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KANSAS STATE COLLEGE OF AGRICULTURE
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DEPARTMENT OF AGRONOMY



INFLUENCE OF FERTILIZER ON POTATO YIELD

Potatoes harvested from 1-32-acre plots, Douglas county, Kan., 1931. (A) Harvested from a plot receiving no fertilizer. (B) Harvested from a plot receiving 22 pounds of nitrogen and 43 pounds of available phosphoric acid (P_2O_5) per acre.

COMMERCIAL FERTILIZERS FOR POTATOES IN THE KANSAS RIVER VALLEY¹

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IMPORTANCE OF THE AREA IN POTATO PRODUCTION²

The largest commercial potato-producing area in Kansas is located in the Kansas river valley and extends approximately 100 miles west of the east line of the state. The six counties, Douglas, Jefferson, Johnson, Leavenworth, Shawnee, and Wyandotte, through which this area extends had an average pro-

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1. Contribution No. 243 from the Department of Agronomy.
2. See page 12 for "Table of Contents."

duction of 1,905,478 bushels of potatoes annually over the 15-year period, 1919 to 1933. This is 42 per cent of the average annual production of the state for this period. The study of the use of fertilizers for potato production given in this circular was conducted on the representative soil types of this area.

IMPORTANCE OF HIGH YIELDS IN POTATO PRODUCTION

The cost of producing commercial potatoes is high compared to that of many other crops. The value of soil adapted to the production of this crop is comparatively high. The seedbed must be well prepared. The seed, cultivation, and insect and disease control costs are all high. These costs are to a considerable extent fixed and do not vary greatly, regardless of the yield. When the cost is fixed, any increase in yield reduces the cost per unit and thereby increases the possibility of profit. A smaller number of acres producing a high yield is usually a more sound basis of potato production than an expanded acreage of comparatively low yield. When a fertilizer will increase the yield sufficiently to pay all added costs and leave a profit, the grower can afford to use it. The recommendations in this circular are made on this basis.

METHODS OF SECURING INFORMATION

The results reported in this circular were secured from fertilizer tests conducted in cooperation with commercial potato growers in the Kansas river valley. Test plots four rows wide and of varying length, were located in commercial potato fields. The seed was planted with an Aspinwall planter at the rate of approximately 17 bushels per acre. The fertilizer was applied with a fertilizer attachment in a band on each side of the row and slightly below the seed piece. Due to the effect of atmospheric conditions on the mechanical condition of the fertilizers, the rate of application was frequently slightly above or below the intended rate. It is thought, however, that this variation was not sufficiently large to influence results materially. The test plots were cultivated and handled throughout the season in the same manner as the general field. All plots were harvested by the growers in the regular manner under the supervision of a member of the Agricultural Experiment Station staff. The weight of U. S. No. 1 potatoes was secured by grading with commercial graders.

TREATMENTS USED

The tests conducted in 1932, 1933, and 1934 consisted of two untreated and six treated plots. The tests conducted in 1931 included the treatment received by plots 4, 5, and 7 but not those received by plots 1, 2, and 8. Table I gives the analysis of the fertilizers used, the rate at which they were applied, and the

number of pounds of nitrogen (N), available phosphoric acid (P_2O_5), and water soluble potash (K_2O) applied per acre. The analysis of a fertilizer is indicated by a series of three numbers, for example, 11-48-0. The first figure given in the analysis is the percentage of nitrogen, the second, phosphoric acid (P_2O_5), and the third, potash (K_2O).

TABLE I.—ANALYSIS AND RATE OF APPLICATION OF FERTILIZER USED ON EACH PLOT.

Plot No.	Analysis of fertilizer used			Pounds of fertilizer applied per acre	Pounds of nutrients applied per acre		
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)		Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)
1	20.56	0	0	107	22	0	0
2	0	44	0	100	0	44	0
3	No treatment						
4	11.6	23.2	11.6	180	22	44	22
5	14.7	29.4	0	150	22	44	0
6	No treatment						
7	11	48	0	200	22	96	0
8	11	48	0	400	44	192	0

Plot 1 received nitrogen alone in the form of ammonium sulphate. Phosphoric acid alone in the form of superphosphate was applied to plot No. 2. Plots 3 and 6 received no fertilizer treatment. Plot 4 received a complete fertilizer which carried the same amount of nitrogen as was applied to plot 1, the same amount of phosphoric acid as was applied to plot 2, and 22 pounds of potash (K_2O) per acre. This fertilizer was made by mixing 53 per cent of 16-20-0 ammonium phosphate, 27 per cent of 11-48-0 ammonium phosphate, and 20 per cent of 0-0-58 potassium chloride. Plot 5 received the same amount of nitrogen and phosphoric acid as plot 4 but no potash. This fertilizer consisted of 66 2/3 per cent of 16-20-0 ammonium phosphate and 33 1/3 per cent of 11-48-0 ammonium phosphate. The fertilizer applied on plot 7 supplied the same amount of nitrogen and slightly more than twice as much phosphoric acid as that used on plot 5. Plot 8 received a heavier application of fertilizer than any other plot. It contained twice as much nitrogen and phosphoric acid as the treatment applied to plot 7. Ammonium phosphate, 11-48-0, was used on plots 7 and 8.

CALCULATION OF FERTILIZER MIXTURES

The quantity of fertilizer per acre that must be applied to supply the needed nitrogen and phosphorus can be determined

easily by making use of the analysis given on the label which is attached to each bag of fertilizer offered for sale within the state. The label gives the percentage of nitrogen expressed both as nitrogen (N) and as ammonia (NH_3), the percentage of phosphorus expressed as (P_2O_5) and the percentage of potassium expressed as (K_2O). (Fourteen pounds of nitrogen is equivalent to 17 pounds of ammonia.)

When it is desired to apply 22 pounds of nitrogen and 44 pounds of phosphoric acid (P_2O_5) using ammonium sulphate (20.56 per cent nitrogen) and superphosphate (44 per cent P_2O_5), it is necessary to apply 107 pounds of ammonium sulphate and 100 pounds of 44 per cent superphosphate. If this same analysis is to be made up from ammonium phosphate containing 11 per cent N and 48 per cent phosphoric acid (P_2O_5) and ammonium sulphate carrying 20.56 per cent nitrogen, it will be necessary to mix 91.7 pounds of the ammonium phosphate and 58 pounds of ammonium sulphate. This amount should be applied to one acre.

If the superphosphate contains 16 per cent P_2O_5 it would be necessary to add 275 pounds of this material in addition to the 107 pounds of ammonium sulphate. These amounts are obtained by proportion; that is, a material carrying 16 per cent P_2O_5 will contain 16 pounds of P_2O_5 per hundred pounds, and in order to get 44 pounds, it will be necessary to apply $44/16 \times 100$, or 275 pounds. This same principle is involved in all calculations.

EFFECT OF VARIATION IN CLIMATIC CONDITIONS ON RESULTS SECURED BY THE USE OF COMMERCIAL FERTILIZERS

The Kansas river valley potato-producing area receives an average annual rainfall of approximately 35 inches. The average rainfall received at Lawrence during the potato-growing season is 3.1 inches in April, 4.7 in May, and 4.9 in June. The rainfall increases slightly to the east and decreases slightly to the west of Lawrence but this variation is not large within the potato-growing section of the valley during a normal season. The variation of both the annual and seasonal rainfall over a period of years is frequently large. Within a 16-year period, 1915 to 1930, the annual rainfall at Lawrence varied from 25.8 to 51.61 inches, and the rainfall for April, May, and June, the potato-growing season, varied from 9.57 to 27.37 inches.

The variation in temperatures during the growing season within the commercial potato-growing area of the Kansas river valley is slight. There is, however, a slight increase in temperature from east to west. Differences in temperature during the growing seasons of the years, 1931 to 1934, undoubtedly had considerable effect on the potato yield.

The combined rainfall of April and May of 1931 was nearly

normal at all points in the valley with the exception of Topeka, where the May rainfall was 2.45 inches below normal. The June rainfall was below normal at all points except Lawrence. The temperatures were near normal in April but considerably below normal in May, which retarded the development of the crop sufficiently for the low June rainfall and June temperatures of 4 to 6 degrees above normal to reduce the yield. The yield of potatoes in the Kansas river valley in 1931 was the same as the average for the 15-year period, 1920-1934. It is probable that the fertilized plots were more mature than the unfertilized plots at the time of low rainfall and high temperatures which accounted for the large yield differences with medium total yield.

Temperatures during the growing season of 1932 averaged considerably above normal, but the rainfall was rather close to normal. The April rainfall was sufficient to provide ample moisture and the temperatures were about 3 degrees above normal. Under these conditions the plants started a vigorous early growth. The rainfall was below normal in May but this shortage was mostly replaced in June and a large yield was produced. The average yield in the Kansas river valley in 1932 was the third largest during the period of 1920-1934. The results secured from the use of fertilizer that year are probably the same as could be expected in any good potato-producing year.

The rainfall in 1933 was slightly below normal in most parts of the valley in April but above normal in May. The temperatures were normal in April and May. The crop grew well and promised a high yield. The June rainfall was about 3.5 inches below normal at various points in the valley and the average June temperatures ranged from 6.1 to 8.4 degrees above normal. This combination of drouth and high temperatures retarded the development of the tubers so early that the fertilized plots did not make a very large increase over the untreated plots. The yield was low on all plots. The average yield of potatoes in the Kansas river valley in 1933 was slightly lower than that of any previous year in the period 1920-1934.

The 1934 growing season was a continuation of the winter drouth and one of abnormally high temperatures. The rainfall was below normal each month of the growing season at all points in the valley with the exception of Lawrence and Topeka in May. The temperatures averaged 3.5 degrees above normal in April, nearly 6 degrees above in May, and from 7.6 to 9.6 degrees above in June. This combination of drouth and high temperatures made moisture the limiting factor in potato production and reduced the plant nutrient factor to a minimum.

The four years during which this work was conducted represent the variation which might be expected in climatic condi-

tions in the Kansas river valley. The 1931 Kansas river valley potato yield equalled the 15-year average, the 1932 yield was above average, the 1933 yield, below average, and the 1934 yield, extremely low.

The average yield of potatoes in Douglas, Jefferson, Johnson, Leavenworth, Shawnee, and Wyandotte counties for the four-year period, 1931-1934, was 104 bushels per acre, which is 21.5 bushels less than the average of 125.5 bushels for the 15-year period, 1920-1934. Since the results of this work indicate a tendency for larger increases to result from the use of fertilizers in years of higher yields, it can reasonably be expected that as large or larger increases than those reported here will be secured over a period of years.

SOILS

The results reported in this circular were secured from fertilizer tests conducted on sandy loam, fine sandy loam, silt loam, and clay loam soils so distributed that they represent the major potato-producing soils of the eastern Kansas river valley.

The limited information obtained so far indicates that the response to the treatments used is similar on the sandy and heavier soils. It appears, therefore, that recommendations made in this circular will apply to all soil types now used for producing potatoes in the Kansas river valley.

DISTRIBUTION OF FERTILIZER IN RELATION TO SEED PIECE

The distribution of the fertilizer in the soil with respect to the seed piece materially influences the effectiveness of the fertilizer. The greatest yield usually will be secured by applying the fertilizer in bands 2 inches to each side and on the same level as the seed piece or slightly below. Applying the fertilizer above, below, or in the row with the seed piece will retard the germination and produce a lower yield than applying it in bands on both sides of the row. The increase in yield secured from broadcasting the fertilizer usually will be greater than that secured by applying the fertilizer above, below, or in the row with the seed piece, but less than that secured from fertilizer applied in bands to the side of the seed piece.

The fertilizer attachment of the Aspinwall planter used in the experiments reported in this circular deposits the fertilizer in bands on each side of the seed piece, approximately 2 inches from and slightly below the seed piece. Plant counts made on the plots in the spring of 1934, at the time of emergence of the plants, indicated that none of the treatments used influenced the germination or growth of the plant during the first two weeks.

YIELD RESULTS

The value of the use of fertilizers in the production of potatoes is determined partially by the amount of the increased yield secured. Table II gives the average yield per acre of graded potatoes without fertilizer and with six different treatments. There is a large variation in the annual yield as indicated by the yield of the untreated plots. In 1931, the plots which received no fertilizer produced nearly 10,000 pounds of graded potatoes per acre; in 1932, slightly more than 20,000; in 1933, the two untreated plots averaged slightly less than 6,000 pounds

TABLE II.—YIELD OF GRADED POTATOES PRODUCED WITH FERTILIZER TREATMENTS AS INDICATED.

Plot No.	Pounds of fertilizer applied per acre	Analysis of fertilizer (a)	Yield in pounds per acre					
			1931	1932	1933	1934	Average, 1931-'34	Average, 1932-'34
1	107	21-0-0	.....	20,707	6,133	4,414	.....	10,418
2	100	0-44-0	.....	20,966	6,150	4,390	.....	10,502
3	No treatment	.....	9,995	20,727	6,130	4,022	10,219	10,293
4	190	12-24-12	13,024	22,876	6,980	4,885	11,891	11,514
5	150	15-30-0	12,878	21,537	6,890	5,152	11,614	11,193
6	No treatment	.....	9,921	19,509	5,757	4,082	9,817	9,783
7	200	11-48-0	13,709	21,976	6,933	4,181	11,700	11,030
8	400	11-48-0	.....	22,946	6,727	4,353	.....	11,342

(a) Analysis given here is approximate. See Table I for exact analysis. The first figure represents the percentage of nitrogen, the second the percentage of available phosphoric acid (P₂O₅), and the third the percentage of water soluble potash (K₂O).

per acre; and in 1934, slightly over 4,000. The four-year period afforded an opportunity to study the results secured in a year of high yields, 1932; one year of medium yields, 1931; and two years of low yields, 1933 and 1934.

YIELDS OF FERTILIZED PLOTS COMPARED TO NEAREST UNTREATED PLOTS

The value of a soil treatment cannot be determined by the yield secured but by the difference between the yield of the fertilized and unfertilized plots. Table III gives this difference in pounds of graded potatoes per acre.

The treatment which gave the largest increase in yield consists of a combination of nitrogen and phosphorus. Neither nitrogen alone nor phosphorus alone gave an appreciable increase in any year of the test. A fertilizer with an analysis of 16-30-0, applied at the rate of 150 pounds per acre supplying

22 pounds of nitrogen and 44 pounds of available phosphoric acid (P_2O_5) per acre, gave a consistently high increase over the adjacent untreated plot. This increase amounted to nearly 3,000 pounds per acre in 1931, 2,000 in 1932, over 1,000 in both 1933 and 1934, and an average annual increased yield of 1,812 pounds per acre for the four-year period, 1931-1934.

The 11-48-0 fertilizer applied at the rate of 200 and 400 pounds per acre gave highly increased yields in years of high total yield, 1931 and 1932, but the increased yields were not so

TABLE III.—AVERAGE INCREASE IN YIELD OF FERTILIZED PLOTS OVER THAT OF NEAREST UNTREATED PLOT

Plot No.	Pounds of fertilizer per acre	Analysis of fertilizer (a)	Yield in pounds per acre					
			1931	1932	1933	1934	Average, 1931-'34	Average, 1932-'34
1	107	21-0-0	.....	b -20	3	332	.....	105
2	100	0-44-0	.....	239	20	308	.....	189
4	190	12-24-12	3,029	2,149	850	803	1,658	1,261
5	150	15-30-0	2,957	2,028	1,133	1,130	1,812	1,430
7	200	11-48-0	3,788	2,467	1,176	159	1,898	1,267
8	400	11-48-0	.....	3,437	970	331	.....	1,579

(a) Analysis given here is approximate. See Table I for exact analysis. The first figure represents the percentage of nitrogen, the second the percentage of available phosphoric acid (P_2O_5), and the third the percentage of water soluble potash (K_2O).

(b) The minus sign indicates a lower yield than the nearest untreated plot.

high in years of low total yield, 1933 and 1934. The average increase secured by the use of 200 pounds per acre of 11-48-0 fertilizer was only slightly above that secured by the use of 150 pounds of 15-30-0 over the four-year period, 1931-1934, and less than that secured with the lighter application in the three-year period, 1932-1934. The heaviest application of nitrogen and phosphorus, 400 pounds per acre of 11-48-0, supplying 44 pounds of nitrogen and 192 pounds of available phosphoric acid (P_2O_5) per acre, gave only slightly higher average yield for the three-year period, 1932-1934, than 150 pounds of 15-30-0, and the cost was considerably higher as will be shown later.

Evidently the heavier applications of nitrogen and phosphoric acid; namely, 200 and 400 pounds per acre of 11-48-0 will tend to increase the yield over the lighter application, 150 pounds per acre of 15-30-0, in years of high yield, but not in years of low yield and not to an appreciable extent over a period of years.

The plot which received a complete fertilizer, 12-24-12 at

the rate of 190 pounds per acre, produced only a slightly larger increase over the adjacent untreated plot than did the plot which received 150 pounds of 15-30-0 in any year, and in some years, 1933 and 1934, produced a smaller increase.

Plot 4 which received the complete fertilizer produced an average increased yield for the four-year period of 1,658 pounds per acre over the adjacent untreated plot, while the adjoining plot 5, which received the same amount of nitrogen and phosphoric acid but no potash, produced an increase of 1,812 pounds per acre.

When the yields of plots 4 and 5 are compared directly as shown in Table II, it is found that the plot which received potash made a slightly higher yield than the one which received no potash but the same amount of nitrogen and phosphorus. Since this difference is small, 277 pounds per acre over a four-year period, it may be due to soil variation as is indicated by the difference in yield of the two untreated plots, Nos. 3 and 6. The addition of potash generally does not increase the yield of other crops on Kansas soils.

PROFIT FROM INCREASED YIELD

The profit or loss due to the use of fertilizers of various analyses is given in Table IV. The rate of application is indicated in the left-hand column. The cost of fertilizer was calculated on the basis of current prices in ton lots, f.o.b. Kansas City and Topeka. The cost of picking, grading, sacking, and hauling the increased yield shown in Table III, is calculated at

TABLE IV.—PROFIT OR LOSS DUE TO USE OF COMMERCIAL FERTILIZER CALCULATED ON BASIS OF INCREASED YIELD GIVEN IN TABLE III.

Plot No.	Pounds of fertilizer applied per acre	Analysis of fertilizer (a)	Cost of fertilizer per acre	Profit or loss (—) per A. for each treatment					
				1931	1932	1933	1934	Average, 1931-'34	Average, 1932-'34
1	107	21-0-0	\$ 2.14	\$	\$-2.29	\$-2.12	\$-0.23	\$	\$-1.53
2	100	0-44-0	2.75	....	-1.38	-2.64	-0.98	....	-1.66
4	190	12-24-12	5.17	12.25	7.19	-2.03	-1.71	4.37	1.74
5	150	15-30-0	4.11	12.90	7.55	2.41	2.39	6.31	4.12
7	200	11-48-0	6.13	15.65	8.05	0.63	-5.22	4.79	1.15
8	400	11-48-0	12.26	....	7.51	-6.68	-10.36	....	-3.18

(a) Analysis given here is approximate. See Table I for exact analysis. The first figure represents the percentage of nitrogen, the second the percentage of available phosphoric acid (P₂O₅), and the third the percentage of water soluble potash (K₂O).

17 1/2 cents per hundred pounds. The value of the increased yield was calculated at 75 cents per hundred.

The combination nitrogen and phosphoric acid treatment made a higher net profit each year than any other fertilizer tested. The light application, plot 5, 150 pounds per acre of 15-30-0, made the highest net profit in 1933, 1934, and in the three- and four-year averages. The fertilizer applied to plot 7 carried the same amount of nitrogen as was applied to plot 5 but more than twice as much phosphoric acid (P_2O_5). Plot 7 produced the highest net profit in the years of higher yields, 1931 and 1932. This treatment, however, produced only 63 cents per acre profit in 1933 and caused a loss of \$5.22 per acre in 1934. The heaviest application, 400 pounds of 11-48-0 per acre, produced a profit only one year, 1932, the year of highest total yield. The plants on this plot often evidenced signs of burning. Evidently this treatment is too heavy for the average climatic conditions found in the Kansas river valley.

The potash in the complete fertilizer, used on plot 4, failed to increase the yield over plot 5 sufficiently to pay the increased fertilizer cost in any year. The nitrogen-alone and phosphorus-alone treatments caused a loss each year.

This work indicates that the treatments which show the highest profits are those consisting of a combination of nitrogen and phosphorus when applied at the rate of 150 pounds per acre of 15-30-0, or 200 pounds per acre of 11-48-0. The first treatment gave a net profit each of the four years used, and the second treatment, three of the four years.

GREEN-MANURE CROPS

The majority of the tests reported in this circular were planted following some form of a green-manure crop. The use of soil-improving or green-manure crops is advisable. Commercial fertilizers should not be expected to replace the use of these crops but should be used to supplement them. Definite experimental investigations on the value of various crop sequences and the use of green-manure crops are now being conducted at the Newman potato experiment field. The results of this work will no doubt be available within a few years.

SUMMARY

1. In these tests commercial fertilizers used in the production of potatoes in the Kansas river valley have returned a profit when the correct proportion of nutrients was used and the fertilizer properly applied.

2. A combination of nitrogen and phosphoric acid (P_2O_5) applied at the rate of 150 pounds per acre of 15-30-0 fertilizer, produced a profit more consistently than any other commercial fertilizer tested. This treatment may be secured by applying

200 pounds per acre of fertilizer analyzing 11 per cent N, 22 per cent P_2O_5 , and no K_2O ; 85 pounds of a mixture consisting of 60 pounds of 11-48-0 and 22 pounds of ammonium sulphate; or by applying a mixture of 107 pounds of ammonium sulphate (20.56 per cent N) and 100 pounds of 44 per cent superphosphate per acre.

3. The combination of nitrogen and phosphoric acid at the rate of 200 pounds of 11-48-0 per acre returned the highest profit in years of high yields.

4. Potash did not increase the yield sufficiently to pay the added cost of the fertilizer.

5. Nitrogen alone and phosphoric acid alone caused a loss in each of the three years tested.

6. Commercial fertilizers should be applied in a band on each side but not touching the seed piece.

7. The use of commercial fertilizers should not eliminate the practice of growing green-manure crops in rotation with potatoes.

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OTHER STATION PUBLICATIONS

Other recent publications of the Agricultural Experiment Station of interest to farmers (especially farmers in eastern Kansas) include the following:

Bul. No.

- 238 Corn Production in Kansas. (42 pp., 19 illus.)
- 242 Alfalfa Production in Kansas. (42 pp., 12 illus.)
- 253 Tame Pastures in Kansas. (39 pp., 10 illus.)
- 254 Growing an Orchard in Kansas. (43 pp., 13 illus.)
- 260 Soil Fertility. (59 pp., 21 illus.)
- 265 Sorghum Production in Kansas. (47 pp., 18 illus.)
- 267 Lawns in Kansas. (32 pp., 14 illus.)
- 269 Field Bindweed and Methods of Control. (26 pp., 12 illus.)

Circ. No.

- 122 Poultry Management on the Farm. (50 pp., 19 illus.)
- 144 The Taxation System of Kansas. (24 pp., 1 illus.)
- 148 Farm Dairying. (31 pp., 12 illus.)
- 150 Accounts for Kansas Farms. (35 pp., 4 illus.)
- 163 Korean Lespedeza. (6 pp.)
- 172 Growing Tomatoes in Kansas. (14 pp., 4 illus.)
- 173 Flax Production in Kansas. (16 pp., 3 illus.)

Copies of any of these publications in which the reader may be interested may be secured as long as available by addressing a request to:

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