A STUDY OF THE EFFECTS OF AMOUNTS AND COMPOSITION OF FERTILIZERS ON YIELD AND QUALITY OF POTATOES

THESIS FOR THE DEGREE OF M. S.

JOHN W. SIMS

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A STUDY OF THE EFFECTS OF ACIDS AND COMPOSITION OF FERTILIZERS ON YIELD AND QUALITY OF POTATOES

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John W. Sims

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ACKNOWLEDGMENT

The interest in potato fertilization by the farmers and County Agricultural Agents of the potato growing sections of the State of Michigan caused the selection of this subject. The writer wishes to express his appreciation to these farmers and County Agricultural Agents for their cooperation; and particularly to Dr. L. M. McCool for his valuable suggestions and criticisms.

CONTENTS

A STUDY OF THE EFFECT OF AMOUNTS AND COMPOSITION OF FERTILIZERS ON YIELD AND QUALITY OF POTATOES.

INTRODUCTION

Approximately 300,000 acres of potatoes are grown annually in Michigan. In many counties this crop constitutes the chief cash crop and the economic conditions of such rural sections is directly reflected by the yield and price of potatoes.

The potato grower realizes that his success depends quite largely upon getting a fair to good crop under adverse conditions, hence is vitally interested in any soil treatment that would facilitate such results.

The ten year average per acre yield of potatoes in Michigan for the period ending 1921 was 103 bushels. However, the National Fertilizer Association (2.) in a survey of 100 Michigan potato growers reported that on an average the yield without fertilizer was 115 bushels, per acre while with fertilizer the average yield was 175 bushels.

Potato growing has comparatively a high per acre cost for seed, soil preparation, spraying, harvesting, etc.; so the elements of plant food must be applied in ample amounts, of the proper proportions and from the best sources. Just what the proper amounts are; how the fertilizer should be applied; the optimum percentages of the various necessary elements; and from what sources these nutrients should be derived are still controversial matters, even though a great deal of experimental work has been conducted.

A U. S. report (32) gives the yield of potatoes in various potato growing countries for an average of 4 years (1923-1927 incl.) as follows:

England	233.7	bu. per A.
Germany	194.5	" " "
Poland	178.9	" " "
Sweden	155.9	" " "
Czechoslovakia	153.7	" " "
France	143.4	" " "
U. S.	114.9	" " "
Michigan	103.2	" " "

PLAN OF EXPERIMENT

Since both early and late potatoes are grown commercially in Michigan, the experimental work herein reported was conducted with each. For convenience the results obtained are reported separately. The experiments here reported are comparisons of the nitrogen requirements, nitrogen carriers, potash requirements, amounts to apply, effect of commercial fertilizer on scab and method of applying commercial fertilizers.

Early Potatoes:

From former experimental work with early potatoes, conducted in this and adjoining states, it seemed that a commercial fertilizer approximating a 4-10-6 was best suited for this crop. All fertilizer was applied with a hand drill on a level with and approximately two inches to each side of the potato seed piece. This was done by first turning a furrow with a walking breaking plow, cleaning it out to a width of six inches, applying the fertilizer in two strips approximately five and one-half inches apart and dropping the potato by hand or with a planter.

The plots were laid out one-hundred feet long and three rows in width. Only the middle row however was harvested for experimental results. The rows were three feet apart and the potatoes were spaced approximately fifteen inches apart in the row.

Late Potatoes:

The rows in these plots extended the entire length of the respective fields. The plots were three rows in width, only the middle

row being harvested for experimental results. The rows were three feet apart with the plants approximately eighteen inches apart in the row. The fertilizers were home mixed just before applying, using sulphate of ammonia as the sole carrier of nitrogen, twenty percent superphosphate and muriate of potash. Sand was used as a filler to make the several mixtures up to a standard weight. This was desireable in order that the "set" of the fertilizer attachment might be left as adjusted. The adjustment of the planter was determined by trial on another part of the field. Seven series of plots were harvested in 1929 and two in 1930.

The Soil:

Since the soil type is a major factor in fertilizer studies, the soils selected were those on which potatoes are commonly grown in the state.

The soil types of the fields on which the early potatoes were grown are as follows:

Field Number I Fox sandy loam

" " II Colonia Loamy sand

" " III Bellefountain sandy loam

" " IV " " "

" " V Hillsdale sandy loam

The late potatoes were on soils classified as follows:

Field Number I Kalkaska sandy loam

" " II Lancelona sandy loam

" " III Rosen stony loam

" " IV Onaway loam

" " V Emmett sandy loam

" " VI Onaway loam

" " VII Onaway loam

YIELD OF EARLY POTATOES AND RATE OF FERTILIZER.

Potato prices fluctuate a great deal. This causes the potato grower to increase or decrease the rate of applying fertilizers to the crop according to his idea as to the probable price that he may get for his crop. Since considerable work has been done on the optimum amounts of fertilizer to use per acre on late potatoes under Michigan conditions; this study is with the early varieties.

RATE OF APPLICATION OF FERTILIZERS.

Four fields were included in these studies in 1939. The source of the nitrogen in the mixtures used was two-thirds from sulphate of ammonia and one-third from nitrate of soda. The phosphorus was from 20 percent superphosphate and the potassium from muriate of potash. The results are given in Table I

TABLE I Effect of Rate of Application on the Yield of Early Potatoes. (Results are given in bushels per acre).

Treatment	Field Number 1	2	3	4	Average
4-10-6 at 500#	150.3	165.0	130.6	108.5	138.4
4-10-6 at 1000#	114.8	170.0	157.3	144.5	148.1
4-10-6 at 1500#	100.4	211.2	139.6	130.5	136.3
No Treatment	66.0	144.5	135.7	94.6	107.7

Probably because of the season being so dry, fields 3 and 4 gave a smaller yield with an application of 1500# than with 1000#. On field 1, the plot receiving the 1500# application gave a smaller yield than the plot receiving 500#. No reason for this was noted. Since in normal years more moisture is available, it would appear that a rate of application of 1500# of a fertilizer such as a 4-10-6 would be advisable for early potatoes under Michigan conditions.

The rate of application recommended in various states differs somewhat. Irwinn (27) of Missouri states that a 500# application suits conditions in that state.

White (32) compared amounts ranging from 200 to 1600# per acre applied in the row, using 4-7-3; 4-7-4; and 4-7-8 analysis and three year average results showed decided injury when more than 400# per acre was used.

With a broad cast application however, the amount used with safety can be increased a great deal. This is well illustrated by results secured by Houghland (27) who used much higher amounts. His results summarized are as follows: Using a 7-6-5 mixture, yields for 1000# per acre applied broadcast was 137 bu.; for 1500# - 137 bu.; 2000# - 150 bu.; 2500# - 222.5 bu.; 3000# - 215.5 bu.;

Blair (1) reports distinct injury when using 1000# of 1:-8-16 He fails to state just how the fertilizer was applied.

The amount used depends so much upon how it is applied that it does not seem practicable to recommend amounts without stating how it is to be applied. Potato planters with fertilizer attachments vary a great deal in the placing of fertilizers. Undoubtedly such machinery will be greatly improved in the near future. If so, larger amounts can be recommended with row application.

EFFECTS OF POTASH.

The use of potash is probably receiving more attention among potato growers in Maine than any other element. This is probably because of the high potash requirement of the potato plant and the activity of potash promotional agencies.

RATES OF APPLICATION OF POTASH.

The following table shows results secured in 1920 by using fertilizers containing varying amounts of potash. The fertilizer was made up and applied as explained under "Rate of Application."

TABLE II

The Effect of Different Amounts of Potash on the Yield of Early Potatoes.

Treatment	Field Number 1	2	3	4	5	Average
4-10-6	114.8	176.0	157.3	144.5	139.0	146.3
4-10-12	121.0	176.0	145.7	103.5	176.9	145.2
4-10-18	137.8	155.0	201.7	123.8	139.3	157.3
None	66.0	144.5	135.7	94.6	113.1	108.8

It should be noted that field 2 had received quite heavy applications of potash in previous years. On three of the five fields the mixture which contained 12 percent potash gave the same or less bushels per acre than did the one which contained 6 percent potash, the 18% potash mixture however gave the highest yield in three of the five cases.

If potash is a factor in increasing the resistance of a plant to diseases, then the above results might be explained by the possibility of some fields having more disease than others. All of the above fields except No. 5 were sprayed with Bordeaux mixture for control of diseases as frequently as weather conditions necessitated.

The above results indicate that while potash is essential for early potatoes, possibly the 6 percent when applied at the rate of 1000# per acre is sufficient. At least the increases in yield when more is used were not consistent even though 1920 was comparatively a dry year. (At which time it is thought that potash gives best results.)

TABLE III

The Effect of Different Amounts of Potash on the Yield of Late Potatoes.

Treatment	1	2	3	4	5	6	7	Av.	% Yield No. Treatment as 100%
4-16-4	196.8	75.3	104.1	195.8	286.0	215.2	345.8	202.4	117.5
4-16-8	232.0	95.3	129.1	202.0	279.4	204.2	359.9	223.1	129.6
4-16-16	199.8	75.3	115.6	182.2	330.8	258.5	376.6	228.1	132.4
None	175.6	64.2	101.9	104.5	253.2	216.4	312.7	172.2	100.0

These studies were conducted in 1929 with the fertilizer applied at the rate of 100# per acre in the same manner as explained for Table 5.

The fertilizer containing 8% potash produced marked increases over that having only 4% potash in all except field 5. The 16% potash mixture gave increases over the 8% however in only three of the seven fields. The fields had been manured at from 7 to 14 tons of barnyard manure per acre. While the average yield from the 4-16-16 is slightly higher than that from the 4-16-8, it is not sufficient to warrant its use in preference to the 4-16-8.

TABLE IV.

Comparison of 4% and 8% Potash on the Yield of Late Potatoes (1930)

Treatment	Field Number 1	2	Average	% Yield with no treatment as 100%
None	264.0	379.4	321.7	100.0
4-16-4	405.8	529.2	467.5	131.5
4-16-8	538.2	402.7	470.4	146.2

More moisture was available during the later part of the growing season in 1933 than in 1933. In this test the fertilizer having 8% potash did not yield as well as did the 4%, even though the application was comparatively light.

These results indicate that under Michigan conditions from 4% to 6% potash when applied at the rate of from 500 to 1000# per acre is probably sufficient.

Broom (4) found from 4 to 6% potash to be satisfactory.

Deitz (12) secured marked increases on Long Island with a 5-10-10 as compared with a 5-10-5.

Vanderburg (13) from tests in New York concludes that not more than 5% of potash is justified when combined with 4% of nitrogen and 8% of phosphoric acid.

Wood (24) and associates have shown that from 4 to 6% of potash when combined with 4% nitrogen and 13% phosphoric acid gives best results on late potatoes in Michigan.

Livesay (21) states that under Virginia conditions 5% of potash may be expected to give better results than either 7% or 3% when combined with 7% of ammonia and 7% of phosphoric acid.

New Hampshire (23) tests indicate that 4% of potash is sufficient when used at 1200# per acre combined with 4% ammonia and 6% phosphoric acid.

Comparison of Carriers of Potash.

No effort was made in these studies to compare carriers of potash. Such a comparison has been made by many investigators, some of the results of which are as follows:

Brown (9) secured as good results from muriate as from sulphate of potash on potatoes.

Findlay (14) reports that in dry years there was no difference in results from muriate and sulphate of potash; but in wet years the sulphate was distinctly superior.

Rowland (17) secured slightly better yields with muriate than with sulphate of potash. Both were superior to manure salts.

Jacob (18) reports that in 15 out of 20 tests that sulphate of potash gave better yields than did the muriate.

Rothamsted (40) reports show that the muriate is as good as the sulphate of potash.

Kinsely (33) secured better results with the muriate when using 130# per acre but the sulphate was better when using 520# per acre.

SUPERPHOSPHATE VS COMPLETE FERTILIZER.

Because many potato growers believe that a superphosphate is all that is needed for potatoes where they follow sod and where barnyard manure has been applied to it; it was used alone in six of the seven field tests during 1923. With the exception of field 2, leguminous sods were turned under for the potato crop. The timothy and blue green sod on field 2 was manured before it was plowed.

TABLE V

Comparison of 0-16-0 with Complete Fertilizers.

Treatment	2	3	4	5	6	7	Av.	% yield no treatment as 100%
2-16-8	80.7	118.1	145.7	304.3	275.0	318.1	308.1	120.1
4-16-8	85.3	139.1	302.0	279.4	264.2	333.9	221.3	129.1
4-16-4	76.3	104.1	135.8	283.0	315.2	345.8	295.4	118.5
0-16-0	82.0	95.3	138.7	220.0	264.5	322.3	193.4	114.5
None	64.2	101.9	104.5	233.2	313.4	313.7	171.3	100.0

Pictures from Field No. 1.

Farly Potatoes - No treatment.

Farly Potatoes - 1000# of 4 - 10 - 6.

This table shows a comparison of 0-16-0 with analysis generally recommended in Michigan. Even though the 0-16-0 mixture does show an average increase over no treatment, it does not equal any of the complete mixtures. In fields 3 and 5 the 0-16-0 yielded less than check, probably because of its effect in hastening maturity.

METHOD OF APPLYING FERTILIZER FOR POTATOES.

Just where commercial fertilizer should be placed in relation to the potato seed piece has received considerable attention from investigators during the past several years. Row and broadcast applications have been compared with somewhat variable results.

To be of any importance in reaching conclusions, tests on the method of application of commercial fertilizers, should be conducted on the same field. However using the yield on the check plots as 100%, the 4-16-8 plots on six of the seven fields in 1939 where the fertilizer was applied with the fertilizer attachment on the potato planter averaged 137%. On the one field where the fertilizer was broadcast the potatoes on the 4-16-8 plot yielded 146.4% of the check in the same field. This field (#2) however was in a very low state of fertility.

In 1938 on one field where the fertilizer was broadcast by hand the potatoes on the 4-16-8 plot yielded 145.7% of its check, while on the field where the fertilizer was applied with the planter the potatoes on the 4-16-8 plot yielded 147% of its check.

More difference in favor of the row application is usually secured than the above results give.

Cooper and Rapp (11) report best results secured on potatoes by placing the fertilizer in the row at planting time.

Parker & Mathews (15) conclude that all fertilizer for potatoes should be applied in the row, to either side of the seed piece, rather than above or below it. They believe that much of the fertilizer which is applied broadcast is lost to the potato because of its limited root system.

Hoagland (17) found that delayed applications of fertilizer on potatoes gave less yield than when the fertilizer was applied at planting time.

Jordan & Bircine (19) found only 5% difference in yield of potatoes in favor of row application when comparing it with the broadcast method.

McCool and Assistants (33) report an average of 19 fields with total yields for row application 213.1 bu.; and broadcast, 202.8 bushels per acre.

Rogers (35) got a 5 bushel greater yield as an average of 6 years when top dressing potatoes with sodium nitrate just as they came up rather than mixing it in the row at planting time.

Clinton Brown (21) as an average of 4 years produced 261 bu. when the fertilizer was applied in the row at planting time, as compared with 243 bushels when one-half was applied at planting time and one-half after the potatoes were up.

Cools (34) secured 6 barrels more per acre on plot fertilized in the row than on plots on which the fertilizer had been broadcasted.

Chapman & Hutson ( ) recommend that where possible, the fertilizer be applied at the side and a little lower than the seed piece.

Coe (10) placed 300# of 10-40-10 fertilizer in the following places with the following results:

In direct contact with the seed piece 1[illegible] bushels

Mixed with the soil in the row 1[illegible] Bu.

Above the seed, with soil between 133 "

At side and level with seed piece 175 "

No treatment 64 "

Martin (9) reports that 37% of Ammo-Phos, when applied in the row with a potato planter, greatly inhibited the germination.

Summarizing all results it would seem to be best (if possible) to apply the fertilizer for potatoes at the side of (but not in contact with) the seed piece at planting time.

[illegible]

New nitrogen carriers are being introduced. This promotes the interest that has been manifest for several years as to which carrier of nitrogen is best.

TABLE IV.

A COMPARISON OF NITROGEN CARRIERS ON THE YIELD OF GREEN MOUNTAINS.

Treatment	Field Number 1	2	3	5	Average
4-10-6 -- N 2/3 from $NH_4 (SO_4)2$ & 1/3 $NaNO_3$	114.6	173.0	137.5	139.0	143.5
4-10-6 -- N from $NaNO_3$	133.4	181.1	137.7	133.4	149.4
4-10-6 -- N " $NH_4 (SO_4)$	132.1	184.1	158.7	130.2	153.5
4-10-6 -- N " "Calnitro"	158.0	210.8	172.7	136.5	169.4
None	64.0	144.5	125.7	113.1	112.3

One plot in field four was accidentally destroyed so this field was not included. The fertilizer was applied at the rate of 1000# per acre in the manner described for Table I.

Why did the calnitro plots outyield the others? The ammonium sulphate plots averaged but very little higher than the sodium nitrate. No conclusions can be drawn from these results and perhaps no definite indications can be pointed out except that further comparisons using calnitro should be made.

Results from various sources show a marked lack of agreement as to the best source of nitrogen for potatoes.

Findlay (14) reports that sulphate of ammonia gave best results on potatoes in Scotland.

Brown (3) states that in spite of all general teachings, very satisfactory results were secured from the use of urea as the nitrogen carrier.

Blair (2) reports a New Jersey test which shows but little difference between sodium nitrate, fish refuse and tankage as source of nitrogen. However sulphate of ammonia gave approximately 13% lower yields than any of the others.

Ohio reports (37) giving the average of 30 years comparison of sodium nitrate, oil meal, dried blood, ammonium sulphate, and nitrate of lime shows the following results:

Nitrate of lime	Av. Yield	170.2 bu.
Ammonium Sulphate	" "	157.8 "
Dried Blood	" "	156.3 "
Oil Meal	" "	155.2 "
Nitrate of Soda	" "	157.2 "

These results might have been different if conducted for two or three years only, because of the comparatively slow availability of the organic carriers.

Woods (30) shows but little difference in yields when comparing sources of nitrogen, in Maine for 5 years and states "The sodium nitrate gave no better yields in cold unfavorable seasons than did the sulphate of ammonia."

Cooper & Rapp (11) found that sodium nitrate gave better results than cotton-seed meal in Arkansas.

Martin (21) found in a New Jersey experiment no difference in yields when comparing nitrogen from organic and inorganic sources.

Brown (3) gives results of tests conducted 3 years in Virginia, 2 years in New York, and 3 years in Maine and found no consistent differences in the yield of potatoes when using nitrogen from different sources.

Because of the comparatively high price of nitrogen in commercial fertilizers, potato growers purchase nitrogen very cautiously. Many times too little is used.

Rate of Application of Nitrogen:

The percentage of nitrogen in the fertilizer mixture was varied on both early and late potatoes.

On the early potato fields, all fertilizer carried 10% phosphoric acid (P_2O_5) and 12% potash. Two-thirds of the nitrogen was derived from sulphate of ammonia and one-third from nitrate of soda. The fertilizer was uniformly applied at 1000# per acre. Due to an accident to a few of the plots on one of the fields, it is not reported here.

THE EFFECT OF DIFFERENT RATES OF FERTILIZER ON THE YIELD OF EARLY POTATOES.

Treatment	Field Number 1	2	3	5	Average
4-10-12	131.0	175.0	141.7	176.9	154.4
6-10-12	156.2	201.3	154.0	142.1	155.4
8-10-12	154.0	169.6	150.3	200.5	173.5
None	66.0	144.5	143.7	113.1	112.3

Results are given in bushels per acre.

It is to be noted that only in case of field 5 did the plot which received a mixture carrying 6% of nitrogen outyield that which received a fertilizer carrying 8% of nitrogen. This increase however was so great that it brought the average of the plots receiving 8% of nitrogen approximately 10 bushels higher than the plots receiving 6% of nitrogen. The error is probably on the plot receiving the 6-10-12 in field 5. The yield on this plot was unexplainably low. The top growth of the potatoes with the higher nitrogen application was much greater. Probably there was too much top growth for the moisture supply in the later stages of growth, since the rainfall was considerably less than normal.

Similar studies were conducted with late potatoes. Only sulphate of ammonia was used as the source of nitrogen in the fertilizer mixtures employed. The fertilizer was applied with the fertilizer attachment on the potato planter at the rate of 300 per acre, except field two, here the same amount was applied by the hand broadcast method and dragged in with a spring tooth harrow before planting.

Pictures from Field No. 1.

Early Potatoes - 1000# of 6 - 10 - 15.

Early Potatoes- No Treatment and 1000# of 4 - 10 - 15 compared.

TABLE VIII

THE EFFECT OF DIFFERENT RATIOS OF NITROGEN ON THE YIELD OF LATE POTATOES (1930).

Treatment	1	2	3	4	5	6	7	Av.	% yield no treatment as 100%
2-10-8	219.8	80.7	116.1	146.7	304.3	275.0	312.1	206.8	120.1
4-10-8	252.0	95.3	129.1	202.0	279.4	264.2	353.9	233.1	139.1
6-10-8	239.0	91.7	150.7	199.3	258.7	303.2	331.7	218.6	126.9
None	175.1	64.3	101.9	104.3	235.2	213.4	311.7	173.2	100

All fields showed a decrease in yield when the nitrogen was increased from 4% to 6% except 5 and 6. It would seem that for high rainfall conditions, the proportion of nitrogen in a 6-10-8 is too high for late potatoes.

Table 4 gives results of a comparison of 2% and 4% nitrogen on two fields in 1929. It was because of these average results that the nitrogen was raised to 6% in 1930.

TABLE IX.

Comparison of 2% and 4% Nitrogen on Late Potatoes (1930).

Treatment	Field Number 1	2	Average	% yield with no treatment 100%
None	264.0	379.4	321.7	100
2-10-8	381.2	544.5	462.8	144.9
4-10-8	348.2	553.7	470.4	146.2

The 500% application was applied with the fertilizer attachment on field one and broadcast on field two.

From these results, fertilizer applied at the rate of from 500 to 800% per acre in the hill should contain approximately 4% nitro

for Michigan conditions on late potatoes. On early potatoes somewhat higher applications will probably pay best with the same or slightly higher percentage of nitrogen.

In this state the field being prepared for potatoes is usually a sod which has had from eight to fifteen tons of barnyard manure applied per acre.

Winn (37) found that under Missouri conditions two or three percent of nitrogen at the rate of 400# to 600# per acre gave very satisfactory results.

Slate & Brown (30) as a result of 4 years experimental work in Connecticut concluded that on fields which had been manured the complete fertilizer should carry 6% ammonia and on run down fields 8% ammonia. They recommend 2000# applications but do not state how the applications are to be made.

[illegible]

In many sections of Michigan, scab on potatoes, especially early potatoes, is becoming very serious even though the seed has been treated with the various preventatives.

Field I of the early potatoes had been in late potatoes the previous year and scabby seed was used although it had been quite carefully treated with corrosive sublimate. Practically all of the potatoes harvested had some scab but those from some plots were affected a great deal more than others. Weights were taken of the potatoes on the plots which were treated with the different nitrogen carriers.

The potatoes on which the scab was so serious as to lower the market grade were weighed and percentages calculated.

TABLE X.

The Effect of the Source of Nitrogen in Commercial Fertilizers on Scab of Early Potatoes.

N. Carrier	Percent sufficiently scabby to lower grade
Sulphate of Ammonia	26 %
Nitrate of Soda	70 %
Calnitro	45 %
2/3 Sul. of A. & 1/3 Nit. of Soda	44 %

It appears from this that conditions may be such that the alkalinity of the fertilizer used may be of a sufficient factor to promote conditions for scab development. The other fields showed no difference in this respect. Investigators have found various factors where the amount of scab may have been affected by the source of fertilizer elements.

Deisz (18) states that from one years results the amount of potash may have some effect on scab and other diseases of potatoes. Where more potash was used less disease was evident.

Lint (20) recommends the use of 300# of sulphur broadcast on the soil either before or after planting to control scab of potatoes.

Martin (21) reports that increased scab accompanied the extensive use of sodium nitrate.

White (33) reports more scab on plots on which lime had been applied just previous to planting.

Pictures from Field No. 3.

Early Potatoes - no Treatment.

Early Potatoes - 1000# of 4 - 10 - 6.

ECONOMICAL USE OF POTATO FERTILIZATION.

According to a survey conducted by the National Fertilizer Association, Michigan potato growers use approximately 18,000 tons of fertilizer on potatoes annually.

Experiment Station recommendation for fertilizer on potatoes is 400 or more per acre. Since there is 300,000 acres of potatoes grown annually, growers should be using 60,000 tons of fertilizer on it, that is if only the minimum amount recommended were used. Would the consumption of this amount of commercial fertilizer result in profits to the potato growers? In order to answer the question it is necessary to consider the increase in yields resulting in the application of the fertilizers to the soil, the market price of the crop and the cost of the fertilizer and others.

TABLE II

Economy of Fertilizers on Early Potatoes.

Treatment	Bu. Increase	Cost of Fertilizer	Return above cost with potatoes at variable values				
			50¢	75¢	$1.00	$1.25	$1.50
4-10-6 @ 500'	31.6	11.85	-$0.05	$3.87	$11.77	$17.67	$23.57
" @ 1000'	39.3	23.35	- 4.00	5.62	15.55	25.47	35.39
" @ 1500'	57.3	35.48	- 6.75	7.34	22.02	36.69	50.76
4-10-12 @ 1000'	36.4	27.40	* 9.30	-0.10	9.00	18.10	27.20
4-10-12 @ 1000'	46.5	31.15	- 6.90	5.22	17.35	29.47	41.59
6-10-12 @ "	54.6	30.85	- 3.35	10.10	23.75	37.40	51.05
8-10-12 @ "	64.7	34.30	- 1.95	14.33	30.40	46.37	62.74

All data are given on the per acre basis. If early potatoes were worth only 50¢ per bushel every treatment showed a loss, which the higher potash treatments showing the larger losses. However this being a dry season the increases in yield were lower than they would have been in a normal year. In general, such a low price would have prevailed only in a year when yields were higher. Had yield been higher it would have been caused by more favorable weather conditions which in turn would have given larger increases from the use of fertilizer. This year the early potatoes sold by the growers on whose farms the tests were conducted ranged from $1.25 to $3.00 per bushel.

According to a recent crop report for Michigan the average farm price for potatoes for the last 20 years on August 15th, was $1.25 per bushel. The lowest August 15th per bushel price during this period was 43¢ in 1915, and the highest price was $3.01 in 1920. The average price on September 15th for the same period was $1.04 per bushel. The highest price on this date during the twenty years was $2.12 per bushel in 1919, and the lowest price was 42¢ in 1915. Considering either average or the prices for this year, all fertilizer treatments gave very substantial increases in profit.

TABLE XII.

Economy of Fertilizers on Late Potatoes.

600# per A. Treatment	Av. Increase	Cost of Fertilizer	Returns above cost with potatoes at variable values				
			.40	.70	1.00	1.30	1.60
3-12-6	54.6	14.46	-0.83	9.76	20.14	30.52	40.90
4-12-8	56.9	15.52	1.84	13.11	24.38	49.65	64.92
6-12-6	46.4	14.69	-0.03	13.29	17.61	31.73	45.85
4-16-4	58.2	15.03	-2.35	6.11	15.17	24.23	33.29
4-12-12	57.9	19.53	2.54	13.01	23.48	33.15	42.82
0-12-0	34.4	8.20	1.53	8.88	17.20	23.53	30.84

These results indicate that the 4-16-8 is the most reliable mixture when used at 700# per acre. More nitrogen or more potash showing greater possibilities of loss when potatoes are cheap.

The average price for potatoes in Michigan for the past 20 years was 73¢ per bushel on Nov. 15th. The lowest price being 31¢ in 1 10 and the highest price was $1.71 in 1925. At the average November price there is but little difference in the income above cost between the 4-16-8 and 4-16-16 fertilizers. The average price for Feb. 15th for the past 20 years was 85¢ per bushel; with 31¢ being the lowest Feb. 15th price in 1915; and $2.07 the highest, in 1920.

It is safe, from these results, to conclude that commercial fertilizers, when used according to recommendations by the Soils Department of the Experimental Station, make a good investment for the potato farmers of Michigan.

At average prices which have prevailed for the past twenty years; every dollar spent for recommended analysis will return two dollars or more according to the results obtained above. It is also well to remember that these results were secured in a comparatively dry year. Had the season been normal, there would undoubtedly have been larger increases from the use of commercial fertilizers.

In the data given above the entire cost of the commercial fertilizers is charged to the potato crop. It is evident that this is unfair because there will be a residual effect of the fertilizers on succeeding crops. Just what percentage of the value of the fertilizers should be charged to the succeeding crops is variable. The soil, amount and distribution of rainfall, the crop, what nutrients the fertilizer

contains and the carriers used are also the factors affecting the residual value of the fertilizer.

Voelcker & Hall (41) give what they term a rough approximation of the residual value of commercial fertilizers as follows:

	Part still in the soil after 1st Crop	2nd Crop	3rd Crop
Superphosphate	2/3	1/3	1/9
Kainet & potash salts	1/2	1/4	
Sul. of Am. -Nit. of Soda			
Nit. of Lime - cyanamide			
Dried blood	-- nothing		

Riddell (43) in making recommendations as to the unused value of commercial fertilizers quotes the soils section as follows:

"In case readily available fertilizer other than nitrogen is applied at the rate of from 150 to 250 pounds per acre, the tenant shall be recompensed at the rate of 40 per cent of his share of the purchase price after the first crop year, 20 per cent after the second crop year and 10 per cent after the third crop year. In case larger applications are used, recompense should be made at the rate of 50 per cent, 25 per cent and 15 per cent, or more, of his share of the purchase price after the first, second, and third crop year respectively."

"Mixed fertilizers containing nitrogen in addition to other plant food elements shall have $9.00 per ton deducted from the purchase price for each two units of ammonia. Recompense for the remaining plant food shall be based on the remainder of the purchase price at the rates specified in the preceding paragraph.

"If a nitrogen fertilizer alone, such as sulphate of ammonia or nitrate of soda is used no recompense shall be given after the first crop year."

SUMMARY.

1. Both early and late potatoes were grown on various potato soil types. The yields with varying amounts of complete fertilizers as well as varying amounts of the different nutrients was noted.

2. The amount of fertilizer giving best results depended somewhat upon method of application. On early potatoes, as much as 1500# of a 4-10-6 mixture gave good returns.

3. A fertilizer mixture containing 6% potash when applied at 1000# or more per acre was the most economical mixture; when combined with 4% nitrogen and 10% phosphoric acid (P_2O_5) on early potatoes. On late potatoes 6% potash was sufficient when applied at the rate of 800# per acre and combined with 4% nitrogen and 10% phosphoric acid.

4. The superphosphate when used alone did not give satisfactory results.

5. Nitrogen from calnitro gave best results when compared with sulphate of ammonia and nitrate of soda. Nevertheless studies are not sufficient to warrant such conclusions in general.

6. On early potatoes as much as 6% of readily available nitrogen may profitably be used when combined with 10% of phosphoric acid and 12% of potash and applied at 1000# per acre. On late potatoes a fertilizer mixture containing 4% nitrogen gave most economical results when applied at the rate of 800# per acre and combined with 10% phosphoric acid and 6% potash.

7. On one field, much less scab was developed on plots receiving nitrogen from sulphate of ammonia than on plots where the nitrogen was derived from an alkaline carrier.

8. Using twenty year average prices for early potatoes at harvest time; the value of the increased yields secured from fertilizers ranged from $17.67 to $46.57 per acre, above the cost of the fertilizer. On late potatoes this same value of increase over cost ranged from $6.11 to $19.31 per acre.

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