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SOIL MANAGEMENT *for* POTATOES

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SUMMARY

In general, potatoes are grown on sandy loam and loam soils which are not so high in plant food content as are the better soils of the state. The need for maintaining or increasing the humus content of potato soils and of supplying an abundance of plant food through manuring and use of commercial fertilizer is well recognized.

Manure supplemented with complete commercial fertilizer (4-16-8 or similar analysis) is an excellent fertilizer for potatoes. In case complete fertilizer is not used the plant food ratio in the manure should be balanced by use of superphosphate.

Experiments in use of commercial fertilizer were started in 1923. This report summarizes the results for 15 years, including 800 plots on 70 farms.

A fertilizer of 4-16-8 or similar composition gave increases in yield which were consistently among the highest produced by the different fertilizer analyses used in the tests on different soil types and under the varied weather conditions encountered during the years covered by the experiments. A fertilizer containing more potash in relation to the phosphoric acid as a 3-12-12 frequently gave as good or better yields than the 4-16-8, especially on the sandier soils.

Fertilizer containing as much or more potash than phosphoric acid tended to delay maturity of the crop and frequently produced immature tubers at digging time.

Considering the cost of fertilizer, danger of drouth, and the uncertainty of potato prices, fertilizer applications of approximately 500 to 600 pounds per acre were found most advisable, although somewhat larger increases in yield were frequently obtained with heavier applications. The limited rainfall of Michigan compared to that of other important potato growing states, as Maine, associated with the moderate moisture-holding capacity of the typical potato soils, accounts for the comparatively small quantity of fertilizer which can be applied economically.

Fertilizer placed in bands on both sides of the seed piece, on the level with or a little deeper than the seed and about two inches from it, has given slightly better average yields than the same quantity of fertilizer applied in other locations.

Sprout emergence was delayed by fertilizer mixed in the soil around the seed piece. On the other hand, sprout emergence was frequently hastened by fertilizer applied in bands two inches to the sides of the seed piece and vine growth was greater on plots so fertilized until late in the growing season. Under irrigation, it was found that heavier applications of fertilizer were efficiently used. Applications could be made closer to the seed piece without resulting in injury.

When fertilizer was not applied near the seed piece at planting time, an application with an attachment to the cultivator at the time of first cultivation proved advisable.

SOIL MANAGEMENT FOR POTATOES

G. M. GRANTHAM, C. E. MILLAR AND A. H. MICK[1]

In 1937, Michigan ranked first in acreage and third in the production of potatoes among the states. The acreage planted to potatoes has gradually decreased from 317,000 acres in the period 1899-1918 to 277,000 acres for the 1919-38 period. The acreage for the 10-year period 1926-35 was 271,800 acres. In 1935, 159,002 farmers, or about 81% of the total number in the state, were growing potatoes as a market crop or for home use. The average annual value of this crop for the 10-year period 1926-35 was $15,293,000 with the annual average price per bushel of 67 cents. It is evident from those facts that the production of potatoes is a major enterprise on a large number of Michigan farms.

Among Michigan potato growers, some obtain yields ranging from 350 to 400 bushels per acre, although the average state yield was 92 bushels per acre during the period 1926-35. This yield is influenced by many factors, among which the more important are climatic conditions, soil fertility, variety, insect and disease injury, and cultural practices. In an effort to understand in what manner these various factors interact to influence potato production, much research work has been conducted. Extensive tests have been made with a view to increasing the yield per acre. With larger yields, the profit to be derived from the crop is greater, since many of the items of expense incurred in growing an acre of potatoes are not greatly increased by the production of a high yield.

SOIL TYPES ON WHICH POTATOES ARE GROWN

Every Michigan county produces an appreciable acreage of potatoes. The percentage of tillable land used for the crop in each year varies from 1 to 14. The average was 2.7 per cent for 1934 (see Fig. 1). In districts growing potatoes as a major farm enterprise, the largest acreage is found on sandy loam soil although considerable acreage is

[1]Certain of the results presented herein pertaining to fertilizer placement, rate of application, potash, and fertilizer analysis studies, were obtained with the cooperation of the Division of Soil Fertility Investigations, Bureau of Plant Industry, and the Division of Mechanical Equipment, Bureau of Agricultural Engineering, U. S. Department of Agriculture. The writers express their appreciation to B. E. Brown and G. V. C. Houghland, Division of Soil Fertility Investigations, and to G. A. Cumings, W. H. Redit, and L. G. Schoenleber, Division of Mechanical Equipment for cooperation in connection with these studies. In connection with the 1931 and 1932 fertilizer placement work acknowledgment is made of the cooperation of H. R. Smalley and Ove Jensen of the National Fertilizer Association.

Under any given climatic condition, drouth danger may be minimized by proper soil management. This is due to the fact that the moisture-holding capacity of the plow soil is influenced not only by the soil texture (that is, the percentage of particles of different sizes) and character of the subsoil, but also by soil structure, or degree of granulation, and by the amount of organic matter contained therein.

The effect of organic matter in influencing the amount of water a soil will hold is explained in the following manner. Soil moisture available for plant use is held by the soil in two ways—namely, (a) in the small crevices between particles, and in films around them, and (b) in the organic matter itself, which being sponge-like, literally soaks up water. In very fine textured soil, a clay for instance, the particles may become packed in such a dense mass that there is little room left for moisture. This condition is often the result of plowing or allowing stock to graze on the land when it is too wet. The pore spaces in light sands and sandy loams, on the other hand, may be too large to hold the greatest amount of moisture. In these soils the particles are so loosely packed together that the water drains right through the openings between the particles, little remaining for crop use.

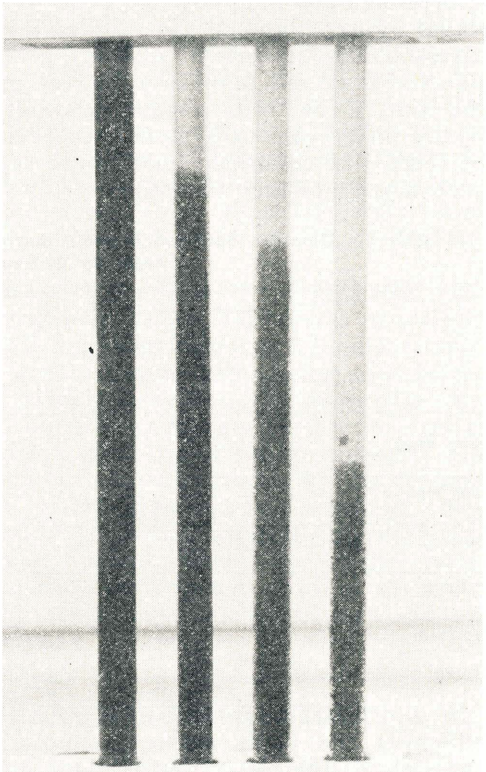

Fig. 2. Tubes filled with a soil mineral to demonstrate the difference in height of capillary rise and quantity of moisture held in material of different sizes. In the tube on the left the mineral is the size of silt and gets progressively coarser in succeeding tubes until it is a coarse sand.

The texture or size of particles in a soil not only influences the quantity of water held but also the extent of capillary rise in the soil. This point is illustrated in Fig. 2. All four glass tubes contain the same soil mineral but the soil is ground to different degrees of fineness. That in the tube on the left is ground to the size of silt, and in the remaining tubes the mineral gradually becomes coarser, until, in the tube at the right the particles are as large as coarse sand. The spaces between the particles are very small in the first tube, but in the last tube they are much larger. Notice how the height to which the water has risen increases as the soil particles become smaller. The quantity of water held will vary more or less in proportion to the height it has risen.

A farmer can do nothing to change the texture of his soil. If it is a sandy loam it will remain a sandy loam.[1] Soil structure, however, may be improved by plowing and cultivating when the soil contains the right amount of moisture. Also, soil structure is affected by organic matter, additions of which tend to alleviate the faults of both too heavy and too light soils. Where potatoes are grown on heavy soils, a high organic matter content minimizes tuber deformities, thus increasing crop quality. On the opposite extreme, organic matter remedies the textural weaknesses of light soils by partially filling in the spaces between grains making the water reservoirs smaller but more numerous and effective. Possessing glue-like properties, organic matter also tends to draw the soil particles together into clusters which improve moisture retention and decrease soil blowing. The action of organic matter in absorbing and retaining moisture is well understood and may easily be demonstrated by noting the swelling and water absorption of a lump of dry peat or muck upon standing in water. Actual figures showing the marked influence of organic matter on the water-holding capacity of soils are given in Table 1. Soil samples were collected from old fence rows where grass had grown for many years and from a few rods distant in adjoining fields which had been cultivated under various systems. In every case the samples taken under the fence row contained much more organic matter, and, consequently, much more moisture than those from the cultivated areas.

Table 1. Relation between organic matter content and moisture-holding capacity in five soils.

Soil Class	Organic Matter Content	Available Moisture
	Per cent	Per cent
Loamy sand	1.0 3.2	4.9 11.5
Sandy loam	1.1 1.8	5.9 10.5
Loam	2.9 4.4	10.9 18.2
Silt loam	3.7 4.8	12.1 14.5
Clay loam	2.4 3.1	15.5 29.3

In addition to its moisture-holding capacity organic matter also influences the plant nutrient supply. The value of decaying plant materials in the liberation of plant nutrients must not be overlooked in enumerating the benefits of a high soil organic matter content. It is only in the form of organic matter that a supply of nitrogen can be built up in the soil. This is because nitrogen in a readily soluble form is leached away by drainage water. Furthermore, it is only through the decay of soil organic matter that the stored nitrogen is liberated

[1]The texture of the surface often seems to change because of the loss of the true top soil through erosion. After several years of poor management the surface may appear to be richer in clay owing to the subsoil being exposed.

for crop use. In addition, organic matter, particularly humus, has the power to absorb or hold other plant food elements which become soluble and leach beyond the reach of plant roots unless so held.

The best way to increase the organic matter content of potato soils is to plow under sods of clover, alfalfa, or sweet clover. More material is added if the entire crop is plowed under, as is done by some very successful growers. These legume crops, when inoculated, collect nitrogen from the air, and produce plant tissue rich in this element. As humus contains one pound of nitrogen to about 20 pounds of weight, the necessity of adding plant residues rich in nitrogen is apparent if the humus content of the soil is to be increased.

Since alfalfa and clovers do not grow well on soils which are strongly acid, it is necessary to apply lime to such soils in preparation for those crops. Potato scab is, however, much more prevalent on soils of slight acidity than on strongly acid soils, so that some potato growers hesitate to apply lime on potato soils. They avoid this difficulty, in part, by making light applications of lime, only sufficiently heavy to obtain a stand, just before seeding alfalfa or clover. In the course of several years, when the field is again planted to potatoes, the effects of the lime have disappeared, and the soil is again acid. Other growers prefer not to apply lime at all, but to plow under buckwheat, alsike or rye and similar acid-tolerant crops as a source of humus. Although the use of these cereal crops is beneficial it must be remembered that they do not take nitrogen from the air but draw all of their plant food from the soil and hence are very inferior to alfalfa, sweet clover, and clover as soil-building crops.

Straw, corn stover, and similar non-leguminous plant materials contain only about one pound of nitrogen to 100 or 200 pounds of weight, and, hence, are not very effective in building up the soil humus supply. These crop residues are often of greatest value after being used in the stable to absorb liquid manure which increases the otherwise low nitrogen content. They may also be advantageously used when spread on the land and plowed under with a leguminous sod or manure. The latter material, of course, is very valuable in restoring the organic matter supply of a soil because of its high nitrogen content. Any addition of fertilizer, lime, manure or such materials indirectly increases the organic matter supply of the soil. This is due to the resulting increase in plant growth and root development leading to larger quantities of plant residues which are in turn converted into soil organic matter and finally into humus.

PLANT FOOD REQUIREMENTS OF POTATOES

Large yields of high quality potatoes cannot be obtained if the soil is deficient in plant food. One hundred fifty bushels of potatoes contain 31.5 pounds of nitrogen, 13.5 pounds of phosphoric acid and 45.0 pounds of potash. These amounts of phosphoric acid and nitrogen correspond closely to those contained in 25 bushels of wheat or 50 bushels of oats. The potatoes, however, contain about 6 times as much potash as does the wheat, and between 4½ and 5 times as much as the oats. These comparisons show that potatoes remove comparatively large quantities of plant food from the soil—probably much larger than are removed by grain crops, considering the grain only, produced under similar conditions. Should the yields approach 250 or 300 bushels per acre, as is frequently the case with many good potato growers, the plant food requirements are very high indeed. In this connection, it is well to remember that sandy and sandy loam soils usually do not contain so large quantities of plant food as do the silt loam and clay loam soils. This fact is illustrated by the data in Table 2 which contrast the plant food content of several sandy and sandy loam soils with that of several soils of heavier texture.

Table 2. Analyses of several sandy and sandy loam soils, and of several soils of heavier texture.

Sample	Sandy and sandy loam soils			Sample	Silt loam and clay loam soils		
	Per cent N	Per cent P_2O_5	Per cent K_2O		Per cent N	Per cent P_2O_5	Per cent K_2O
1	.074	.064	1.989	1	.162	.103	1.766
2	.069	.101	1.619	2	.125	.104	1.779
3	.068	.071	1.360	3	.146	.101	1.920
4	.078	.119	2.050	4	.188	.134	1.591
5	.081	.096	1.678	5	.181	.151	2.134
				6	.213	.137	1.880
				7	.142	.117	1.771
Average	.075	.091	1.739	Average	.151	.121	1.834

Here it is shown that the lighter soils are decidedly lower in nitrogen and contain appreciably less phosphoric acid and potash than the heavier soils. It thus becomes evident that the problem of soil fertility is decidedly an important point of consideration in potato production.

The necessity of maintaining soil fertility in the production of profitable potato crops was early discovered and, with it, came a demand for more information concerning the management of soils for potato growing. The Soils Section of the Michigan Agricultural Experiment Station undertook to answer questions relative to the subject, and, toward that end, began a systematic study of the problem in 1923. The investigations were confined mainly to the soil types best suited to the production of potatoes, because it is on these that the Michigan potatoes must be grown if they are to compete successfully with those grown in other states and so maintain their places in Michigan agriculture. The soil survey, by classifying the soils of the state, has made possible a definite and systematic basis for the work.

The information sought was classified under several headings, chief of which were:

1. The value of manure as a potato fertilizer.

2. The correct proportion of the three plant food elements—nitrogen, phosphoric acid, and potash—which should be contained in commercial fertilizers used on Michigon soils in order to obtain the highest yields. In other words, to determine the correct commercial fertilizer analysis to use.

3. How much commercial fertilizer should be applied.

4. Where commercial fert'lizer should be placed with reference to the seed piece to obtain the earliest emergence of the plant and the highest yields of marketable tubers.

5. In what manner irrigation practices would modify soil management.

6. The value of applying a side dressing of fertilizer at the time of the first cultivation.

The following pages are devoted to these points, the conclusions being based on the evidence obtained from the data and results of the last 15 years work. With the few exceptions noted, late potatoes were used in all of the studies. The exact varieties were not recorded, but in every case, they were suited to the locality of the test fields.

MANURE AS A FERTILIZER

Manure, the value of which has been demonstrated each season, was probably the first fertilizer used in Michigan for potato growing. In early years, however, growers were cautioned against its use on the basis that it would increase damage by scab. The same opinion is often heard today. There may be some reason for this warning, although it should be remembered that if the soil or seed is infected with the scab organism, scabby potatoes will result when conditions are suitable regardless of whether the land has been manured. Careful treatment of seed and the use of a rotation which does not permit planting the crop on the same land oftener than once in five or six years are the best safeguards against scab. The value of manure as a fertilizer and source of humus is too great to warrant discontinuance of its use through fear of increasing scab damage. As a late application of fresh manure may materially increase the damage from a light soil infection of scab, **fresh manure,** when used should be applied **several months before planting time.**

Manure which is very "strawy" should be applied and plowed under as early in the spring as possible, so that the straw may be largely decayed before the potatoes are planted. Otherwise, the bacteria that are decaying the straw will use up some available nitrogen, causing a scarcity for the potato plants. Rotted manure should be used if the application is to be made a short time before planting. Rotting manure before application is not advised as a general practice, however, because of the large loss of plant food and organic matter which occurs.

Manure is not a well balanced fertilizer, due to its low content of phosphoric acid, and, in consequence, much of its nitrogen and potash may be lost instead of being used by the plants. In general, best results have been obtained when manure was supplemented with an application of complete commercial fertilizer. Where this is not used, superphosphate in quantities amounting to 40 or 50 pounds per ton of manure should be applied. The complete fertilizer or superphosphate application is usually made through the fertilizer attachment on the planter, in preference to mixing with the manure when it is spread.

There is some danger of applying too much manure for potatoes, but a moderate application of from 6 to 10 tons to the acre supplemented with fertilizer makes a more efficient use of this material than larger quantities used alone. These principles are well illustrated by the

Table 3. Effect of manure on yields of potatoes. Rossman field on Isabella sandy loam. Montcalm County, 1928.

Treatment		Yield (in bushels per acre)	Increase due to treatment (in bushels per acre)
Kind of fertilizer	Rate		
No fertilizer		67	0
Manure	8 tons	234	167
Manure and 8-16-8	8 tons, 300 lb.	283	236
8-16-8	300 lb	122	55
No fertilizer		119	0
Manure	8 tons	232	113
Manure and 2-12-6	8 tons, 500 lb.	280	161
2-12-6	500 lb	228	109
Manure and 2-12-6	8 tons, 1,000 lb.	361	242
2-12-6	1,000 lb	305	186

data shown in Table 3 obtained in an experiment on the farm of Mr. R. Rossman in Montcalm County in 1928.

Large increases in yields resulted wherever manure or commercial fertilizer was applied but the largest increases in yields were obtained where both manure and fertilizer were applied.

COMMERCIAL FERTILIZERS

Analyses Best Suited to Potatoes

Experiments to determine which fertilizer analysis[1] was best for potatoes were started in 1923. In that year, six similar experimental fields were established on six different farms in the dominant potato-producing areas in the northwest section of the lower peninsula. As previously mentioned, these fields were located on soil types particularly adapted to potato production. Four different commercial fertilizers containing various proportions of the plant food elements were selected for the study. The first was a 0-16-0 mixture, carrying only phosphoric acid (P_2O_5), then nitrogen (N) was introduced in a 3-12-0 analysis, and, finally, two complete fertilizer mixtures containing N, P_2O_5, and potash (K_2O) were employed in an effort to determine the effect of all three plant food elements on potato yields. Two complete fertilizers were used, because it was thought that the combination of plant food elements producing the highest yield might thus be dis-

[1]The analysis of a commercial fertilizer (required by state law to be shown on all bags and packages) indicates the amounts of the plant food elements—nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) present in the material. Thus a 4-16-4 fertilizer contains 4% total N, 16% available P_2O_5, and 4% water soluble K_2O.

covered. Each of the six experimental fields was divided into five plots of approximately 1/10 acre in size. Fertilizers were broadcast by hand at the rate of 400 pounds per acre and dragged in before the potatoes were planted. One plot in each field received no fertilizer at all in order that the gain in production due to each kind of fertilizer could be determined.

An examination of the data presented in Table 4 shows that substantial increases in yields were gained on all except the Hammer field by the use of commercial fertilizers. The small proportion of No. 2 potatoes harvested from fertilized plots indicates that the size of the tubers was also increased. These effects occurred on all of the soil types represented, so it may be inferred that most potato soils would give greatly improved potato yields under proper fertilizer treatment. The small responses to fertilization observed on the Hammer field in Kent County were due to the fact that this field was under excellent management and in a high state of fertility. That fact is emphasized by comparing the check plot yields from this farm to those from other fields.

Table 4. Effect of fertilizer analysis on potato yields in 1923.*

Location of field	Emmet County		Kent County				Antrim County				Mecosta County		Average Increase due to fertilizer (Bu. per acre)	
Cooperator	Reberg Bros.		E. A. Kellogg		J. Hammer		G. Tobias		R. C. Bennett		J. Noud			
Soil type	Onaway loam		Isabella loam				Mancelona sand				Kent loam			
Grade of potatoes	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0-16-0	296	118	317	7	220	10	34	9	177	8	238	2	32	1
3-12-0	179	9	357	9	266	8	152	5	148	9	235	4	26	−1
3-12-4	189	10	254	4	295	6	158	7	198	5	282	2	32	−3
3-8-6	187	7	320	5	296	14	157	7	182	7	231	1	31	−2
Check	160	7	270	8	285	7	106	10	155	15	204	2	....	....

*Yields in bushels per acre.

The following year, similar experiments were established on three farms in about the same area in the northern part of the lower peninsula. Three complete fertilizers were used as shown in Table 5. The size of plots, method, and rate of fertilizer application were exactly the same as in the previous year.

Again as shown by the results in Table 5 it was found that fertilizer treatments resulted in increased yields. The proportional increase of No. 1's over No. 2's again indicated that the tuber size was increased by use of fertilizers. There was little difference in the effect of the various fertilizers, although increases in the potash content seemed to increase the yields on more than half of the plots.

The desire to throw more light on this doubtful point led to the

Table 5. Effect of fertilizer analysis on potato yields in 1924.*

Location of field	Antrim County		Kalkaska County		Wexford County		Average increase in yield due to fertilizer treatment (Bu. per acre)	
Cooperator	G. Tobias		Antrim Seed Co.		G. Elmore			
Soil type	Rubicon sand		Mancelona sandy loam		Emmet sandy loam			
Grade of potatoes	1st	2nd	1st	2nd	1st	2nd	1st	2nd
0-16-0	199	6	126	10	174	33	49	9
3-12-0	190	10	139	14	156	33	43	11
3-12-2	185	7	95	14	139	25	21	7
3-12-4	209	5	109	17	156	25	39	8
3-12-6	187	2	88	17	213	16	44	4
Check	142	0	82	17	119	8	......	......

*Yields in bushels per acre.

establishment of a series of plots in 1925 and 1926 on the farm of Mr. E. E. Ferguson in Antrim County. Seven plots were laid out in 1925. The next year, six plots were established in a new field but on the same soil type which was a Mancelona gravelly sandy loam. Fields on which potatoes had been grown within five or six years were always avoided in order to minimize danger of disease. An application of 300 pounds per acre of each fertilizer was broadcast before planting time the first year. The following season the application was increased to 400 pounds per acre. The results of this work are given in Table 6.

Table 6. Effect of fertilizer analysis on potato production in 1925 and 1926. Yields are in bushels per acre.[1]

Analysis used	0-12-0	3-12-0	3-12-4	3-12-8	3-12-12	3-12-16	Check
1925 Yields—No. 1	199	120	130	122	121	100	99
No. 2	9	16	6	8	9	10	5
1926 Yields—No. 1	....	153	172	177	192	194	141
No. 2	....	18	21	16	13	18	9
Average increase in yield due to fertilizer over two years—No. 1	....	16	31	30	36	27	....
No. 2	....	10	6	5	4	7	....

In 1925, as in the two preceding years, a fertilizer supplying P_2O_5 alone was used. As in several other cases during the course of the

[1]When interpreting this type of data, it should be remembered that because of seasonal variations the figures in different years cannot be compared. For instance, the 1926 yields were greater than those of 1925 because climatic conditions were more favorable to potato production in that year. For these reasons the conclusion that a 3-12-8 analysis is much better than a 3-12-12 is entirely erroneous. A true analysis of the data can be made only by comparing yields of a single season.

Table 7. Effect of fertilizer analysis on potato yields in 1927 and 1928.*

Cooperator	Location (County)	Soil Type	Fertilizer Analysis															Check
			0-16-8	2-16-8	4-16-8	6-16-8	8-16-8	4-0-8	4-8-8	4-16-8	4-24-8	4-32-8	4-16-0	4-16-4	4-16-8	4-16-12	4-16-16	
Peeble, P. S.	Antrim.......	Onaway sandy loam...	156	147	189	169	176	191	202	205	193	193	195	183	226	198	205	165
Mankowski, V...	Otsego.......	Roselawn sandy loam..	191	194	209	197	214	187	194	214	200	229	157	157	172	185	186	178
Griswold, E.....	Kent........	Kewanee sandy loam..	190	204	201	210	198	173	190	206	192	189	140	167	183	208	215	150
Woodstock, Wm.	Emmet.......	Onaway sandy loam...	341	343	333	318	267	261	340	348	358	393	333	370	390	408	379	187
Hoopfer, W.....	Kalkaska.....	Onaway sandy loam...	264	272	268	249	221	240	237	253	254	231	207	228	239	257	268	227
Crebbs, W. C....	Antrim.......	Rubicon sandy loam...	242	246	247	268	258	208	208	228	232	250	236	246	252	250	249	172
Bennett, R. C...	Antrim.......	Rubicon sandy loam...	146	183	208	226	226	205	214	233	229	221	200	206	218	222	212	161
Inglis, W. G.....	Presque Isle..	Onaway sandy loam...	293	299	329	207	301	279	286	300	293	300	244	324	242	314	332	272
Greenman, C....	Otsego.......	Mancelona sandy loam.	237	264	279	265	260	262	269	279	296	265	268	302	287	286	280	242
Gray, R........	Kent........	Isabella loam.........	125	139	131	151	181	140	139	152	177	167	83	109	138	196	212	91
Dreff, A. M.....	Otsego.......	Roselawn sandy loam..	132	110	161	174	132	142	131	122	140	133	106	104	126	125	175	86
Stimson, J......	Alpena.......	Onaway loam.........	263	234	335	318	.....	.....	.....	.....	.....	.....	344	337	335	327	278	285
Rossman, R.....	Montcalm....	Isabella sandy loam....	169	176	159	.....	142	78	120	.....	96	98	22	98	.....	163	198	75
Average increase in yield due to fertilizer treatment.......			35	40	58	45	48	30	44	55	54	55	19	42	50	65	70	.....

*Yields in bushels per acre.

investigations, this fertilizer produced greater increases in yields than can be accounted for in view of the fact that so much evidence has been obtained which points to the superiority of a complete fertilizer. Other fertilizers employed in this two-year test contained N and P_2O_5 in a constant ratio while the proportion of potash was changed, thus forming a potash series. According to the results presented in Table 6 it may be seen that the inclusion of 4% of K_2O in the fertilizer resulted in a decided increase in yield. The increase of this amount to 8% did not enlarge the average increase in yield; and the increase when the K_2O content was raised to 12% was comparatively small.

The next year, a very comprehensive project was started in order to study in more detail the influence of N, P_2O_5, and K_2O in relation to one another. Thirteen test fields were located in the northern part of the lower peninsula and in the Greenville area. Each field was divided into 16 plots, 15 of which received fertilizer leaving one as a check. Fertilizer treatments were divided into three groups of five each. In the first group, the amount of P_2O_5 and K_2O in each fertilizer remained constant and the percentage of N varied. The second group contained constant amounts of N and K_2O with the amount P_2O_5 changing. A K_2O series made up the last group; that is, the amounts of N and P_2O_5 remained the same while the K_2O content increased. Applications consisted of 500 pounds per acre broadcast before planting time.

Here again the use of commercial fertilizers resulted in consistent increases in yields. In most cases, much higher yields were obtained from the fertilized plots. At the bottom of the table is shown the average increase in yield of fertilized plots over yields of unfertilized plots. The averages illustrate the importance of a balanced fertilizer mixture. For instance, in the first series of 5 plots, the yields increased with increases in the N content of the fertilizer until it reached 4%. Additional nitrogen not only failed to result in greater yields, but actually caused a decrease. This is explained by the fact that excess nitrogen results in a heavy, verdant foliage and delayed maturity. Increasing the top growth makes a large, well-distributed rainfall imperative, while the failure of the crop to ripen normally increases the hazards of late blight and frost damage. Thus, too much nitrogen may indirectly lead to smaller yields. In the second series of five plots, increases in yields due to increases in the amount of P_2O_5 contained in the fertilizer were fairly constant until 16% was reached. Thereafter greater additions of P_2O_5 failed to make additional increases in production. Similar results were given by the potash series although there was a slight increase when the K_2O content was raised from 12 to 16%. Most rapid increases occurred as the K_2O content of the fertilizer approached 8%. This point is emphasized again in later results.

In summing up the yields obtained in these two years, it is apparent that a 4-16-8 analysis gave the most efficient returns. This conclusion was substantiated the following year when this fertilizer was compared with four other analyses on the farms of Mr. K. King, near Greenville in Montcalm County, and Mr. R. C. Bennett, near Alba in Antrim County. In both fields the 4-16-8 analysis gave considerably greater yields than did any other grade. The average yields are shown in Table 8 with the increases obtained.

Table 8. Effect of fertilizer analysis on potato production in 1929. (Yields and increases are in bushels of marketable potatoes per acre.)

Fertilizer analysis	4-16-4	4-16-8	4-16-12	8-16-8	6-8-6	Check
Average yield	176.9	192.3	154.9	148.1	171.6	147.1
Increase due to fertilizer	29.8	45.2	7.8	.4	34.5	0

The following year, 1930, was very dry with poorly distributed rainfall during the growing season. Consequently, on many of the experimental plots, moisture, rather than lack of plant nutrients, was the most limiting factor. No definite nor accurate conclusions can, therefore, be drawn from the tests of that year. The data in Table 9 are significant, however, in that they show to what extent potato yields are actually limited by lack of soil moisture.

All of the plots gave extremely low yields. Because of the dry season fertilizer applications did not consistently increase potato production; in fact, in a number of cases the yields were decreased by fertilization.

Table 9. Effect of fertilizer analysis on potato production in 1930. (Yields are in bushels of marketable potatoes per acre.)

Cooperator	Location (County)	Soil Type	Fertilizer Analysis Used							
			0-16-8	2-16-8	4-16-8	4-16-0	4-16-2	4-16-4	4-16-16	Check
Blin, W.	Ingham		80.8	.....	.....	62.2	.....	.....	68.7	56.1
Aseltine, L.	Ingham		50.2	.....	.....	48.1	.....	.....	48.0	55.7
MacPherson, D.	Kent	Isabella loam	.....	63.5	57.9	.....	65.8	61.3	.....	65.6
Bird, S.	Ionia	Isabella sandy loam	.....	69.1	65.3	.....	72.2	67.8	.....	70.3
King, K.	Montcalm	Fox sandy loam	.....	95.0	75.0	.....	97.6	86.9	.....	77.8
Griswold, E.	Kent	Kewanee sandy loam	.....	115.2	115.8	.....	116.3	121.0	.....	106.6

Looking back over the investigations, particularly from 1925 on, it will be noticed that the role of K_2O in increasing potato yields is not so well defined as that of N or P_2O_5. In general, however, the yields seem to increase directly with the K_2O content of the fertilizer providing N and P_2O_5 are supplied in the ratio of about 1 to 4. The analysis studies during the period 1931 to 1937, inclusive, were confined to the investigation of this point in order that some definite conclusions could be obtained as to the effect of K_2O on potato production. This work was done on two farms—that of Mr. K. King (Montcalm County) and of Mr. S. P. Mathias in Antrim County. Results obtained in the Greenville area are shown in Table 10. Applications were made at planting time in the manner and at the rate indicated in the table. Each treatment was repeated five, and in some cases six, times in order to eliminate the variable factors of soil and topography of the land.

In 1938 a series of experiments was established on the heavier potato soils in Emmet County. Treatments consisted of 500 pounds per acre of the various fertilizers applied in bands two inches out on both sides of the seed piece and on the same plane. Applications were made by means of a standard fertilizer attachment on the planter. In order to eliminate the effects of variation in soil, four replications of each treatment were made.

Table 12. Effect of fertilizer analysis on potato production in 1938.

(Yields are in bushels per acre.)

Location of field	Emmet County		Emmet County		Emmet County		Per cent increase in average yields of marketable potatoes
Cooperator	O. R. Cook		O. Overholt		F. Sluyter		
Soil type	Onaway loam		Onaway loam		Onaway loam		
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	
0-12-12	277	18	265	21	220	10	38
3-12-12	307	21	295	25	219	12	49
3-12-6	259	20	262	25	215	13	37
3-16-8	276	18	273	25	213	14	39
4-16-8	308	18	276	26	214	14	45
3-9-18	275	19	309	22	231	9	46
Check	205	19	200	26	116	12	....

The data in Table 12 show that all fertilized plots produced substantially larger yields than did the untreated plots. No single analysis, however, consistently produced more than any other on all three farms although the 3-9-18 fertilizer produced slightly greater yields in two out of three cases. The percentage increase of the average yields of fertilized over untreated plots shows that the 3-12-12, 4-16-8, and 3-9-18 fertilizers produced somewhat greater increases than did the remaining three.

To summarize the analysis studies, the 4-16-8 more often than any other fertilizer gave large and efficient increases in potato yields. Season after season, under a variety of weather conditions and on every soil type, no other analysis as consistently produced yields ranking among the highest. There is, however, sufficient evidence to justify the opinion that a higher proportion of potash to phosphoric acid as would be supplied in a 3-12-12 fertilizer would, under certain conditions, give as good or possibly better results.

Rate of Application Studies

The study of the effect of the amount of fertilizer applied on potato production was started in 1925 on the farm of Mr. R. C. Bennett in Antrim County. The plots were located on Mancelona sand. A blanket application of 500 pounds per acre of 3-12-4 was broadcast over all

Table 13. Effect of rate of fertilizer application on potato production in 1925.

Plot No.	1	2	3	4
Total fertilizer application	1,000	1,250	1,500	2,000
Yields (bushels per acre)	240	250	286	262

plots before planting time. Additional applications of 3-12-4 were applied in the row at the time of planting.

The data presented in Table 13 show that the yields increased with increasing amounts of fertilizer until the application exceeded 1,500 pounds per acre. Since a large part of the application was made directly in the row, the decrease in yields with heavier applications was in all probability due to injury to the potato sprout.

In 1927, experiments were laid out on four different farms. None of these plots received an initial broadcast treatment as in the preceding year.

The data presented in Table 14 show that in 1927 commercial fertilizers generally increased potato yields. Except in the case of the Hoopfer field the yields increased with increasing quantities of fertilizer, but there is little indication from the data that applications in excess of 500 pounds were advisable.

In 1929, the experiments were continued and as shown by the data in Table 15 the conclusions to be drawn strengthen those of the preceding year. That is, on an average, an application of 500 pounds per

Table 14. Effect of rate of fertilizer application on potato production in 1927. (Yields are in bushels per acre of salable potatoes.)

Cooperator	Judson, F.	Demerest, M. M.	Hoopfer, W. J.	Orr, W. D.
Location (County)	Lenawee	Otsego	Antrim	Montcalm
Soil type	Berrien sand	Roselawn sandy loam	Onaway sandy loam	Isabella sandy loam
Fertilizer used	4-16-4	2-16-6	2-16-6	2-16-6
Method of application	Bands 2″ out and on same plane	Bands 2″ out and 2″ below seed piece		
250 lbs./acres	125	. . .	215	134
375 lbs./acres	. . .	88	. . .	. . .
500 lbs./acres	134	. . .	211	145
750 lbs./acres	. . .	100	. . .	. . .
1,000 lbs./acres	127	. . .	207	147
1,500 lbs./acres	. . .	137	. . .	. . .
Check	125	66	186	142

Table 15. Effect of rate of fertilizer application on the yields of potatoes in 1929. (Yields are in bushels of marketable potatoes per acre.)

Cooperator	Judson, F.	Valentine, J.	Rossman, R.	
Location (County)	Lenawee	Tuscola	Montcalm	
Soil type	Berrien sand	Fox sandy loam	Isabella sandy loam	
Fertilizer used	4-16-4	2-16-8	4-16-4	2-12-6
250 lbs./acre	88	...	...	65
300 lbs./acre	...	...	140	...
500 lbs./acre	128	170	146	119
1,000 lbs./acre	136	178	...	175
1,500 lbs./acre	...	...	...	157
Check	78	157	90	61

acre seemed to give the most economical results. Higher rates, however, were considerably more effective when the 2-12-6 was used on the Rossman farm.

Mr. Judson cooperated in 1930 and again in 1932 on similar field tests. In the former year, a 2-16-8 analysis was used in bands two inches out and two inches below the seed piece. In the latter year, the same placement was employed, but the analysis was changed to a 4-16-4. The soil type was Berrien sand.

The data shown in Table 16 indicate that from 250 to 500 pounds of fertilizer per acre are sufficient. Larger applications did not result in increases sufficiently large to compensate for the extra expense involved.

More conclusive evidence to this effect is found in the data obtained from an experiment which was repeated four years on the farm of Mr. K. King in Montcalm County.

In two of the four seasons a 600-pound application gave the highest yield. In 1932 and in 1934 heavier applications gave larger yields, but the economy of these increases is questionable. This is especially true in the latter year when the 600-pound applications gave a substantial,

Table 16. Effect of rate of fertilizer application on potato yields in 1930 and 1932. (Yields are in bushels per acre of marketable potatoes.)

Year	1930	1932
250 pounds per acre of 4-16-4	72	107
500 pounds per acre of 4-16-4	107	88
1,000 pounds per acre of 4-16-4	109	96
Check pounds per acre of 4-16-4	68	75

Table 17. Effect of rate of fertilizer application on potato production. King field. (Yields are in bushels of marketable potatoes per acre.)

Year		1931	1932	1933	1934
Soil type		Montcalm sandy loam	Fox sandy loam	Montcalm sandy loam	
Analysis used		4-8-7		4-12-8	
Method of placement		2 inches out on both sides and 2 inches below the plane of the seed piece			
Rate of application in lbs. per acre	300	152	187	139	260
	600	180	190	163	276
	900	175	188	139	283
	1,200	178	210	144	276
	Check	143	169	139	238

and probably profitable, increase in production. Increasing the application 50% resulted in only a slight increase in yield. The next effect was to decrease the profit derived from the crop.

A similar test was conducted on the farm of Mr. Mathias in Antrim County. The soil type was Mancelona gravelly sandy loam. The treatment consisted of varying amounts of 4-12-8 placed two inches out on both sides and on the same plane as the seed piece.

In 1936 substantial increases were obtained for every addition of fertilizer. Under certain conditions, such results are not infrequently observed. But, even so, the questions of fertilizer costs, the uncertainty of the potato market, and the danger of sprout injury from heavy applications cannot be overlooked when considering fertilizer needs. With those problems in mind, it generally seems inadvisable to plan applications heavier than 500 pounds per acre.

Table 18. Effect of rate of fertilizer application on potato production. Mathias field.

Year		1936	1937
Rate of application	200 pounds per acre of 4-12-8	123	...
	300 pounds per acre of 4-12-8	128	132
	400 pounds per acre of 4-12-8	139	...
	500 pounds per acre of 4-12-8	162	153
	700 pounds per acre of 4-12-8	172	...
	Check	101	87

METHOD OF PLACEMENT OF COMMERCIAL FERTILIZERS*

It was early observed that the placement of commercial fertilizers with regards to the seed piece had some effect on potato yields. Especially was this true when sprout injury due to contact with the fertilizing material was noted. An attempt at a systematic investigation of this problem in Michigan was made in 1924. At that time, fertilizer attachments on the planter were not widely used so that the question of placement was simply whether the fertilizer should be scattered over the entire field or whether it should be mixed in the soil over the seed piece. Another alternative was to broadcast a portion of the application and place the remainder in the rows. It was with such placement methods that the early studies were concerned. The rate of fertilizer application was in all cases 400 pounds per acre.

Table 19. Effect of fertilizer placement on potato production in 1924. (Yields are in bushels of marketable potatoes per acre.)

Analysis of fertilizer	Method of placement	Cooperator		Average yield	Increase of row application over broad-casting
		Antrim Seed Co.	G. Elmore		
0-16-0	Broadcast	136	207	173	
	Row	139	147	143	−30
3-12-0	Broadcast	153	189	171	
	Row	133	172	152	−19
3-12-2	Broadcast	109	164	136	
	Row	122	221	172	+36
3-12-4	Broadcast	126	210	153	
	Row	146	238	192	+39
3-12-6	Broadcast	105	230	167	
	Row	124	234	179	+12

From the data shown in Table 19 it is evident that in more than 60% of the cases the potatoes fertilized in the row out-yielded those receiving broadcast applications. When the size of the increases are compared there is but little doubt that the row applications were to be preferred. The crop does not get the full benefit of fertilizers broadcast over the entire field. The fertilizer does not move through the soil except where carried down by percolating water or brought upward with capillary moisture, and hence plants make use of the fertilizer only when the growing roots make actual contact with the area containing the nutrients. In fields on which fertilizers are broadcast, plant roots reach a large portion of the fertilized area only after the elapse of considerable time. Indeed, a major part of the soluble nitrogen may be washed beyond the reach of the plant before its roots

*A report of regional activities covering studies of fertilizer placement for potatoes, including cooperative studies in Michigan, is given in U. S. Department of Agriculture Technical Bulletin No. 669 entitled "Fertilizer Placement for Potatoes" by G. A. Cumings, G. V. C. Houghland and Collaborators (Issued in February, 1939).

have filled the soil between the rows. Furthermore, as a portion of the soluble phosphoric acid changes to a relatively insoluble form when mixed with the soil it is to be expected that an equal quantity of fertilizer concentrated near the plant should lead to larger yields.

No more studies were made in this connection until 1930 when the increasing popularity of attachments to planters for placing fertilizers with or near the seed piece again brought a demand for placement tests. Accordingly, studies lasting over a period of six years were established on the farm of Mr. King. A 4-8-7 analysis was employed the first two years, but during the last four years the more concentrated 4-12-8 was used. In all, six different methods of placement were studied, as listed at the left of Table 20, with the resulting crop yields shown on the right.

Table 20. Effect of various fertilizer placements on potato production, King field. (Yields are in bushels of marketable potatoes per acre.)

		1931	1932	1933	1934	1935	1936	Average 1931-34
Year		1931	1932	1933	1934	1935	1936	
Rate of application (pounds per acre)		800	800	800	800	500	500	
Placement with reference to seed piece	Untreated	143	169	139	238	167	175	172
	1. Bands ½ to 2″ below	173	168	127	270	192	...	184
	2. Bands 4″ out on both sides and on same plane	155	180	164	279	...	...	195
	3. Same, but only 2″ out	185	197	162	274	199	200	205
	4. Same, but only 1″ out	...	199	143	251	...	...	...
	5. Bands 2″ out, 2″ below	168	192	136	267	...	...	191
	6. Mixed around seed piece	179	175	115	237	171	...	177

A study of this table shows that during the six-year period treatment No. 3 consistently ranked among the highest yielding placements. In 1934 it ranked first, but in the following year it was surpassed by a margin of two bushels by treatment No. 4, a very similar method of placement. The next year, 1933, treatment No. 3 was again in second place, treatment No. 2 surpassing it by the same narrow margin of two bushels. Treatments 2 and 3 again headed the others in 1934, but in 1935 and 1936 treatment No. 3 again took the lead. It is, therefore, apparent that the most satisfactory method of fertilizer placement is in bands about 2 inches out on both sides and in the same plane as the seed piece. This is clearly shown by the average yields for the years 1931 to 1934.

During the six-year period, 1932-37 a similar series of tests were carried out on the farm of Mr. S. P. Mathias in Antrim County. In this case the soil type was Mancelona gravelly sandy loam. Fertilizer applications were made in various ways by means of a specially constructed planter. The rates, methods of placement and results of these studies are shown in Table 21.

As in the tests on the King farm, a continuous band placement 2 inches out on both sides of and on the same plane as the seed piece (treatment 3) produced yields ranking among the highest. But here

Table 21. Effect of various fertilizer placements on potato yields. Mathias field. (Yields are in bushels per acre of marketable potatoes.)

		1932	1933	1934	1935	1936	1937	Average 1932-35
Year		1932	1933	1934	1935	1936	1937	
Rate of application (pounds per acre)		400	800	500	500	700	700	
Treatment with reference to seed piece	Untreated	170	52	188	138	101	87	137
	1. Bands ½ to 2″ below	...	122	272	180	...	...	...
	2. Bands 4″ out on both sides and on same plane	...	...	258	182	...	...	...
	3. Same, but only 2″ out	182	119	269	173	168	184	186
	4. Same, but only 1″ out	...	118	281	178	...	...	...
	5. Bands 2″ out and 2″ below	197	121	245	162	...	...	182
	6. Mixed around seed piece	...	...	260	181	...	...	...

the treatment did not so consistently out-yield other methods of placements, although it should be noted that no other single method was significantly better throughout the six seasons. With two exceptions, the highest yielding placement was a variation of No. 3. These two exceptions, No. 5 in 1932 and No. 1 in 1933, indicate that the fertilizer may be more advantageously placed slightly below the plane of the seed instead of on the same level. The degree of difference is so slight, however, and the number of differences so few that they are of little if any significance. Another factor to be considered here is the additional draft on the planter caused by placing the fertilizer below the

Table 22. Effect of method of fertilizer placement on potato production in 1934. (Yields are in bushels per acre of marketable potatoes.)

Year		1934		
Cooperator		E. C. Burley	S. P. Mathias	J. Gaylord
Location		Antrim Co.	Antrim Co.	Antrim Co.
Soil type		Mancelona gravelly sandy loam		
Fertilizer analysis		4-16-4	4-16-8	4-16-8
Rate of application		500	500	500
Method of placement with regard to seed piece	1. Check	194	198	210
	2. In bands 2″ out and on same plane	230	260	305
	3. In bands 2″ out and 2″ below	237	258	284
	4. In a single band ½ to 2″ below	232	249	289
	5. Mixed around seed	231	252	304

level of the seed piece. From this viewpoint as well as from a consideration of yield placement 3, with the fertilizer on a level with the seed, is the most logical one to use.

Other placement studies were made in 1934 as shown in Table 22. The results again indicate that continuous bands of fertilizer 2 inches out on both sides, and either on or two inches below the plane of the seed piece, produced the greatest yields. According to these figures, there is little difference between placing the fertilizer on the same level or below the seed piece, although the former method produced the highest yields most frequently.

During the progress of these placement studies it was noted that the different placement methods often seemed to influence the size of the tubers. In order to arrive at some definite conclusions in respect to such observations an actual count of the potatoes was made on the King tests in 1932 and again in 1934. These measurements were made, of course, on an equal number of representative hills from each test plot.

Table 23. Effect of method of fertilizer placement on the number and weight of potato tubers in an equal number of hills. King field.

Year		1932 (10 hills)		1934 (25 hills)		Average		Gross weight in grams
		Number of No. 1 potatoes	Average weight (grams)	Number of No. 1 potatoes	Average weight (grams)	Number	Weight	
Method of placement with reference to seed piece	1. Bands 2″ below	46	130	125	144	85	137	1,169
	2. Mixed around seed	44	127	116	135	80	131	1,048
	3. 2″ out, same plane	54	124	126	133	90	129	1,156
	4. 2″ out, 2″ below	49	120	120	138	85	129	1,094
	5. 4″ out, same plane	52	119	121	135	86	127	1,094
	6. 1″ out, same plane	52	123	125	136	89	130	1,143
	7. Check	45	105	122	115	83	110	914

Although the data presented in Table 23 show that fertilizer applications increased the number of large potatoes and also the average weight, yet there is no conclusive evidence that any single placement method was outstanding. The most remarkable fact is that all placements gave approximately the same yield, as is indicated by the data in the right-hand column which show the gross weight in grams of the No. 1 tubers.

Regarding the various placement methods it was also observed that mixing the fertilizer thoroughly in the soil around the seed invariably delayed the emergence of the sprouts. The sprouts penetrated the fertilized area very slowly. On the other hand, applying the fertilizer in bands 2 inches out on both sides of the seed piece (both on and below its level), frequently advanced sprout emergence. The plants on these plots also showed superior top growth until late in the season.

Considered as a whole, all of the placement studies indicate that the most efficient use of fertilizer is obtained when applied near the seed piece. Thus, if the choice be between broadcast or row application, then the latter will generally give the greatest yields for equal amounts of commercial fertilizer used. That is, it will most often give the highest return per dollar spent on fertilizer. If a planter is employed so that the application is made with an attachment, then the fertilizer should be placed in bands about two inches out on both sides of the seed and on or a little below the plane of the seed piece. In this way the greatest benefit from commercial fertilizers will be realized most often.

*IRRIGATION STUDIES AT THE LAKE CITY EXPERIMENT STATION

In 1938 an extensive series of tests was carried out at the Lake City Experiment Station in Missaukee County to determine the influence of placement and rate of application of fertilizers on potato yields when under irrigation. The soil type on which these studies were made was Ottawa loamy sand on which crop production is often limited because of insufficient moisture. In order to minimize this limiting factor a system of irrigation was employed. By comparing the yields of irrigated and non-irrigated plots it was thought that some idea might be obtained as to the extent to which an inadequate or poorly distributed rainfall actually limits potato yields. Furthermore, by comparing results of treatments which include sufficient moisture the true effect of fertilizers on crop yields could be determined.

The fertilizer treatments included four different methods of application as follows:

1. In bands about 1 inch out on both sides, and in the same plane as the seed piece.
2. In bands 2 inches out on each side and 2 inches below the plane of the seed piece.
3. In bands 2 inches out on each side and on the same plane as the seed.
4. Mixed thoroughly in the soil around the seed piece.

The analysis of the fertilizer used was 4-16-8. This was applied at four different rates 400, 800, 1,200, and 1,600 pounds per acre in each of the above placement methods. All treatments were replicated four times so that the results shown in Table 24 are averages.

These data illustrate the detrimental effect of an inadequate moisture supply on potato yields as the irrigated plots in all cases produced more than those which received only the normal rainfall. This result is clearly shown in Table 25 where the foregoing data are summarized to show the percentage increase in yields of the irrigated over the unirrigated plots under the same fertilizer treatments.

In this season the rainfall at the Lake City Station was high and fairly well distributed over the growing period. This favorable moisture supply resulted in greater returns than would normally be expected on the unirrigated plots. The efficiency of the various place-

*These studies were in cooperation with E. J. Wheeler of the Farm Crops Section and O. E. Robey of the Agricultural Engineering Section.

Table 24. Effect of placement and rate of application of fertilizer on potato yields under irrigation at the Lake City Experiment Station. 1938.

Placement	In bands 1 inch out on both sides, same plane								In bands 2 inches out on both sides, same plane								In bands 2 inches out on both sides and 2 inches below								Mixed around seed piece								Check	
Rate (lb. per acre)	400		800		1,200		1,600		400		800		1,200		1,600		400		800		1,200		1,600		400		800		1,200		1,600			
Grade of potatoes	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Not irrigated	234	34	239	20	295	19	253	22	255	25	268	29	239	22	322	28	236	28	287	22	279	27	301	25	240	22	248	22	284	24	304	26	174	31
Irrigated	284	20	304	18	405	20	370	16	293	20	332	30	321	24	363	19	310	26	356	24	350	21	377	17	312	18	321	18	344	14	363	19	198	22

Table 25. Increase in potato yields due to irrigation. Calculations are based on the yields of salable potatoes in bushels per acre.

Placement	In bands 1 inch out on both sides, same plane				In bands 2 inches out on both sides, same plane				In bands 2 inches out on both sides and 2 inches below				Mixed around seed piece			
Rate (per acre in 100 pounds)	4	8	12	16	4	8	12	16	4	8	12	16	4	8	12	16
Increase (per cent)	13	24	35	39	12	22	32	9	28	23	22	21	26	25	16	6

ments was little influenced as shown by the comparatively high yields from all plots on which the band methods were used, particularly when the bands were placed 2 inches out on both sides, and on or below the level of the seed piece. However, heavier fertilizer applications resulted in considerably greater increases in yield than did the lighter applications. This was doubtless due to the excess rainfall.

Regardless of the abundant moisture supply, irrigation did have some additional effect in changing crop responses to different rates of fertilizer application and different placement methods. This is shown by the fact that 1,200 or 1,600 pounds of fertilizer produced in every case the highest yields under irrigation while the light applications consistently yielded less. These heavy applications gave the greatest increases when applied close to the eed piece. Under ordinary growing conditions this practice would result in sprout injury, but under irrigation the danger is minimized because the presence of more water decreases the concentration of the soil solution. Since less time is required for the roots to reach fertilizer so applied, very rapid and efficient plant responses are obtained.

SIDE-DRESSING WITH COMMERCIAL FERTILIZER*

Many farmers grow a small acreage of potatoes which contributes appreciably to the farm income but is not large enough to warrant the owning of a potato planter. The fertilization of potatoes planted by hand has presented a problem which some farmers have attempted to solve by throwing a handful of fertilizer on top of the hill and some by applying fertilizer broadcast before planting. Neither method is satisfactory and hence trials were undertaken in which fertilizer was applied as a side-dressing with an attachment to a cultivator at the time of the first cultivation. The results of these trials are presented in Table 26.

No previous fertilizer treatments had been made on any of the test plots so that all increases are due to the side-dressing. With but three exceptions the fertilized plots gave much larger yields than those which did not receive fertilizer. In a majority of cases the increases were without doubt sufficiently great to warrant a recommendation that potatoes not fertilized at planting time be side-dressed with fertilizer at the time of the first cultivation.

*These tests were conducted by P. J. Rood, Extension Specialist, and E. C. Sackrider, former Extension Specialist in Soils.

Table 26. Effect of fertilizers applied as side-dressing on potato production. (Yields are in bushels per acre.)

Year	Cooperator	Soil type	County	Fertilizer		Yields	Increase due to fertilizer treat-ment
				Analysis	Rate lb. per acre		
1935	Holtz, O.....	Maumee loam...........	Monroe....	2-16-8.. 4- 8-6.. check..	1,000 1,000 0	235 246 145	90 101 ....
	Gorsline, J...	Berrien sandy loam......	Arenac.....	0-20-0.. check..	130 0	78 118	−40 ....
	Olson.......	Roselawn loam sand.....	Alcona.....	0-20-0.. check..	170 0	107 82	25 ....
	Harsch, C...	Onaway sandy loam.....	Iosco......	2-12-6.. check..	170 0	176 170	6 ....
	Wendling, G.	Bellefontaine sandy loam.	Lapeer.....	0-20-0.. 2-12-6.. check..	200 310 0	156 144 143	13 1 ....
	Tripp, G....	Fox sandy loam.........	Lapeer.....	0-20-0.. 2-12-6.. check..	178 255 0	142 141 101	41 40 ....
1936	Lilley, J.....	Rubicon loamy sand.....	Alcona.....	0-20-0.. 2-12-6.. check..	259 220 0	97 120 123	−26 − 3 ....
1937	France, W...	Kalkaska sandy loam....	Cheboygan.	0-20-0.. 2-12-6.. check..	370 370 0	258 273 149	109 124 ....
1938	Ellis, R......	Rubicon loamy sand.....	Arenac.....	0-20-0.. 2-12-6.. check..	230 177 0	207 202 156	51 46 ....
	White, M....	Arenac sandy loam......	Arenac.....	0-20-0.. 2-12-6.. check..	175 171 0	129 141 127	2 14 ....
	Bonnett, R..	Onaway sandy loam.....	Cheboygan.	0-20-0.. 4-16-8.. check..	190 194 0	129 153 93	36 60 ....
	Bonк, S.....	Emmet sandy loam......	Otsego.....	0-20-0.. 4-16-8.. check..	171 171 0	132 129 118	14 11 ....
	Rambadt, E..	Onaway sandy loam.....	Presque Isle	0-20-0.. 4-16-8.. check..	200 200 0	308 293 283	25 10 ....

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