in each region was planted by hand and by machine, in the two years concerned, is shown in table 64:

TABLE 64. METHOD OF PLANTING AND TYPE OF MACHINE USED IN THE FOUR REGIONS SURVEYED

Region	Per cent of total acreage planted by		Per cent of total machine-planted acreage planted by	
	Machine	Hand	2-man planter	1-man planter
Long Island, 1912	98	2	23	77
Steuben County, 1912	25	75	60	40
Monroe County, 1913	74	26	87	13
Franklin and Clinton Counties, 1913	82	18	56	44
Average	70	30	56	44

It might be presumed that growers of the larger acreages in each region would be more inclined to use planters than those having a smaller acreage. Whether this was true in these four regions is shown in table 65:

TABLE 65. RELATION OF SIZE OF POTATO ACREAGE TO METHOD OF PLANTING

Region	Average potato acreage per farm	Average potato acreage planted by machine	Average potato acreage planted by hand
Long Island, 1912	24.8	24.6	33.5
Steuben County, 1912	14.6	17.9	13.7
Monroe County, 1913	12.4	13.1	10.6
Franklin and Clinton Counties, 1913	7.2	6.5	8.6

It is evident that growers in none of these regions find it unprofitable to plant by machine so far as average acreage of the crop is concerned. In Steuben and Monroe Counties there was a tendency to use more planters on the larger acreages. The 2 per cent of acreage on Long Island planted by hand averaged higher per farm than the balance which was machine-planted. The same relation held with the 18 per cent of hand-planted acreage in Franklin and Clinton Counties. It is clear, from tables 64 and 65, that the average potato acreage per farm, considered in the light of percentage of total acreage planted by hand and by machine in each region, has no bearing on the extent of machine planting in these four regions.

As indicated in table 64, two types of planters were commonly used. One was of the picker type, employing only one man, while the other was usually of the platform type and required two men for its operation. As the second man on a two-man planter is charged with the duty of seeing that there are no skips, better stands of potatoes are expected from this type of planter. It is shown in table 64 that, whereas about three-fourths of the Long Island acreage was planted with one-man planters, the two-man type predominated in the other three regions.

A study of the relative yields obtained from the acreage planted with each type in the four regions is shown in table 66. Of the total of 635 growers using machine planters — about one-half of all the farmers visited — the numbers using each type of planter were approximately equal. The weighted averages in table 66 show that with about the same amount of seed per acre used in each planter, the yield was 19.3 bushels per acre higher from the acreage planted with the one-man planter. This average is not a true criterion of the two types of planters, however, because a large proportion of the total machine-planted acreage was on Long Island,

TABLE 66. RELATION OF TYPE OF PLANTER TO YIELD IN THE FOUR REGIONS SURVEYED

Region	Two-man planter			One-man planter		
	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)
Long Island, 1912	74	171.6	12.5	249	175.6	12.5
Steuben County, 1912	43	158.1	11.8	28	148.8	12.9
Monroe County, 1913	175	132.1	13.2	28	116.3	13.2
Franklin and Clinton Counties, 1913	22	196.4	14.7	16	181.8	14.4
Total	314	....	....	321	....	....
Weighted average	......	151.4	12.8	......	170.7	12.6
Unweighted average	......	164.6	13.1	......	155.6	13.2

where 77 per cent of the machine-planted area was planted with the one-man type of planter. On the contrary, the difference in average yield, even on Long Island, was only 4 bushels per acre in favor of the picker planter, a difference so small as to lie within expected probable error. In the other three regions, where approximately equal rates of planting were used, the average yields favored the two-man planter by differences ranging from 9.3 to 15.8 bushels per acre. The unweighted averages in the table furnish a true comparison of the efficiency of the two types of planters, and may be accepted as an indication of the increased yield from a more perfect stand resulting from the use of the extra man on the platform planter.

CHECKROW AS COMPARED WITH DRILL PLANTING

A decision as to whether to plant potatoes in checkrows or in drills involves such factors as the cost of labor, available soil fertility and moisture, land value, weed control, and the use of machine planters. Of these factors, weed control is probably the most influential. The statements of many growers in Steuben County concerning their reason for checkrow planting emphasized the facility of weed control by cross cultivation in times when hand labor is scarce or when the pressure of other farm work or a wet season might make weed control otherwise difficult. The cost of labor as a determining factor is debatable, for, while checkrowing may reduce to a minimum the cost of taking care of the crop, the seed may be planted at less cost when planters are used, and planters cannot be used to plant the hills in checkrows. Moreover, while a marker is carried by the machine planter, extra labor is necessary to mark the field in checks for checkrow planting. As is shown in later tables, less seed per acre is usually planted by the checkrow system than by the drill method, since the seed pieces are spaced farther apart. Therefore, from the standpoint of land economy, checkrowing is the less desirable method where land is high in value, as on Long Island. An ample spacing between hills is shown by the typical checkrowed field in Steuben County illustrated in figure 144.

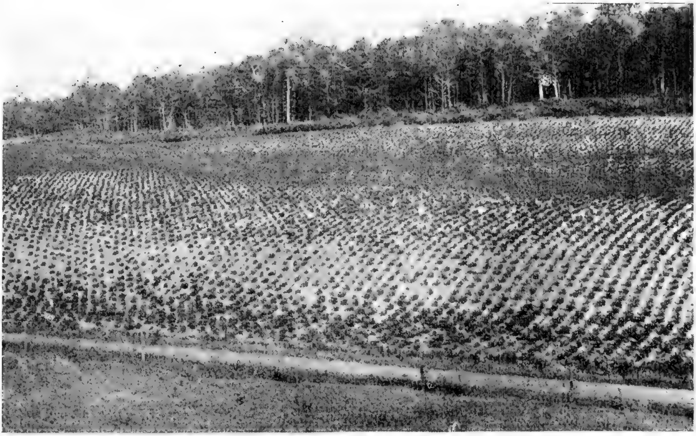

Fig. 144. A checkrowed potato field, common in Steuben County

The smaller amount of seed planted per unit of space in the checkrow system may be desirable wherever soil moisture and fertility are likely to be taxed to their limit. However, the foregoing studies on the relation between rate of planting and yield do not indicate that this point was reached in Steuben County in 1912.

Harwood (1893) reported comparative yields from twenty-four experiments conducted at the Michigan station, in which the varieties Early Ohio and Rural New Yorker No. 2 were planted in hills and in drills. These tests are especially valuable because equal amounts of seed per acre were used in both systems of planting. Altho drill planting did not always give the higher yield, the general average showed a difference of 12 bushels per acre for the Early Ohio and 29 bushels for Rural New

Yorker No. 2 in favor of this method. These differences were due, not to a difference in rate of planting, but to the system of spacing the seed pieces. Shepperd and Churchill (1911), using the variety Early Ohio and varying the rate of planting according to the space between seed pieces, compared the yields from planting at distances of from 10 to 36 inches in the row. Here the yield decreased directly as the interspace increased, the 10-inch spacing giving the best yield. Zavitz (1916), in a six-years test, using equal-sized large whole seed and equal-sized medium whole seed, compared the results of spacing the seed 1, 2, and 3 feet. While his total yields increased directly as the spacing decreased, he obtained the largest net yield from the 2-foot spacing of large whole seed and from the 1-foot spacing of medium whole seed. In another test, running for nine years and with the same rate of planting in both systems of spacing, he compared the yields from planting in checks 33 inches apart and from planting in the drill row with the seed pieces 1 foot apart. The results showed a nine-years average difference of 39.8 bushels per acre in favor of the drill-planted seed. From a review of the tests here reported, it appears that, irrespective of rate of planting, the yield from planting in drills is generally better than that from planting in checkrows.

None of the 330 Long Island growers who were questioned regarding their 1912 crop had planted in checkrows. The almost universal use of planters in this region precludes the possibility of planting by the check-row method. Furthermore, the greater land values encourage economy of space, and the better yields from closer planting have convinced the growers of this region that drill planting is the better method. The method of planting most common in each of the four surveyed regions is indicated in table 67:

TABLE 67. SYSTEM OF PLANTING IN THE FOUR REGIONS SURVEYED

Region	Per cent of growers planting in drills	Per cent of growers planting by checkrow
Long Island, 1912	100	0
Steuben County, 1912	29	71
Monroe County, 1913	74	26
Franklin and Clinton Counties, 1913	18	82

In contrast to the conditions on Long Island, approximately three-fourths of the crop in Steuben and in Franklin and Clinton Counties was planted in checkrows. This may be accepted as evidence that relatively cheap land and scarcity of labor make this the better method for these regions. About three-fourths of the Monroe County crop was planted in drills in 1913.

The influence of the planting system on yield and on the amount of seed used is strikingly shown, for these three regions, in table 68. As is indicated in this table, in all three regions the drill system of planting gave an average

TABLE 68. RELATION OF PLANTING SYSTEM TO YIELD IN THREE OF THE REGIONS SURVEYED

Region	Planted in drills				Planted by checkrow			
	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Steuben County, 1912...	101	153.0	12.2	$12.09	251	129.2	9.2	$ 9.35
Monroe County, 1913...	221	128.5	13.2	11.91	77	120.6	10.2	9.68
Franklin and Clinton Counties, 1913........	54	188.4	14.5	12.94	243	177.2	11.4	13.20
Total..................	376	....	....	....	571	....	....	....
Average..............	....	156.6	13.3	$12.31	....	142.3	10.3	$10.74

yield varying from 7.9 to 23.8 bushels per acre higher than that from planting in checkrows. It is shown further that invariably about 3 bushels more of seed per acre was required to plant by the drill system. The yield was sufficiently higher from this method, however, to more than pay for the extra seed necessary.

On the basis of yield alone, these results favor the drill system of planting for all the regions surveyed. However, it is possible that there are seasons in which weed control is largely dependent on the possibility of cross cultivation. The choice at such times becomes one of producing a medium yield by checkrow planting with a minimum of labor, or a much smaller yield by drill planting.

DEPTH OF PLANTING

Depth of planting is a factor which, tho given some experimental attention by various stations for many years, has received little consideration from the potato grower. The depth at which the seed piece is usually placed depends principally on the soil type and the method of planting. Just as plowing and tillage are normally more shallow in heavy than in light soil, so potatoes are normally planted less deeply in heavy than in light soil. However, the depth at which the potato root system is allowed to develop depends not alone on the depth of planting, but also on the system of tillage employed. This is a factor too often neglected in the study of the influence of depth of planting on yield. For example, the seed may be planted shallow and the crop given ridge culture, or the seed may be planted deeper and the crop receive level culture. With either method the root system might develop at exactly the same depth. Therefore, in studying this factor by reviewing experimental data, false conclusions may easily be drawn. In studying it by survey methods, however, the problem is not so complicated, because of the fact that approximately the same system of culture is used thruout a given locality.

Harwood (1893) reported a test of depth of planting conducted at the Michigan station, using three varieties and planting on sandy loam soil. The depth of planting was varied from 2 to 6 inches. The highest total yield came from the 3-inch planting, while the 4-inch depth was second best. The highest marketable yield came from planting 5 inches deep, altho there was practically no difference between this and the 4- and 6-inch depths. Emerson (1907) compared the yields from plantings at from 1- to 6-inch depths, and obtained a constant increase in yield with each increase in depth up to and including 5 inches. The 6-inch depth gave the second highest yield. Emerson concluded that the better quality and shape of the tuber resulting from planting from 4 to 5 inches deep, more than offset the extra labor of digging necessary for these depths. Sandsten and Delwiche (1909) harvested the highest total yield from the 4-inch depth of planting, the yield decreasing with the increase in depth below that level. Shepperd and Churchill (1911) compared the yields from plantings at depths of 3, 4, 5, 6, 7, and 8 inches. The 4-inch depth gave 8 per cent higher yield than any deeper planting, and 4.5 per cent more than the 3-inch depth. These investigators did not mention soil type, but reported the greatest yield of marketable tubers and the highest quality from the deeper plantings.

Emerson (1914), studying the influence of depth of planting on the value of the harvested crop for seed purposes, planted at 1, 4, and 7 inches. Seed from the 7-inch planting yielded the best, both in total and in marketable yield, in both of the tests he conducted. Also, seed from the 4-inch planting yielded much better than did that from the 1-inch depth. According to Emerson, the higher quality of the seed from such deep planting is probably due to the fact that it was produced under soil conditions which fluctuated very little in temperature and moisture.

Clement and Werner (1917) did not mention soil type in reporting a six-years test on planting at depths of 3, 4, 5, 6, 8, and 10 inches. They obtained the highest marketable yield from the 4-inch depth, and there was a fairly consistent decrease in yield from plantings above and below that depth. Macoun (1905) made a thoro test of the influence of depth of planting, by comparing the yields for six years, on sandy loam soil, from planting at depths of from 1 to 8 inches. In every one of the six years he obtained the best yield from the 1-inch depth of planting. The second-best average yield came from the 3-inch planting. Since Macoun explained that cultivation during each season eventually placed the seed at a depth of about $2\frac{1}{2}$ inches, it cannot be correctly concluded that 1 inch was a better depth to plant than 3 inches. Macoun's yields decreased rapidly in the plantings that were deeper than 6 inches. Zavitz (1916), using the clay loam soil at the Ontario station for seven years, planted seed 1, 3, 5, and 7 inches deep, and practiced level cultivation. He obtained the best, and practically equivalent, yields from planting 3 and 5 inches deep. He noted that when his seed was planted either shallower or deeper than 4 inches, the new tubers showed a tendency to develop nearer the 4-inch level than at the depth of planting.

The evidence presented in the foregoing experiments indicates that, depending to some extent on the soil type and the kind of tillage, the yields are usually better when the seed is planted about 4 inches deep than when it is planted either shallower or deeper. The fact that tubers tend to form near the 4-inch level, irrespective of depth of planting, is in itself an indication that soil moisture and temperature are the most favorable at this depth. While seed planted deeper is normally subjected to temperatures too cool for rapid growth, and the resulting crop forms too deep to be dug easily, seed planted less deep is subjected to a greater fluctuation in moisture and temperature, resulting in ill-shaped tubers and very often in a high proportion of sunburned or even blighted tubers.

In this investigation an attempt was made to determine whether soil type and method of planting have any influence on depth of planting. The average depth of planting in each region, by machine, by hand, and for the region, is shown in table 69:

TABLE 69. Depth of Planting in the Four Regions Surveyed

Region	Average depth planted (inches)	Average depth planted by machine (inches)	Average depth planted by hand (inches)
Long Island, 1912	3.3	3.3	3.4
Steuben County, 1912	3.1	3.0	3.1
Monroe County, 1913	3.2	3.1	3.0
Franklin and Clinton Counties, 1913	2.6	3.2	2.5

Of the four regions, the deepest planting is found on Long Island and the shallowest in Franklin and Clinton Counties. Inasmuch as the potato soils of these two regions are lighter than those of either Steuben or Monroe County, no influence of soil type on depth of planting is evident in this study. The only significant influence of method of planting on depth is in Franklin and Clinton Counties, where machine-planted potatoes were placed, on the average, 0.7 inch deeper than those planted by hand. Whether or not the average depth of planting shown for each region approximates the optimum depth is considered in the following paragraphs and tables.

The relation of this factor to yield on Long Island in 1912 is shown in table 70. The depth of planting appears to have influenced the yield in

TABLE 70. RELATION OF DEPTH OF PLANTING TO YIELD ON 329 LONG ISLAND FARMS IN 1912

Depth planted (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Less than 3	68	166.7	12.1	$30.25
3–4	144	178.0	12.5	32.60
4–5	99	176.7	12.9	33.41
5 and more	18	182.2	12.8	33.65
Total	329	....	....	....
Average, 3.3 inches	......	175.6	12.5	$32.42

this region very little. Altho the average yield increased slightly as the depth increased, the increase in yield beyond the 3-inch depth was no greater than would probably be due to the slight increase in seed and in the value of manure and fertilizer used. Apparently, the average depth of 3.3 inches for 1912 was approximately the best.

The results of a similar study in Steuben County are shown in table 71:

TABLE 71. RELATION OF DEPTH OF PLANTING TO YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Depth planted (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer	Per cent of total yield rotted in field
1–2	6	148.1	10.1	$ 9.39	1 .0
2–3	83	139.6	10.2	11.09	14.5
3–4	179	134.4	10.1	9.79	14.7
4 and more	92	136.0	10.1	9.97	17.4
Total	360	....	....	....	....
Average, 3.1 inches	....	136.4	10.1	$10.06	15.2

Altho six growers are too few to permit of the drawing of definite conclusions as to the shallowest planting found, there is considerable evidence that planting not more than 2 inches deep in the heavy soils of Steuben County is desirable, at least in a year as wet as was 1912. Under a constant rate of planting at all depths, and with the least manure and fertilizer used at the shallowest depth of planting, this depth gave the highest average yield and the smallest percentage of field-rotted tubers in 1912. In fact, the percentage of field rot increased with the depth of planting. Assuming that there had been no rot from blight and wet weather that year, the average yield of the fields planted at the shallowest depth would still have been the highest.

The relation of depth of planting to yield in Monroe County in 1913 is shown in table 72. It is clear from this table that in 1913, planting shal-

TABLE 72. RELATION OF DEPTH OF PLANTING TO YIELD ON 260 MONROE COUNTY FARMS IN 1913

Depth planted (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
1–2	11	151.5	11.5	$10.43
2–3	67	143.1	12.8	11.11
3–4	110	131.[illegible]	12.6	11.83
4 and more	72	132.6	12.5	11.91
Total	260	......	......	......
Average, 3.2 inches	......	135.6	12.6	$11.61

lower than the average of this region would have given more than average yields. With the least seed and fertilizer, the shallowest-planted fields gave the highest yields. Since the potato soils of this region are heavier than those of either Long Island or Franklin and Clinton Counties, and, in fact, are rather heavier than ideal potato soil should be, this gives further evidence that potatoes should be planted shallower on heavy than on light soils. With an increase in the value of manure and fertilizer, and an approximately constant amount of seed used per acre, an increase in depth of planting was accompanied by decreased yield on fields planted deeper than 2 inches.

The importance of depth of planting as influencing yield in Franklin and Clinton Counties is shown in table 73. The average yields in this region increased with the depth of planting, down to a depth of 4 inches. A part of this increase must be attributed to an increased use of seed and fertilizer.

TABLE 73. RELATION OF DEPTH OF PLANTING TO YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Depth planted (inches)	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
Less than 2	44	172.3	11.2	$12.27
2–3	111	175.4	11.9	12.95
3–4	91	184.9	12.3	13.25
4 and more	54	182.6	12.4	13.25
Total	300	......	......	......
Average, 2.6 inches	......	179.3	12.0	$13.01

The evidence in table 73 indicates that the yields began to decrease from planting at depths greater than 4 inches. Evidently, in soils as light as those of this locality, planting at greater depths than the average of 2.6 inches for 1913 may be recommended.

Depth of planting is a factor which would require controlled experiments covering several years in order to determine the most effective depth for any given region. The evidence of a single year from the surveyed regions indicates that in the heavier soils it is safe to plant shallower, and in the lighter soils deeper, than the average depth for 1912 and 1913.

DEPTH OF CULTIVATION

The term *cultivation* has been used so promiscuously in agricultural literature that it seems well to define its limitations as used in this study before entering on any discussion of its influence on the yield of potatoes. Cultivation has for its primary objects, weed control and moisture conservation. Any operation on the crop after it is up, which stirs the soil for either or both of these purposes, is therefore included within the meaning of the term as here used. Such operations as using the weeder, pulling weeds, hoeing, and hilling or ridging the crop, are comprehended by the term. This will account for the great frequency of cultivation noted in the studies of the influence of this factor on yield.

Harwood (1893) reported the results of forty-four tests on the influence of depth of cultivation on yield. Considering 1.5 inches as shallow and 5 inches as deep culture, forty of the forty-four tests gave total and marketable yields favoring deep culture. As a rule, the greatest yield of small and sunburned tubers was obtained from shallow culture. Schweitzer (1896), in a one-year test on potatoes planted 4 inches deep, compared deep and shallow tillage. Altho his yields were almost equal, he obtained a slightly higher marketable yield from deep cultivation and a slightly higher total yield from shallow cultivation.

Information on depth of cultivation in the four regions surveyed, was obtained in relative terms, denoting general depth rather than actual inches. The variation in depth thruout the growing season was noted also. It has therefore not been possible to make any definite correlation of this factor with yield in these studies, because of the fact that much variation in opinion may have existed among growers as to just what constituted deep, medium, or shallow culture. Furthermore, it is a common practice in all four regions to ridge the rows more or less late in the growing season. This practice really amounts to a deep cultivation at the center of the row while little or none is given close to the plants. Altho considerable variation in the depth of cultivation was found at different times during the growing season, a plurality of the growers practiced relatively deep early-season cultivation and shallow late-season cultivation. This would seem to be good cultural practice, inasmuch as deep tillage early would enlarge the soil area suited to tuber and root development, while shallower tillage later would avoid undue root pruning and disturbance after tuber formation.

The practice with respect to this factor, and its apparent influence on yield in each of the regions, is shown in table 74. Of the 1290 growers

TABLE 74. Relation of Seasonal Depth of Cultivation to Yield in the Four Regions Surveyed

Type of cultivation	Long Island, 1912		Steuben County, 1912		Monroe County, 1913		Franklin and Clinton Counties, 1913	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Deep early and shallow late	267	172.9	164	141.5	106	146.0	89	183.7
Medium early and medium late	9	165.1	112	123.3	21	130.3	58	172.1
Deep early and deep late	34	195.0	38	149.5	67	128.5	35	175.4
Deep early and medium late	12	149.3	23	121.6	29	122.9	30	196.2
Total	322	....	337	....	223	....	212	....
Average	....	175.2	....	135.7	....	136.7	....	181.2

concerned in the whole survey, approximately 1100 practiced one of the four types of cultivation listed in this table. Each of the remainder practiced one of the other possible five types of deep, medium, and shallow early- and late-season cultivation. On the basis of weighted averages, the best average yields were obtained from deep cultivation early in the season and shallow cultivation late.

RIDGE AS COMPARED WITH LEVEL CULTURE

The system of potato culture in vogue almost universally thruout the New England and Middle Atlantic States has been that of varying degrees of ridging or hilling. An extreme ridging, comparable to that followed in Aroostook County, Maine, is practiced in Franklin and Clinton Counties. In only a few limited areas, notably the Long Island potato areas, is anything approaching level cultivation common in these sections of the United States. Regardless of the fact that several station experiments have shown superior merit in point of yield from level culture, ridge culture is by far the commoner. The more obvious advantages of ridge culture consist in (1) greater ease in digging, (2) more efficient weed control by covering rather than by removing and disturbing the root system close to the row, (3) more friable soil for tuber development, (4) protection of tubers from the spores of the late-blight fungus (*Phytophthora infestans*), and (5) greater surface evaporation of moisture, a factor of special value on heavy soils in regions of possible excess, or poorly distributed, growing-season rainfall.

Geismar (1905) compared hill and level culture on both fall- and spring-planted potatoes. His yields favored level culture for both the fall- and the spring-planted crops by 5 and 7 per cent increases, respectively. Geismar very mistakenly added these increases and credited the total to the advantage of level culture. This was a blight year at the Michigan station, and, altho Geismar stated that the damage from the disease was confined to the tops, it is possible that some protection from ridging was furnished the ridged plots, and that in a dry year the advantage in level culture would have been even greater. Stone (1905), at the Cornell station, compared various frequencies of hilled and level culture for five years on medium light soil. In each of these years, the yields were best under level culture, the differences ranging from 1 to 37 bushels per acre, the average favoring level culture by 14 bushels. Stone did not explain why the smallest differences in yield occurred in the two driest years, when the greatest advantage from level culture might have been expected. During three of these five years, he compared continuous level culture up to nine cultivations, with laying by and ridging the crop after from three to five cultivations. In these tests, the continuous level culture gave an average advantage of 54 bushels per acre. Shepperd and Churchill (1911), altho reporting no data, stated that level culture has given far better results than ridging in North Dakota, even in sections having the heaviest rainfall.

Since the system of cultivation as well as the depth of planting may have a part in determining the ultimate depth of the seed piece, this factor of depth of seed piece should be controlled in all tests of the influence of system of cultivation on yield. Woods and Bartlett (1909) and Woods (1911) reported a comparison of the yields from shallow planting and high ridging and from medium planting and medium ridging. In these tests the depth of seed piece was constant. The medium-ridge culture gave a three-years average yield of 10 bushels per acre more than the high-ridge culture. Woods (1914), reporting a continuation of these tests but including deep planting and level culture, showed a four-years average yield for the years 1910 to 1913, inclusive, of 276 bushels per acre from medium ridging, 261 bushels per acre from level culture, and 232 bushels per acre from high ridging. Thus, over a long period of years, in a region of relatively high rainfall and with the depth of seed piece constant, the yields favored a system ranging from medium-ridge to level culture. Because of the greater difficulty of harvesting the crop from level culture, however, Woods concluded that, for Maine conditions of soil and climate, there is little choice between these three methods.

Macoun (1905) reported four-years average yields, from level and from ridge culture, favoring ridge culture by 22 bushels per acre. Level culture proved the better in one of the four years, and, altho one of the four was a drought year, this was not the year in which the level culture yielded the best. Macoun's results were obtained at the Ottawa station, in a moist sandy loam not subject to drying out. Zavitz (1916), in a nine-years test, obtained an average difference of 7.6 bushels per acre in favor of ridge culture. He stated that three of the nine years were comparatively dry, and in these three years level culture gave the higher yields. Clinton (1916), in a six-years comparison of ridge and level culture, obtained yields slightly favoring ridge culture during three years and yields slightly favoring level culture during the remaining three years. He concluded that the only difference in the influence of these two systems on yield is in an advantage from a lower percentage of blight rot under the ridge-culture system.

It must be concluded from the above review of experiments that, in general, level culture has given slightly better yields than has ridging. The advantage has been most marked in dry years and in the lighter soils. Depending on regional soil type and seasonal rainfall, however, the advantages generally conceded to ridging should be considered in choosing the best system to fit a specific locality.

Owing to the lack of variation in tillage methods within each of the regions studied, it was not possible to correlate this factor with yield by survey methods. Altho some variation in the degree of ridging exists within each region, lack of information on a definite measurement of this degree makes its use in these studies impossible.

Level culture is the system generally understood to be practiced on Long Island. However, nearly all the growers there, while maintaining level culture thruout most of the season, cultivate a slight ridge toward the row late in the season, at either the last or the last two cultivations. The reasons given by growers of the 1912 crop for this practice, were (1) that digging was made easier and (2) that the tubers were protected from the spores of the late-blight fungus. Altho the potato soils of Long Island are relatively light in texture, the growing-season rainfall of this region, as shown in figure 127 (page 1149), is relatively high. All growers of the 1912 crop reported the practice of level culture.

In Steuben County a system of relatively high ridging is practiced. A ridge is gradually worked toward the row at each cultivation thruout the season, and this is increased late in the season by a specialized implement called a *hiller*. Because of the heavy soil of this region, ridge culture is doubtless of some merit due to the greater ease in harvesting and the protection from blight rot which it affords. All the growers whose 1912 crop was studied practiced ridge culture.

Of the 300 growers in Monroe County, 272 reported the practice of level culture, with a slight ridging toward the end of the growing season. The other 28 growers in this region practiced continuous level culture in 1913.

Only 1 of the 300 growers in Franklin and Clinton Counties practiced level culture in 1913. Ridging is here begun as soon as the crop is up, the tops, and such weeds as have grown since planting, being covered at that time. By the end of the growing season an extreme ridge has been developed, greater than that used in Steuben County. Altho the growing-season rainfall of this region is almost as high as that of Long Island, the light soils which prevail in most of the section do not seem to warrant such extreme ridging. This is a problem apparently impossible of solution by survey methods and one requiring years of test.

FREQUENCY OF CULTIVATION

Cultivation as a prime requisite of good crop yields thru its resulting in weed control, moisture conservation, and increased availability of plant food, is one of the oldest known practices of agriculture. However very few experiments of value have been conducted for the express purpose of determining the optimum frequency of cultivation. The value of such tests is, of course, dependent on such other factors as duration of the experiment, condition of the seed bed, replication, and time of cultivation. Conclusions drawn must give due consideration to the available soil moisture and fertility and the soil type under which the test is conducted.

Stone (1905), in a carefully controlled experiment covering six years at the Cornell station, compared the yields of potatoes from cultivating three, four, five, six, seven, eight, nine, eleven, and thirteen times during the season. During these years he obtained average yields favoring seven, eight, and nine cultivations, by from 8 to 100 bushels per acre. The plots were replicated from two to four times. Stone's tests showed clearly that under the conditions of his experiment it was possible to cultivate beyond the limit of maximum production. Emerson (1907) compared yields from what he called *poor*, *medium*, and *thoro* cultivation. Under poor tillage, the land was harrowed three times and cultivated twice, the land not being kept free from weeds even early in the season. Under medium tillage, the land was harrowed three times and cultivated four times, the weeds growing only in the rows after the crop was nearly ripe. Under thoro tillage, four harrowings and six cultivations were given, no weeds being allowed to grow. The yield of the medium-cultivated crop exceeded that from poor tillage by 60 per cent and that from thoro tillage by about 9 per cent. Emerson concluded (1) that tillage can be overdone, (2) that cultivation to control weeds only is sufficient, and (3) that, in eastern Nebraska, two or three harrowings and five or six cultivations are sufficient for potatoes.

The high frequency of cultivation recorded for some of the regions included in this study must not be construed to mean that this frequency applies only to operations with a cultivator. As already explained, all operations which stir the soil and control weeds after planting are included. Inasmuch as the rate of planting and the value of manure and fertilizer have already been shown to be very influential on yield, frequency of cultivation is here studied for each region in connection with these factors.

Frequency of cultivation on Long Island

Long Island is the only region, of the four surveyed, in which the Hallock weeder is used extensively. This implement is used principally just before or just after the crop comes up. Having a broad sweep, it removes very efficiently those small weed seedlings which develop between planting time and the time at which the plants come up. Since the entire crop in this region is planted in drills, cross cultivation is impossible and much hand hoeing is therefore done to remove the weeds that develop during the growing season. Many growers reported also hand pulling of weeds. These operations, in addition to the usual cultivations between the rows, resulted in the highest frequency of cultivation in this region, the average in 1912 being 10.9 times.

The relation of this factor to yield, under constant rates of planting, is shown in table 75. The averages for the 329 farms listed in this table indicate that in 1912 it did not pay to cultivate more than ten times. In fact, these averages seem to indicate that frequency of cultivation above

TABLE 75. RELATION OF FREQUENCY OF CULTIVATION AND RATE OF PLANTING, TO YIELD, ON 329 LONG ISLAND FARMS IN 1912

Number of times cultivated	Amount of seed planted							
	Less than 12 bushels		From 12 to 14 bushels		14 bushels and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 10......	44	183.7	42	165.5	28	190.9	114	176.6
10–13............	59	158.7	52	183.9	24	194.1	135	177.1
13 and more.......	35	155.7	32	157.4	13	222.8	80	168.6
Total............	138	....	126	....	65	....	329	....
Average..........	....	166.2	....	170.2	....	197.8	....	175.7

ten was not influential on yield. A further study of the table, however, shows that as the rate of planting increased, the efficiency of the higher frequencies of cultivation increased. This phenomenon may possibly be explained by considering it in connection with the figures in table 76,

TABLE 76. RELATION OF FREQUENCY OF CULTIVATION AND VALUE OF MANURE AND FERTILIZER, TO YIELD, ON 330 LONG ISLAND FARMS IN 1912

Number of times cultivated	Value of manure and fertilizer							
	Less than $30		From $30 to $40		$40 and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 10......	32	175.3	65	181.2	18	166.5	115	178.4
10–13............	57	155.7	62	191.2	16	191.9	135	177.1
13 and more......	40	151.1	26	163.1	14	217.9	80	168.6
Total............	129	....	153	....	48	....	330	....
Average..........	....	158.7	....	182.2	....	194.4	....	175.5

showing the relation of frequency of cultivation and value of manure and fertilizer to yield. The variation in the average yields in tables 75 and 76 exhibits a very obvious similarity. It is evident in both tables that more than ten cultivations were efficient only when the greater amounts of seed and of manure and fertilizer were used. This may indicate either that a greater amount of tillage was necessary to control the greater weed growth produced by the increased fertility, or that more tillage was necessary to make available sufficient plant food to support the increased stand of potatoes. It may be concluded that, on the average, it did not pay to cultivate potatoes more than ten times in this region in 1912. The coefficient of correlation between this factor and yield, as shown in figure 145, is -0.087 ± 0.037. This slightly

Number of times cultivated	Yield per acre, in bushels: 26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	
3–4		1											1
5–6				1	2		3	1	2	1			10
7–8		1	5	5	19	3	11	11	6	3			64
9–10	1	1	11	9	17	10	17	8	7	3		1	85
11–12		1	6	10	20	17	18	2	6	4	4	2	90
13–14		1	3	10	11	5	6	4	1	2	3		46
15–16			2	2	5	6	2		1		1		19
17–18				1	5	1	2	1					10
19–20						1							1
21–22					1		1						2
23–24					1								1
25–26													0
27–28		1											1
	1	6	27	38	81	43	60	27	23	13	8	3	330

$r = -0.087 \pm 0.037$

FIG. 145. CORRELATION OF FREQUENCY OF CULTIVATION AND YIELD ON 330 LONG ISLAND FARMS IN 1912

negative value indicates that the average frequency was a little too high for maximum production. However, the relatively high probable error renders the coefficient insignificant.

Frequency of cultivation in Steuben County

Cultivation was not so thoroly practiced in Steuben County in 1912, as on Long Island, the average frequency being 7.6 cultivations. Weed control is much more of a problem here than elsewhere because of the fact that potatoes are usually grown on sod land of several years standing and on land containing a considerable quantity of weed seed or stubble. Furthermore, the seed bed is here more poorly prepared than in most other regions because of the susceptibility of the soil to extreme puddling. Under these conditions, the factor of frequency of cultivation would be expected to have a direct positive influence on yield. The relationship of this factor and the rate of planting, to yield, is shown in table 77:

TABLE 77. RELATION OF FREQUENCY OF CULTIVATION AND RATE OF PLANTING, TO YIELD, ON 349 STEUBEN COUNTY FARMS IN 1912

Number of times cultivated	Amount of seed planted							
	From 6 to 10 bushels		From 10 to 14 bushels		From 14 to 18 bushels		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
1- 4	78	122.5	70	135.6	4	168.6	152	130.3
4- 7	67	123.5	97	141.5	10	201.3	174	138.0
7-13	2	108.3	15	164.2	6	192.1	23	168.4
Total	147	....	182	....	20	....	349	....
Average	....	122.8	....	141.4	....	191.3	....	136.4

Four of the groups studied in table 77 contain too few farms to give reliable results, yet the study shows clearly enough that the average yields increased as the frequency of cultivation increased, irrespective of the

TABLE 78. RELATION OF FREQUENCY OF CULTIVATION AND VALUE OF MANURE AND FERTILIZER, TO YIELD, ON 147 STEUBEN COUNTY FARMS IN 1912

Number of times cultivated	Value of manure and fertilizer							
	From \$4 to \$12		From \$12 to \$20		From \$20 to \$50		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
1- 4	23	136.5	20	150.1	5	165.9	48	145.0
4- 7	35	142.4	24	172.5	21	165.7	80	157.0
7-13	10	166.0	4	169.9	5	173.5	19	168.4
Total	68	....	48	....	31	....	147	....
Average	....	145.0	....	162.9	....	167.1	....	155.1

rate of planting. To further allay suspicion that the increased yields, apparently due to increased cultivation, were not in part due to corresponding increases in the value of manure and fertilizer, a study of this factor in connection with value of manure and fertilizer is presented in table 78. Altho comparatively few farms are involved in the study in this table, the positive influence of frequency of cultivation on yield is well shown. In contrast to Long Island, it is apparent that growers in this region did not exceed the profitable limit in number of cultivations in 1912. This statement is further proved by the coefficient of correlation, 0.231 ± 0.034, shown in figure 146.

Yield per acre, in bushels

Number of times cultivated	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	351–375	
3	1					1										2
4			2	1	2	3	1	2								11
5			4	5	10	10	10	1								40
6	1	2	8	9	12	17	9	10	4	1						73
7		2	6	18	15	11	5	5		1		1			1	65
8		1	5	16	14	10	15	8								69
9				6	7	16	5	2		3						39
10			1	5	5	4	2	3	1	1		1				23
11				2	6	4	2	4	1							19
12				1	1	1	1	1	2	1						8
13				1		1		2								4
14									1							1
15					1		2			1						4
16										1						1
17																0
18																0
19																0
20										1						1
	2	5	26	64	73	78	52	38	9	10	0	2	0	0	1	360

r = 0.231 ± 0.034

FIG. 146. CORRELATION OF FREQUENCY OF CULTIVATION AND YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Frequency of cultivation in Monroe County

The common rotation of one to two years of cultivated crops, followed by two years of grain, followed by only one to two years of hay, makes the problem of weed control less of a limiting factor to yield in Monroe County than in Steuben County. The growing-season rainfall for this region, however, as shown in figure 127, is lower than that for the other three areas, and, because of this, cultivation for moisture conservation might be presumed important. The average frequency of cultivation in 1913 was 8.1 times. The relation of this factor, in connection with the rate of planting and the value of manure and fertilizer, to yield, is shown in tables 79 and 80, respectively:

TABLE 79. RELATION OF FREQUENCY OF CULTIVATION AND RATE OF PLANTING, TO YIELD, ON 300 MONROE COUNTY FARMS IN 1913

Number of times cultivated	Amount of seed planted							
	Less than 12 bushels		From 12 to 15 bushels		15 bushels and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 7	34	117.1	29	117.9	15	112.1	76	116.6
7–9	41	115.3	60	114.4	23	145.6	124	120.8
9 and more	25	113.2	54	133.6	21	172.5	100	138.8
Total	100	....	143	....	57	....	300	....
Average	....	115.4	....	122.7	....	150.1	....	126.2

TABLE 80. RELATION OF FREQUENCY OF CULTIVATION AND VALUE OF MANURE AND FERTILIZER, TO YIELD, ON 300 MONROE COUNTY FARMS IN 1913

Number of times cultivated	Value of manure and fertilizer							
	Less than $10		From $10 to $20		$20 and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 7	36	106.8	33	122.6	7	137.6	76	116.6
7–9	59	114.2	56	125.9	9	133.9	124	120.8
9 and more	41	120.6	47	150.1	12	159.2	100	138.8
Total	136	....	136	....	28	....	300	....
Average	....	114.4	....	134.3	....	145.5	....	126.2

Altho increased frequency of cultivation did not produce increased yields for growers using less than 12 bushels of seed per acre, this does not apply to the growers who used more seed. Furthermore, since the group of growers using less than 12 bushels of seed per acre included those who planted in checkrows, it was doubtless possible to control weeds with fewer cultivations than were necessary for fields planted in drills. A fairly consistent positive influence of frequency of cultivation on yield, irrespective of the value of manure and fertilizer used, is shown in table 80. It is evident that the highest frequencies of cultivation were productive of profitably increased yields except for the few growers who, because of checkrow planting which made cross cultivation possible, were able to control the weeds with fewer cultivations. The coefficient 0.169 ± 0.038 (fig. 147), while small, is positive and is significant in value.

Number of times cultivated	Yield per acre, in bushels: 1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	326–350	
4				1	1	1									3
5	1	1		5	6	4	1	3							21
6		1	10	16	8	9	4	2	2						52
7		1	9	14	8	12	8	4	1	3					60
8		1	10	16	14	14	1	6	2						64
9		2	4	7	6	7	4	4	1					1	36
10		1	1	7	3	4	7	3					1		27
11			2	3		4	6	1	1	1		1			19
12			2		1	1	1								5
13					2	2	1		1						6
14						2	1								3
15															0
16				1											1
17					1										1
18								1							1
19															0
20						1									1
	1	7	38	70	50	61	34	24	8	4	0	1	1	1	300

$r = 0.169 \pm 0.038$

FIG. 147. CORRELATION OF FREQUENCY OF CULTIVATION AND YIELD ON 300 MONROE COUNTY FARMS IN 1913

Frequency of cultivation in Franklin and Clinton Counties

Cultivation in Franklin and Clinton Counties is not generally continued as late in the growing season as in most other regions of the State. On the other hand, ridging is begun early in the season and the crop is given the final ridging soon after blossoming. The average number of cultivations in this region in 1913 was 6.3. As shown in table 15, this was the only region of the four in which a very significant proportion of the total acreage was plowed in the fall. This practice allows earlier and better seedbed preparation in the spring than would otherwise be possible, and makes later cultivations during the growing season less necessary. The relation of this factor in connection with the amount of seed and the value of manure and fertilizer used, to yield, in 1913, is shown in tables 81 and 82, respec-

TABLE 81. RELATION OF FREQUENCY OF CULTIVATION AND RATE OF PLANTING, TO YIELD, ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Number of times cultivated	Amount of seed planted							
	Less than 12 bushels		From 12 to 14 bushels		14 bushels and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 6	46	164.1	49	184.0	30	189.0	125	177.2
6–8	41	162.5	35	192.0	30	204.8	106	187.7
8 and more	38	159.6	20	191.2	11	184.5	69	172.0
Total	125	....	104	....	71	....	300	....
Average	....	162.1	....	188.1	....	195.0	....	179.3

TABLE 82. RELATION OF FREQUENCY OF CULTIVATION AND VALUE OF MANURE AND FERTILIZER, TO YIELD, ON 297 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

Number of times cultivated	Value of manure and fertilizer							
	Less than $10		From $10 to $14		$14 and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 6	44	173.0	41	177.5	38	189.0	123	179.1
6–8	31	177.7	38	188.4	37	188.4	106	185.2
8 and more	19	142.5	27	177.0	22	188.9	68	171.5
Total	94	....	106	....	97	....	297	....
Average	....	168.2	....	181.3	....	188.7	....	179.5

tively. As shown in these tables, there was no apparent gain in yield in 1913 from cultivating more than seven times. In fact, it is questionable whether the small gain shown in most cases from cultivating more than five times was sufficient to pay the extra cost of the labor involved. This means that the average frequency for the year concerned was not far from optimum. The coefficient 0.055 ± 0.039 (fig. 148), while positive, is

Number of times cultivated	Yield per acre, in bushels: 76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	Total
3	1		3	1	3	2				10
4	2	3	4	9	6	5	3			32
5	3	5	14	17	15	18	5	4	2	83
6	3	4	12	7	19	5	9	2	3	64
7	1	4	6	8	16	2	3	2		42
8	1	5	6	3	8	3	2	1		29
9		5	2	3	1	1		3		15
10		1	2	3	2	1		1		10
11	1			1	1					3
12							1			1
13			1		3	1	1			6
14					2		2	1		5
	12	27	50	52	76	38	26	14	5	300

$r = 0.055 \pm 0.039$

FIG. 148. CORRELATION OF FREQUENCY OF CULTIVATION AND YIELD ON 300 FRANKLIN AND CLINTON COUNTY FARMS IN 1913

too small and insignificant to indicate any real correlation of frequency of cultivation with yield. It must be concluded, therefore, that in practically all cases sufficiently frequent cultivation was given so that it was not a factor limiting yield.

SPRAYING

Spraying as a factor in potato production must have been first practiced in this country sometime after 1859. This is the date when the Colorado potato beetle (*Leptinotarsa decemlineata*) began its movement eastward from the Rocky Mountains (Fraser, 1912). The potentiality of this pest to cause complete defoliation has since resulted in the extensive use of such arsenical insecticides as paris green, arsenate of lead, and arsenite of soda, for its control. The extent to which insecticides have been used in a given locality has depended on the prevalence of the beetles. The fact that growers in a certain locality did not spray for insects during a certain season, is evidence that insects were scarce or almost absent. A study of the influence of spraying with insecticides on yield in a given region, therefore, may not be expected to show positive results. On the contrary, positive influence on the yield from spraying with a fungicide for the simultaneous control of late blight (*Phytophthora infestans*), early blight (*Alternaria solani*), and tipburn, as well as for the control of flea beetles (*Epitrix cucumeris*), may be expected in most potato regions every year if the spraying is done thoroly. As a standard fungicide, bordeaux mixture has been used for this purpose for about thirty-six years, the practice having begun in France in 1885 (Macoun, 1905). Probably the first systematic and continuous series of spraying experiments with bordeaux conducted in this country, were begun by Jones at the Vermont station in 1891. Lutman (1911) has reported a twenty-years summary of these experiments. During this period, late blight occurred fifteen years out of the twenty, the loss in yield from the resulting rot varying from year to year. These tests showed a gain in yield every year from spraying, the percentage of gain per acre ranging from 18 in a year of no blight, to 215 in a year of much blight, and the average gain per acre for the twenty years being 64 per cent. Altho the frequency of spraying in these tests varied from one to five times a season, the influence of spraying cannot be studied because different frequencies were not used within any one year.

Second in importance to the Vermont experiments are those of ten years duration conducted by the New York station at Geneva, under the direction of Stewart, French, and Sirrine (1912). These tests were duplicated, one series being conducted on heavy clay loam soil at Geneva, and the other on light sandy loam soil at Riverhead. During the test, late blight occurred six years out of the ten at Geneva and only three years out of the ten at Riverhead. As might be expected, therefore, the greater average gain from spraying was obtained from the Geneva plots. However, there was not one year out of the ten on either series of plots in which a gain from spraying was not obtained. In years of no blight this gain was attributed to the control of such factors as flea beetles, early blight, bugs, and tipburn. Spraying every two weeks during the growing season was each year compared to spraying but three times. With but one slight exception, the more frequent spraying resulted in the higher yield. The ten-years average difference in yield due to this difference in frequency of spraying was 28.5 bushels per acre for Geneva, and 20.7 bushels per acre for Riverhead. Spraying every two weeks gave a ten-years average gain in yield of 97.5 bushels per acre at Geneva and 45.7 bushels per acre at Riverhead.

Clinton (1916) reported the results of spraying in a thirteen-years test at the Connecticut station. Altho no data are presented on the influence of the various frequencies of spraying, increased yields ranging from 10 to 101 bushels per acre (the average being 38 bushels per acre) were reported. At this station, also, increased yields due to spraying were obtained every year, including years of no blight, in which the average increase was 29 bushels per acre. In all but four of twenty-two tests, the increased yield more than paid the cost of spraying, the average net gain per acre being $15.

Stone (1905) varied the frequency of bordeaux spraying from year to year in a six-years experiment in which unsprayed checkrows were used. But he did not vary the frequency between plots in any single year. Therefore, no data on frequency of spraying, of any value, are available from this source. A gain in yield from spraying, ranging from 7 to 83 bushels per acre, was obtained during five of the six years. Stone did not attempt to explain the one year of loss apparently due to spraying, altho the loss averaged more than 30 bushels per acre.

Somewhat conflicting data were obtained by Sandsten and Milward (1906) in a two-plot experiment of one year duration. Comparing the results from two, three, five, and six applications of bordeaux to each plot, they found, on one plot, a constant increase in yield with each increased application up to and including five, the increase dropping off slightly with six applications. The second plot showed a general tendency for yields to increase with the frequency of applications, but the data are inconsistent, three applications resulting in a yield lower than that of the check plot, while five applications resulted in a 172-per-cent increase.

Testing the influence of frequency of spraying on yield in a blight-free year, Kohler (1909) compared yields from plots duplicated four times and sprayed two, three, four, and six times, respectively. His results showed a decrease in yield of marketable tubers, of 0.7 bushel per acre, from spraying two times, and increased yields of 8.4, 15.8, and 18.7 bushels per acre, respectively, from spraying three, four, and six times, as compared to check plots. A year later, when again there was no occurrence of blight, Kohler (1910) obtained an average increase in yield of 17.4 and 18.8 bushels per acre over the yields of the unsprayed plots, from four and six applications, respectively. Kohler therefore concluded that, irrespective of late blight, better yields may be expected from sprayed plots because of the healthier condition of the foliage.

The value of thoroness in applying bordeaux has been well demonstrated by Zavitz (1916) in his report of a seven-years test at the Ontario station. In five of the seven years, no blight rot occurred. In spite of this, both total and marketable yields increased directly with the frequency of spraying, in spraying three, four, and five times during each of the five years. Zavitz found that spraying both the tops and the bottoms of the plants in all three applications, rather than spraying only the tops, gave an increase in total yield of 13.5 bushels per acre, thus demonstrating the value of thoroness. In 1910, a year of blight rot, spraying from two to six times gave a proportionate increase in the yield of sound potatoes, a constant increase in the length of the growing period of the plants, and a constant decrease in the percentage of rot in the crop.

Macoun (1905) did not test the influence of frequency of spraying, but by spraying four times in 1901 and in 1902, and five times in 1904, he obtained an average increased yield, for the three years, of 94.5 bushels per acre.

In spite of the loss of millions of dollars to the growers in New York caused by the occurrence of blight every two or three years, and in spite of the proved value of bordeaux mixture as a preventive of this disease, relatively few growers make a practice of using a fungicide. Altho blight has frequently been epiphytotic in all four of the regions surveyed except Franklin and Clinton Counties, only one-third of the growers on Long Island in 1912, 5 per cent in Steuben County in 1912, and 25 per cent in Monroe County in 1913, sprayed their crops with a fungicide. Occasional attacks of blight have been observed in Franklin and Clinton Counties, but epiphytotics are practically unknown; and even when the fungus is present on the foliage, it seldom attacks the tubers to any serious extent in this region. Only 1 per cent of the growers in this region sprayed for blight prevention in 1913. So few growers used fungicide in Steuben, Monroe, and Franklin and Clinton Counties, that the influence of frequency on yield could not be studied in detail. The extent to which insecticides and fungicides were used in the four regions, and the average yields per acre under the various treatments, are given in table 83. In

TABLE 83. SUMMARY OF SPRAYING IN THE FOUR REGIONS SURVEYED

Treatment	Long Island, 1912		Steuben County, 1912		Monroe County, 1913		Franklin and Clinton Counties, 1913	
	Per cent of farms	Average yield per acre (bushels)	Per cent of farms	Average yield per acre (bushels)	Per cent of farms	Average yield per acre (bushels)	Per cent of farms	Average yield per acre (bushels)
No spraying	3	190.7	51	130.2	12	150.3	36	186.1
Insecticide only	64	161.7	44	137.3	63	121.5	63	177.3
Fungicide	33	197.1	5	171.5	25	126.2	1	152.3
Average	100	175.5	100	136.4	100	126.2	100	179.3

this table, a reliable criterion of the beneficial effects of spraying with fungicide is not evident in those cases in which the percentage of growers following any one of the three practices was below 15.

Spraying on Long Island

Spraying was done to a greater extent on Long Island than in the other three districts surveyed. Only 9 growers out of 316 did not spray at all in 1912. About one-third of all the growers used a fungicide for the control of blight, tipburn, and flea beetles. Ten per cent of the growers reported their crops affected with blight, while nearly one-fourth reported flea-beetle injury. The spraying practices and the average yields, together with the amount of seed and the value of the fertilizer used, are given in table 84. The number of growers not spraying at all was too small

TABLE 84. Relation of Spraying Practice to Yield on 316 Long Island Farms in 1912

Spraying practice	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
No spraying	9	190.7	12.2	$33.08
Insecticide only	204	161.7	11.8	31.42
Fungicide	103	197.1	13.5	33.65
Total	316	....	....	....
Average	....	175.3	12.5	$32.27

to allow of attaching any significance to the average yield obtained by these growers. The increase in yield per acre of over 35 bushels, resulting from the use of a fungicide rather than an insecticide, is significant, altho a part of this difference in yield was due to the use of more seed and fertilizer.

Results of further studies on the influence of frequency of spraying with fungicide, on yield, are shown in tables 85 and 86, in which the factors of seed

TABLE 85. Relation of Number of Times Sprayed with Fungicide, and Rate of Planting, to Yield, on 109 Long Island Farms in 1912

Number of times sprayed	Amount of seed planted							
	Less than 12 bushels		From 12 to 14 bushels		14 bushels and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 5	11	154.6	15	189.7	7	181.5	33	179.5
5–7	11	197.2	19	196.5	18	197.0	48	196.9
7 and more	4	217.2	8	197.5	16	220.5	28	213.8
Total	26	....	42	....	41	....	109	....
Average	....	187.5	....	194.2	....	201.6	....	196.8

TABLE 86. RELATION OF NUMBER OF TIMES SPRAYED WITH FUNGICIDE, AND VALUE OF MANURE AND FERTILIZER, TO YIELD, ON 109 LONG ISLAND FARMS IN 1912

Number of times sprayed	Value of murane and fertilizer							
	Less than $30		From $30 to $40		$40 and more		Average	
	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)	Number of farms	Average yield per acre (bushels)
Less than 5	15	161.4	12	177.9	6	236.3	33	179.5
5–7	13	182.8	25	202.8	10	188.6	48	196.9
7 and more	2	170.0	17	191.3	9	248.6	28	213.8
Total	30	....	54	....	25	....	109	....
Average	....	170.0	....	195.4	....	228.1	....	196.8

and fertilizer, respectively, are separated. It appears from table 85 that the yield increased directly with the frequency of spraying, irrespective of the rate of planting. In table 86, the influence of frequency of spraying does not appear to have been so marked. This is due partly, however, to the insufficient number of growers in some of the groups. As a whole, these data indicate that the growers who sprayed the greatest number of times, obtained at least enough increase in yield to pay the extra cost of the labor and materials involved. The correlation of frequency of bordeaux spraying with yield is further shown in figure 149. The coeffi-

Yield per acre, in bushels

Number of times sprayed with bordeaux	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	251–275	276–300	301–325	
1			1	1	1	2		1			1		7
2					2	3	5	1		2	1		14
3			1		3	2	4						10
4	1			1		3	4	3	3			1	16
5			1		3	3	4	3	2	1	2	1	20
6			1		5	2	5	2	4	2			21
7					1	2	3					1	7
8			1		1	1	2		2	1			8
9													0
10								1			1		2
	1	0	5	2	16	18	27	11	11	6	5	3	1

$r = 0.133 \pm 0.065$

FIG. 149. CORRELATION OF FREQUENCY OF BORDEAUX SPRAYING, AND YIELD, ON 105 LON ISLAND FARMS IN 1912

cient, 0.133 ± 0.065, while positive, is not significant because of the relatively high probable error. Since all factors influencing yield are involved in this correlation, such a coefficient need not detract from the real measure of efficiency of bordeaux spraying. Much of interest regarding the actual practice of spraying thruout the region may be observed in the frequency table shown in figure 149.

Spraying in Steuben County

The year 1912 was a year of blight epiphytotic in Steuben County, many of the growers reporting more than half their crop left rotted and unharvested in the field. More than 93 per cent of the growers found that the late-blight fungus affected either tops or tubers, or both. Such conditions should afford excellent means for determining the influence of frequency of bordeaux spraying on yield. The practice of spraying in this region in 1912, the average yield, the rate of planting, and the value of manure and fertilizer per acre, are shown in table 87. The two facts

TABLE 87. RELATION OF SPRAYING PRACTICE TO YIELD ON 360 STEUBEN COUNTY FARMS IN 1912

Spraying practice	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
No spraying	184	130.2	9.9	$ 9.97
Insecticide only	160	137.3	10.2	10.23
Fungicide	16	171.5	11.5	12.96
Total	360	....	....	....
Average	....	136.4	10.1	$10.06

most clearly set forth in this table are: (1) that, whereas less than half the growers of this region did any spraying in 1912, only about 4.5 per cent used a fungicide for blight control; and (2) that those growers who sprayed the most thoroly also used more seed and fertilizer per acre than the average, and obtained correspondingly higher yields.

Spraying in Monroe County

The treatment accorded the potato crop for blight, tipburn, and flea-beetle control in Monroe County in 1913 is shown in table 88. These data indicate no advantage whatever, as to yield, from fungicidal spraying in 1913. Evidently there was none. The explanation doubtless lies in the fact that the principal functions of bordeaux mixture lie in the protection of the tubers from blight rot and in the prolongation of the plant's

TABLE 88. RELATION OF SPRAYING PRACTICE TO YIELD ON 282 MONROE COUNTY FARMS IN 1913

Spraying practice	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
No spraying	33	150.3	12.2	$11.40
Insecticide only	177	121.5	12.2	11.07
Fungicide	72	126.2	13.3	11.90
Total	282	....	....	....
Average	....	126.0	12.5	$11.33

growing season, thereby increasing yield. The latter function naturally is asserted late in the growing season. In 1913, Monroe County experienced one of the earliest killing fall frosts in its history. As a result, not only the bean crop, but the potato crop as well, was cut down, causing serious loss to the grower. Only about 7 per cent of the potato growers reported the occurrence of late blight up to the time of this frost. It is therefore evident that the possible advantages from fungicidal spraying this year were almost entirely nullified. Under these conditions, frequency of spraying could not be expected to show a normal influence on yield. The correlation coefficient (fig. 150) is 0.084 ± 0.081. This shows insignificant correlation in respect to both the coefficient and its probable error.

Yield per acre, in bushels

Number of times sprayed with bordeaux	51–75	76–100	101–125	126–150	151–175	176–200	201–225	226–250	
1	4	3	3	4	1	1			16
2	3	8	1	4	1	1		1	19
3	1	3	2	4	3	1			14
4	1	2	1	3	4				11
5	1	1			2				4
6		1		1					2
7	1								1
8									0
9									0
10									0
11									0
12				1					1
	11	18	7	17	11	3	0	1	68

$r = 0.084 \pm 0.081$

FIG. 150. CORRELATION OF FREQUENCY OF BORDEAUX SPRAYING, AND YIELD, ON 68 MONROE COUNTY FARMS IN 1913

Spraying in Franklin and Clinton Counties

As previously stated, the late-blight fungus (*Phytophthora infestans*) seldom attacks the potato crop in Franklin and Clinton Counties. Very probably the reason for this is that muggy atmospheric conditions, so conducive to the disease, seldom prevail here after rains. On the contrary, wide spacing of plants and the frequent breeze that follows rain afford the plants ideal air circulation, thus preventing conditions favorable to blight. Only 3 per cent of the growers reported blight in 1913.

The extent to which spraying is practiced in this region is shown in table 89. Altho the three growers who used fungicide used more than the

TABLE 89. Relation of Spraying Practice to Yield on 273 Franklin and Clinton County Farms in 1913

Spraying practice	Number of farms	Average yield per acre (bushels)	Average amount of seed used per acre (bushels)	Average value of manure and fertilizer
No spraying	98	186.1	12.1	$12.59
Insecticide only	172	177.3	11.8	13.29
Fungicide	3	152.3	12.3	15.38
Total	273	....	....	....
Average	....	179.9	11.9	$13.08

average quantity of seed and fertilizer, they obtained less than the average yield. However, no significance can be attached to this fact, because of the extremely small number of farms. For this same reason, no correlation study of the frequency of spraying with the yield in this region has been made.

RELATION OF DATE OF HARVEST TO YIELD

The date of harvest of the potato crop is dependent on such factors as (1) the date of maturity of the crop, (2) the date of the first killing frost in the region, (3) the influence of early market prices, (4) the relation of the potato harvest to other farm work, and (5) the weather. The relative importance of each of these factors varies with the region, in New York State. There are sufficient experimental data available to prove that ordinarily the crop should not be harvested until the foliage is entirely dead because of natural maturity. The basis of this proof lies in the fact that the yield is increased rapidly during the last stages of growth of the plant. Jones (1899) tested the influence of the date of harvest on the yield of potatoes planted on May 20, by digging every ten days from August 2 to September 22. The yield increased from 30 bushels per acre on August 2, to 353 bushels per acre on September 22. Of this increase, 119 bushels came after September 1, and 50 bushels developed during the last ten days. Kohler (1910), working with the variety Early Ohio planted on June 3, similarly tested the rapidity of development of the yield by digging about every seven days from July 31 to August 30. During that period, the foliage developed from an entirely green condition to complete maturity, and the marketable yield increased from 10.9 bushels to 226.8 bushels per acre. There was a gain in marketable yield of about 7 bushels a day thruout the period, the yield increasing 44.7 bushels per acre during the last week. These data emphasize the possible mistake which some growers make, of digging the crop prior to maturity in order to avoid unfavorable weather or to take advantage of the relatively high early-market prices.

It was not possible, for four reasons, to study by survey methods the influence of date of harvest on yield in the four regions surveyed. First, the information concerning the date of harvesting for Long Island was insufficient; secondly, about 93 per cent of the growers in Steuben County reported the crop more or less affected with late blight; thirdly, a large proportion of the growers in Monroe County reported a killing frost in 1913 which cut down their crop exceptionally early, long before maturity, and reduced the yield much below the average; and fourthly, in Franklin and Clinton Counties the foliage is almost always killed by frost before it is mature, as was the case in 1913. The average date of harvest in the four regions for the years concerned in the survey, and the average date of the first killing fall frost for each region, are given in table 90:

TABLE 90. AVERAGE DATE OF HARVEST, AND AVERAGE DATE OF FIRST KILLING FROST, IN THE FOUR REGIONS SURVEYED

Region	Year	Number of farms	Average date of harvest	Average date of first killing fall frost
Long Island	1912	37	September 1	October 1–25
Steuben County	1912	348	September 27	October 5
Monroe County	1913	269	October 12	October 15
Franklin and Clinton Counties	1913	295	September 24	October 1–10

As is seen in table 90, the Long Island crop was harvested nearly a month before that of any of the other regions, the average date of planting being correspondingly earlier in this region due to climatic conditions. With the exception of Irish Cobbler and other early varieties grown in Nassau County, the crop in this district is usually mature before it is dug. These early varieties are often harvested and marketed before maturity in order to reap the benefit of the early-market prices. Furthermore, growers of early varieties in Nassau County harvest early in order to be able to follow the potato crop with a crop of vegetables or root crops for the fall market. A harvest of Cobbler potatoes in Nassau County, in the middle of July, is shown in figure 130 (page 1152). It can be noted that the foliage, as separated from the tubers, is not yet mature. On the following day this same field was ridged for turnip planting.

As is evident from table 90, the Long Island crop is seldom affected by a killing fall frost. The Long Island growers aim to market their crop as soon after maturity as is possible, in order to supply the New York City market before the earliest crop of other sections of the State is ready to harvest. For the years concerned in this study, the crop in the other three regions was harvested at an average date earlier than the average date of the first fall frost because of the severe blight epidemic of Steuben County, the early and severe frost in Monroe County, and the early frost in Franklin and Clinton Counties. Partly because of the tempering influence of Lake Ontario, the average date of harvest and the average date of the first fall frost in Monroe County are considerably later than for the other regions. Similarly, because of the influence of Lake Champlain, the growers located around Peru, in Clinton County, harvested their 1913 crop approximately two weeks later than did other growers in the county.

METHOD OF HARVESTING IN THE FOUR REGIONS SURVEYED

The factors that ordinarily determine whether potatoes shall be dug by hand or by machine are, size of acreage, available labor supply, and soil conditions affecting the efficiency of machine diggers. The author (Hardenburg, 1915 a) found, for Steuben County in 1912, that when the potato acreage per farm was at least 5, the saving in labor cost by machine digging more than outweighed the interest, depreciation, and repair costs of digging by this method. Since the minimum acreage of potatoes per farm recorded in these studies was 5, the factor of economy in the use of machines for digging is probably of no concern in any of the other three regions. There are many farms in Steuben County with fields so steep as to limit the use of heavy elevator diggers. In 1912 the writer (Hardenburg, 1915 a) found the average slope of potato fields dug by hand to be somewhat steeper than that of machine-dug fields. A special type of digger, known as the *Boss*, or *Keeler*, which removes the tubers by a rotating reel, has been adapted to the hilly sections of Steuben County because of its exceptionally light draft and its adaptation to slopes too steep for elevator diggers. A study of the influence of slope of field on the type of digger used in 1912 in Steuben County revealed the fact that the fields dug with the reel digger had a higher average slope than those dug with the elevator type (Hardenburg, 1915 a).

The method of harvesting, and the average potato acreage per farm, for the four regions surveyed, is shown in table 91. It is evident that the

TABLE 91. METHOD OF HARVESTING, AND AVERAGE POTATO ACREAGE PER FARM, IN THE FOUR REGIONS SURVEYED

Method of harvesting	Long Island, 1912		Steuben County, 1912		Monroe County, 1913		Franklin and Clinton Counties, 1913	
	Per cent of farms	Average potato acreage	Per cent of farms	Average potato acreage	Per cent of farms	Average potato acreage	Per cent of farms	Average potato acreage
Elevator digger....	84	24.3	11	17.0	71	12.9	15	8.0
Reel digger.......	5	21.8	48	14.9	0	....	1	7.5
Shovel plow shaker	5	19.1	12	13.4	11	10.7	0	....
Hand............	1	41.6	23	15.4	3	9.2	76	6.9
Various...........	5	....	6	....	15	....	8	....
Average..........	....	24.8	....	14.7	....	12.4	....	7.2

reel digger is not popular outside of Steuben County, probably decause this digger leaves the tubers in a more or less bruised and scattered condition. As indicated by the figures for both Long Island and Monroe County, the elevator digger was used extensively in these regions, where the soil is relatively light and the fields vary from rolling to level. Growers in Franklin and Clinton Counties have not used the elevator digger extensively because of relatively small acreages per farm and an abundance of large boulders, which make the use of such a digger next to impossible. More than three-fourths of the crop in this region was dug by hand in 1913.

As a whole, the figures in table 91 show that the average acreage dug by hand was smaller than that dug by machine, and that the average acreage dug by the elevator digger was greater than that dug by any other type of machine. In cases of close planting and heavy top growth, it is often desirable to remove the tops from the tubers before picking them up. In figure 151, a view taken in Franklin County, two men are shown using forks for this purpose, behind an elevator digger drawn by four horses. This illustrates the necessity of using more than two horses because of the heavy draft of these machines.

Three types of carriers were found in common use in the regions visited — the standard bushel slatted crate, a hamper basket, and fertilizer bags of various sizes. On Long Island, the commonest carrier in Suffolk County is the fertilizer bag, and that in Nassau County is the fertil.zer bag supplemented by hamper baskets of about a bushel capacity. These

Fig. 151. removing vines from tubers to facilitate picking up the crop

hampers as used in Nassau County, with the owner's initial painted on them, are shown in figure 152. This illustration shows also the common practice in this region of throwing from three to five rows together before picking up the tubers. The prime tubers are then picked up first, the culls remaining until later, as illustrated. Most of the crop of Nassau County — which is marketed directly from the field — is taken, either in these baskets or in bags, by wagon or motor truck, to the Wallabout Markets of Brooklyn, as shown in figure 153. In Suffolk County the crop is taken from the field mainly in bags and is hauled in them to the car or the storehouse, where the potatoes are dumped on the grader if they were not already graded when they were picked up, and are thence emptied into the car for shipment in bulk.

The commonest carrier used in the other three regions is the bushel crate, in which the crop is taken to storage, and there it is either dumped into piles or stored in the crate. By far the greater part of the crop is stored in bulk. In these three regions, the crop is taken to the car either loose in wagon boxes, or in bags, or both ways, with the bags piled on top of the load.

FIG. 152. THE BUSHEL HAMPERS COMMONLY USED FOR BOTH PICKING UP AND HAULING TO MARKET IN NASSAU COUNTY

FIG. 153. A NASSAU COUNTY ROAD WAGON, LOADED FOR THE WALLABOUT MARKETS OF BROOKLYN

TYPES OF STORAGE IN THE FOUR REGIONS SURVEYED

Since Appleman (1912) has shown the importance of low temperature in proper potato storage, it is of interest to note the types of storage used for the crops concerned in these studies. In no case was any grower's crop kept in a refrigerated storage. The proportion of the total stored crop in each region which was stored in various types of storage facilities is given in table 92. The reason for the larger number of farms indicated in Steuben

TABLE 92. Types of Potato Storage in the Four Regions Surveyed

Region	Number of farms	Per cent of stored crop stored in				
		House cellar	Barn cellar	Special storage	Barn shed	Pit storage
Long Island, 1912	231	61	22	12	3	2
Steuben County, 1912	378	85	11	3	0	1
Monroe County, 1913	320	72	24	3	0	1
Franklin and Clinton Counties, 1913	300	98	1	1	0	0

and Monroe Counties than were actually visited in the survey, is due to the fact that a number of the growers in these regions stored their crop in more than one type of storage.

Practically all of the Franklin and Clinton County crop of 1913 was stored in the house cellar. In fact, this was the principal type of storage, tho to a lesser extent, in the other regions studied. The next most popular type of storage was the barn cellar. As a rule, both house and barn cellars were constructed with stone walls and dirt floors. Wherever a barn cellar was used, it was generally in close proximity to the stable, advantage being thus taken of the animal heat therefrom to prevent freezing. This was not considered a safe practice in Franklin and Clinton Counties because of the greater severity of the winters in that region. A number of special storage houses were found on Long Island. Since only a small proportion of the Long Island crop is held for more than a few days, these special storages were built not so much to store the harvested crop as for a place of storage for the seed supply brought in from the North to be held until planting time.

LENGTH OF STORAGE PERIOD

In determining the length of time that the crop was held by the growers in each region, the actual date of sale of all or of parts of the crop was taken as an indicator of the storage period. It was found that a large part of the crop in all four regions was marketed either directly from the field, or after only a few days of holding for proper grading and bagging at the barn. In table 93, the proportion of the crop so handled is considered as not stored.

TABLE 93. LENGTH OF STORAGE PERIOD IN THE FOUR REGIONS SURVEYED

Region	Per cent of crop stored							
	None	For one month	For two months	For three months	For four months	For five months	For six months	For seven months
Long Island, 1912.	88	5	0	3	2	1	0	1
Steuben County, 1912..........	64	6	12	6	8	3	1	0
Monroe County, 1913..........	38	3	11	21	11	10	5	1
Franklin and Clinton Counties, 1913..........	42	1	12	21	17	1	5	1

As is indicated in table 93, a larger proportion of the crop is stored for one or more months in the three regions of western and northern New York than on Long Island. Except on Long Island, the general practice is to market at least that part of the crop for which there is insufficient storage capacity, at harvest time, the remainder being disposed of as prices warrant and as weather and country roads permit. Much of the crop in Steuben County is grown under contract for local buyers. The grower's delivery of this crop mainly at harvest time accounts for the relatively high proportion of the crop not stored in this region.

SUMMARY

Climate, elevation, and soil, as factors influencing yield, were found by this study to be so closely and inseparably related as to make difficult the determination of the influence of each one. The study of available data shows that, whereas the climate for potatoes is generally best at the highest elevations, soil fertility is generally the greatest at the lower elevations. In a year of blight, farms at high elevations are likely to show the best yields; while in years of no blight, better yields may be expected from the more fertile soils at the lower elevations.

The value of potato land as appraised by the growers, proved to be correlated with yield up to the point at which the land was affected by real-estate valuation. This point was reached for a few farms located in close proximity to cities or villages. The appraised valuation of these farms was evidently beyond the valuation justified by their productive ability.

From information obtained in the survey of the four regions, it has been possible to determine the status of many factors which, tho not studied as to their influence on yield, have nevertheless a vital relation to production. Among these may be listed the time of plowing, the home-mixing of fertilizer, the analysis of fertilizer, the use of lime, the source of seed, the chemical treatment of seed, the date of planting, the method of planting, the date and method of harvesting, the type of storage, and the length of the storage period.

Both biometrical and tabulation studies have shown the amount of seed used and the value of manure and fertilizer per acre to be the most influential factors as relating to yield of all the factors studied. Second to these are depth of plowing, frequency of cultivation, and frequency of spraying. The influence of these five factors, expressed biometrically in terms of *r*, is summarized for each region in table 94. For obvious reasons, based

TABLE 94. SUMMARY OF COEFFICIENTS OF CORRELATION FOR FIVE FACTORS IN THE REGIONS SURVEYED

Factor	Long Island, 1912	Steuben County, 1912	Monroe County, 1913	Franklin and Clinton Counties, 1913
Depth of plowing	r = 0.159 ± 0.036	r = 0.190 ± 0.034	r = 0.006 ± 0.039	r = 0.028 ± 0.039
Value of manure and fertilizer...	r = 0.244 ± 0.035	r = 0.289 ± 0 033	r = 0.258 ± 0.036	r = 0.169 ± 0.038
Bushels of seed used..........	r = 0.275 ± 0.034	r = 0.374 ± 0.031	r = 0.247 ± 0.037	r = 0.367 ± 0.034
Frequency of cultivation.......	r = -0.087 ± 0.037	r = 0.231 ± 0.034	r = 0.169 ± 0.038	r = 0.055 ± 0.039
Frequency of bordeaux spraying.	r = 0.133 ± 0.065	....	r = 0.084 ± 0.081	....

chiefly on environmental differences between the four regions, considerable variation in the value of coefficients is shown in the table. In a single case, that for frequency of cultivation on Long Island, the coefficient is negative. Five coefficients out of the eighteen given are too small to be significant, the probable reasons for this being, in most cases, explained in the foregoing text. In but two cases is the probable error greater than the coefficient, these being the probable errors of the coefficients for depth of plowing in Monroe County and in Franklin and Clinton Counties.

Probably a more reliable measure of the true influence of these five factors on yield may be obtained from the tabulation studies for each region. In view of the proved importance of these factors, a comparison of the averages of some of them for the fifty highest- and the fifty lowest-yielding farms in the four regions is given in table 95. In general, the values given in this table confirm the results shown in the discussion of these factors.

TABLE 95. COMPARISON OF FIFTY HIGHEST- AND FIFTY LOWEST-YIELDING FARMS OF THE FOUR REGIONS SURVEYED, IN AVERAGE YIELD, POTATO ACREAGE, SEED USED, AND FERTILIZER USED, AND PERCENTAGE OF GROWERS SPRAYING WITH FUNGICIDE

Region	Average yield per acre (bushels)		Average potato acreage per farm		Average amount of seed used per acre (bushels)		Average value of manure and fertilizer		Per cent of growers spraying with fungicide	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
Long Island, 1912	254.6	95.6	29.8	18.2	13.6	11.6	$35.35	$29.56	50	16
Steuben County, 1912	204.6	72.4	15.1	12.0	11.2	9.0	13.65	7.78	16	0
Monroe County, 1913	205.1	64.0	13.2	12.8	13.6	11.7	14.12	9.08	20	22
Franklin and Clinton Counties, 1913	247.8	114.8	7.0	7.5	13.6	10.7	15.09	11.78	0	2

Factors of less, but by no means negligible, influence on yield, as developed by these survey studies, are: method of applying fertilizer, varietal type of potatoes, sun-sprouting of seed, interval between cutting seed and planting, dusting cut seed, type of seed, system of planting, depth of planting, system of cultivation.

CONCLUSIONS

The foregoing study of crop production by survey methods has, wholly apart from the facts brought out, shown the broad possibilities of this method of research. It does have limitations, however, as is evidenced by certain conflicting data and by the occasionally inconclusive results reported herein. It cannot be used as a substitute either for the present carefully executed research of the state and federal experiment stations, or for more generally localized controlled experiments. On the basis of facts and indications revealed in this study, however, the survey method can and should play a more prominent part in supplementing the present scope of research. In general, too much emphasis has been placed on conclusions drawn from limited experimentation without due attention to their application to local conditions. Too little research of regional application has been done. Cooperative experiments have been tried, but they have not been sufficiently extensive in duration.

A crop survey, to be of greatest value, should be replicated in a given region, depending on the normality of seasonal conditions. The year 1912, while possibly normal for Long Island, was a year of severe loss from blight to the potato crop in Steuben County. The year 1913, while possibly normal for Franklin and Clinton Counties, was a year with an extraordinarily early killing fall frost in Monroe County. These factors have doubtless vitiated to some degree the results of the present study of the influence of certain factors on yield. A larger number of records for each region, and replication of the survey, may be suggested as the best and probably the only means of obviating these conditions. Whereas sufficient records were not available for the detailed study of some factors, the number used has, on the whole, afforded means for fairly definite conclusions. For as extensive a study of details as has been pursued in the present investigations, not less than three hundred, and preferably four hundred, records should be used. Aside from the relative influence of various factors on yield as revealed in these studies, it has been possible to correct, as well as to verify, many popular ideas of long standing. Altho the "what," the "why," and the "how" of crop production have for years been projected to the farmer, the regional study of actual cause and effect by survey methods has at least contributed to the knowledge as to the "how much."

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NEW YORK STATE COLLEGE OF AGRICULTURE
CORNELL UNIVERSITY, ITHACA, N. Y.
DEPARTMENT OF FARM PRACTICE AND FARM CROPS

Farm No.................. Potato Record for 1912. Date 1913

Operator .... Age .... P. O. .... County ....

Location.......... Miles to shipping point.......... Soil types .... Elevation..........

Topography of farm .... Drainage .... Exposure 1912 ....

Acres farmed.......... Value of land per acre.......... Acres potatoes 1912 ....

Tenure.......... Years owner.......... Years renter ....

Rotation 1 .... 2 .... 3 .... 4 .... 5 .... 6 ....

CROP PRODUCTION FOR 1912

Crop	Acres	Yield per acre	Total
Corn, grain		bu.	bu.
Corn, silage		tons	tons
Corn, other		tons	tons
Wheat		bu.	bu.
Rye		bu.	bu.
Oats		bu.	bu.
Barley		bu.	bu.
Buckwheat		bu.	bu.
Hay		tons	tons
Alfalfa		tons	tons
Oat Hay		tons	tons
Oats and Barley		tons	tons
Oats and Peas		tons	tons
Field Beans		bu.	bu.
Cabbage		tons	tons
Cauliflower		bbl.	bbl.
Brussels Sprouts		crates	crates
Apples Bearing		bu.	bu.
Apples not Bearing			

POTATO PRODUCTION FOR 1911, 1912 AND 1913.

Year	Varieties	Acres	Yield per acre	Total yield
1911 Early				
1911 Late				
1911 Total				
1912 Early				
1912 Late				
1912 Total				
1913 Early				
1913 Late				
1913 Total				

DISPOSAL OF 1912 CROP

	Date	Bushels	Price per bu.	Total
Sold			$	$
Seed				
Feed				
Home use				
Total			(Ave.)	

SPECIAL EQUIPMENT

	Cost	Value 1912	Life	Depreciation	Cost of repairs
Planter	$	$		$	$
Sprayer					
Digger					
Cutter					
Other equip.					
Total					

EXPENSES 1912

	Amount	Price per unit	Total
Rental value of land	acres	$	
Fertilizer	tons		
Manure from preceding crop	tons		
Manure, used by 1912 crop	tons		
Seed, farm and bought	bu.		
Dust for cut seed	lbs.		
Copper sulphate	lbs.		
Lime (form for spray)	lbs.		
Insecticide (kind)	lbs.		
Carriers not returned			
Equipment Rented			
Rental value of storage			
Repairs on machinery			
Depreciation on machinery			
Man labor	hrs.		
Horse labor	hrs.		
Equipment labor	hrs.		
		Total	

SUMMARY

Total receipts $

Total expenses $

Profit 1912 crop $

Profit per acre $

LABOR ITEMS

	Date	Acres	Per acre m.	Per acre h.	Total m.	Total h.
Manuring						
Plowing, Spring						
Plowing, Fall						
Dragging, times						
Discing, times						
Rolling, times						
Cutting seed						
Treating seed						
Removing sprouts, times						
Starting sprouts						
Marking						
Planting, machine						
Planting, hand						
Fertilizer						
Recovering, times						
Weeding, times						
Cultivating, times						
Hilling, times						
Spraying, times						
Digging and picking up, (hand)						
Digging and picking up, (machine)						
Harrowing after digging						
Sorting and bagging in cellar						
Hauling to storage						
Hauling to market						
Hauling from storage to market						
Work on equipment						
Work on storage						
	Total					

MISCELLANEOUS FACTORS

Manure. Kind used.......... Tons per acre.......... Source, if bought.......... Where applied.......... Name of spreader, if used.......... How often in rotation.......... Piled or spread.......... Plowed in or harrowed..........

Value of residual manure on potatoes, 1912 per cent..........

Plowing. Depth of plowing..........

Seed. Source.......... Amt. used..........

Seed Treatment. Corrosive sublimate. Formalin. Formaldehyde gas. Flowers of sulphur. Formula.......... How treated..........

Satisfactory ? Consequent injury to vitality ?..........

Starting Sprouts. Increase in yield noted.......... Increased earliness noted..........

Cutting Seed. Amt. cut.......... Name of the cutter, if any..........

Satisfactory ?.......... Type of seed planted :

1. Small whole..........
2. Medium whole..........
3. Large cut, 3 or 4 pieces..........
4. Medium cut, 2 or 3 pieces..........
5. No. eyes to piece..........

How long cut before planted.......... Cut seed dusted..........

Fertilizer. Amt. per acre.......... Formula.......... Brand.......... Co..........

Source of N.......... Source of P.......... Source of K..........

Home mixed.......... Ingredients used.......... Amt.......... Price..........

Time of application......... ... In hills, broadcast, fert. drill, planter, or strung ?
Above, with or below seed.... Amt. lime per acre ....
Place and frequency in rotation

Planting. Date, Early...... ...'12. Late . '12. By hand or planter ?.................................... Type of planter.................................. What kind would you buy ....Marker used
How covered.................Depth planted Distance apart of rows......................Distance apart in rows.............

Cultivating. Type of cultivator.... ....Deep or shallow.................
No. times in row at each cultivation............... . ... Cultivated both ways or one............

Hilling. Checkrowing, ridging or level culture

Spraying. Type of sprayer used..................What would you buy next time
Fungicide used .....Strength used
Insecticide used.. ....Amount used
Spray injury noted ?...........................Increased yield noted... ..... Yield on sprayed
Yield on unsprayed..............................Date of first spraying... .. .. Last spraying

Digging. How dug...... ....Name of digger..... . .. Type of digger
What kind would you buy..

Sorting. Sorted directly into boxes, sorting table, or sorter..Resorted ?
Times.............................. Reason ....

Bagging or Barreling. Type of carrier used ....Capacity .

Marketing. Commission rates......... ....System of marketing
Shipping rates.................................. Where shipped................

Storage. Type of storage.... Description of storage

Diseases Evident.

Effect of manure or lime on diseases

Labor.....................................
Wages per month....................
Wages per month and board ....Wages per day.
Wages per day and board..... ....Board
Work done by women and children

FACTORS ON 1912 COST OF PRODUCTION

Total acreage......		Cost per bu..............	
Crop acres........		Receipts per acre	
Per cent in crops...		Cost per acre ..	
Acres in potatoes............................		Profit per acre......	
Per cent of crop acres in potatoes		Profit per man hour	
Value of land per acre..............		Profit per horse hour..	
Rental value of land per acre		Profit per bushel..	
Crop index..................................			
Value of potato crop per acre		Per cent of cost, man labor	
Potato crop index..................		Per cent of cost, horse labor	
Total potato production, 1912...		Per cent of cost, land labor....	
Average yield per acre......		Per cent of cost, manuring	
Total man hours per acre		Per cent of cost, fertilizing	
Total horse hours per acre..		Per cent of cost, cultivation .	
Cost of fertilizer per acre		Per cent of cost, spraying	
Cost of manure per acre		Per cent of cost, digging	
Cost of cultivation per acre		Per cent of cost, special equip.	
Cost of spraying per acre...			
Cost of digging per acre....			
Cost of special equip. per acre			

Remarks :