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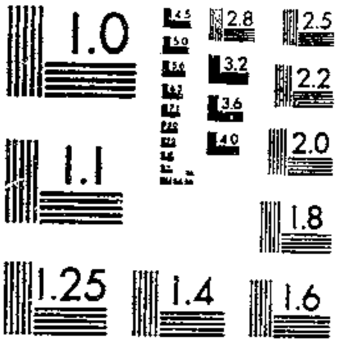

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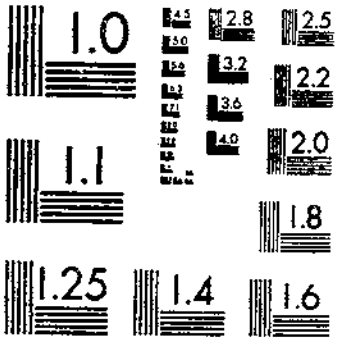

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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UNITED STATES DEPARTMENT OF AGRICULTURE

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FERTILIZER PLACEMENT FOR POTATOES[1]

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INTRODUCTION

A study was conducted on an extensive scale during the period 1931–37 to determine the most advantageous placement in which commercial fertilizer may be deposited with respect to the potato seed piece. This study was inaugurated in 1931 in New Jersey, Ohio, and Michigan; in Maine and Virginia in 1932; and in New York in 1934.

The large yearly investment for fertilizing the potato crop makes any appreciable increase in fertilizer efficiencies resulting from the introduction of new methods or through the improvement of the prevailing methods of application, a matter of outstanding importance to the growers. Approximately 10 percent of the total commercial fertilizer tonnage of the United States is applied to the potato crop and now represents an annual investment by the growers of roughly $20,000,000. The area in potatoes during the past 10 years has averaged approximately 3,300,000 acres but not all this acreage was fertilized. The amount of fertilizer applied to an acre of potatoes varies according to geographical location of the commercial areas and the existing local conditions but ranges from a few hundred pounds to more than a ton an acre of ordinary-grade fertilizer. Thus the fertilizer in many of the principal areas represents a major item of potato production costs and in some cases amounts to $30 or more per acre.

[1] Submitted for publication August 16, 1938.

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The potato is grown to some extent in practically every section of the country on soils of various types. The soils most commonly used for large-scale commercial production range from sands to loams including various combinations of these two classes. In certain areas muck is used to a considerable extent, but the bulk of the crop throughout the country is grown on upland soils. So-called heavy soils, such as clays or clay loams, are usually the least suitable for commercial production unless they contain an adequate supply of organic matter. Many highly productive potato soils contain some gravel, stones, or shale, but excessively stony land is seldom used for this crop.

As an adequate supply of moisture is very important in growing the potato crop, the soils used are generally either capable of retaining sufficient moisture, or the crop is grown at a time of year when the rainfall is usually sufficient. Therefore sandy loams relatively low in organic matter can be used successfully for early potatoes whereas loams much higher in organic matter are normally required for the late crop.

Most of the fertilizer used for potatoes usually contains 17 to 22 total units of the plant foods—nitrogen, phosphoric acid, and potash—per ton. Fertilizers of high analysis containing a total of 40 or more units of plant food per ton are sometimes used but at rates commensurate with the increased concentration of plant food. The mechanical condition of potato fertilizers varies from the more bulky type containing a portion of the nitrogen from organic materials such as fish scrap and tankage to the more compact type with little or no nitrogen from such sources. There is a great difference in the flow of these two types of fertilizers when applied with a sower or potato-planter equipment. It is not uncommon to find a change of 25 percent or more in the rate of application with the same machine adjustment when changing from one type of fertilizer to the other. As a rule, however, potato fertilizers are fairly free-flowing and little difficulty is experienced in their even distribution.

Potatoes are most heavily fertilized throughout the eastern section of the country where 1,200 to 2,500 pounds per acre of the usual grade of fertilizer is normally applied, the amount and kind being largely determined by local conditions. In the midwestern potato sections from 500 to 700 pounds of fertilizer per acre are usually sufficient, but here also the rate of application differs according to existing conditions.

EARLY METHODS AND EQUIPMENT

The first machines employed in the application of commercial fertilizer were largely simple distributors of both the broadcast and row types which apply the fertilizer in a separate operation. Distributors of these types are now available in numerous styles, and the distribution of the fertilizer ranges from one or two narrow bands in the row to broadcasting over the entire soil surface.

Among the first fertilizer-placement attachments or depositors on potato planters was that of True (*1*),[2] developed about 1879, which placed the fertilizer in the furrow with the seed. Bockman's (*2*) fertilizer equipment integral with a potato planter patented about the same time was apparently designed to scatter the fertilizer in the row largely above the seed. During the following 40 years potato planters

[2] Italic numbers in parentheses refer to Literature Cited, p. 47.

with fertilizer depositors were improved and refined in various respects, and provision was made to place the fertilizer either in a band above or below the seed or to mix it with the soil in the row. The first depositors for the potato planter with which the fertilizer could be placed in a distinct band at each side of the row were introduced about 1920. One of the early side-placement fertilizer depositors is shown in figure 1. From 1920 to 1930 the various types of equipment were used without any general outstanding trends toward standardization with regard to fertilizer placement.

METHODS COMMONLY USED

The methods of applying commercial fertilizer to potatoes and the equipment employed vary widely in general farm practice. The

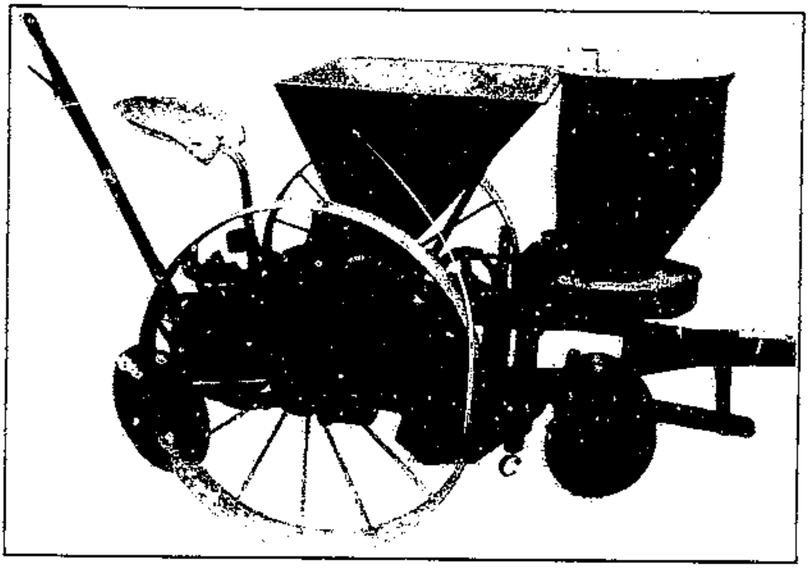

FIGURE 1.—A combined potato planter and fertilizer distributor equipped with one of the early side-placement fertilizer depositors: *a*, Fertilizer hopper; *b*, pair of single-disks for opening a furrow at each side of the row for the fertilizer; *c*, fertilizer-delivery tube.

placement of the fertilizer in relation to the seed likewise varies. Such variations were more widespread at the beginning of the general study herein described than at the present time. The methods of application in common use may be classified into two general groups, namely: (1) Application of the fertilizer as a separate field operation usually by means of a distributing machine or sower, and (2) application of the fertilizer simultaneously with the planting of the seed by means of distributing equipment combined with the potato planter. Numerous types of planters used in group (2) method of application are available, including single and multiple-row units some of which are drawn by horses and others by tractors.

The application of fertilizer in a separate operation before planting is a common practice, particularly in the South, and is followed to some extent in other sections. When the fertilizer is applied in a separate operation, the relative placement of fertilizer and seed depends upon the type of distributing machine and the tillage operations after distribution and prior to planting the seed. The ultimate placement of fertilizer by this method ranges from thorough mixing and wide distribution in the soil to concentration in a narrow band in the row. Furthermore, the location of the fertilizer may be above, below, at the side, or around the seed. One of the common types of distributors in this group is shown in figure 2.

Potato planters equipped with fertilizer distributors are widely employed in the northern potato areas and are used to some extent in practically all sections. The relative placement of fertilizer and seed with these machines depends on the design of the fertilizer depositors [3] and the adjustment of the soil-working tools. At present the equipment used on potato farms places the fertilizer under, above, around,

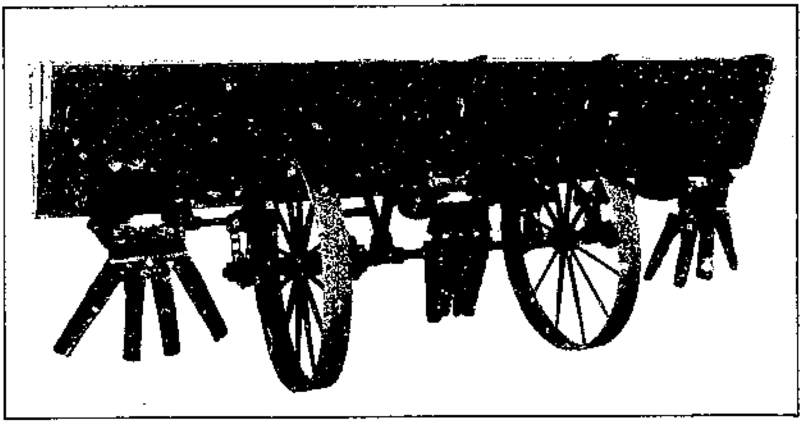

FIGURE 2.—A common type of fertilizer distributor used to apply fertilizer for three rows in advance of planting the potato seed. The width of the fertilizer strip or band for each dispensing unit may be varied by adjusting the delivery tubes as indicated.

or at each side of the seed, either in bands or mixed somewhat with the soil. Although certain makes of planters have fertilizer attachments that permit variations in fertilizer placement not all of the above-mentioned placements can be obtained with a particular make. A typical combined planter and fertilizer distributor is shown in figure 3.

The situation in 1931 at the beginning of the studies covered by this bulletin were briefly as follows: Organic nitrogenous materials had been replaced to a considerable extent by soluble and readily available inorganic materials. The average application of commercial plant food per acre had been substantially increased. It was recognized that with such changes, greater care in the application of fertilizer and more definite and accurate placement were essential. Although many of the machines had been greatly improved and refined and were adaptable to precise operations a wide variation of

[3] The word "depositor" as used in this bulletin pertains to that part of the fertilizer-distributing equipment that determines the manner in which the fertilizer is placed in the soil. The depositor may be merely a fertilizer-delivery tube or a combination of furrow openers and other devices for directing the fertilizer into the soil.

the relative placement of fertilizer and seed was obtained with the available fertilizer-distributing equipment. The particular method of fertilizer application adopted was ordinarily regarded by the grower

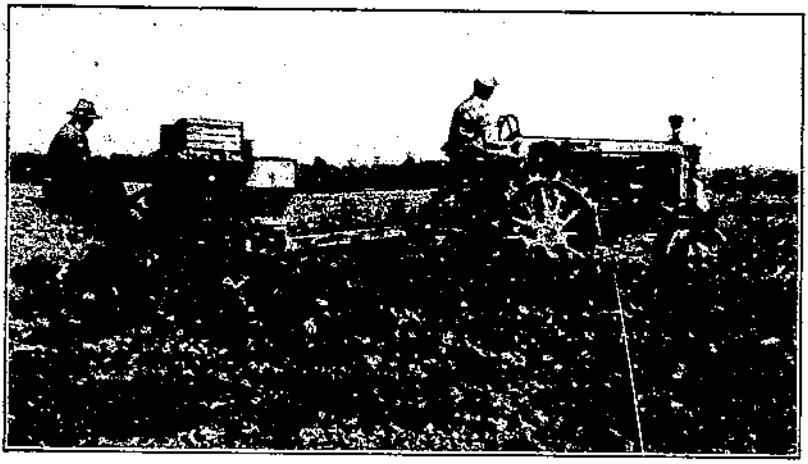

FIGURE 3.—Combined potato-planting and fertilizer-distributing machine of the two-row tractor-drawn type.

as satisfactory and any irregularity of stand and plant growth was usually attributed to other factors. Severe adverse effects on stand and plant growth due to improper placement of the fertilizer have

FIGURE 4.—Broken stand in a potato field resulting from improper placement of fertilizer in rows *a*, *b*, and *c*. Eastern Shore of Virginia, 1931.

been observed as illustrated in figure 4. The need for extensive field studies to establish definitely the most advantageous placements of the fertilizer for potatoes in different sections of the country was apparent and with this objective in view the general study was undertaken.

PREVIOUS INVESTIGATIONS

Methods of fertilizer application have received more or less attention since the fertilizer industry became well established. However, the early problems connected with the application of fertilizer were somewhat different from those of more recent years because of various developments and changes that have taken place. The earlier fertilizer-placement work largely involved the general methods of broadcast versus row applications, without the required facilities for and apparent need of precise placement.

Deterrent effects on seed germination were observed as early as 1876 (*8*) and fertilizer-placement tests were reported as early as 1899, the effects of fertilizer salts on seeds also being reported by several investigators about this time. Bell (*5*) in 1916 called attention to the increased use of commercial fertilizer and the urgent need of research on the method of application. Bell suggested experiments along the lines pursued in recent years. Coe (*9*) and Truog and associates (*26*) briefly reviewed much of the earlier work bearing on fertilizer placement and the effects of various salts on different kinds of seeds and plants. Truog and Jensen (*27*) gave an extensive annotated bibliography relating to methods of applying fertilizer to potatoes and other crops prior to 1928. Martin and Brown (*19*) gave a brief account of the more recent fertilizer-placement research with potatoes during the period 1918–28.

One of the first reports on fertilizer-placement research with potatoes was issued by the Hatch Experiment Station (*20, p. 11*) in 1894. Application in the row was found to be superior to broadcasting the fertilizer. Superiority of row application compared to broadcasting was later shown by Jordan and Sirrine (*16*), Bailey (*4*), and Cooper and Rapp (*10*) particularly at the lower rates of fertilizer application. When the fertilizer was applied in the row, damage to the seed and plant in its early stage of growth was observed when a relatively large amount of fertilizer was used. The differences in the results of the various investigators may be accounted for primarily by the different kinds of soils used, different rates of fertilizer application, and different procedures followed in separately applying the fertilizer and planting the seed.

Bailey's (*4*) work on the placement of individual plant-food elements near the seed is of interest. Nitrate of soda, sulphate of ammonia, superphosphate, and muriate of potash were applied in each treatment in amounts equivalent to a ton per acre of 4–8–10 mixture.[4] Each chemical was in turn separately applied in the furrow with the seed with the remaining chemicals applied broadcast. The highest percent stand of plants and the highest potato yields, both marketable and total, were obtained where the superphosphate was applied in the furrow with the seed. Relative to stand the other chemicals placed in the furrow with the seed ranked as follows: Muriate of potash, nitrate of soda, sulphate of ammonia. However, these treatments showed comparatively small differences in yields.

Coe (*9*) in 1922 studied several representative fertilizer placements accomplished with depositors attached to a conventional potato

[4] All fertilizer analyses refer to percentages of nitrogen, phosphoric acid, and potash in the order given.

planter—a procedure which permitted, in large-scale experiments, precise placement of the fertilizer with respect to the seed. The following definitely described fertilizer placements were employed: In a band at each side of the row (1) on seed level, and (2) below seed level; (3) mixed with the soil in the row; (4) in the furrow with the seed; and (5) above the seed. With applications of 1,950 pounds per acre of 4–10–4 fertilizer, also with 600 pounds of ammo-phos plus 156 pounds of muriate of potash per acre, Coe obtained the highest potato yield with the fertilizer placed in a continuous band 1 to 2 inches to each side of and a little below the level of the seed. The lowest yield resulted from the application of the fertilizer in the furrow in contact with the seed.

The results of the work of Truog and associates (*26*) a little later, using applications of 1,000 pounds per acre of 4–8–6 and 4–7–6 fertilizer, favored a placement one-half inch to each side of the seed and also immediately under the potato seed piece.

SCOPE OF THE STUDY

The present study was confined to representative potato districts in the eastern and northern sections of the country. These districts are located in northern Maine, central New Jersey, on Long Island, N. Y., on the Eastern Shore of Virginia, in northeastern Ohio, and in two localities in western Michigan. Representative soil types and fertilizer mixtures were used in each area. The quantity of fertilizer applied per acre in each experiment was equal to or, in the case of double-strength fertilizer, equivalent to that recommended for the district although in some cases a range of rates was employed. The methods of application included various representative fertilizer placements with respect to the seed, different distances of the fertilizer from the seed, and applications in both continuous strips along the row and in broken bands consisting of short bands with a spacing corresponding to the individual hill spacing.

In conducting the experiments two methods of procedure were considered: (1) The use of selected types of standard fertilizer-distributing and potato-planting machines, to obtain a range of representative fertilizer placements found in farm practice, and (2) the use of a single machine with interchangeable fertilizer-depositing attachments and adjustments to obtain various specified representative placements of the fertilizer with respect to the seed. Although the first-mentioned procedure would afford a comparison of the existing machines and methods employed in farm practice, it was not followed in this project primarily because of the prohibitive cost of transporting a number of machines to points in widely separated States and the improbability of readily adjusting the various machines to the same rates of fertilizer application, seed spacing, and planting depth.

The procedure selected and followed involved the use of a combined fertilizer distributor and potato planter having suitable attachments and adjustments with which representative fertilizer placements could be obtained, and other conditions maintained uniformly throughout the entire experiment in order that the effects of the various fertilizer placements could be directly compared. The machine and equipment were easily transferred from one location to another by truck.

FERTILIZER PLACEMENTS

The different placements of the fertilizer selected for the initial phase of the general study were largely representative of the various methods employed in farm practice. These placements, which consisted of continuous strips or bands of fertilizer along the row, are

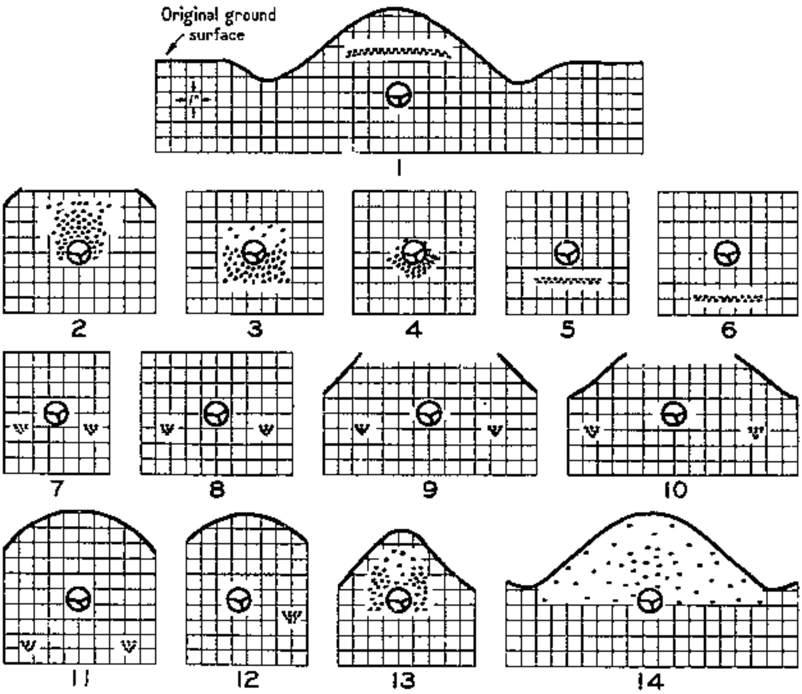

FIGURE 5.—Placement of the fertilizer with respect to the potato seed piece as represented by cross-sectional sketches of the seedbed, the fertilizer being deposited in continuous strips or bands along the row: (1) Band 7 inches wide, 2 inches above seed; (2) lightly mixed with soil largely above seed; (3) well mixed with soil largely below seed; (4) in furrow with the seed, thus a slight amount of fertilizer is in contact with the seed piece; band 4.5 inches wide (5) 1 inch under seed piece and (6) 2 inches under seed piece; band level with bottom of seed piece; (7) 1 inch, (8) 2 inches, (9) 3 inches, and (10) 4 inches to each side; (11) band 2 inches to each side, 2 inches below level of seed piece; (12) band 2 inches to one side and level with bottom of seed piece; (13) Aroostook method, a local practice in Maine; (14) Eastern Shore method, a local practice in eastern Virginia.

illustrated in figure 5 by sketches representing a cross section of the seedbed.

The size and shape of the whole potatoes and seed pieces planted obviously varied, but, for convenience in showing the fertilizer placements graphically, the section of the potato seed piece is represented as a circle 1.5 inches in diameter. Such a size represents the dimensions of the seed piece usually observed when examining the placement of the fertilizer.

Treatments were discontinued or new treatments introduced from time to time when justified by the findings and circumstances. Several treatments either of local interest primarily or considered supplementary to the main study were included only in certain experiments.

Referring to figure 5 it will be observed that placements Nos. 1, 5, and 6 consist of thin bands, the width and placement of which are given in the legend. Each band, however, was uniform in thickness, averaging only a small fraction of an inch.

Placement No. 2 represents the distribution of fertilizer obtained with those types of machines that deposit the fertilizer on the surface of the soil ahead of the seed shoe.

Placement No. 3 represents a common method of mixing the fertilizer in the row although the zone throughout which the fertilizer is distributed is possibly of somewhat less extent than that obtained in some farm practices.

Placement No. 4 was accomplished by depositing the fertilizer in the furrow with the seed. The seed shoe formed a narrow groove in the bottom of the furrow where most of the fertilizer was found. The fertilizer actually in contact with the seed was obviously only a small portion of the application.

Placements Nos. 7 to 12 consisted of narrow bands at the side of the row. Practically all of the fertilizer was confined to bands about 1 inch in width and from 0.5 to 1 inch in depth. The side placements are described as the inches of fertilizer-free soil both laterally and vertically between the seed piece and the fertilizer band.

Placements Nos. 13 and 14 represent local methods of fertilizer application used in Aroostook County, Maine, and eastern Virginia, respectively.

A later phase of the study involved the application of fertilizer in a broken band at each side of the row more specifically designated as hill placement. The fertilizer was deposited at each side of the row in a short band centered on the seed piece. The length of the bands was controlled, and varied from 5 to 10 inches, depending on the seed spacing and the specifications for the experiment. The lengths of the bands specified were approximately one-third, one-half, and two-thirds of the seed spacing. Thus the actual lengths of band representing one-half the seed spacing were 6, 7.5, and 8 inches for seed spacings of 12, 15, and 16 inches, respectively.

Hill placements of the fertilizer representative of those employed are shown in figure 6. The position of the bands with respect to the seed piece both laterally and along the row were varied in some of the experiments.

Representative hill placements of fertilizer are shown in figure 6 for a 15-inch spacing of the seed, and each band is placed 2 inches laterally from and on the level of the seed as shown in the cross-sectional sketches. Placement No. 15 consists of two thin bands each 2 inches wide and 5 inches long and centered on the seed. The bands in placement No. 16 are 1.75 inches wide and 7.5 inches long while those in placement No. 17 are 1.5 inches wide and 10 inches long. Placement No. 18 consists of continuous bands 1.5 inches wide which, from the standpoint of hill placement, might also be considered 15-inch bands which join between the hills. The increased width of the shorter bands was caused by a wider spreading of the deeper mass of fertilizer.

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EXPERIMENTAL EQUIPMENT

A combined planter and fertilizer distributor of special general design was constructed and used for the major portion of the experimental work. The machine is shown under operating conditions in figure 7. The general design and major units of the special machine are shown in figure 8. In order satisfactorily to use various types of fertilizer depositors and other soil-working tools, a machine of the four-wheel type somewhat longer than the conventional potato planter was required. The planter could be drawn either by horses or a tractor. Because of the comparatively heavy draft of the machine, tractor power proved more satisfactory in obtaining the desired slow uniform rate of travel.

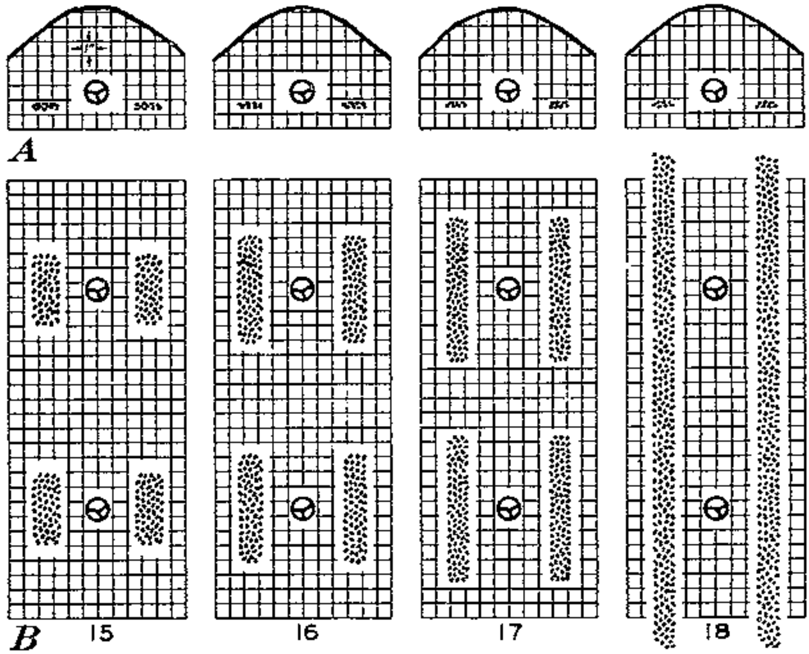

FIGURE 6.—Representative hill placements of fertilizer: *A*, Cross-section of seedbed showing relative placement of fertilizer and seed in a vertical plane at right angles to the row; *B*, longitudinal section showing placement of fertilizer in a horizontal plane for a seed spacing of 15 inches: (15) Bands 2 inches wide and 5 inches long; (16) bands 1.75 inches wide and 7.5 inches long; (17) bands 1.5 inches wide and 10 inches long; (18) bands 1.5 inches wide and 15 inches long which constitute continuous bands along the row.

The type of planting mechanism used is shown in figure 8, *C*. The seed conveyor moves in front of the operator, who has an opportunity to correct the feed by removing seed from the overloaded cells and filling the empty cells. This feature is advantageous in plot work, especially when seed of different sizes are planted. The automatic picker-type planter is commonly used by commercial growers because it functions satisfactorily with seed of reasonably uniform size and a man is not required to correct the feed of each planting unit.

A patented fertilizer distributor [5] (fig. 8, *B*) of the rotating-cylinder top-delivery type, having positive delivery action was selected for the special machine. The principle of operation of such a dispensing mechanism has been previously described (*21*). Two hoppers were required for adequate capacity and convenient use of the delivery tubes.

The primary reasons for selecting the top-delivery fertilizer hopper were as follows: (1) The fertilizer is fed to the delivery tubes by positive action in which case variations in the flowing properties of a fertilizer do not affect the rate of delivery; (2) since the dispensing action is positive, the adjustment for any desired rate of application can be determined mathematically; and (3) the ability to use either one or

FIGURE 7.—A special machine designed and constructed for use in fertilizer-placement experiments with potatoes. The machine was photographed while operating at Onley, Va.

more discharge openings with long flexible delivery tubes is not only convenient but essential for a universal machine with which fertilizer is applied in various ways. The adjustments for different application rates of each fertilizer were figured mathematically after the revolutions of the planter drive wheel for a known distance under field conditions and the weight of the fertilizer per unit volume were known.

The front wheels were mounted directly ahead of the rear wheels, to insure the same elevation with respect to any point along the row. Since the fertilizer depositors were near the front wheels (fig. 8, *A*) and the seed shoe was near the rear wheels, such an alinement of wheels was necessary to maintain a definite vertical relationship in the soil between the seed and fertilizer. A 2-inch flange was attached to each rear wheel as illustrated in figure 8, *A*, *c*, for the purpose of reducing

[5] COLE, EUGENE M. GUANO DISTRIBUTOR. United States Patent No. 1654414. Filed August 30, 1926; granted December 27, 1927. U. S. Patent Office Off. Gaz. 365: 880, illus. 1927.

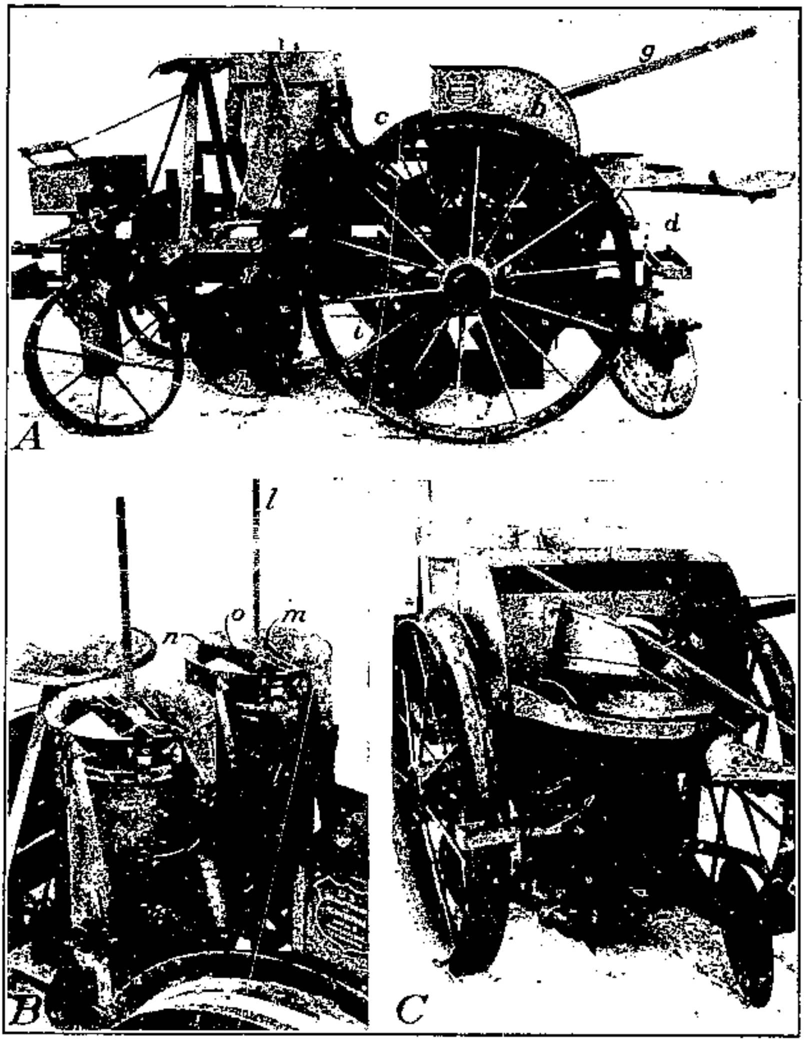

FIGURE 8.—A special combined potato planter and fertilizer distributor used in the fertilizer-placement studies with potatoes. *A*, General design of the machine: *a*, Fertilizer hopper; *b*, standard potato-planting mechanism; *c*, 2-inch flange on the drive wheel; *d*, wheel scraper; *e*, interchangeable sprockets in the fertilizer-hopper drive system; *f*, subframe to which all soil-working tools were attached; *g*, lever for adjusting the subframe vertically and controlling the driving mechanisms; *h*, pair of single-disk furrow openers for placing the fertilizer in a band at each side of the row; *i*, auxiliary bedding disks for returning disturbed soil to the row ahead of the seed shoe; *j*, seed shoe; *k*, seed-covering or bedding disks. *B*, Fertilizer hoppers of the rotating-cylinder top-delivery type: *l*, Plunger lifting screw; *m*, split-nut for releasing the lifting screw; *n*, fertilizer-discharge opening; *o*, fertilizer-delivery blade; *p*, fertilizer-delivery tube; *q*, rotating cylinder. *C*, Potato-planting mechanism of the cell-conveyor type with a seed-spacing attachment: *r*, Seed-elevating wheel; *s*, feed wheel on which the operator corrects the feed; *t*, seed-spacing attachment synchronized with the feed wheel; *u*, cam for operating the fertilizer hill-placement device; *v*, rod to transmit cam action to fertilizer valves.

the angling of the machine along lateral slopes and of providing increased and more uniform traction of the drive wheels.

The soil-working tools, including the fertilizer depositors, seed shoe, and bedding disks, were mounted rigidly on a horizontal subframe to insure uniform relative placement of fertilizer and seed. Each soil-working tool could be adjusted independently, but for any particular setting they remained in the same positions relative to each other as the entire subframe was raised and lowered to alter the planting depth. The auxiliary bedding disks (fig. 8, *A*, *i*) immediately ahead of the seed shoe were provided to return disturbed soil to the row in order that ridges of uniform height would be formed by the regular bedding disks regardless of the soil-disturbing action of different types of fertilizer depositors.

The depositors used for obtaining the various placements of fertilizer when applied in continuous bands are shown in figure 9. A pair of single-disk furrow openers, (fig. 9, *A*, *a*) with both vertical and lateral adjustments was used to deposit the fertilizer in a narrow band at each side of the row. Each disk was equipped with a tube (*b*) extending low enough to insure delivery of the fertilizer to the bottom of the furrow.

The placement of fertilizer in a band under the seed was accomplished with the shovel (fig. 9, *B*, *j*) to which shields were attached for maintaining a definite width of the fertilizer band. The colter (*i*) was mounted ahead of the shovel to avoid clogging difficulties especially where a green-manure crop such as rye had been plowed under immediately before planting.

The fertilizer was mixed lightly with the soil largely above the seed (placement No. 2, fig. 5) by raising the shovel (fig. 9, *B*, *j*) sufficiently to merely smooth the soil surface on which the fertilizer was deposited ahead of the seed shoe. The fertilizer was moved to either side by the seed shoe and then returned to the row over the seed by the bedding disks. The fertilizer was thus mixed to some extent with the soil and finally located in the zone above the seed.

The fertilizer was mixed with the soil largely below the seed placement No. 3 (fig. 5) in the following manner: The fertilizer was first deposited in a band 4.5 inches wide at a depth 1 inch below seed level with shovel (fig. 9, *C*, *j*); then the special stirring shovel (*k*), operating deeper than the fertilizer band, thus lifted the fertilizer with a definite amount of soil and thoroughly mixed the mass as it passed over the mixing fingers. Finally the fertilizer-soil mixture was covered by the auxiliary bedding disks.

Provision was made for inserting the fertilizer-delivery tube in the special spout (fig. 9, *A*, *g*) on the seed shoe in order to place the fertilizer in the furrow with the seed.

The application of fertilizer in a wide band directly above the seed was accomplished in a separate operation after the seed were planted. For this operation the seed shoe was removed from the planter. The ridge was lowered to the desired level above the seed by means of the scraper (fig. 9, *D*, *l*) behind which the fertilizer was deposited. The fertilizer was then covered and the ridge was reshaped by the regular bedding disks.

Placement of the fertilizer largely above the seed according to the so-called local Aroostook method in Maine (No. 13, fig. 5) was accom-

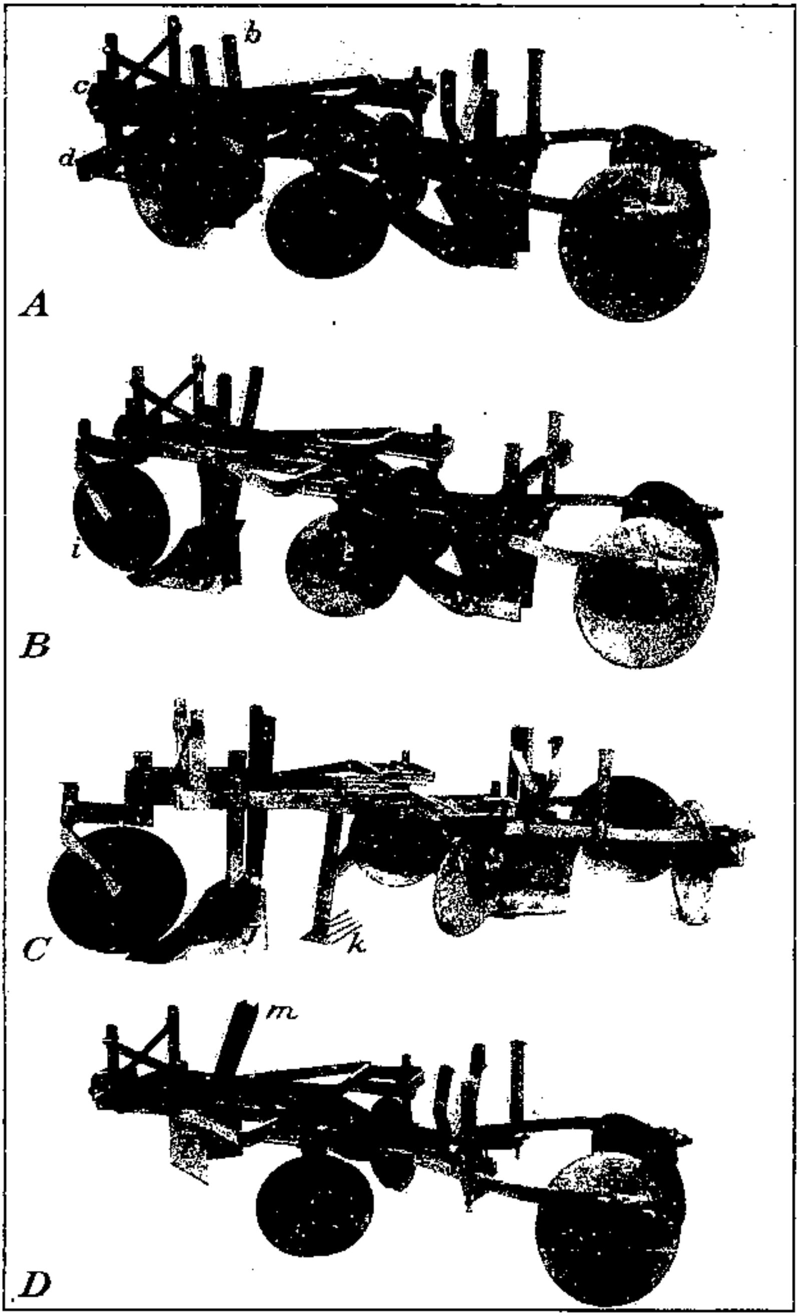

FIGURE 9.

(See legend on opposite page)

plished in the following manner: The furrowing disks were adjusted to deposit the fertilizer in a shallow furrow at each side of the row and the bedding disks were adjusted to move the fertilizer into the upper zone of the ridge.

The placement of fertilizer throughout the ridge above the seed according to a local Virginia practice (No. 14, fig. 5) was accomplished in three operations: (1) The fertilizer was deposited in a wide band on the marked row; (2) the fertilizer was mixed with the surface soil in a strip 15 inches wide, by means of a one-horse cultivator, and (3) the planter was then centered on the row and by its operation the fertilizer-soil mixture was moved into the ridge over the seed.

The hill placement of fertilizer in the later experiments was accomplished by interrupting the usual continuous stream of fertilizer, thus depositing the fertilizer for each hill in a specified zone with respect to the seed piece. The hill-placement depositing equipment is shown in figure 10. The fertilizer-hilling device is mounted behind a pair of single disks which open the two furrows. The fertilizer from the hopper is directed through flexible tubes to the depositor.

The hilling device is shown in figure 10 and consists essentially of a chamber 8 inches long and 1.5 inches wide with a longitudinal flap valve serving as a bottom. The valve in a closed position is set at an angle of about 45°, as shown in figure 10, *B*. Two movable vertical partitions are mounted above the valve for varying the length of the valve surface on which the fertilizer is collected, which in turn determines the length of the fertilizer band deposited. The valve in an open position is shown in figure 10, *C*. The valve is actuated through a system of rods and cranks by means of a cam on the seed-spacer drive shaft (fig. 10, *A*, *f* and fig. 8, *C*, *u*). Thus synchronization of the seed-spacing and fertilizer-hilling mechanisms to place the fertilizer in any desired position with respect to the seed in the line of travel was accomplished with a rotary adjustment between the cam and the seed-spacer drive shaft. The housing (fig. 10, *A*, *c*) with a shovel at the front, properly shapes the furrow, excludes the soil, and limits the maximum width of the fertilizer band.

The combination machine used in the initial experiments of 1931 was a standard product with special furrowing attachments and adjustments for varying the placement of the fertilizer with respect to the seed. A similar machine shown in figure 11 was used in the experiments in Maine in 1933–36. Fertilizer depositors similar to those described for the special four-wheel machine were adapted to this planter.

FIGURE 9.—Subframe and fertilizer depositors with which the fertilizer was placed in continuous bands or strips in different positions with respect to the potato seed piece. *A*, Subframe with side-placement disk depositors attached: *a*, Pair of single-disk furrow openers; *b*, fertilizer-delivery tube; *c*, disk vertical adjustment; *d*, disk lateral adjustment; *e*, auxiliary bedding disk; *f*, seed shoe; *g*, special spout for depositing the fertilizer in the furrow with the seed; *h*, conventional bedding disks. *B*, Depositor for placing fertilizer in a band under the seed: *i*, Colter; *j*, shovel with shields for controlling the width of fertilizer band. *C*, Depositor for mixing fertilizer thoroughly with the soil largely under the seed: *j*, Shovel for depositing fertilizer in a band; *k*, special mixing shovel. *D*, Equipment and arrangement of tools for placing the fertilizer in a wide band above the seed: *l*, Scraper for lowering the ridge to desired level above the seed; *m*, fertilizer-delivery tubes.

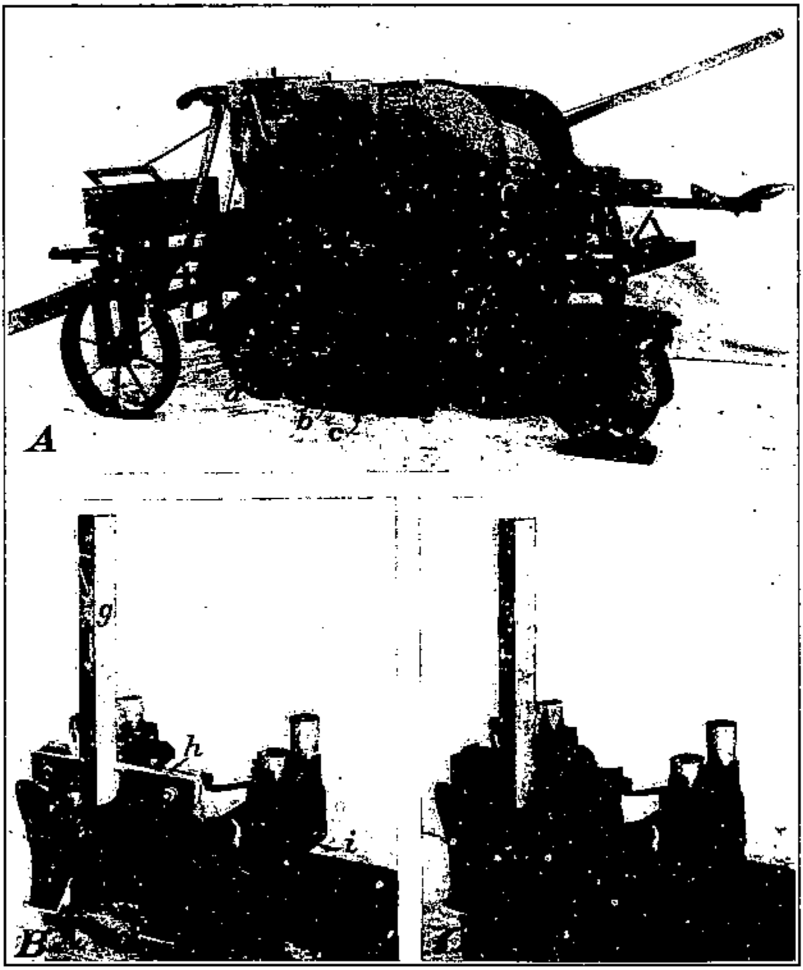

FIGURE 10.—Fertilizer-hilling equipment used to interrupt the continuous flow of fertilizer and thus deposit the fertilizer in short bands corresponding to each hill or seed piece. *A*, Fertilizer-hilling device mounted on the machine: *a*, Disk furrow opener; *b*, fertilizer-hilling device; *c*, depositor housing or shields to exclude the soil and control the maximum width of fertilizer band; *d*, fertilizer-delivery tubes, *e*, adjustment for movable partitions above the fertilizer valve to vary the length of fertilizer band; *f*, cam on seed-spacer shaft for operating the fertilizer valves. *B*, Fertilizer-hilling mechanism with the valve closed: *g*, Standard used for sliding vertical adjustment of the device; *h*, lateral adjustment; *i*, inclined longitudinal fertilizer flap valve; *j*, valve operating crank. *C*, Fertilizer-hilling mechanism with the valve open.

TABLE 1.—*General information for fertilizer-placement experiments with potatoes, 1931–37*

State	Location of experiment	Year	Soil type	Fertilizer: Single strength: Analysis	Fertilizer: Single strength: Amount[1] per acre	Fertilizer: Double strength: Analysis	Fertilizer: Double strength: Amount per acre	Seed planted: Variety	Seed planted: Whole or cut	Row spacing	Seed spacing	Date of planting	Emergence count: Date	Emergence count: Days after planting	Final stand count: Date	Final stand count: Days after planting	Date harvest started
					Pounds		*Pounds*			*Inches*	*Inches*			*Number*		*Number*	
Maine	Presque Isle	1932	Caribou loam	4-8-7	2,000	8-16-14	1,000	Green Mountain	Cut	34	12.5	May 24	June 22	29	July 11	48	Sept. 24
		1933	do	4-8-7	2,000	8-16-14	1,000	Irish Cobbler	do	34	12	May 20	June 15	26	July 6	47	Sept. 14
		1934	do	4-8-7	2,000	8-16-14	1,000	Green Mountain	do	34	12	May 17	do	29	July 9	53	Oct. 3
		1935	do	4-8-7	2,000			do	do	34	12	May 22	June 17	26	July 10	40	Oct. 8
		1936	do	4-8-7	2,000			do	do	34	12	May 20	June 16	21	June 22	27	Oct. 16
New Jersey	Bridgeton	1931	Sassafras sandy loam	5-8-7	2,000	10-16-14	1,000	Irish Cobbler	do	32	12	July 27	Aug. 21	25	Sept. 25	60	Oct. 20
Do	Cranbury	1931	Sassafras loam	5-8-7	2,000	10-16-14	1,000	do	do	34	13	Apr. 20	May 26	36	June 8	49	Sept. 5
		1932	do	4-8-7	2,000	8-16-14	1,000	do	do	33	12	Apr. 28	do	28	June 30	63	Sept. 13
		1933	do	4-8-7	2,000	8-16-14	1,000	do	do	34	12	May 1	June 3	33	June 13	43	Sept. 7
		1934	do	4-8-7	2,000			do	do	33	12	Apr. 26	May 23	27	June 29	64	Aug. 22
		1935	do	4-8-7	2,000			do	do	33	12	Apr. 19	May 21	32	June 26	68	Sept. 13
		1935	Sassafras sandy loam	4-8-7	2,000			do	do	34	14	Apr. 16	May 25	42			Sept. 12
Virginia	Onley	1932	do	6-6-5	2,000	12-12-10	1,000	do	do	30	13	Mar. 17	Apr. 27	41	May 26	70	July 7
		1933	do	6-6-5	2,000	12-12-10	1,000	do	do	30	15	Mar. 15	Apr. 20	45	May 24	70	July 6
		1934	do	6-6-5	2,000	12-12-10	1,000	do	do	30	15	Apr. 6	May 5	29	June 6	61	July 9
		1935	do	6-6-5	2,000			do	do	30	15	Mar. 14	Apr. 25	41	May 13	59	July 11
		1936	do	6-6-5	2,000			do	do	30	15	Mar. 25	May 1	38	May 15	53	June 29
		1937	do	6-6-5	2,000			do	do	30	15	Mar. 22	Apr. 30	39	do	54	July 7
New York	Mattituck	1934	do	4-8-7	2,000			Green Mountain	do	34	13	Apr. 21	May 15	21	June 25	62	Sept. 10
		1935	Sassafras loam	4-8-5	2,000			do	do	34	14	Apr. 16	May 17	31	June 14	59	Sept. 9
	Water Mill	1935	Bridgehampton silt loam	4-8-5	2,000			do	do	33	14	Apr. 8	May 22	44	June 13	66	Sept. 10
	Mattituck	1936	Sassafras loam	4-8-5	2,000			do	do	34	15	Apr. 20	do	32	June 12	53	Sept. 1
	Southold	1937	do	4-8-7	2,000			Irish Cobbler	do	34	14	Apr. 8					Oct. 1
Ohio	Lexington	1931	Chenango gravelly silt loam	4-10-6	1,500	8-20-12	750	Rural Russet	Whole	30	11	May 15			June 23	39	Oct. 22
	Smithville	1932	Canfield silt loam	4-10-6	1,500			do	Cut	30	11	May 18			July 11	54	Oct. 6
		1933	do	4-10-6	1,500			do	do	30	11	June 2			July 6	34	Oct. 16
	Reedsburg	1934	Chenango silt loam	4-10-6	1,500			do	(2)	32	11	May 31			June 29	29	Oct. 11
	Hiram	1930	Canfield gravelly loam	4-8-8	1,500			do	Whole	30	12	May 20	June 22	24			Oct. 10
Michigan	Greenville	1931	Montcalm sandy loam	4-8-7	500	8-16-14	400	do	Cut	36	16	May 25	June 17	22	July 14	49	Oct. 20
		1932	Fox sandy loam	4-8-7	800			do	do	36	16	June 11	July 8	27	July 25	44	Oct. 3
		1933	Montcalm sandy loam	4-12-8	800			do	do	36	16.8	June 7	July 1	24	July 15	38	Oct. 23
		1934	do	4-12-8	800			do	do	35	16	May 23	June 13	18	Oct. 15	142	Oct. 16
		1935	do	4-12-8	500			do	Whole	36	16	May 21			July 5	45	Oct. 12
		1936	Fox sandy loam	4-12-8	500			do	Cut	36	16	June 5	July 2	27			Oct. 16
		1937	do	4-12-8	600			Katahdin	do	36	12	May 29					Oct. 12
Do	Mancelona	1933	Mancelona gravelly silt loam	4-12-8	800			Rural Russet	Cut	36	15	June 5	June 23	18	July 8	33	Oct. 18
		1934	do	4-12-8	800			do	Whole	35	16	May 21	June 22	29			Oct. 8
		1935	do	4-12-8	500			do	do	36	16	May 22			July 6	45	Oct. 14
		1936	do	4-12-8	500			do	Cut	36	16	June 3	July 1	28			Oct. 13
		1937	do	4-12-8	400			do	Whole	36	16	May 25					Oct. 4

[1] Standard rate of application for the experiment—additional rates which were used in certain experiments are given in the tables of results.
[2] Experiment consisted of 2 parts, 1 planted with cut seed and the other planted with whole seed.

SOILS

The soil types on which the experiments were located are given in table 1. Soil types were selected in the various States that were extensively used for potato production. Detail descriptions of the soils and local conditions of the districts represented in the following experiments are given in soil survey reports: Presque Isle, Maine (*15*); Mattituck, Water Mill, and Southold, N. Y. (*18*); Cranbury (*17*) and Bridgeton (*3*), N. J., Onley, Va. (*24*); Smithville (*7*) and Hiram, Ohio (*22*); and Mancelona, Mich. (*28*). The soils in the study at Greenville, Mich., have not been surveyed but the same types of soils are described in a report (*30*) covering an adjacent county.

In planning the work it was not intended that each major soil type for potatoes should be represented but rather an attempt was made to locate the experiments in districts largely devoted to the commercial production of the crop. Thus some soil types were used more than once. The Sassafras sandy loam as represented in the Virginia experiments was the typical Coastal Plain early-potato soil, low in organic matter, sandy in texture, and entirely free from stones or gravel. The same soil type used on Long Island and in New Jersey was not quite so sandy and contained some gravel.

The soils of a gravelly or stony nature were the Canfield gravelly loam in Ohio and the Mancelona gravelly sandy loam in Michigan. The Caribou loam of Maine, which is among the highest potato-yielding soils, also contains numerous free surface stones. While suitable commercial planting and harvesting equipment are successfully used on these soils, the presence of stones is likely to cause some difficulty in the operation of intricate mechanisms which are not properly protected with release and other safety devices.

Although some of the fields used for the experiments were as much as 1,000 miles apart yet all the soil types represented fell into but two of the great soil provinces, the glacial and loessial province and the Atlantic and Gulf Coastal Plain province. The glacial origin of the soil types used in Ohio, Michigan, and Maine accounts for the presence of gravel and stones.

FERTILIZERS

The fertilizers used in all the experiments were dry-mixed from analyzed materials which were thoroughly broken up and screened when this was required to get uniform mixing.

It will be noted from table 1 that the analysis ($N-P_2O_5-K_2O$) of the fertilizer varied with the location of the experiments; occasionally changing slightly from year to year at the same location. Most of these changes were made to conform as nearly as possible to local practice and to the preferences of the grower or the State agency cooperating. For the same reasons the rate was not the same at all locations. In some instances a study of different rates was combined with the major placement study.

In formulating the fertilizer mixtures, superphosphate and muriate of potash were generally used, except for the double-strength mixtures which were formulated with Ammo-Phos and treble superphosphate when required. Usually not more than one and one-half units of nitrogen were derived from organics, principally dried ground fish, packing-house tankage, or dried blood. The inorganic nitrogen was

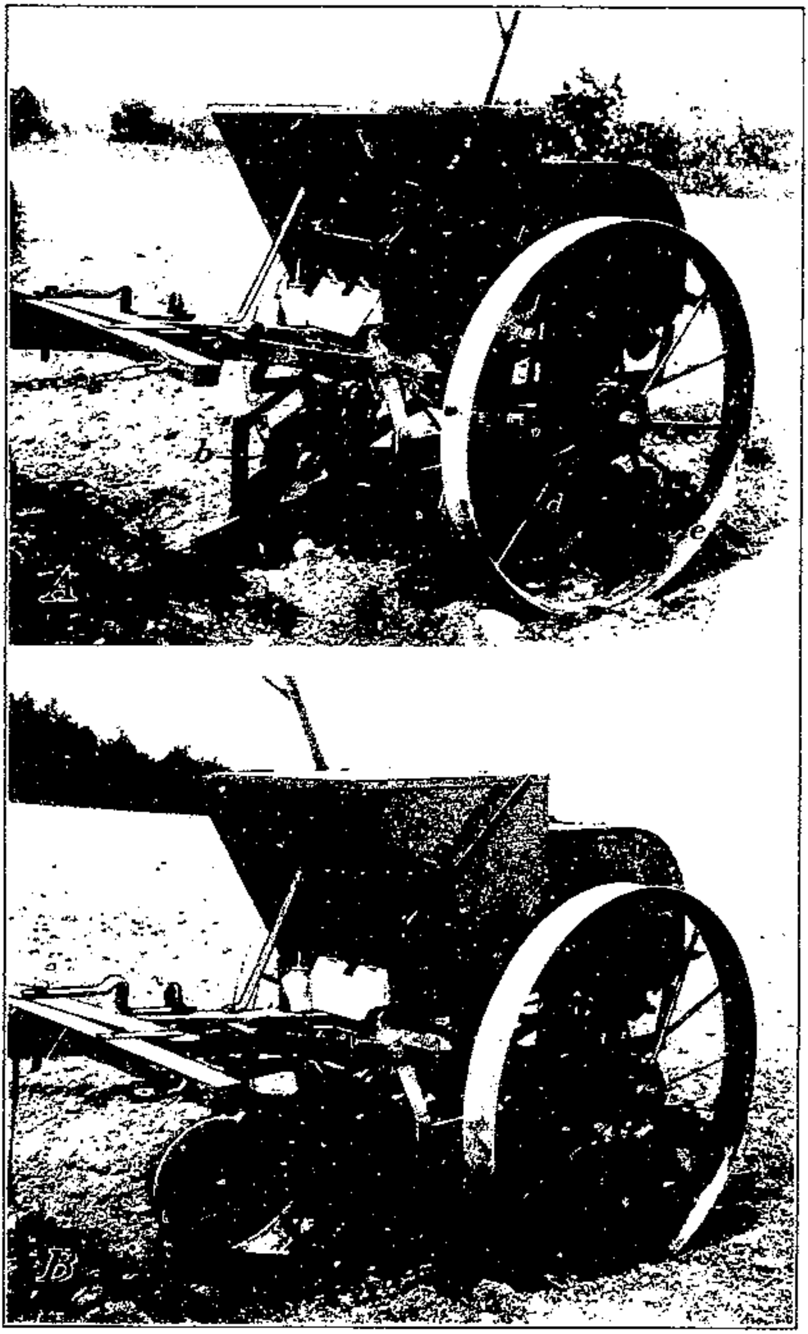

FIGURE 11.

(See legend on opposite page)

supplied by sulphate of ammonia and nitrate of soda. When conditions warranted, the fertilizer was neutralized with dolomitic limestone. No changes of major importance were made in the analysis or formula of the fertilizers used at any one location from year to year. The mixtures formulated were equivalent to commercial mixtures as indicated by comparable potato yields.

SEED

The importance of planting good seed reasonably free from virus and other diseases was recognized from the outset of the experimental work. Therefore the very best seed available was always obtained. In one instance seed potatoes were grown especially for the experiment.

Three of the major commercial varieties, Green Mountain, Irish Cobbler, and Russet Rural were used primarily, depending on the location of the experiment and the choice of the grower cooperating (table 1). Both whole and cut seed were used, the whole seed being entirely of the Russet Rural variety. As a rule, the seed were supplied and cut by the grower, therefore meeting the usual local standards acceptable for commercial production.

CULTURAL PRACTICES

The experimental areas were plowed and the seedbeds otherwise prepared in accordance with approved local practices. In some cases the potato plots were located on land on which another crop had been grown the previous year in a rotation while in other instances a winter cover crop was grown and turned under between successive potato crops. Without exception the seedbeds were well prepared and in proper condition which is an essential requirement of approved cultural practices.

The spacing of the rows given in table 1 for each experiment ranged from 30 to 36 inches. Usually the distance between rows is rather definitely established, especially on each farm where cultivating, spraying, and other equipment have been selected and adjusted for a particular spacing.

The spacing of seed in the row given in table 1 ranged from 11 to 16.8 inches. The seed spacing varied somewhat even on individual farms, and was determined largely by local conditions, variety of seed, and date of planting.

The planting and harvesting dates were determined mainly by the geographical location of the experiments (table 1). In a few of the experiments beginning in March and April, cold weather and rain delayed planting but not to an extent that would affect the study.

After planting, the experimental field was treated in practically the same manner as a larger field, including cultivating, spraying, digging,

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FIGURE 11.—Standard combined potato planter and fertilizer distributor used to a limited extent in the fertilizer-placement study with potatoes. *A*, Machine equipped with depositor for side placement of the fertilizer: *a*, Pair of single-disk furrow openers for depositing the fertilizer in a band at each side of the row; *b*, fertilizer-delivery tube; *c*, special auxiliary bedding disk; *d*, seed shoe; *e*, standard bedding disk. *B*, Machine equipped with special furrowing tools to place the fertilizer under the seed: *f*, Rolling colter; *g*, shovel with shields attached for depositing the fertilizer in a band under the seed; *h*, mixing shovel for mixing the fertilizer with the soil largely under the seed.

and grading. Indeed, the experiment was frequently an integral part of a commercial field and received precisely the same treatment throughout the growing season.

The tillage operations following planting differed at the various locations but was in accordance with local practices and prevailing conditions. Precautions were taken to avoid excessive and deep tillage during the later stages of plant growth particularly in dry periods. The crop was sprayed at such intervals as was required for the control of insects and diseases. Little damage from these sources occurred.

FIELD LAY-OUT AND PROCEDURE

In selecting the experimental areas an attempt was made to obtain reasonably level fields and uniform soil of representative type and condition. It was recognized that the relative placement of fertilizer and seed would be most accurate when the experimental machine was operated on level land. In all cases the individual plots as well as the experimental areas were relatively large, ranging from a total of 1 to 5 acres.

Single-row plots were arranged in blocks ranging from four to six in number. In a few instances the plots were systematically arranged although in most cases they were randomized within each block. The arrangement of blocks differed materially according to the shape of the fields at the various locations. The total length of the single-row plots ranged from about 200 to 600 feet but areas were discarded at each end and the entire row was not used to obtain crop records. The shortest length of plot from which harvest records were taken was 128 feet.

In those experiments where frequent spraying was ordinarily required the plots were arranged to eliminate any effect on the experiment of excessive packing of the soil by the sprayer wheels. Four-row guards were spaced throughout the experiment at intervals corresponding to the effective width of the sprayer. In each sprayer operation, the wheels traveled between the inner and outer rows of the four-row guard.

At certain intervals shortly after planting, observations were made to determine the best time for taking emergence counts. These counts were made from 18 to 45 days after planting depending on the season, variety grown, and the location. The counts were made either on the length of row intended for harvest, a total of several hundred feet, or some arbitrary length suitable for estimating the percentage of emergence. All sprouts above ground were counted. In some instances several counts were made at definite intervals, usually 7 to 10 days. Final-stand counts were taken either just before harvest or at a time during growth when all the sprouts were believed to be above ground.

It was customary to make periodic inspections of the fields during the growing season in order to record any unusual effects of the treatments on root growth, set of tubers, etc., and to make observations on the relative vine growth. In making early root examinations in the field, the soil was first cut with a spade about 5 inches from the center of the hill and parallel to the row, then a quantity of soil was removed to a depth of about 12 or 15 inches below the surface. In this way the soil immediately at the side of the hill remained intact, permitting careful uncovering of the roots and fertilizer. Many of the roots, of course, were broken or otherwise destroyed but enough usually remained intact to make observations on the type and condition of root growth especially in proximity to the fertilizer. In some instances whole hills with most of the roots intact were removed from the field in blocks of soil, the roots later being carefully uncovered with water.

At harvesttime the experimental area was carefully measured and staked so that all potato hills adjacent to but outside this area could be dug by hand and removed. This preliminary digging usually pertained to a 5- to 10-foot area at each end of the experimental rows and sometimes intersectional areas of 5 to 20 feet in width. Whenever intersectional areas were not previously dug, rows of stakes were used to mark the section divisions and the potatoes at the intersections were separated by hand as they were dug.

Digging was usually done with a mechanical digger either tractor or horse-drawn. As a rule, alternate rows were dug, thus preventing the potatoes from adjacent rows becoming mixed by rolling. Most of the early Irish Cobbler crops in Virginia were plowed and scratched out in the customary manner.

Grading was done with a mechanical grader either in the field or other suitable place, the potatoes being hauled to the grader in bags or crates properly tagged or marked. In Virginia grading was usually done in the field by hand except in the last 2 years when the crops were graded with a mechanical grader having a metal belt sheathed with rubber. Weights of No. 1 or Primes graded for size only were recorded separately.

RAINFALL AND GENERAL CONDITIONS

The monthly rainfall records during the crop season at or near the location of each experiment and the departure from normal are given in table 2 according to the records of the United States Weather Bureau. The points at which the precipitation was measured were reasonably near the experimental fields although in a few cases they were at a distance of several miles. However, it is believed that the monthly records here presented even for those experiments several miles from the weather station adequately represent any unusual or general rainfall conditions that might have some bearing on the study.

TABLE 2.—*Monthly rainfall during the crop season at or near the various locations of fertilizer-placement experiments with potatoes* [1]

Location [2] of Weather Bureau station and experimental plot	Month	1931		1932		1933		1934		1935		1936		1937	
		Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Presque Isle, Maine (Presque Isle)	May	(3)		2.10	−0.55	3.16	0.51	1.84	−0.96	2.06	−0.74	6.36	3.61	(3)	
	June			2.80	−.49	3.43	.14	4.51	1.05	5.52	2.06	4.00	.40		
	July			3.48	−.03	2.51	−1.00	5.69	2.08	2.87	−.74	3.52	−.10		
	August			3.58	.39	2.57	−.62	2.23	−.83	2.18	−.88	4.03	1.03		
	September			4.56	1.63	4.04	1.11	3.93	.73	3.66	.41	3.93	.61		
	October			5.47	2.21	3.94	.68	2.21	−1.23	1.36	−2.08	5.19	1.86		
New Brunswick, N. J. (Cranbury)	April	2.37	−1.37	1.97	−1.77	4.30	.56	3.70	.09	2.26	−1.35	2.97	−.64	(3)	
	May	3.21	−.65	2.09	−1.80	6.80	2.91	4.07	.41	2.17	−1.49	4.33	.67		
	June	4.60	.84	4.07	.31	2.85	−.91	3.92	.24	3.62	−.06	4.92	1.24		
	July	5.65	.61	1.49	−3.55	3.12	−1.92	2.22	−3.01	6.23	1.00	1.20	−4.03		
	August	5.21	.00	3.46	−1.69	9.62	4.47	3.05	−2.35	1.35	−4.05	3.69	−1.71		
	September	1.16	−2.44	3.46	−.14	5.26	1.66	9.13	5.77	5.71	−2.35	4.50	1.14		
Onley, Va. (Onley)	March	(3)		2.96	−.76	2.31	−1.41	6.55	2.73	2.27	−1.55	5.45	1.48	2.33	−1.64
	April			3.66	.09	3.60	.03	2.06	−1.53	4.80	1.21	3.98	.72	6.99	3.73
	May			2.13	−1.10	5.93	2.70	8.03	4.78	3.94	.69	.48	−2.74	2.72	−.50
	June			4.02	.69	1.34	−1.99	3.73	.42	2.53	−.78	2.66	−.68	4.08	.71
	July			3.26	−.94	4.70	.50	6.31	2.27	4.89	.85	1.74	−2.54	4.34	.06
Cutchogue, N. Y. (Mattituck)	April	(3)		(3)		(3)		5.70	1.61	2.98	−1.11	3.61	−.38	4.63	.64
	May							6.97	3.65	1.63	−1.69	1.34	−2.08	2.57	−.85
	June							3.35	.00	3.74	.39	6.19	2.92	4.83	1.56
	July							1.49	−2.04	3.46	−.07	1.28	−2.38	1.35	−2.31
	August							1.71	−2.33	.75	−3.29	2.44	−1.65	5.10	1.01
	September							5.16	1.74	5.35	1.93	2.59	−.76	3.11	−.24
Wooster, station No. 1,[5] Ohio (Smithville).[6]	May	3.96	−.50	1.93	−1.90	4.77	.96	.43	−3.38	2.74	−1.00	1.40	−2.23	(3)	
	June	2.85	−1.46	3.44	−0.68	1.67	−2.43	4.50	.40	4.07	.28	2.29	−1.31		
	July	4.38	.38	3.14	−1.11	1.73	−2.52	2.55	−1.70	4.03	.40	2.98	−.88		
	August	7.51	4.33	2.01	−1.32	3.85	.57	4.21	.93	7.28	4.03	4.62	1.20		
	September	4.09	.94	1.93	−1.46	4.23	.89	6.11	2.77	2.30	−1.03	2.79	−.51		
	October	2.20	−.56	3.56	1.08	1.49	−.98	.97	−1.50	1.97	−1.16	2.91	−.36		
Greenville, Mich. (Greenville)	May	3.88	.51	4.42	1.05	5.22	1.85	1.60	−1.77	3.51	.14	1.39	−2.09	2.56	−.92
	June	2.54	−1.19	4.87	1.14	1.61	−2.12	1.57	−2.16	4.18	.45	1.82	−1.90	2.32	−1.40
	July	1.53	−1.13	4.26	1.60	.92	−1.74	.48	−2.18	5.12	2.46	.23	−2.97	1.34	−1.86
	August	1.01	−1.57	5.60	2.99	1.26	−1.35	1.73	−.88	3.61	1.00	3.83	.43	5.02	1.62
	September	8.47	5.32	1.10	−2.05	2.37	−.78	6.37	3.22	2.27	−.88	4.68	1.11	2.42	−1.15
	October	2.07	−.71	4.99	2.21	5.28	2.50	1.92	−.86	.88	−1.90	3.30	.49	2.11	−.70

East Jordan,[7] Mich. (Mancelona)	May	([1])		([3])		2.74	−.16	1.24	−1.66	.99	−1.91	3.14	.21	1.31	−1.59
	June					2.23	−.64	3.60	.70	3.95	1.05	1.49	−1.41	.98	−1.92
	July					.80	−2.10	1.38	−1.52	2.09	−.81	1.75	−1.15	4.50	1.60
	August					1.01	−1.89	1.81	−1.09	7.24	4.34	3.86	.96	.96	−1.94
	September					2.72	−.18	6.54	3.64	4.11	1.21	5.06	2.16	5.32	2.42
	October					4.96	2.03	2.48	−.42	2.23	−.67	4.85	1.95	3.21	.31
Bridgeton, N. J. (Bridgeton)	July	2.55	−1.94	([3])		([3])		([3])		([3])		([3])		([3])	
	August	9.61	5.02												
	September	1.58	−1.73												
	October	2.78	−.81												

[1] Climatological data of the Weather Bureau, U. S. Department of Agriculture.
[2] Location of experiments shown in parenthesis. (See table 1.)
[3] Experiment was not conducted.
[4] Experiment located at Southold, N. Y., in 1937.
[5] Rainfall records taken at Mansfield in 1931 and Hiram in 1935 and 1936.
[6] Experiment located at Lexington in 1931, Smithville in 1932 and 1933, Reedsburg in 1934, and at Hiram in 1935 and 1936.
[7] Departure for East Jordan records not given by Weather Bureau; calculated on the basis of the average monthly precipitation over a period of 11 years.

The rainfall during the periods covered by the general study was doubtless subject to the usual variations. Some extreme departures from normal occurred for certain months at certain locations. Only in a comparatively few cases could the crop season at individual locations be considered extremely dry or wet. The influence of abnormal rainfall on the crop obviously depends largely on the amount of departure even for a single month and the stage of crop development; thus any deviations of significance in this respect will be mentioned under the discussion of the crop.

EFFECT OF FERTILIZER PLACEMENT

The study of fertilizer placement for potatoes as previously indicated consisted of two principal phases, the first involving representative placements of fertilizer applied in continuous bands and the second involving different placements of fertilizer confined to short bands at the sides of each seed piece or hill. Since the first phase of the work at several locations consisted of identical series of placements for both single-strength and double-strength fertilizers, these designations may be regarded as two main subdivisions.

As stated earlier, the investigations were progressive to the extent that treatments were either discontinued or added when, in view of the previous findings, such changes seemed desirable. In the initial work the fertilizer was placed in the row both lightly and well mixed with the soil and in a band in positions above, under, and at each side of the seed row, as will be noted in the tables of results.

It was soon definitely indicated that placement of fertilizer directly above the seed piece was an inferior method and this was discontinued after the second season. Also, after four seasons' work, it became evident that the use of only one type of fertilizer in each experiment was sufficient to determine the relative standing of the different methods of application, hence the use of the fertilizer designated as "double-strength" was discontinued.

As the study progressed additional comparisons seemed essential and other methods of fertilizer application were introduced. These included fertilizer applied at two different depths directly under the seed, closer intervals of fertilizer bands in a wider range of distances to each side of the row, placement at both sides and at only one side of the row, and the comparison of two distinctive local practices with the other methods specified. Among other changes introduced was the use of different quantities of fertilizer per acre.

Since the inauguration of the study a number of progress reports [6] (*6, 14, 19*) have been issued both on individual experiments and on one or more season's work. Although the essential conditions and the most pertinent data are presented here a number of the progress reports on the individual experiments include additional detailed information.

PLACEMENT IN CONTINUOUS BANDS

The results obtained from varying the placement of fertilizer in continuous bands are discussed on the bases of stand, plant growth, and yield. Major emphasis is given the general trends because of their widespread importance in the fertilization of the potato crop.

[6] NATIONAL JOINT COMMITTEE ON FERTILIZER APPLICATION. PROCEEDINGS 8-13. 1932-37. [Mimeographed.]

TABLE 3.—*Rapidity of emergence as indicated by the percent stand of potato plants during the emergence period for different placements of both single-strength and double-strength fertilizers, 1931–37*

SINGLE-STRENGTH FERTILIZER

Placement of the fertilizer		Maine					New Jersey							Virginia						New York		Average [3] eastern experiments	Michigan (Greenville)				Michigan (Mancelona)		Average [4] midwestern experiments	General average [5]
No.	Description	1932	1933	1934	1935	1936	1931 [1]	1931 [2]	1932	1933	1934	1935	1936	1932	1933	1934	1935	1936	1937	1935	1936		1931	1932	1933	1934	1933	1934		
X	No fertilizer ... percent	56	11	23	72	41	94	89	69	83	57	57		67	70	52	54	75	76	54	84	61	86	71	71	67	25	65	64	62
1	Band 7 inches wide, 2 inches above seed ... do						99	87	66					50																
2	Mixed lightly with soil largely above seed ... do							69								27	42			47	85			60		46		85		
3	Mixed with soil largely under seed ... do	49	3	4	57		93	68	42	77	48	47		66	71	37	44			26		49	72	61	46	40	11	70	50	49
5	Band 4.5 inches wide, 1 inch under seed ... do	54	3	5	62		96	76	46	78	46	35		64	58	50	41			20		51	80	54	61	25	26	70	53	51
6	Band 4.5 inches wide, 2 inches under seed ... do		7												74										60		24			
7	Band 1 inch to each side on seed level ... do	58	15	17	66					82	54			55	71	58				57	82			76	62	44	33	60		
8	Band 2 inches to each side on seed level ... do	58	20	18	77	41	99	88	77	86	63	63	96	70	74	63	46	93	82	55	81	65	86	71	70	61	30	69	65	65
9	Band 3 inches to each side on seed level ... do			27	63														73											
10	Band 4 inches to each side on seed level ... do	64	22	22	65		94	92	60	84	63			70	75	62				60		64	80	65	77	68	31	64	66	65
11	Band 2 inches to each side, 2 inches below seed ... do	60	33	26	71		97	92	68	81	66			76	78	60				59		67	82	73	70	63	45	56	65	66
12	Band 2 inches to one side on seed level ... do					48							97					91			81									
13	Local method used in Maine ... do	40	22	23	78																									
14	Local method used in Virginia ... do														74	58	62	95	79											
	Fertilizer analysis ... do	4-8-7	4-8-7	4-8-7	4-8-7	4-8-7	5-8-7	5-8-7	4-8-7	4-8-7	4-8-7	4-8-7	4-8-7	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	4-8-5	4-8-5		4-8-7	4-8-7	4-12-8	4-12-8	4-12-8	4-12-8		
	Fertilizer applied, per acre ... pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000		800	800	800	800	800	800		

DOUBLE-STRENGTH FERTILIZER

Placement of the fertilizer		Maine					New Jersey							Virginia						New York		Average [3] eastern experiments	Michigan (Greenville)				Michigan (Mancelona)		Average [4] midwestern experiments	General average [5]
No.	Description	1932	1933	1934	1935	1936	1931 [1]	1931 [2]	1932	1933	1934	1935	1936	1932	1933	1934	1935	1936	1937	1935	1936		1931	1932	1933	1934	1933	1934		
1	Band 7 inches wide, 2 inches above seed ... percent						90	84	76					50																
2	Mixed lightly with soil largely above seed ... do							52								26														
3	Mixed with soil largely under seed ... do	55	9	7			96	53	55	74				69	63	37						52	85							55
5	Band 4.5 inches wide, 1 inch under seed ... do	56	8	6			97	67	50	77				56	64	35						52	85							55
6	Band 4.5 inches wide, 2 inches under seed ... do		13												68															
7	Band 1 inch to each side on seed level ... do	62	24	18					58	84				52	70	47														
8	Band 2 inches to each side on seed level ... do	58	22	18			100	90	74	83				66	76	54						61	83							66
9	Band 3 inches to each side on seed level ... do			27																										
10	Band 4 inches to each side on seed level ... do	61	21	23			96	84	74	82				60	73	55						63	78							64
11	Band 2 inches to each side, 2 inches below seed ... do	65	29	21			94	93	67	84				74	74	62						66	85							68
13	Local method used in Maine ... do	44	19	29																										
14	Local method used in Virginia ... do														74	54														
	Fertilizer analysis ... do	8-16-14	8-16-14	8-16-14			10-16-14	10-16-14	8-16-14	8-16-14				12-12-10	12-12-10	12-12-10							8-16-14							
	Fertilizer applied, per acre ... pounds	1,000	1,000	1,000			1,000	1,000	1,000	1,000				1,000	1,000	1,000							400							

[1] At Bridgeton, N. J.
[2] At Cranbury, N. J.
[3] Averages of 13 eastern experiments with single-strength fertilizer: Maine, 1932–35; New Jersey, 1931–34; Virginia, 1932–34; New York, 1935. Averages of 10 experiments with double-strength fertilizer: Maine, 1932–34; New Jersey, 1931–33; Virginia, 1932–34.
[4] Averages of 6 midwestern experiments with single-strength fertilizer: Michigan (Greenville), 1931–34; Michigan (Mancelona), 1933–34; and with double-strength fertilizer only for Michigan (Greenville), 1931.
[5] General averages of comparable items comprising those included in the 2 sectional averages, or a total of 19 items for single-strength fertilizer and 11 items for double-strength fertilizer.

EMERGENCE OF SEED SPROUTS

In many sections where potatoes are grown commercially, rapid emergence of the sprouts above ground is sometimes taken as an early indication of a good crop. This criterion has not always proved reliable because numerous conditions often prevailing between sprout emergence and harvest can seriously affect the yield. However, there are sound reasons for wanting fairly rapid sprout emergence even under many widely different conditions of growth. Perhaps the principal reason is to avoid damage from *Rhizoctonia* (*23*). In certain late-potato districts, the shallow-cover method of planting is used extensively in order to induce rapid sprout emergence while in other

FIGURE 12.—Rapidity of emergence of Irish Cobbler potatoes for different placements of 6–6–5 fertilizer at 2,000 pounds per acre on Sassafras sandy loam at Onley, Va., planted April 6, photographed April 27, 1934: *a*, Band 1 inch to each side on seed level; *b*, mixed lightly with soil largely above seed; *c*, band 4.5 inches wide 1 inch under seed; *d*, band 4 inches to each side on seed level.

districts producing early potatoes, rapid emergence is induced by leveling off the ridges.

In general, the effect of a fertilizer-placement method on the rate of sprout emergence is an important consideration in determining the relative value of the method (*13*). Data concerning the effects of various methods of fertilizer placement under different soil and seasonal conditions are given in table 3 and comparable averages are shown graphically in figure 17. The figures in table 3 represent percentages of perfect stands—that is, a ratio of the actual number of plants counted to the number of seed pieces planted as calculated from the observed seed spacing.

As a basis for discussing table 3, the placements may be conveniently grouped. Placements Nos. 7, 8, 9, 10, and 11 constitute a group of side placements in which the essential difference is the distance the fertilizer was placed from the seed piece. This group of placements gave the most rapid emergence of sprouts throughout all the experiments. In this group no one side placement was particularly outstanding with respect to sprout emergence.

When the fertilizer was placed in a single wide band underneath the seed (placements Nos. 5 and 6) the rate of emergence was retarded, especially in the eastern experiments (fig. 12). In the midwestern experiments, fertilizer placed underneath the seed in the manner described retarded emergence in Michigan even with the relatively small amounts of fertilizer applied. Fertilizer coming in contact with the seed (placement No. 4) under Ohio conditions gave a sharp

FIGURE 13.—Rapidity of emergence of Irish Cobbler potatoes for different placements of 6–6–5 fertilizer at 2,000 pounds per acre on Sassafras sandy loam at Onley, Va., planted April 6, photographed April 27, 1934: *a*, Band 4 inches to each side on seed level; *b*, mixed with soil largely under seed; *c*, band 2 inches to each side on seed level.

decrease in the rate that the sprouts emerged as indicated in the early stage of plant growth (fig. 16).

Fertilizer mixed with the soil as described for placements Nos. 2 and 3 gave rather consistently delayed emergence as compared to side placement in all experiments. These comparisons are shown in figures 13 and 14. Retardation of emergence also occurred in the New Jersey and Virginia experiments when a wide band of fertilizer was applied above the seed. The rapidity of sprout emergence for the local method used in Virginia was practically the same as that for the side placement in bands 2 inches from the seed piece.

When double-strength fertilizer is used the method of placement can assume even greater importance with respect to emergence of sprouts than is sometimes the case with single-strength mixtures. However, the results of the emergence studies with double-strength fertilizers

TABLE 4.—*Final stand as indicated by the percent of a perfect stand of potato plants after the usual emergence period for different placements of both single-strength and double-strength fertilizers, 1931–37*

Placement of the fertilizer		Maine					New Jersey						Virginia						New York			Average eastern experiments[3]	Ohio					Michigan (Greenville)					Michigan (Mancolona)		Average midwestern experiments[6]	General average[7]
No.	Description	1932	1933	1934	1935	1936	1931[1]	1931[2]	1932	1933	1934	1935	1932	1933	1934	1935	1936	1937	1934	1935	1936		1931	1932	1933	1934[4]	1934[5]	1931	1932	1933	1934	1935	1933	1935		
	SINGLE-STRENGTH FERTILIZER																																			
X	No fertilizer ... percent	90	89	78	92	70	98	90	98	89	81	71	93	94	84	88	90	92	94	87	95	90		87	85	88	89	99	75	83	88	95	87	81	86	89
1	Band 7 inches wide, 2 inches above seed ... do						96	99	91				90											80												
2	Mixed lightly with soil largely above seed ... do							98							92	88			98	83	93		90			89	96		70		90	92		84		
3	Mixed with soil largely under seed ... do	94	84	82	93		91	98	93	83	84	74	91	93	89	90			97	82		90	93	82	76	72	92	99	67	78	85	95	74	82	81	86
4	In furrow with seed ... do																							86	51	58	91									
5	Band 4.5 inches wide, 1 inch under seed ... do	92	87	79	86		98	94	96	86	82	71	93	91	95	91			96	88		90	90	84	82	87	94	98	63	86	81	95	85	81	84	88
6	Band 4.5 inches wide, 2 inches under seed ... do		86											95											88					92			84			
7	Band 1 inch to each side on seed level ... do	92	87	87	90					87	86		91	93	95				98	85	96			91	80	83	88		80	85	84		87	84		
8	Band 2 inches to each side on seed level ... do	91	88	93	92	77	98	93	92	92	82	75	95	93	95	92	97	92	97	82	93	92	90	86	85	88	91	99	77	85	85	98	84	83	86	90
9	Band 3 inches to each side on seed level ... do			77	88													85																		
10	Band 4 inches to each side on seed level ... do	94	89	82	92		96	99	98	89	83		80	94	94				97	83		91	92	87	83	90	89	97	70	88	89		85	80	86	89
11	Band 2 inches to each side, 2 inches below seed ... do	93	88	87	89		94	100	96	97	84		96	93	96				98	80		92	89	86	82	85	91	98	77	83	86		88	80	86	89
12	Band 2 inches to one side on seed level ... do					81											100				94															
13	Local method used in Maine ... do	87	88	87	93																															
14	Local method used in Virginia ... do													96	100	90	99	90																		
	Fertilizer analysis ... do	4-8-7	4-8-7	4-8-7	4-8-7	4-8-7	5-8-7	5-8-7	4-8-7	4-8-7	4-8-7	4-8-7	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	4-8-7	4-8-5	4-8-5		4-10-6	4-10-6	4-10-6	4-10-6	4-10-6	4-8-7	4-8-7	4-12-8	4-12-8	4-12-8	4-12-8	4-12-8		
	Fertilizer applied, per acre ... pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000		1,500	1,500	1,500	1,500	1,500	800	800	800	800	500	800	600		
	DOUBLE-STRENGTH FERTILIZER																																			
1	Band 7 inches wide 2 inches above seed ... percent						87	94	90				90																							
2	Mixed lightly with soil largely above seed ... do							89							88								92													
3	Mixed with soil largely under seed ... do	95	87	80			94	95	96	87			94	82	94							90						97								91
5	Band 4.5 inches wide, 1 inch under seed ... do	94	88	76			96	94	97	81			91	90	93							90						99								91
6	Band 4.5 inches wide, 2 inches under seed ... do		89											93																						
7	Band 1 inch to each side on seed level ... do	92	91	86					97	90			98	94	97																					
8	Band 2 inches to each side on seed level ... do	89	92	92			95	100	86	94			95	91	94							93	91					96								93
9	Band 3 inches to each side on seed level ... do			76																																
10	Band 4 inches to each side on seed level ... do	93	89	82			93	96	98	88			96	90	91							92	90					93								92
11	Band 2 inches to each side, 2 inches below seed ... do	91	88	83			91	99	98	92			95	91	87							92						96								92
13	Local method used in Maine ... do	90	90	88																																
14	Local method used in Virginia ... do													94	97																					
	Fertilizer analysis ... do	8-16-14	8-16-14	8-16-14			10-16-14	10-16-14	8-16-14	8-16-14			12-12-10	12-12-10	12-12-10								8-20-12					8-16-14								
	Fertilizer applied, per acre ... pounds	1,000	1,000	1,000			1,000	1,000	1,000	1,000			1,000	1,000	1,000								750					400								

[1] Bridgeton, N. J.
[2] Cranbury, N. J.
[3] Averages of comparable items for 14 eastern experiments with single-strength fertilizer, Maine 1932–35, New Jersey 1931–34, Virginia 1932–34, New York 1934–35 and for 10 experiments with double-strength fertilizer, Maine 1932–34, New Jersey 1931–33, Virginia 1932–34.
[4] Cut seed planted.
[5] Whole seed planted.
[6] Averages of comparable items for 10 midwestern experiments with single-strength fertilizer, Ohio 1932–34, Michigan (Greenville) 1931–34, Michigan (Mancolona) 1933–35, and with double-strength only for Michigan (Greenville) 1931.
[7] General averages of comparable items comprising those included in the 2 sectional averages, or a total of 24 items with single-strength fertilizer and 11 items with double-strength fertilizer.

given in table 3 indicate that side placement is generally as desirable with this type of fertilizer as with single-strength mixtures.

FINAL STAND

Although rapid sprout emergence is important in order to promote early plant growth, yet generally the final stand of potato hills or plants in a large measure determines the yield produced. To a large extent the percentage of final stand depends on the quality of seed used. It is conceivable also that some methods of placing fertilizer may cause reductions in stand either directly or indirectly.

In experiments where it can be definitely shown that the final stand is significantly affected by the treatments being studied, then stand

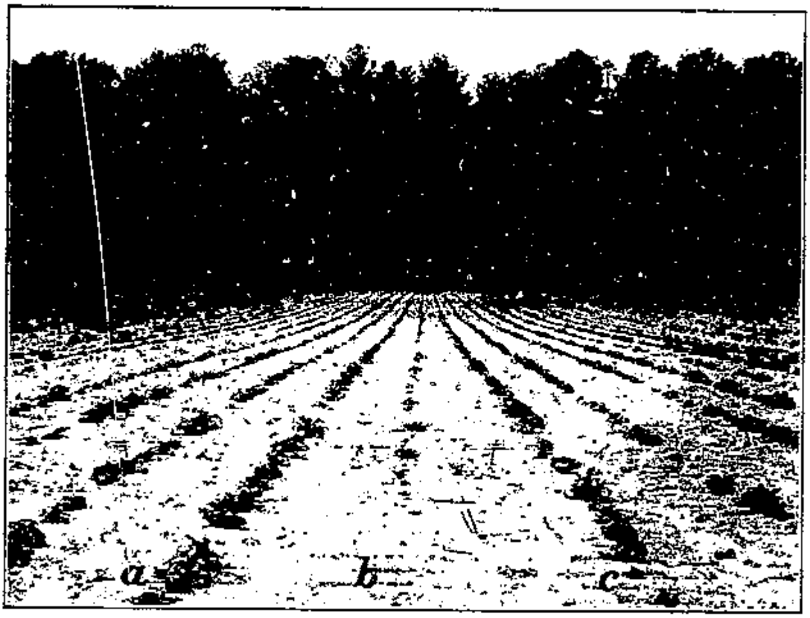

FIGURE 14.—Rapidity of emergence of Irish Cobbler potatoes for different placements of 6–6–5 fertilizer at 2,000 pounds per acre on Sassafras sandy loam at Onley, Va., planted April 6, photographed April 27, 1934: *a*, Band 2 inches to each side 2 inches below seed; *b*, mixed lightly with soil largely above seed; *c*, mixed with soil throughout the ridge—a local practice in eastern Virginia.

automatically becomes a function of the treatment, inasmuch as the yield produced is ultimately affected. In this event correction of the final yields for stand differences is not only not valid, but, if done, will tend to minimize the actual difference in yields obtained. Early in the present work, a few instances were found where the final stand was significantly affected by the fertilizer placements used, hence no corrections for stand differences were made.

From the final-stand data presented in table 4 and comparable averages shown graphically in figure 17 it is evident that the methods of fertilizer placement studied generally had no definite or pronounced effect on the final stand. The minor fluctuations that occurred in the stand data for any one placement from year to year can undoubtedly be attributed to variations in seed quality and to weather conditions. In contrast to the variations in time and rapidity of emergence that occurred on some of the fields, the final stand results appear remarkably uniform.

It is recognized that where missing hills occur the remaining space may prove to the advantage of adjacent hills thus causing them to yield more than they otherwise would under competitive conditions. Stewart (*25*) found a 53.8-percent increase in yield of hills adjacent to a missing hill and Werner and Kiesselbach (*29*) 58- to 63.2-percent increase.

In order to determine the importance of the missing-hill effect, competitive hills were dug separately in several instances and the yields were calculated from these selected hills. It was found that the yields from individually harvested hills of this kind compared

FIGURE 15. Stand and early growth of potato plants for different placements of 4-10-6 fertilizer at 1,500 pounds per acre on Canfield silt loam at Smithville, Ohio, 1933: *a* Band 2 inches to each side on seed level; *b* band 4.5 inches wide 1 inch under seed; *c* band 1 inch to each side on seed level.

very favorably with yields based on the entire harvested plot. Since the final stand was usually unaffected by the methods of placing the fertilizer used in the present studies, whatever advantage was derived from missing hills apparently was also uniformly distributed and had little or no effect on the relative yields.

PLANT GROWTH

The above-ground portion of the potato plant commonly referred to as vine growth constitutes the mechanism by which the plant is able to utilize solar energy and perform the necessary functions required to maintain itself and produce a crop of tubers. It is therefore important that adequate vine growth be produced to maintain a satisfactory balance between environmental conditions and the functioning of the leafy plant.

It is rather difficult, if not practically impossible, to show a qualitative relationship under field conditions between vine growth and ultimate yield of tubers because occasionally large vine growth proves to be a detriment under unusually dry soil conditions accompanied by hot winds.

The method of placing fertilizer has been observed to affect both the amount and nature of potato-vine growth. These observations frequently served as a basis for distinguishing certain unmarked plots in the field but less frequently afforded a reliable indication of probable crop yield. Changes in relative vine growth were observed to take place during the growing season, therefore the growth obtained with one or another of the fertilizer placements depended a good deal on the date of the observation, the season, and the variety grown. In general, however, at blossom time or later the vine growth obtained from placing the fertilizer underneath, above, or in contact with the seed was inferior to that from side placement. The increased early

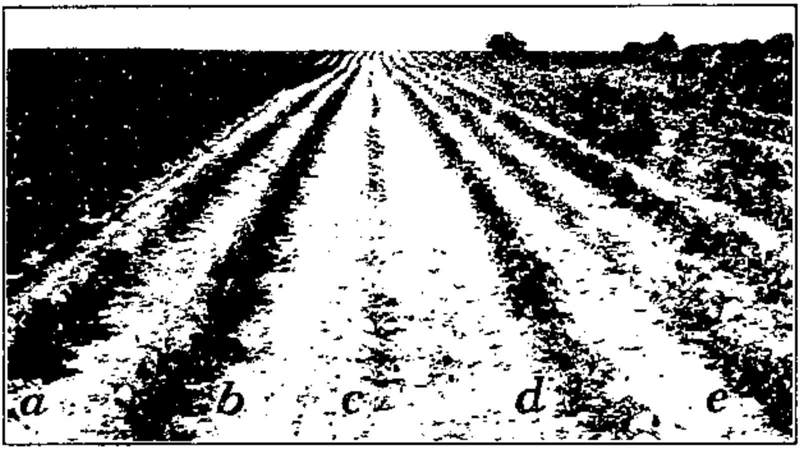

FIGURE 16.—Stand and early growth of potato plants for different placements of 4-10-6 fertilizer at 1,500 pounds per acre on Canfield silt loam at Smithville, Ohio, 1933. *a* Band 4.5 inches wide 1 inch under seed; *b* band 2 inches to each side on seed level; *c* in furrow with seed; *d* band 4.5 inches wide 2 inches under seed; *e* no fertilizer.

vine growth resulting from side placement compared to underneath placement of fertilizer under Ohio conditions is shown in figures 15 and 16. Inferior vine growth also could occasionally be detected when the fertilizer was mixed with the soil under or above the seed piece. Side placement of fertilizer in bands 2 inches away from the seed on the same level usually gave satisfactory vine growth and many times produced the best growth of vines in the experiment.

Equal in importance to vine growth is root growth. No attempt was made to conduct a comprehensive study of root growth in relation to this phase of the fertilizer-placement work, but numerous root observations were made on plants in the field. These observations failed to disclose any apparent injury to the roots from the fertilizers used at the rates and in the manner described. Furthermore, no evidence was obtained to indicate excessive concentration of roots near the fertilizer when band distribution was used. It is sometimes from 10 to 20 days after planting before potato root growth is established. During this period considerable change can take place in the fertilizer. The soluble ingredients can permeate the soil above and below the band and other changes can take place which may render the fertilizer less likely to cause root injury or to cause excessive concentration of root growth.

Although injury to the roots was not visible from the field observations of the root systems, yet it was evident from the results on rapidity of sprout emergence that fertilizer had some deterrent effects when applied either immediately under or above the seed piece.

TOTAL YIELDS

There is no one generally recognized manner of reporting the yields in potato experiments. Results may be given for total yields including all potatoes harvested, as in table 5, or as yields of primes (U. S. No. 1) graded with respect to size only as in table 6, or as marketable potatoes. As far as this study is concerned most of the results worthy of important consideration have remained practically unaltered regardless of the two bases selected for reporting. This similarity of results for total yields and primes might be expected from consideration of the fact that usually seconds and culls comprise less than 15 to 20 percent of the total yield, depending largely on location and season. Moreover the actual quantity of seconds and culls harvested has frequently been found to fluctuate very little in any one experiment, apparently without much regard to the total yield. This relationship, found to be especially true in the Long Island experiments, undoubtedly exists at other locations also.

The total yields presented in table 5 may be conveniently grouped for discussion according to types of fertilizer placement. The first group consisting of comparable side placements may include placements Nos. 7, 8, 9, 10, 11. Throughout the entire work, including the use of both single- and double-strength fertilizer, this group of fertilizer placements has included most of the highest yields and practically none of the low yields. The manner in which high yields have persisted in this group at the various locations throughout the 7 years, may be accepted as very convincing evidence of the desirability generally of placing the fertilizer for potatoes in bands at the side of the seed.

It is not to be expected, however, that this general conclusion was without exception. Chief among these occurred in the data from Virginia in 1932, Ohio in 1931, Greenville, Mich., in 1931, Mancelona, Mich., in 1933 and 1935, and Maine in 1932, the latter with double-strength fertilizers. These exceptions to the superiority of side placement of fertilizer, however, detract little from the bulk of evidence presented by the data in table 5. The average yields for 13 eastern experiments and those for 5 midwestern experiments further emphasize the superiority of side placement. These averages are graphically presented in figure 17.

For further purposes of comparison and to simplify presentation, the results from all groups of fertilizer placements have been compared with those from placement No. 8—band 2 inches to each side on seed level. The results of these comparisons are shown in figure 18.

The selection of placement No. 8 as a base for comparisons of the other placements in figure 18 was not entirely arbitrary. This par-

TABLE 5.—*Total yields of potatoes per acre for various placements of both single-strength and double-strength fertilizers, 1931–37* [1]

SINGLE-STRENGTH FERTILIZER

No.	Placement of the fertilizer: Description	Maine 1932	Maine 1933	Maine 1934	Maine 1935	Maine 1936	New Jersey 1931 [2]	New Jersey 1931 [3]	New Jersey 1932	New Jersey 1933	New Jersey 1934	New Jersey 1935	New Jersey 1936
X	No fertilizer ... bushels	223	157	341	303	357	100	207	188	145	125	202	
1	Band 7 inches wide, 2 inches above seed ... do						117	307	211				
2	Mixed lightly with soil largely above seed ... do							300					
3	Mixed with soil largely under seed ... do	298	280	436	384		118	292	235	216	182	334	
5	Band 4.5 inches wide, 1 inch under seed ... do	290	314	493	347		135	286	229	211	175	219	
6	Band 4.5 inches wide, 2 inches under seed ... do		298										
7	Band 1 inch to each side on seed level ... do	295	320	515	407					245	200		
8	Band 2 inches to each side on seed level ... do	312	300	582	374	453	134	331	252	236	201	351	258
9	Band 3 inches to each side on seed level ... do				359								
10	Band 4 inches to each side on seed level ... do	296	307	525	380		137	307	249	231	209		
11	Band 2 inches to each side, 2 inches below seed ... do	316	318	499	384		147	329	255	254	199		
12	Band 2 inches to one side on seed level ... do					512							238
13	Local method used in Maine ... do	290	304	517	416								
14	Local method used in Virginia ... do												
	Fertilizer analysis ... percent	4-8-7	4-8-7	4-8-7	4-8-7	4-8-7	5-8-7	5-8-7	4-8-7	4-8-7	4-8-7	4-8-7	4-8-7
	Fertilizer applied per acre ... pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000

No.	Placement of the fertilizer: Description	Virginia (Eastern Shore) 1932	Virginia 1933	Virginia 1934	Virginia 1935	Virginia 1936	Virginia 1937	New York (Long Island) 1934	New York 1935	New York 1936	New York 1937	Averages [4]
X	No fertilizer ... bushels	86	94	57		61	60					
1	Band 7 inches wide, 2 inches above seed ... do	114										
2	Mixed lightly with soil largely above seed ... do			263	329			228	350	232	364	
3	Mixed with soil largely under seed ... do	134	207	232	339			189	282			249
5	Band 4.5 inches wide, 1 inch under seed ... do	128	187	248	295			197	292			252
6	Band 4.5 inches wide, 2 inches under seed ... do		191									
7	Band 1 inch to each side on seed level ... do	122	213	318				218	348	221	392	
8	Band 2 inches to each side on seed level ... do	123	220	307	345	203	212	212	327	215	388	270
9	Band 3 inches to each side on seed level ... do						207					
10	Band 4 inches to each side on seed level ... do	132	200	328				197	328			273
11	Band 2 inches to each side, 2 inches below seed ... do	132	203	291				200	326			275
12	Band 2 inches to one side on seed level ... do					179				207		
13	Local method used in Maine ... do											
14	Local method used in Virginia ... do		220	244	339	169	189					
	Fertilizer analysis ... percent	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	4-8-7	4-8-5	4-8-5	4-8-7	
	Fertilizer applied per acre ... pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	

DOUBLE-STRENGTH FERTILIZER

No.	Description	Maine 1932	Maine 1933	Maine 1934	Maine 1935	Maine 1936	New Jersey 1931 [2]	New Jersey 1931 [3]	New Jersey 1932	New Jersey 1933	New Jersey 1934	New Jersey 1935	New Jersey 1936
1	Band 7 inches wide, 2 inches above seed ... bushels						102	302	226				
2	Mixed lightly with soil largely above seed ... do							259					
3	Mixed with soil largely under seed ... do	325	303	487			123	274	231	194			
5	Band 4.5 inches wide, 1 inch under seed ... do	267	338	479			133	286	243	218			
6	Band 4.5 inches wide, 2 inches under seed ... do		300										
7	Band 1 inch to each side on seed level ... do	305	332	516					248	241			
8	Band 2 inches to each side on seed level ... do	313	316	522			134	332	254	240			
9	Band 3 inches to each side on seed level ... do			550									
10	Band 4 inches to each side on seed level ... do	274	316	489			146	311	240	233			
11	Band 2 inches to each side, 2 inches below seed ... do	307	322	541			138	330	251	234			
13	Local method used in Maine ... do	307	323	508									
14	Local method used in Virginia ... do												
	Fertilizer analysis ... percent	8-16-14	8-16-14	8-16-14			10-16-14	10-16-14	8-16-14	8-16-14			
	Fertilizer applied per acre ... pounds	1,000	1,000	1,000			1,000	1,000	1,000	1,000			

No.	Description	Virginia (Eastern Shore) 1932	Virginia 1933	Virginia 1934	Virginia 1935	Virginia 1936	Virginia 1937	New York (Long Island) 1934	New York 1935	New York 1936	New York 1937	Averages [4]
1	Band 7 inches wide, 2 inches above seed ... bushels	95										
2	Mixed lightly with soil largely above seed ... do			193								
3	Mixed with soil largely under seed ... do	120	203	251								252
5	Band 4.5 inches wide, 1 inch under seed ... do	121	229	244								256
6	Band 4.5 inches wide, 2 inches under seed ... do		196									
7	Band 1 inch to each side on seed level ... do	114	210	272								
8	Band 2 inches to each side on seed level ... do	112	232	268								272
9	Band 3 inches to each side on seed level ... do											
10	Band 4 inches to each side on seed level ... do	128	239	274								260
11	Band 2 inches to each side, 2 inches below seed ... do	128	223	249								272
13	Local method used in Maine ... do											
14	Local method used in Virginia ... do		231	227								
	Fertilizer analysis ... percent	12-12-10	12-12-10	12-12-10								
	Fertilizer applied per acre ... pounds	1,000	1,000	1,000								

SINGLE-STRENGTH FERTILIZER

No.	Placement of the fertilizer: Description	Ohio 1931	Ohio 1932	Ohio 1933	Ohio 1934 [5]	Ohio 1934 [6]	Michigan (Greenville) 1931	Michigan (Greenville) 1932	Michigan (Greenville) 1933	Michigan (Greenville) 1934	Michigan (Greenville) 1935	Michigan (Greenville) 1937	Michigan (Mancelona) 1933	Michigan (Mancelona) 1934	Michigan (Mancelona) 1935	Averages [7] for 12 north-central experiments	General [8] average for 20 experiments
X	No fertilizer ... bushels		155	169	158	174	143	169	130	239	167		62	188	139		
1	Band 7 inches wide, 2 inches above seed ... do		144					176									
2	Mixed lightly with soil largely above seed ... do	417			144	171				270	192	122		259	170		
3	Mixed with soil largely under seed ... do	411	146	177	149	195	179	175	115	237	191		112	260	181	195	224
4	In furrow with seed ... do		152	109	159	107											
5	Band 4.5 inches wide, 1 inch under seed ... do	417	155	179	156	193	173	168	126	270	192		138	271	180	203	20
6	Band 4.5 inches wide, 2 inches under seed ... do			196					141				122				
7	Band 1 inch to each side on seed level ... do		161	209	182	198		200	143	256			118	231	178		
8	Band 2 inches to each side on seed level ... do	366	153	211	166	195	185	197	162	274	190	144	119	270	173	206	245
10	Band 4 inches to each side on seed level ... do	395	158	211	155	199	155	181	164	280			118	259	182	205	242
11	Band 2 inches to each side, 2 inches below seed ... do	369	153	213	155	193	168	192	133	267			121	246	162	198	240
	Fertilizer analysis ... percent	4-10-6	4-10-6	4-10-6	4-10-6	4-10-6	4-8-7	4-8-7	4-12-8	4-12-8	6-12-5	4-12-8	4-12-8	4-12-8	4-12-8		
	Fertilizer applied, per acre ... pounds	1,500	1,500	1,500	1,500	1,500	800	800	500	800	500	500	800	800	500		

DOUBLE-STRENGTH FERTILIZER

No.	Description	Ohio 1931	Ohio 1932	Ohio 1933	Ohio 1934 [5]	Ohio 1934 [6]	Michigan (Greenville) 1931	Michigan (Greenville) 1932	Michigan (Greenville) 1933	Michigan (Greenville) 1934	Michigan (Greenville) 1935	Michigan (Greenville) 1937	Michigan (Mancelona) 1933	Michigan (Mancelona) 1934	Michigan (Mancelona) 1935	Averages [7] for 12 north-central experiments	General [8] average for 20 experiments
2	Mixed lightly with soil largely above seed ... bushels	434															
3	Mixed with soil largely under seed ... do						161										
6	Band 4.5 inches wide, 1 inch under seed ... do						159										
8	Band 2 inches to each side on seed level ... do	419					156										
10	Band 4 inches to each side on seed level ... do	427					151										
11	Band 2 inches to each side, 2 inches below seed ... do						178										
	Fertilizer analysis ... percent	8-20-12					8-16-14										
	Fertilizer applied, per acre ... pounds	750					400										

[1] See table 1 for detail information concerning each experiment.
[2] Experiment located at Bridgeton.
[3] Experiment located at Cranbury.
[4] Averages of results directly comparable: Maine 1932–35, New Jersey 1931–34, Virginia 1932–34, and New York 1934–35 comprising 14 experiments with single-strength fertilizer and Maine 1932–34, New Jersey 1931–33, and Virginia 1932–34 comprising 10 experiments with double-strength fertilizer.
[5] Cut seed planted.
[6] Whole seed planted.
[7] Averages of results directly comparable; Ohio 1931–34; Greenville, Mich., 1931–34; and Mancelona, Mich., 1933–35.
[8] General averages of comparable items comprising those included in the two sectional averages.

ticular method of placing the fertilizer was, first of all, included in every experiment. In addition, the yields obtained afforded a relatively uniform basis of comparison because they were invariably good yet not always the highest, corresponding more to a mean rather than a mode. In considering figure 18 it should be observed that the white

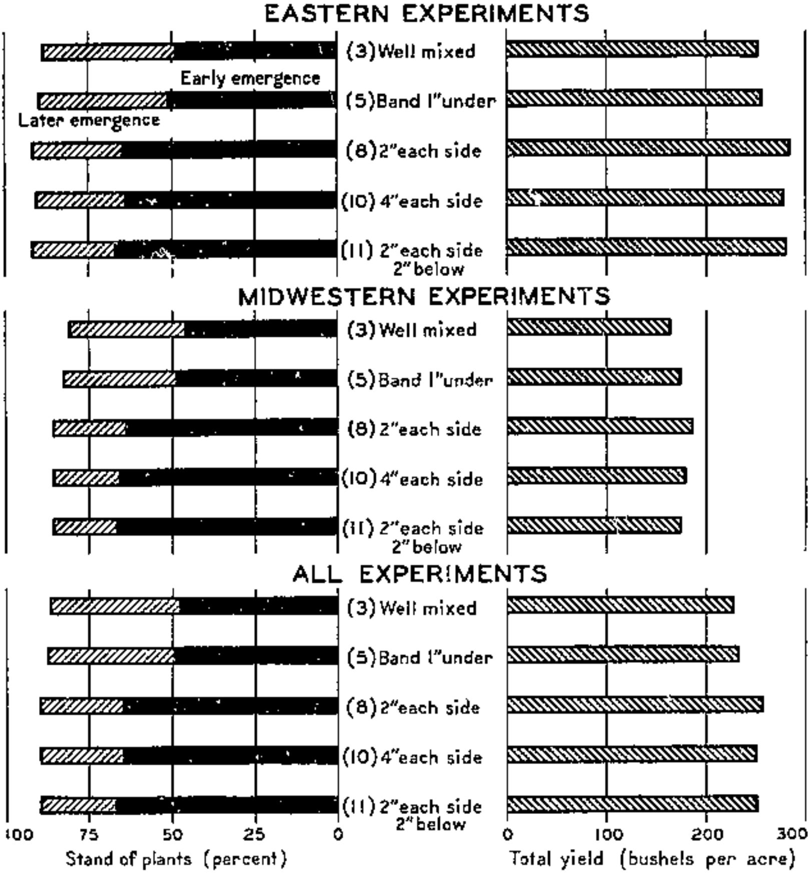

Figure 17.—Stand counts indicating both rapidity of emergence and final stand of plants and the total yields for representative placements of single-strength fertilizer. The number of the different fertilizer placements are given for convenience in referring to the corresponding sketches in figure 5. The bars represent comparable averages for 13 experiments in the eastern section, 5 experiments in the midwestern section, and 18 experiments for the entire area. (Maine 1932–35; New Jersey (Bridgeton) 1931, (Cranbury) 1931–34; Virginia 1932–34; New York 1935; Greenville, Mich. 1931–34; Mancelona, Mich, 1933).

bar representing the results from placement No. 8 is strictly comparable with the placement results represented by the black bar in each case but the black bars are not necessarily comparable with each other.

The results of the eastern experiments shown graphically in figure 18 indicate a satisfactory response from side placements Nos. 7, 9, 10, and 11 as compared with placement No. 8. Placements Nos. 2, 12, and 13 also gave indication of a satisfactory comparison with placement No. 8, but these comparisons cannot be regarded as reliable

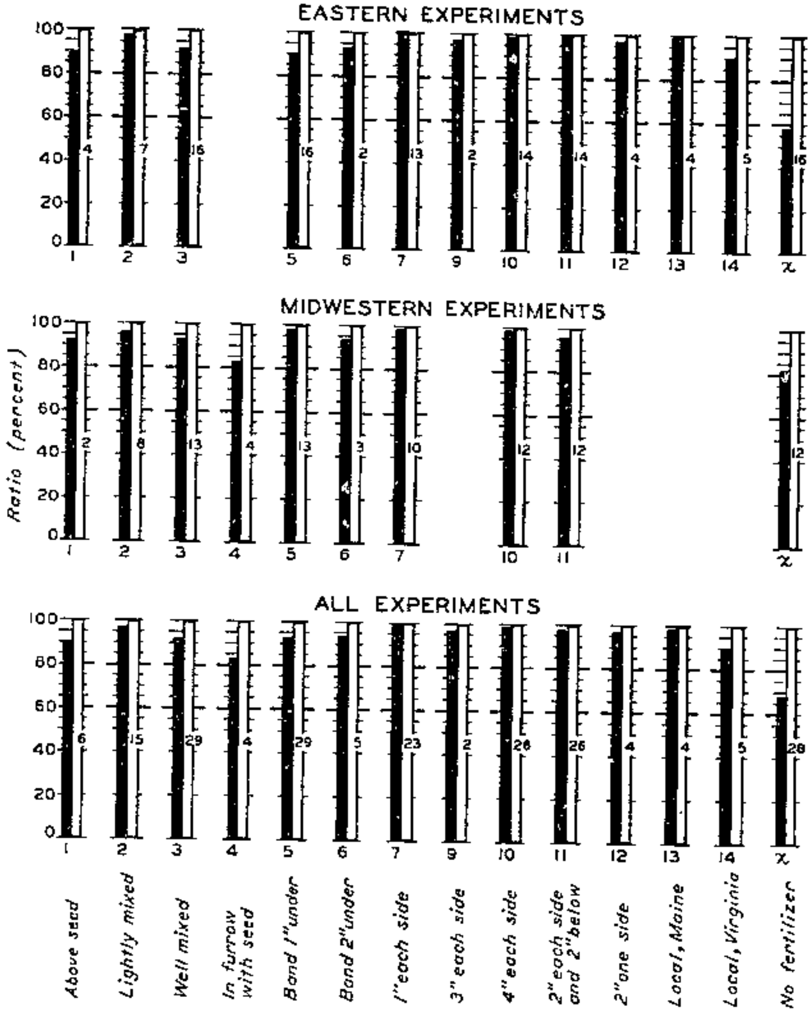

FIGURE 18.—Ratio of average total yields of potatoes for each fertilizer placement (shown by black bar) to the average total yield for placement No. 8—a band 2 inches to each side of and on a level with the seed piece (shown by white bar) which has been designated 100 in each case. The black and white bars making up each pair are comparable, and the number of items averaged is shown by the numeral in the center of the white bar. The average yields represented by the black bars are not necessarily comparable with each other. The numbers of the different fertilizer placements are given for convenience in referring to the corresponding sketches in figure 5.

as those made among most of the side placements where 13 or 14 items were arranged.

The results of the midwestern experiments (fig. 18) are very similar to those of the eastern experiments shown in the same figure. The greatest differences occurred between placements Nos. 11 and 5; the former giving relatively lower yields and the latter relatively higher yields in the midwestern experiments.

When the results for all experiments are grouped and compared with placement No. 8 as shown in figure 18, a broad yet comprehensive picture of the results is obtained. It is plainly evident that placement No. 8—band 2 inches to each side on seed level—was superior to all the other placements used, except placement No. 7 in which the bands were placed 1 inch to each side at seed level. In this one case the average yields were the same.

The relationship of rapidity of sprout emergence and final stands to total yields of potatoes is indicated in figure 17. Under the conditions of these experiments particularly in the East a definite retardation of sprout emergence as occurred with placements Nos. 3 and 5 was associated with reduced yields. The final-stand results in figure 17 correspond in general to the sprout-emergence counts for the midwestern experiments but not in the eastern experiments. It is apparent from figure 17 that the effect of retarded sprout emergence was not entirely overcome during later growth, for even though the final stand of plants appears to be satisfactory, lower yields were obtained.

YIELDS OF PRIMES

The statistics pertaining to the yield records of prime potatoes were obtained by Fisher's analysis of variance (*12*). In conforming with the principles underlying this method of analysis, a field design with the plots arranged in randomized blocks was used almost entirely. The randomized-block arrangement was selected as being more suitable for this particular study than the Latin square arrangement. Because the crops were planted entirely with mechanical equipment, a field arrangement with minimum intersectional areas was almost necessary. Wherever the blocks were arranged end on end, intersectional areas from 15 to 20 feet wide were required in order to satisfactorily manipulate the experimental planter drawn by tractor or team. When such areas were necessary they were usually planted by hand after planting on the experimental plots was completed. At harvesttime it was necessary to dig by hand and remove the potatoes from these areas before operations could be commenced on the experimental area. With the randomized-block arrangement intersectional areas could be reduced to a minimum or eliminated entirely if desired.

The standard error obtained for the experiments at different locations ranged from 2.4 to 9.5 percent (table 6). A standard error of about 5 percent with from four- to six-treatment replications was found to be fairly reliable throughout this work. Where an unusually high standard error was obtained, as for the Virginia experiment in 1932 and Ohio for 1934, it was traceable to the effects of an unusual environmental influence.

There were three instances: Long Island 1937, and Mancelona, Mich., 1934 and 1935, where the calculated Z value did not reach the 5-percent point in spite of an apparently satisfactory standard error. In these instances there is a very definite indication that the treatments in general had only small effect on the yields although the experiment as a whole was satisfactorily conducted.

The yield of prime potatoes is important because it represents the portion of the total crop from which the grower derives his largest returns. As already pointed out, yield of primes in the present instance is taken to mean U. S. No. 1 grade with respect to size only. However, the percentage of unmarketable potatoes included in this grade was always very small.

The yields of primes are presented in table 6. These yields relate to the total yields from the various fertilizer-placement methods that have already been discussed. For reasons previously stated, it will be found that the general results obtained on the basis of yields of primes correspond closely to the total-yield results. As with the total yields, most of the high yields of primes were obtained with the side placements of fertilizer (Nos. 7, 8, 10, and 11) including both single-strength and double-strength mixtures. Fertilizer applied under the seed, placements Nos. 5 and 6, generally gave lower yields than side placement in bands but these differences were not always significant.

Numerous other comparisons in table 6 can be made both at individual locations and for successive years, using the bushels required for significance as a criterion of reliability. In doing this it will be observed that placement No. 2—fertilizer mixed lightly with soil largely above seed—was particularly outstanding on Long Island. Placement No. 7—bands 1 inch to side at seed level—also gave excellent results on Long Island and at all other places used, except Greenville, Mich. It should be noted particularly that this method did not work so well with double-strength fertilizer in Virginia.

Of the four side placements used, Nos. 7, 8, 10, and 11, none gave significant difference in yield indicating superiority generally. However, placement No. 8—band to each side on seed level—consistently produced relatively high yields of primes throughout all of the experiments reported in table 6.

Data on the number and size of tubers in individual hills for different placements of fertilizer, which were determined in several experiments, are neither presented nor discussed in this bulletin. The foregoing data of both primes and total yields indicate the same general trends as similarly classified records of individual-hill determinations.

DOUBLE-STRENGTH FERTILIZER

The subject of fertilizer placement for double-strength mixtures may involve certain considerations not usually recognized as important with single-strength fertilizers. Because the percentage of plant food in double-strength is twice that in single-strength fertilizers, it might appear that special care would be necessary in placing such fertilizers. Comparison of total salt concentrations of the two types of fertilizers (*11*) have shown that the total salt content from double-strength fertilizer in the soil is actually less than that from single-strength fertilizer when corresponding percentages of plant food are applied. In the present work, however, the double-strength frequently contained less organic nitrogen from natural sources than the single-strength fertilizers hence they can be considered more readily soluble.

In the preceding discussion of the general effects of fertilizer placement on the yield of the potato crop, attention was called to the similarity of the results obtained with single-strength and double-strength fertilizers. There was no general exception to this close relationship except for rapidity of sprout emergence (table 3) in the case of placement No. 2. In New Jersey and Virginia light mixing of the double-strength fertilizer with the soil gave a relatively slow emergence.

TABLE 6.—*Yields of prime potatoes per acre for various placements of both single-strength and double-strength fertilizers, 1931–37* [1]

SINGLE-STRENGTH FERTILIZER

Placement of the fertilizer		New Jersey						Virginia (Eastern Shore)						New York (Long Island)				Average [4] eastern experiments
No.	Description	1931 [2]	1931 [3]	1932	1933	1934	1935	1932	1933	1934	1935	1936	1937	1934	1935	1936	1937	
X	No fertilizer....bushels	56	102	158	99	92	165	21	39	12		19	41					
1	Band 7 inches wide, 2 inches above seed....do	53	204	186				53										
2	Mixed lightly with soil largely above seed....do		266							183	291			210	323	198	343	
3	Mixed with soil largely under seed....do	73	265	212	180	145	300	67	188	164	300			169	261			170
5	Band 4.5 inches wide, 1 inch under seed....do	82	241	204	184	133	223	59	153	159	254			176	271			166
6	Band 4.5 inches wide, 2 inches under seed....do								149									
7	Band 1 inch to each side on seed level....do				208	158		64	188	248				194	320	187	361	
8	Band 2 inches to each side on seed level....do	67	282	220	290	157	308	58	186	230	300	172	165	180	295	179	353	188
9	Band 3 inches to each side on seed level....do												158					
10	Band 4 inches to each side on seed level....do	68	255	223	197	158		55	153	240				172	207			182
11	Band 2 inches to each side 2 inches below seed....do	84	279	227	207	154		60	151	189				174	203			182
12	Band 2 inches to one side on seed level....do											145				174		
14	Local method used in Virginia....do								185	172	300	137	152					
	Fertilizer analysis....percent	5-8-7	5-8-7	4-8-7	4-8-7	4-8-7	4-8-7	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	6-6-5	4-8-7	4-8-5	4-8-5	4-8-7	
	Fertilizer applied per acre....pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	

DOUBLE-STRENGTH FERTILIZER

No.	Description	NJ 1931 [2]	NJ 1931 [3]	NJ 1932	NJ 1933	NJ 1934	NJ 1935	Va. 1932	Va. 1933	Va. 1934	Va. 1935	Va. 1936	Va. 1937	N.Y. 1934	N.Y. 1935	N.Y. 1936	N.Y. 1937	Average eastern experiments
1	Band 7 inches wide, 2 inches above seed....bushels	40	258	197				45										
2	Mixed lightly with soil largely above seed....do		226							134								
3	Mixed with soil largely under seed....do	66	241	208	168			58	159	173								153
5	Band 4.5 inches wide, 1 inch under seed....do	71	247	215	180			59	180	165								160
6	Band 4.5 inches wide, 2 inches under seed....do								157									
7	Band 1 inch to each side on seed level....do			223	203			41	168	177								
8	Band 2 inches to each side on seed level....do	58	289	225	198			55	187	177								170
10	Band 4 inches to each side on seed level....do	73	268	217	188			46	182	185								166
11	Band 2 inches to each side, 2 inches below seed....do	69	287	219	198			55	171	161								166
14	Local method used in Virginia....do								108	135								
	Fertilizer analysis....percent	10-16-14	10-16-14	8-16-14	8-16-14			12-12-10	12-12-10	12-12-10								
	Fertilizer applied per acre....pounds	1,000	1,000	1,000	1,000			1,000	1,000	1,000								
	Replications....number							4	5	5	6	4	6	5	5	4	4	
	Standard error of mean....percent							7.5	6.4	6.3	3.1	4.6	4.9	3.8	4.4	5.5	2.4	
	Difference required for significance per acre....bushel							11.6	29.3	30.7	24.1	10.6	23.2	19.4	36.9	28.3		
	Z (calculated)							.5306	1.1068	1.5644	1.1329	.6027	.2755	.6148	.4235	.5851	.2712	
	Z (5 percent point)							.3536	.2532	.2532	.2804	.3241	.2325	.3911	.3911	.3604	.3749	

SINGLE-STRENGTH FERTILIZER

Placement of the fertilizer		Ohio					Michigan (Greenville)					Michigan (Mancelona)		Average midwestern experiments [7]	General average [8]
No.	Description	1931	1932	1933	1934 [5]	1934 [6]	1931	1932	1934	1935	1937	1934	1935		
X	No fertilizer....bushels		130	143	150	157	106	105	209			166	120		
1	Band 7 inches wide, 2 inches above seed....do		128												
2	Mixed lightly with soil largely above seed....do	378			135	150			256	165	111	239	151		
3	Mixed with soil largely under seed....do	360	133	166	144	178	148	127	218	162		241	165	188	179
4	In furrow with seed....do		136	160	153	149									
5	Band 4.5 inches wide, 1 inch under seed....do	361	141	168	150	178	143	130	254	165		252	150	194	180
6	Band 4.5 inches wide, 2 inches under seed....do			183											
7	Band 1 inch to each side on seed level....do		146	192	156	178		123	235			264	157		
8	Band 2 inches to each side on seed level....do	325	136	191	150	174	151	124	252	160	131	247	150	191	190
10	Band 4 inches to each side on seed level....do	352	140	190	149	180	126	119	256			239	162	191	187
11	Band 2 inches to each side 2 inches below seed....do	330	136	193	149	179	143	120	247			226	141	186	184
	Fertilizer analysis....percent	4-10-6	4-10-6	4-10-6	4-10-6	4-10-6	4-8-7	4-8-7	4-12-8	4-12-8	4-12-8	4-12-8	4-12-8		
	Fertilizer applied, per acre....pounds	1,500	1,500	1,500	1,500	1,500	800	800	800	500	600	800	500		
	Replications....number				6	6			6	6	5	6	6		
	Standard error of mean....percent				9.5	7.1			3.4	3.2	3.4	3.0	4.9		
	Difference required for significance, per acre....bushels								21.3	14.9	11.2				
	Z (calculated)				−1.0293	.0033			1.6887	1.0793	.7766	.0960	.0968		
	Z (5 percent point)				.4078	.4078			.2624	.2745	.4309	.4420	.4420		

[1] See table 1 for detail information concerning each experiment.
[2] Experiment located at Bridgeton.
[3] Experiment located at Cranbury.
[4] Averages of comparable items for 10 eastern experiments with single-strength fertilizer, New Jersey 1931–34, Virginia 1932–34, New York 1934–35, and for 7 experiments with double-strength fertilizer New Jersey 1931–33, Virginia 1932–34.
[5] Cut seed planted.
[6] Whole seed planted.
[7] Averages of comparable items for 10 mid-western experiments with single-strength fertilizer, Ohio 1931–32–33–34 [5, 6], Michigan (Greenville), 1931–32–34, Michigan (Mancelona), 1934–35.
[8] General averages of comparable items comprising those included in the two sectional averages, or a total of 20 items with the single-strength fertilizer.

The final stand results with double-strength fertilizers in table 4 correspond closely with those obtained with single-strength mixtures.

The total yield of potatoes from the two types of fertilizer are directly compared in figure 19. Five of the placements have been selected for comparison but these give a sufficient idea of the general relationship that exists. It is obvious from a consideration of the five comparisons in figure 19 that the trend of results with single-strength and double-strength fertilizer was the same. Similar trends can be obtained from comparisons of the yields of primes in table 6.

HILL PLACEMENT OF FERTILIZER

As in the general study of methods for applying fertilizer to the potato crop, the hill-placement study was altered from time to time as the need for information on new treatments arose and the advisability of discontinuing other treatments became apparent. However, a

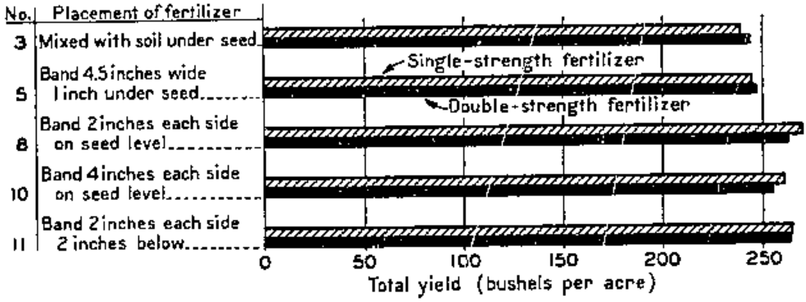

FIGURE 19.—Average total yield of potatoes for both single-strength and double-strength fertilizers in the following experiments—Maine, 1932–34; New Jersey, 1931–33; Virginia, 1932–34 and Michigan (Greenville), 1931. The numbers of the different fertilizer placements are given for convenience in referring to the corresponding sketches in figure 5.

control treatment—fertilizer in a continuous band each side of the row at seed level—was used in every experiment.

When the same amount of fertilizer per acre was applied in each series of hill placements the amount of fertilizer concentrated in each square inch of the band varied inversely with the length of band. For example, the amount of fertilizer per square inch of the 5-inch band shown in figure 6 is roughly three times that of the continuous bands thus the plant roots which penetrate the fertilizer band or the closely surrounding soil probably encounter a similar difference in salt concentration.

The broken-band studies involving different rates of fertilizer application were all conducted on potato fields which may be regarded as better than average in state of fertility. The treatments were not located on the same plots during successive seasons. It is recognized that in a study involving different rates of fertilizer application consideration should be given to cumulative residual effects, which may also apply to a study of broken-band distribution.

EMERGENCE OF SPROUTS

The emergence of potato sprouts above ground as related to hill placement is given in table 7. These figures represent a similar ratio of plants above ground to the calculated perfect stand that was used in previous discussions of emergence. By comparing the continuous-band applications with the corresponding broken-band applications it will be noticed that the emergence was frequently a little slower with continuous than with broken bands. Such a difference is shown in figure 20. In Michigan the reverse seemed to hold when the total fertilizer applied was 500 pounds or less per acre. For the purpose of making general comparisons between broken, and continuous-band applications of fertilizer, the average percentage of emergence for the

FIGURE 20.—Rapidity of emergence and early growth of Irish Cobbler potatoes planted on Sassafras sandy loam at Onley, Va., March 14 and photographed May 1, 1935, for continuous- and broken-band fertilizer applications as follows: (*a*) 2,000 pounds per acre, continuous bands, 2 inches to each side on seed level; (*b*) 2,000 pounds per acre, 5-inch bands at each hill, 2 inches to each side on seed level; (*c*) 1,500 pounds per acre, 10-inch bands at each hill, 2 inches to each side on seed level; (*d*) 2,000 pounds per acre, 10-inch bands at each hill, 2 inches to each side on seed level.

two types of applications may be compared. These average percentages are as follows: Seven eastern experiments, 75 broken bands, 71 continuous bands; three midwestern experiments, 74 broken bands, 68 continuous bands. The averages for the eastern experiments include results from broken bands of a length one-third of the seed spacing used in Virginia and New York and one-half the seed spacing used in New Jersey. The averages for the midwestern experiments include only bands one-half seed spacing. The results for only the highest rate of application were considered in each experiment. Among the broken-band methods themselves there is no definite indication that emergence was increased or retarded as a result of using any particular length of fertilizer band.

TABLE 7.—*Emergence and final stand counts of plants for different hill placements of fertilizer for potatoes in various States, 1935–37 given in percentage of a perfect stand*

EMERGENCE

No.	Item [1]		Virginia			New Jersey		New York		Ohio	Michigan (Greenville)		Michigan (Mancelona)
			1935	1936	1937	1935	1936	1935	1936	1936	1935	1936	1936
	Fertilizer per acre	pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	1,500	700	700	700
15	Bands at hill, length ⅓ of seed spacing	percent	65	91	77			46	83				
16	Bands at hill, length ½ of seed spacing	do		85		64	96		79	50		88	84
17	Bands at hill, length ⅔ of seed spacing	do	63	88	81			45					
18	Bands continuous along the row	do	46	87	82	63	96	36	84	41		86	77
	Fertilizer per acre	pounds	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,250	500	500	500
15	Bands at hill, length ⅓ of seed spacing	percent	59	90	80			46	81				
16	Bands at hill, length ½ of seed spacing	do		91		71	95		87	61		84	82
17	Bands at hill, length ⅔ of seed spacing	do	59	91	89			44					
18	Bands continuous along the row	do		91	83	61	98		81	48		90	84
	Fertilizer per acre	pounds	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,000	400	400	400
15	Bands at hill, length ⅓ of seed spacing	percent	56	92	80			49	85				
16	Bands at hill, length ½ of seed spacing	do		80		68	95		84	47		84	76
17	Bands at hill, length ⅔ of seed spacing	do	58	90	70			43					
18	Bands continuous along the row	do	53	88	81	63	99	37	81	40		87	90
	Fertilizer per acre	pounds								750	300	300	300
16	Bands at hill, length ½ of seed spacing	percent								44		89	72
18	Bands continuous along the row	do								53		89	88
	Period after planting counts were made	days	41	38	39	32	42	41	32	21		27	28

[1] Bands of fertilizer were placed 2 inches to each side of and level with the seed piece.

TABLE 7.—*Emergence and final stand counts of plants for different hill placements of fertilizer for potatoes in various States, 1935–37 given in percentage of a perfect stand*—Continued

FINAL STAND

No.	Item	Virginia			New Jersey		New York		Ohio	Michigan (Greenville)		Michigan (Mancelona)
		1935	1936	1937	1935	1936	1935	1936	1936	1935	1936	1936
	Fertilizer per acre......pounds..	2,000	2,000	2,000	2,000	2,000	2,000	2,000		700		
15	Bands at hill, length ⅓ of seed spacing......percent..	92	100	86			79	86				
16	Bands at hill, length ½ of seed spacing......do....		92		81			88		94		
17	Bands at hill, length ⅔ of seed spacing......do....	93	97	92			78					
18	Bands continuous along the row......do....	92	96	92	75		76	92		93		
	Fertilizer per acre......pounds..	1,750	1,750	1,750	1,750	1,750	1,750	1,750		500		
15	Bands at hill, length ⅓ of seed spacing......percent..	93	99	92			78	87				
16	Bands at hill, length ½ of seed spacing......do....		99		79			89		97		
17	Bands at hill, length ⅔ of seed spacing......do....	93	96	90			77					
18	Bands continuous along the row......do....		96	92	73			91		98		
	Fertilizer per acre......pounds..	1,500	1,500	1,500	1,500	1,500	1,500	1,500		400		
15	Bands at hill, length ⅓ of seed spacing......percent..	92	99	92			79	89				
16	Bands at hill, length ½ of seed spacing......do....		97		80			92		96		
17	Bands at hill, length ⅔ of seed spacing......do....	91	95	89			79					
18	Bands continuous along the row......do....	93	96	90	78		80	92		97		
	Fertilizer per acre......pounds..									300		
16	Bands at hill, length ½ of seed spacing......percent..									96		
18	Bands continuous along the row......do....									97		
	Fertilizer analysis—......do....	6-6-5	6-6-5	6-6-5	4-8-7	4-8-7	4-8-5	4-8-5	4-10-6	4-12-8	4-12-8	4-12-8
	Seed spacing......inches..	15	15	15	12	14	14	15	12	16	16	16
	Time after planting counts were made......days..	50	53	51	68		66	53		45		

FINAL STAND

The final-stand figures representing a ratio with the estimated theoretical stand are also given in table 7. These results indicate a rather uniform effect on final stand from all placements from year to year, similar to those discussed previously in this bulletin under fertilizer-placement methods. The data in table 7 present no evidence to show that the concentration of fertilizer attained by broken-band distribution, at the different rates used, had appreciable effect on the final stand of plants. Aside from a slight indication of a general increase in the rate of emergence with the hill-placement method, the final-stand results are similar to the emergence data.

PLANT GROWTH

Observations on the growth response to hill placement of fertilizer failed to show any distinct differences in growth of vines, except occasionally where the total amount of fertilizer applied per acre was less than that applied in continuous bands. In these instances the continuous- as well as the broken-band applications usually produced less vine growth.

Periodic root examinations were made on selected hills in the manner already described. These root examinations failed to reveal any noticeable indications of root injury from the broken-band method at any of the rates used. In Virginia and on Long Island especially, healthy roots were uncovered near and even penetrating the concentrated layer of fertilizer. Typical root developments with 5- and 10-inch bands of fertilizer are shown in figure 21. The method used in the field for uncovering soil from the roots prevented definite determination of root distribution and type of growth but as far as could be determined by observation the roots neither concentrated around the fertilizer layer nor exhibited excessive branching in this zone.

YIELDS OF PRIMES

The yields of prime potatoes (U. S. No. 1) graded for size only are given in table 8 together with statistical information pertaining to the experiments. It will be noted from the calculated Z value that the 5-percent point was exceeded in all cases except one. It will also be noted that the standard error ranged from 6.5 to about 3.0 percent. These two statistical criteria for all but one of the experiments indicate a very satisfactory treatment response obtained under reliable conditions.

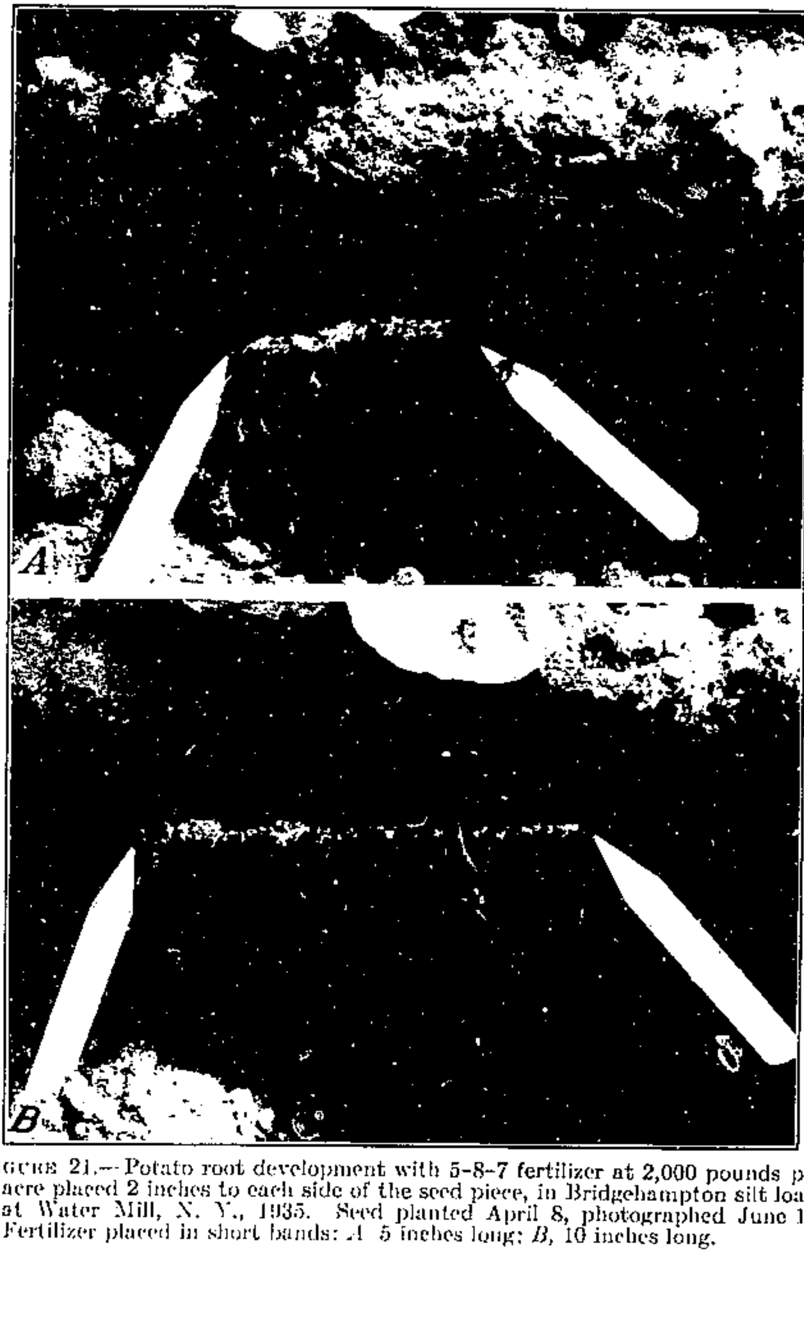

FIGURE 21.—Potato root development with 5-8-7 fertilizer at 2,000 pounds per acre placed 2 inches to each side of the seed piece, in Bridgehampton silt loam at Water Mill, N. Y., 1935. Seed planted April 8, photographed June 12. Fertilizer placed in short bands: *A* 5 inches long; *B*, 10 inches long.

TABLE 8.—*Yields of potatoes per acre for different hill placements of fertilizer in various States, 1935–37*

YIELD OF PRIME POTATOES

No.	Item[1] Description	Unit	Virginia (Eastern Shore) 1935	1936	1937	New York (Long Island) 1935	1936	New Jersey 1935	1936	Ohio, 1936	Michigan (Greenville) 1935	1936	Michigan (Mancelona) 1936	1937
	Fertilizer analysis	percent	6-6-5	6-6-5	6-6-5	4-8-5	4-8-5	4-8-7	4-8-7	4-10-6	4-12-8	4-12-8	4-12-8	4-12-8
	Seed spacing	inches	15	15	15	14	15	12	14	12	16	16	16	16
	Fertilizer per acre	pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	1,500	700	700	700	700
15	Bands at hill, length ⅓ of seed spacing	bushels	298	164	138	190	180	---	---	---	---	---	---	156
16	Bands at hill, length ½ of seed spacing	do	---	159	---	---	157	302	---	311	194	182	154	153
17	Bands at hill, length ⅔ of seed spacing	do	311	158	165	225	---	---	---	---	---	---	---	---
18	Bands continuous along the row	do	300	172	165	226	179	308	---	282	191	195	149	156
	Fertilizer per acre	pounds	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,250	---	500	---	500
15	Bands at hill, length ⅓ of seed spacing	bushels	284	157	153	227	142	---	---	---	---	---	---	---
16	Bands at hill, length ½ of seed spacing	do	---	146	---	---	168	---	---	303	183	164	143	---
17	Bands at hill, length ⅔ of seed spacing	do	279	153	170	217	---	---	---	---	---	---	---	---
18	Bands continuous along the row	do	---	172	153	---	189	---	---	333	169	173	134	---
	Fertilizer per acre	pounds	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,000	400	400	400	400
15	Bands at hill, length ⅓ of seed spacing	bushels	270	146	154	210	199	---	---	---	---	---	---	139
16	Bands at hill, length ½ of seed spacing	do	---	145	---	---	209			294	170	175	123	144
17	Bands at hill, length ⅔ of seed spacing	do	272	162	170	204	---			---	---	---	---	---
18	Bands continuous along the row	do	262	158	166	181	194			317	173	159	124	138
	Fertilizer per acre	pounds	---	---	---	---	---			750	300	300	300	300
16	Bands at hill, length ½ of seed spacing	bushels	---	---	---	---	---			311	157	162	114	---
18	Bands continuous along the row	do	---	---	---	---	---			323	161	174	132	---
	Replications	number	6	4	6	6	4			5	6	5	5	5
	Standard error of mean	percent	3.1	4.6	4.9	5.5	5.5			4.0	3.2	3.6	6.5	2.96
	Difference required for significance, per acre	bushels	21.1	19.6	23.2	32.2	28.3			12.3	14.9	17.2	22.9	12.0
	Z (calculated)		1.1329	.6027	.2755	.4373	.5851			.1465	1.0793	.9120	.9967	.8778
	Z (5 percent point)		.2804	.3241	.2325	.3791	.3604			.3210	.2745	.3579	.3579	.3011

[1] Bands of fertilizer were placed 2 inches to each side of and level with the seed piece. See figure 5 for detail description of fertilizer placements.

TABLE 8.—*Yields of potatoes per acre for different hill placements of fertilizer in various States, 1935–37*—Continued

TOTAL YIELDS INCLUDING PRIMES, SECONDS, AND CULLS

No.	Item: Description	Virginia (Eastern Shore) 1935	Virginia (Eastern Shore) 1936	Virginia (Eastern Shore) 1937	New York (Long Island) 1935	New York (Long Island) 1936	New Jersey 1935	New Jersey 1936	Ohio, 1936	Michigan (Greenville) 1935	Michigan (Greenville) 1936	Michiga (Mancelona) 1936	Michiga (Mancelona) 1937
	Fertilizer analysis ...percent	6-6-5	6-6-5	6-6-5	4-8-5	4-8-5	4-8-7	4-8-7	4-10-6	4-12-8	4-12-8	4-12-8	4-12-8
	Seed spacing ...inches	15	15	15	14	15	12	14	12	16	16	16	16
	Fertilizer per acre ...pounds	2,000	2,000	2,000	2,000	2,000	2,000	2,000	1,500	700	700	700	700
15	Bands at hill, length ⅓ of seed spacing ...bushels	349	199	179	229	215	------	------	------	------	------	------	187
16	Bands at hill, length ½ of seed spacing ...do	------	189	------	------	190	355	262	343	223	209	172	183
17	Bands at hill, length ⅔ of seed spacing ...do	357	194	211	247	------	------	------	------	------	------	------	------
18	Bands continuous along the row ...do	345	203	212	248	215	351	258	309	218	227	168	184
	Fertilizer per acre ...pounds	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,250	------	500	500	500
15	Bands at hill, length ⅓ of seed spacing ...bushels	336	196	204	249	176	------	------	------	------	------	------	------
16	Bands at hill, length ½ of seed spacing ...do	------	184	------	------	208	366	252	334	215	191	162	------
17	Bands at hill, length ⅔ of seed spacing ...do	332	184	216	243	------	------	------	------	------	------	------	------
18	Bands continuous along the row ...do	------	201	196	------	225	341	264	364	199	200	156	------
	Fertilizer per acre ...pounds	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,000	400	400	400	400
15	Bands at hill, length ⅓ of seed spacing ...bushels	319	185	208	235	237	------	------	------	------	------	------	166
16	Bands at hill, length ½ of seed spacing ...do	------	188	------	------	250	329	243	323	202	203	139	174
17	Bands at hill, length ⅔ of seed spacing ...do	319	200	225	228	------	------	------	------	------	------	------	------
18	Bands continuous along the row ...do	314	188	217	201	229	325	252	344	202	187	145	169
	Fertilizer per acre ...pounds	------	------	------	------	------	------	------	750	300	300	300	300
16	Bands at hill, length ½ of seed spacing ...bushels	------	------	------	------	------	------	------	338	194	192	128	------
18	Bands continuous along the row ...do	------	------	------	------	------	------	------	353	193	206	154	------

The results in table 8, for convenience of discussion, may be divided into two parts concerning (1) comparisons of broken-band and continuous-band methods using the same amount of fertilizer per acre, and (2) comparisons of broken bands at reduced rates with continuous bands at higher rates. Comparisons indicated under (1) may be made to determine whether a more efficient use of the fertilizer was possible, simply by concentrating the fertilizer at each hill as in broken-band application. Comparisons indicated under (2) may be made to determine whether normal yield could be obtained by using broken-band application when the fertilizer rate was reduced. In the first instance efficiency may be measured by increased yields per acre, in the second by decreased cost through reduction in the amount of fertilizer applied.

The rates of fertilizer application shown in table 8 were not the same at all locations. The highest rates given in the table may be regarded as normal for the experiments, hence the lower rates would be relatively subnormal.

In general, the yields from the different types of broken bands, at both the normal and subnormal rates of application, showed very few increases over continuous bands at corresponding rates of fertilizer application. None of these increases was significant. In most cases, particularly in the eastern experiments, decreases in yields were obtained from broken bands especially at the two higher rates of application. Four of these decreases were significant.

Because of the higher rates of fertilizer usually applied in these sections, the data for Virginia and Long Island in table 8 have special significance when comparisons are made as indicated under (2) above. In these experiments, subnormal rates of fertilizer 1,500 and also at 1,750 pounds per acre applied in broken bands rather consistently lowered the yields as compared with the normal rate of 2,000 pounds per acre in continuous bands. However there were some exceptions, especially on Long Island where in a few instances an increase in fertilizer efficiency was indicated through the use of broken bands at lower rates (*14*).

In Ohio, broken-band applications at the relatively subnormal rates appear to have given increases over the continuous-band application at the normal rate of 1,500 pounds. However in considering these results attention is called to the exceptionally dry conditions in the vicinity of the experiment (see rainfall data, table 2) which markedly affected the yields. Furthermore, it should be noted that the calculated Z value for this experiment did not exceed the 5-percent point.

In Michigan, broken-band applications at relatively subnormal rates gave consistent decreases in yields as compared to the normal rate of 700 pounds per acre in continuous bands. In all but two instances these decreases were significant.

In general, the results given in table 8 indicate that hill placement of fertilizer or broken-band application have not provided a more efficient use of the fertilizer by the potato crop. Within the ranges used in the present study, apparently it is the total amount of fertilizer applied rather than increased concentration at each hill, as accomplished with broken bands, that is important with this crop.

TOTAL YIELDS

The total yields of potatoes given in table 8 including the results from 2 years' work in New Jersey present the same picture as the corresponding yields of primes previously discussed. Concentration of the fertilizer in short bands beside the seed piece did not significantly increase yields over continuous bands used at the same or lower rates per acre. The total amount of fertilizer applied rather than its concentration beside the seed piece has apparently a greater influence on the yield of potatoes, which is shown graphically in figure 22.

Average yields for seven experiments in the eastern section and for five experiments in the midwestern section are given in figure 22 for the standard and a reduced rate of fertilizer application. The standard rate in pounds per acre was 2,000 in New York, New Jersey, and Virginia, 1,500 in Ohio, and 700 in Michigan. The reduced rate was 1,500 in New York, New Jersey, and Virginia, 1,000 in Ohio, and 400 in Michigan. Hill placement of fertilizer as given in figure 22 consists of short bands at each hill the length of which was one-

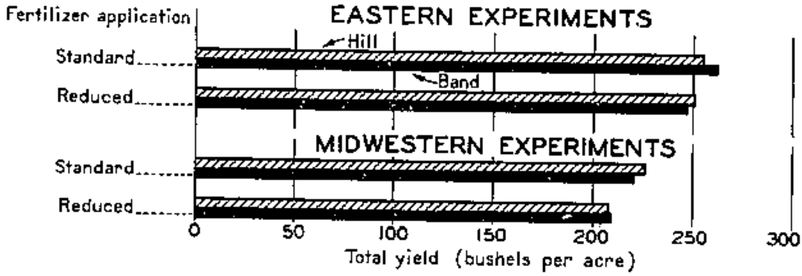

FIGURE 22.—Averages of total yields of potatoes for both hill placement and continuous-band placement of single-strength fertilizer applied at each side of the row at the standard and a reduced rate of application.

third of the seed spacing in the New York and Virginia experiments and one-half of the seed spacing in the New Jersey, Ohio, and Michigan experiments. Averaging the results for short fertilizer bands differing slightly in length permits the use of a larger number of items and seems justifiable because a length of band either one-third or one-half of the seed spacing constitutes distinctively hill placement of the fertilizer.

DISCUSSION

The results of the field experiments definitely indicate that fertilizer should be accurately placed in the soil with respect to the seed piece to be of greatest benefit to the potato crop. Changing the position of the fertilizer only 2 inches in some instances either decreased or increased the potato yields appreciably. The diversity of soil, climatic, and cultural conditions under which this work was conducted adds considerably to the fundamental importance of the definite trends obtained.

A relatively high concentration of fertilizer salts near the seed or in the zone of the first sprouts, such as occurs with placements immediately under, above, or around the seed has certain deterrent effects which were revealed in the records on rapidity of emergence and later reflected in the yields.

A wide distribution of the fertilizer in the surface soil, such as that accomplished with the local Virginia method and as doubtless occurred with the wide band above the seed especially where the ridges were leveled by harrowing, caused some reduction in the efficiency of the fertilizer. This reduced efficiency probably resulted in part from the disturbance of some of the fertilizer by cultivation. Cultivation during the growing season can disturb roots and fertilizer placed as described above, transferring a portion of the plant food to the soil surface.

It has been previously shown in field experiments (*4*) that certain sources of nitrogen, phosphoric acid, and potash which are commonly used in complete fertilizers for potatoes differ in their effect on stand of plants. The individual fertilizer materials were placed separately in the furrow with the seed, the remainder of the mixture being broadcast. Under these conditions nitrate of soda and sulphate of ammonia reduced the stand more than muriate of potash while superphosphate gave no reduction.

Placement of fertilizer in a band at each side of the row was found to be more advantageous than placements above, under, or around the seed piece. Although the general averages of yields did not differ widely among the various side placements, a slightly greater average yield was obtained from a fertilizer band 2 inches to each side of and on the lower level of the seed than from the placement either at a lateral distance of 4 inches on seed level or at a lateral distance of 2 inches on a level 2 inches below that of the seed. The comparisons available indicate that a placement 1 inch to each side was equal to the placement 2 inches to each side, so far as the average yield is concerned but the yields from year to year fluctuated more for the 1-inch distance. A further consideration with respect to placing fertilizer 1 inch to the side of the seed is the possibility in farm practice that either nonalinement of the fertilizer depositor on the planter or angling of the machine on lateral slopes as sometimes encountered might readily cause the fertilizer to be deposited in contact with the seed where injurious effects would result. It would seem, therefore, that placement in a band 2 inches to each side of and on the lower level of the seed piece which was equal to or superior to all other placements would be preferable from the practical standpoint.

Placement of fertilizer in two parallel bands about 5.5 inches apart, that is, a band 2 inches to each side of and on the lower level of the seed piece, can be most accurately obtained by means of a combined potato-planting and fertilizer-depositing machine. With the seed and fertilizer depositors mounted close together on the same machine, comparatively little variation in the relative placement of seed and fertilizer occurs. On land sloping laterally with respect to the direction of travel, the machine slips down grade thus assuming a position at a slight angle to the direction of travel. Inasmuch as the fertilizer depositor is usually mounted ahead of the seed shoe any angling of the machine changes the relative position of the seed and fertilizer. When the machine is operated across relatively steep slopes it is advisable to place the fertilizer well below the lower seed level to avoid any contact of the fertilizer and seed resulting from extreme angling of the machine.

Several makes of machines are designed for applying fertilizer only, in a field operation separate from that of planting the potato seed. Some are equipped with depositors for placing the fertilizer in two parallel bands several inches apart. With proper adjustment of the fertilizer depositor on these machines and later with the planter centered midway between the fertilizer bands in the soil, the most advantageous relative placement of seed and fertilizer as mentioned above would be obtained. Unless some unique method were devised for insuring continuous centering of the planter on the line midway between the fertilizer bands, it is not likely that the desired precision would be obtained. However, the accuracy with which the seed and fertilizer could be placed in separate operations depends to a considerable extent on the proficiency of the operator and the degree of accuracy with which the machine can be controlled.

During the fertilizer-placement study the progress reports issued from time to time and the current findings have come to the attention of the implement manufacturers and many growers directly concerned. After the trends of results became more definite the depositors on several makes of planters were designed to meet the fertilizer-placement requirements indicated by the experiments. Also a large number of potato growers, particularly through the purchase of new machines, adopted the side-placement method of applying fertilizer.

Many demonstrations have been conducted on farms where the superiority of side placement of fertilizer over local practices has usually been evident. In view of the diversity of conditions under which the study was conducted and the substantiating demonstrations some of which were conducted in outlying areas, it seems likely that practical application of the research findings can be made under similar conditions in other potato sections.

Fertilizer has proven to be more effective when concentrated in bands near the row as compared to broadcasting. There is also some indication that fertilizer placed in a band at each side of the row is more effective at a distance of 2 inches than at 4 inches from the seed. Further concentration of the fertilizer mass in short bands to the sides of each hill as included in this study did not further increase the fertilizer efficiency. Hill application of fertilizer involves certain considerations which may be questionable from the practical standpoint. It is presumed that equipment suitable for depositing the fertilizer in short bands at each seed piece or hill would be of an intricate character, undoubtedly more costly than continuous-band depositors, and would require accurate adjustment as well as close attention in the field.

SUMMARY

Placement of fertilizer for potatoes was studied during the period 1931–37 under various prevailing conditions in Aroostook County, Maine; on Long Island, N. Y.; in central New Jersey; on the eastern shore of Virginia; in northeastern Ohio; and in western Michigan.

Fertilizers of both single- and double-strength grades were applied at the usual rates per acre and in a range of rates in some cases on typical potato soils of each district represented.

Crop differences resulting from differences in fertilizer placement were usually greater in the eastern than in the midwestern experiments where the rates of fertilizer application were lower.

Placement of the fertilizer in a band immediately under, or above, or mixed with the soil around the seed piece usually resulted in delayed emergence of the sprout above ground and reduction in yield.

Fertilizer placed in a band at each side of the row rather consistently produced the most rapid emergence of sprouts, the most vigorous plant growth, and the highest yields of primes as well as total yields. Fertilizer placed in a band 2 inches to each side of and on the lower level of the seed piece most consistently produced relatively high yields the average of which either equalled or slightly exceeded the average yields of the other side placements both nearer and farther from the seed. This is considered the preferable placement from the practical standpoint.

Placement of fertilizer in a band at only one side of the row gave lower yields than a band at each side.

Single- and double-strength fertilizers supplying equivalent amounts of plant food gave similar results both with respect to actual potato yields and the order of yields for the various placements.

Hill placement of fertilizer in short bands at each seed piece or hill gave no indication of advantage over comparable placements in continuous bands along the row, for seed spacings ranging from 12 to 16 inches.

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