FERTILIZER AND NUTRITION STUDIES WITH POTATOES IN THE RED RIVER VALLEY OF MANITOBA

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by

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INTRODUCTION

The average annual acreage sown to potatoes in Manitoba during the period 1937 to 1947 was 30,050. The average yield per acre during this period was 112.6 bushels. Of the total acreage sown to potatoes, it is estimated that nearly fifty per cent was on the heavy Red River clay in the vicinity of Winnipeg. In certain areas of this soil region, the average yield in 1946 was reported to be as low as 60 bushels per acre.

Undoubtedly there are many factors contributing to this low yield. Some of these factors are believed to be associated with the availability of, and the relationship between nitrogen, phosphorus, and potassium. While some data from fertilizer experiments are available, the information covers only a period of a few years. In 1944 and 1945, L. A. Yager (40) conducted fertilizer trials at the University of Manitoba. These experiments yielded somewhat inconclusive and inconsistent results. Thus, in an effort to obtain further experimental data on which to base fertilizer recommendations for potatoes in the Red River Valley of Manitoba, fertilizer trials were carried out over a period of two years as a continuation of Yager's work.

Cooking quality of potato tubers is a factor that is of great importance wherever potatoes are grown. In the United States and in some European countries, evidence has been presented indicating that fertilizer applications have affected the quality of potatoes. No experimental work has been carried out to determine the effects of fertilizer on the quality of potatoes in Manitoba. In order to study these effects, an experiment was conducted to determine the relationship that might exist between applications of fertilizers and quality of potatoes.

To evaluate the nutritional requirements of plants, a knowledge of the symptoms due to certain element deficiencies is a distinct advantage. It has been observed that deficiency symptoms in one species frequently differ from those in another. Though considerable work has been carried out in determining these symptoms in various plants, very little has been done to determine the symptoms in potato plants in Manitoba. A study was conducted with the object of determining the major and some of the minor element deficiency symptoms in potato plants.

REVIEW OF LITERATURE

Ellis (15, 16, 17), between the years 1930 and 1932, carried out a series of fertilizer experiments in the principal potato growing areas of Manitoba. He found significant yield responses from applications of a complete NPK fertilizer with a ratio of 1-3-1, of triple superphosphate, and of ammonium phosphate. The results were not entirely conclusive due to the dry weather conditions and to the grasshopper damages during that period. Yager (40) in 1944 and again in 1945 conducted fertilizer experiments to ascertain the nitrogen, phosphorus, and potassium requirements for potatoes in the Red River Valley. He concluded that nitrogen was the limiting factor during 1944 when abundant moisture prevailed. Potatoes responded to applications of phosphorus during the drier season of 1945 but not to potassium. Potassium in combination with phosphorus, and nitrogen in combination with potassium or phosphorus resulted in a significant increase in yield. He found that in 1945, nitrogen applied in the form of ammonium sulphate (20-0-0) at 140 to 270 pounds per acre and triple superphosphate (0-38-0) at 284 pounds per acre gave the greatest yield responses.

Carolus (7) and Chucka *et al*. (9) noted that potato plants absorb 70 per cent of their total consumption of plant nutrients between 50 and 80 days after planting. This agrees with the results obtained by Brasher (3) who found that if fertilizer applications were delayed after planting the yield decreased significantly. Much work has been done to determine the best sources of the three main elements, nitrogen, phosphorus, and potassium, in the fertilizer. Brown (4) has found that ammonium nitrate to be the best source of nitrogen for potatoes. Cox and Odland (11), on the other hand, found ammonium sulphate to be the best source of nitrogen on well limed plots. Gericke (20) noted that mineral phosphorus rather than organic phosphorus gave the higher yield. Smith and Nash (34) found that soils of high pH require larger amounts of phosphorus. Smith (38) found that response to phosphate is greater on heavier soils than on lighter soils. Cox and Odland (11) found that triple superphosphate was the best source of phosphorus. Smith (36) reporting from the work done by Singh and Mehta states that potassium had no effect on yield. Cox and Odland (11) found that muriate of potash tended to depress the yield much more than sulphate of potash.

Campbell et al. (6), Cummings and Houghland (12) and Smith et al. (39) agree that fertilizer placements in bands two inches to each side of and on the lower level of the seed pieces result in consistently higher yield.

Smith (33) concluded that in Manitoba a twelve inch spacing for Warba and a fifteen inch spacing for Irish Cobbler gave the highest yield. Hardenburg (23) and Smith _et al_. (39) obtained similar results at Cornell. They found that twelve to fourteen inch spacings gave the highest yields.

Lorenz (28) investigating the effects of depth of seed piece placement found that four to six inch depth gave the greatest yield. He noted that the size of the tubers increased with depth of seed placement and that the number of tubers decreased with depth. When the seed pieces were placed at a depth of two inches, he observed the largest number of sunburned tubers.

Quality

Rinear (32) has found that mealiness is the one outstanding quality preferred by the consumers. Hotchkiss _et al_. (25) from their two years' survey in the eastern United States concluded that mealiness was the cooking character considered most desirable by both household and institutional buyers. Child and Willaman (8) noted that high dry matter tended to be accompanied by better texture. Cobb (10) associated good cooking quality with high starch content and high dry matter content of the tuber. Nash (30) had found a high correlation between texture and specific gravity and starch content. Akeley and Stevenson (1) and Blood and Haddock (2) used sodium chloride solutions with specific gravity ranging from 1.060 to 1.115 at intervals of .005 to determine the specific gravity of the potato tubers. The tuber was considered to have the specific gravity of the solution in which it barely floated. By using this method of determining specific gravity, these workers found it possible to estimate with a fair degree of accuracy the starch content of the tuber.

Lorenz (27) and Smith (37) reported that increased applications of nitrogen decreased the specific gravity of the potato tuber. Dunn and Nylund (13) found that in the Red River Valley of Minnesota increased applications of nitrogen had no apparent effect on the specific gravity of the tuber. Smith and Nash (35) found that low potassium with high nitrogen gave the highest specific gravity.

Several workers (2, 13, 14) agree that increased applications of phosphorus increased very slighly the specific gravity of the tubers.

Potassium has been reported by some workers (2, 13, 14, 37) to decrease the specific gravity of the tuber. Neil and Whittemore (31) in testing cooking quality found that high potassium gave a more mealy potato.

Nutritional Deficiency Symptoms

Though Miller (29) has reported many investigations have been conducted in determining the deficiency symptoms in various plants, relatively little work has been done to determine the nutritional deficiency symptoms in the potato plant. Hambidge (22) has made a comprehensive study on the deficiency symptoms in potato plants. He has observed the symptoms due to deficiencies of nitrogen, phosphorus, potassium, boron, magnesium, calcium, manganese, sulphur, iron, copper, and zinc in potato plants.

Laurie and Wagner (26) have devised a suitable method of determining the nutritional deficiency symptoms in greenhouse plants. By using a sand culture technique and irrigating with appropriate nutrient solutions, they were able to develope the causes of the various nutrient deficiency symptoms. This technique is adaptable to any class of plants.

MATERIALS AND METHODS

I Fertilizer experiment

A field plot design was set up to study the effects of the three main elements, nitrogen, phosphate, and potash, in all possible combinations at three levels of treatment. This gave 27 treatments which were set up in a factorial design as a 3 x 3 x 3 confounded experiment, as outlined by Goulden (21), Fisher (19) and Yates (41).

In this investigation, the three fertilizer components studied, nitrogen (N), phosphate (P_2O_5), and potash (K_2O) will be referred to by means of the symbols N, P, and K respectively and the three levels of the treatment by means of numerical subscripts. Thus, $N_0P_0K_0$ refers to no fertilizer applications; $N_1P_1K_1$ to the first level of N, of P, and of K; and $N_2P_2K_2$ to the second level of N, of P, and of K. Since in all fertilizer work the sequence NPK is always followed, the abbreviations will be omitted here and only the subscripts used. Thus 102 in the text will refer to N at the first level, absence of P, and K at the second level, i.e. $N_1P_0K_2$.

From the recommendations made by Ellis, the basic or 111 level of NPK application for 1946 was calculated so that the N:P:K ratio would be 1:3:1. The rate of fertilizer application was based to some extent on the work done by Yager (40) and on the recommendations made by Ellis. For 1946 the basic rate of N was set at 140 pounds of 20 per cent ammonium sulphate per acre, of P at 237 pounds of 28 per cent triple superphosphate per acre, and of K at 50 pounds of 60 per cent muriate of potash per acre. Thus, treatment 111, carrying 28 pounds of N, 90 pounds of P, and 30 pounds of K, was applied at the rate of 427 pounds per acre. This basic treatment was equivalent to approximately 333 pounds of 9:27:9 per acre. The ratios and rates of the elements applied to the complete experiment are found in Table 1.

The cultural practices recommended for Manitoba were followed. The seed pieces were approximately two ounces in size and placed twelve to fifteen inches apart in a furrow as recommended by Smith (33) and were placed three to four inches deep as suggested by the Manitoba Potato Committee (18). Since many workers (5, 6, 12, 39) had found the equal-depth band to be the most effective method of applying fertilizer, the applications were made in equal-depth bands on each side of and about two inches away from the seed pieces by means of a seeder adapted with a fertilizer attachment.

The plots were located on fairly well drained clay textured black-earth soils which may be considered typical of the Red River Valley. The plots were summer fallowed

TABLE I

RATES OF APPLICATIONS
OF THE FERTILIZER ELEMENTS AND THE COMBINATIONS
USED AT THE VARIOUS LEVELS IN 1946 AND 1947

	Applications in pounds per acre			
Levels of N P K	Nitrogen* (N)	Phosphate* (P_2O_5)	Potash* (K_2O)	Total fertilizer applied
0 0 0	--	--	--	---
1 0 0	28	--	--	140
2 0 0	56	--	--	280
0 1 0	--	90	--	237
1 1 0	28	90	--	377
2 1 0	56	90	--	517
0 2 0	--	180	--	474
1 2 0	28	180	--	614
2 2 0	56	180	--	754
0 0 1	--	--	30	50
1 0 1	28	--	30	190
2 0 1	56	--	30	330
0 1 1	--	90	30	287
1 1 1	28	90	30	427
2 1 1	56	90	30	567
0 2 1	--	180	30	524
1 2 1	28	180	30	664
2 2 1	56	180	30	804
0 0 2	--	--	60	100
1 0 2	28	--	60	240
2 0 2	56	--	60	380
0 1 2	--	90	60	337
1 1 2	28	90	60	477
2 1 2	56	90	60	617
0 2 2	--	180	60	574
1 2 2	28	180	60	714
2 2 2	56	180	60	854

* The figures used here were calculated from the analysis of the fertilizers used. These were as follows: ammonium sulphate - 20 per cent N; triple superphosphate - 38 per cent P_2O_5; and potassium chloride - 60 per cent K_2O.

the year previous to planting to potatoes.

The rows were 33 feet long and were spaced three feet apart. Each row or treatment plot contained 26 hills. Each of the four replicates were composed of 27 rows or treatment plots.

Total and marketable tuber yields were taken from 24 hills of each treatment. Those tubers which were larger than two inches in diameter were considered as being marketable.

During the growing season, three applications of calcium arsenate plus copper sulphate were applied to control Colorado potato beetles and leaf hoppers and to guard against late blight.

Foundation A Warba seed was used in 1946. This is one of the early maturing varieties recommended in the province. Certified Irish Cobbler seed was used in 1947. This variety constitutes the largest proportion of the potatoes grown in Manitoba. The availability of good seed was a factor considered in the selection of the variety in each year. The ratios and rates of fertilizer application, the method of fertilizer application, the plot sizes, and the cultural practices for 1947 were the same as for 1946.

II Effect of fertilizers on quality of potatoes

The specific gravity method as outlined by various workers (1, 2) to determine the quality of the tubers was used. Sodium chloride solutions ranging in specific gravity from 1.060 to 1.120 at intervals of 0.005 were used. A sample of forty tubers of marketable size picked at random from each plot at the time of harvest was used in the determination of specific gravity of the tubers.

III Nutritional deficiency symptoms

The method used by Laurie and Wagner (26) was followed in determining the deficiency symptoms in the potato plants. Nine different nutrient solutions each deficient in one of the following elements; nitrogen, phosphorus, potassium, boron, calcium, iron, magnesium, manganese, and sulphur, were prepared. A complete nutrient solution containing all of the above elements was also prepared. A check solution of distilled water was included. These solutions were prepared according to Tables II and III. Distilled water was used in the preparation of the stock solutions and the nutrient solutions. The eleven treatments were carried out in four replicates. The young transplants were watered with distilled water for the first day.

The potato plants for the experiment were prepared by removing the eyes from tubers with a potato baller. The eyes were then planted in a light soil mixture. When the shoots were one-half inch in length and had developed a good root system, they were severed from the tubers (Figures 1 and 2), and planted in the sand media. This method of planting only the shoots with the roots minimized the carry-over of the elements contained in the tubers.

The nutrient solutions were given to each plant twice per week. Every two weeks the sand was flushed with distilled water.

When the nutrient deficiency symptoms were noticed, the resultes were recorded in Kodachrome and compared to the characteristics of the plants receiving a complete nutrient solution.

TABLE II

AMOUNTS OF CHEMICALS USED
TO PREPARE THE STOCK SOLUTIONS

Chemical	Grams per litre
KH_2PO_4	68.10
$CaCl_2$	55.50
$Ca(NO_3)_2.4H_2O$	118.10
$MgSO_4.7H_2O$	123.25
$MnSO_4.4H_2O$	5.00
$FeSO_4.7H_2O$	20.00
H_3BO_3	10.00
KCl	37.03
$NaH_2PO_4.H_2O$	69.03
$(NH_4)_2SO_4$	66.07
Na_2SO_4	71.08
$MgCl.6H_2O$	83.95
$MnCl.6H_2O$	3.64
$FePO_4.H_2O$	15.48

TABLE III

COMBINATIONS AND PROPORTIONS OF THE STOCK SOLUTIONS USED TO PREPARE THE REQUIRED NUTRIENT DEFICIENT SOLUTIONS.

Millilitre of stock solution per litre of nutrient solution.

Stock Solution	Check	Complete	Minus N	Minus P	Minus K	Minus B	Minus Ca	Minus Fe	Minus Mg	Minus Mn	Minus S
KH_2PO_4	--	12.66	12.66	--	--	12.66	12.66	12.66	12.66	12.66	12.66
$CaCl_2$	--	2.92	2.92	2.92	2.92	2.92	--	2.92	2.92	2.92	2.92
$Ca(NO_3)_2 \cdot 4H_2O$	--	11.68	--	11.68	11.68	11.68	--	11.68	11.68	11.68	11.68
$MgSO_4 \cdot 7H_2O$	--	4.74	4.74	4.74	4.74	4,74	4.74	4.74	--	4.74	--
$MnSO_4 \cdot 4H_2O$	--	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	--	--
$FeSO_4 \cdot 7H_2O$	--	1.46	1.46	1.46	1.46	1.46	1.46	--	1.46	1.46	--
H_3BO_3	--	0.18	0.18	0.18	0.18	--	0.18	0.18	0.18	0.18	0.18
KCl	--	--	--	6.88	--	--	--	--	--	--	--
$NaH_2PO_4 \cdot 2H_2O$	--	--	--	--	12.83	--	--	--	--	--	--
$(NH_4)_2 \cdot SO_4$	--	--	--	--	--	--	6.53	--	--	--	--
Na_2SO_4	--	--	--	--	--	--	--	--	2.73	--	--
$MgCl \cdot 6H_2O$	--	--	--	--	--	--	--	--	--	--	1.15
$MnCl \cdot 4H_2O$	--	--	--	--	--	--	--	--	--	--	0.43
$FePO_4 \cdot H_2O$	--	--	--	--	--	--	--	--	--	--	1.13

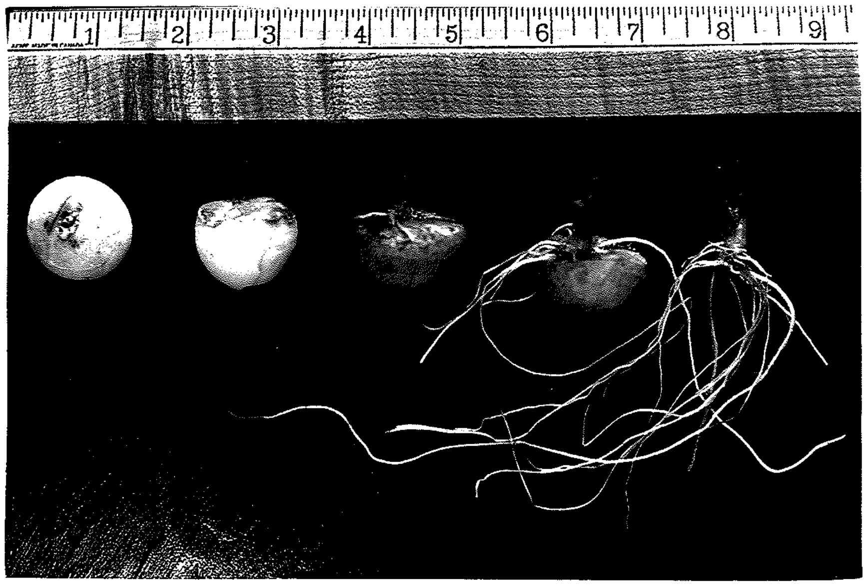

PLATE 1 The stages showing the development of the potato eye for use in the nutrient deficiency studies. The shoot with the roots was detached as shown on the extreme right.

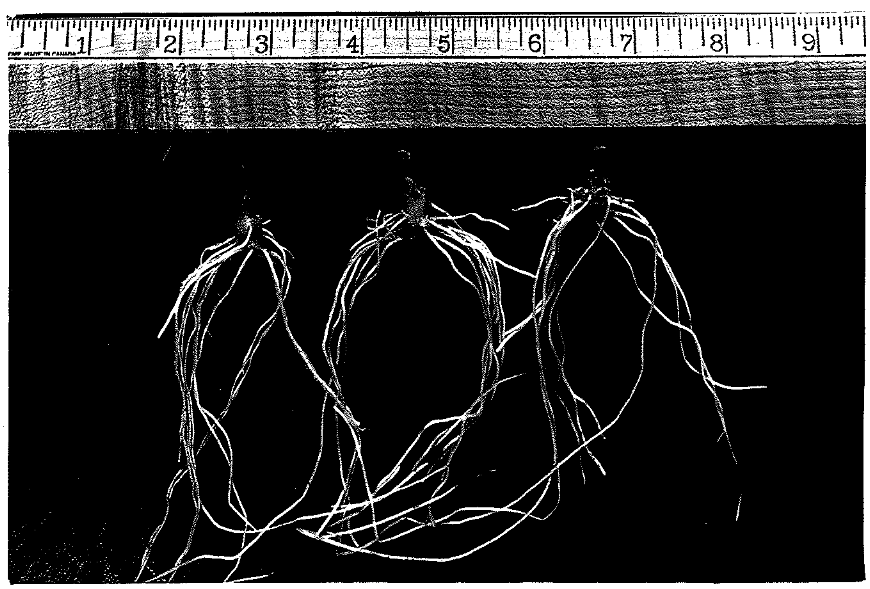

PLATE 2 The stage showing the shoots with the roots just previous to planting in the sand media.

RESULTS AND DISCUSSION

I Observations on the general growing conditions

The 1946 growing season began with very little moisture in the soil. During April and May, the precipitation was 34 per cent of the normal for the two months. For this reason, the seed pieces remained dormant until the end of June when some rain fell to provide sufficient moisture to promote growth. Throughout the balance of the growing season, precipitation continued below normal (Table IV). In view of the fact that the potato plant has its maximum intake of nutrients between the 50th and 80th day after planting (7, 9), this deficiency of moisture was no doubt an important factor in the development of the plants. The plants in the plots receiving the nitrogen treatments were darker green in color than those in plots receiving no nitrogen. Plants in plots receiving phosphorus and potassium did not differ from those in the check plots. No differences were observed in the maturity of the vines. The plants in all plots were generally small and poorly developed.

The 1947 growing season was more representative of a normal growing season. Though May had only 40 per cent of the normal rainfall, there was sufficient moisture carried over from April which month had slightly more

TABLE IV

WINNIPEG WEATHER RECORDS*
FOR THE YEARS 1946 AND 1947 COMPARED TO THE NORMAL

	Precipitation (inches)			Mean monthly temperatures (degrees Fahrenheit)					
	Normal	1946	1947	Normal		1946		1947	
				Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
April	1.32	0.64	1.35	27.2	48.0	32.5	55.7	26.3	44.4
May	2.21	0.58	0.85	39.7	64.3	37.9	62.9	35.0	57.5
June	3.07	2.62	3.68	50.4	73.7	48.8	72.8	50.1	70.4
July	2.92	1.51	2.94	55.2	78.8	56.5	80.5	58.1	81.7
August	2.45	2.13	4.53	52.2	76.2	52.8	75.5	57.9	78.3
September	2.20	3.22	0.85	43.0	65.4	43.3	64.9	41.9	64.4

* Official records compiled by the Meterological Division, Department of Transport.

rainfall than the normal. Top growth of the plants was excessive and very rank. Differences due to treatments were not seen in the plants nor in the maturity of the vines. This may have been due to the high availability of nutrients due to the abundant supply of moisture.

II <u>Fertilizer experiment</u>

A Chi-square test as described by Hayes and Immer (24) was applied to test the homogeneity of the calculated error variances of the experiments in 1946 and 1947. This test showed that the variances were homogeneous and it was legitimate to combine the yield data for the two years.

The mean total yield for each treatment combination for the two years is given in Table V. An analysis of variance for these data reveals a significant response to N and to P but not to K (Table VI). The mean total yield resulting from each element is given in Table VII. When the level was increased from N_0 to N_1, yield increased significantly from 385.4 to 399.5 bushels per acre. Increasing the level to N_2 decreased the yield to 399.4 bushels (Table VII). The highest yield was reached when treatment N_1 was used. Applications below and above this level resulted in a lower yield (Figure I). Thus, N applied at the rate of approximately 140 pounds of ammonium sulphate (20-0-0) per acre gave the highest yield.

When the level of P was increased from P_0 to P_2, yield increased from 383.5 to 396.7 bushels per acre (Table VII). This significant increase is shown in Figure 2 as a solid line. A dotted line joins the yield of P_1 with yields of P_0 and P_2. This intermediate point lies close to the solid line. Yield increased with increase in levels of P, until at P_2 a yield of 396.7 bushels was reached. Thus, P applied at the rate of approximately 474 pounds of triple superphosphate (0-38-0) per acre gave the highest yield.

A significant P x year interaction is shown in Table VI. This indicates that yield reacted differently to P in each year. From the yield data for 1946 and 1947, it may be seen that an increase in P resulted in no increase or a slight decrease in yield in 1946 and in a significant increase in 1947 (Figure 3). Thus, yield responded to P in the normal season of 1947 but not in the drier season of 1946.

TABLE V

YIELDS IN BUSHELS PER ACRE FOR EACH TREATMENT COMBINATION, 1946 AND 1947 COMBINED (TOTAL AND MARKETABLE YIELDS IN LEFT AND RIGHT COLUMNS RESPECTIVELY)

		K_0			K_1			K_2	
N_0	P_0	370.6	328.7	:	392.2	340.3	:	384.5	334.0
	P_1	407.7	330.4	:	366.2	327.2	:	383.3	350.9
	P_2	392.8	330.2	:	384.9	337.8	:	386.8	348.6
N_1	P_0	392.6	344.4	:	361.8	324.3	:	399.6	335.2
	P_1	404.2	345.4	:	401.0	346.1	:	410.7	358.4
	P_2	401.5	340.4	:	405.2	351.9	:	419.5	362.5
N_2	P_0	375.2	332.5	:	371.6	324.9	:	403.5	354.7
	P_1	378.0	331.2	:	390.4	346.4	:	396.8	357.4
	P_2	386.2	339.8	:	400.8	353.9	:	393.1	350.9

TABLE VI

ANALYSIS OF VARIANCE
OF TOTAL YIELD SHOWING CALCULATED F VALUE
FOR LINEAR REGRESSION AND DEVIATION FROM REGRESSION,
1946 AND 1947

Variance due to	D.F.	Calculated F value	F value at 5% point	F value at 1% point
N regression	1	.23		
deviation	1	5.82*	3.91	6.81
P regression	1	4.74*	3.91	6.81
deviation	1	.33		
K regression	1	1.62	3.91	
deviation	1	2.18	3.91	
N x P				
Nr x Pr	1	.08		
Nr x Pd	1	.00		
Nd x Pr	1	1.60	3.91	
Nd x Pd	1	.57		
N x K				
Nr x Kr	1	2.48	3.91	
Nr x Kd	1	.17		
Nd x Kr	1	.11		
Nd x Kd	1	1.06		
P x K				
Pr x Kr	1	.47		
Pr x Kd	1	1.00	3.91	
Pd x Kr	1	.75		
Pd x Kd	1	.19		
Nr x year	1	1.05	3.91	
Nd x year	1	.40		
Pr x year	1	5.80*	3.91	6.81
Pd x year	1	.02		
Kr x year	1	.02		
Kd x year	1	.82		
Error	140			

* significant

TABLE VII

MEAN TOTAL YIELD
IN BUSHELS PER ACRE FOR EACH ELEMENT
AND TREATMENT LEVEL, 1946 AND 1947 COMBINED

	Element		
Level	N	P	K
0	385.4	383.5	389.9
1	399.5*	393.1	386.0
2	388.4	396.7*	397.5

* significant

Necessary difference = 12.0 at the 5 per cent point.

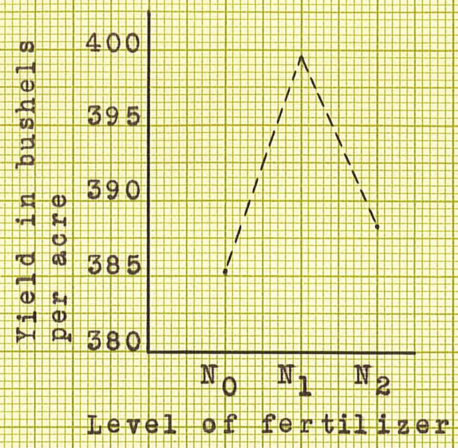

FIGURE 1 - TOTAL YIELD RESPONSE TO NITROGEN, 1946 AND 1947 COMBINED

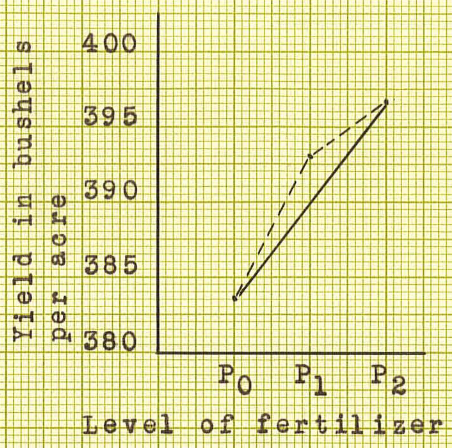

FIGURE 2 - TOTAL YIELD RESPONSE TO PHOSPHORUS, 1946 AND 1947 COMBINED

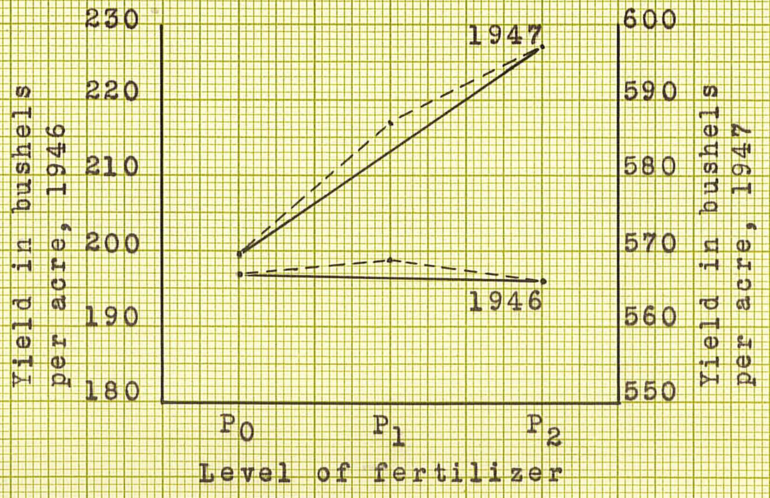

FIGURE 3 - PHOSPHORUS-YEAR INTERACTION

The mean marketable yield for each treatment combination for the two years is given in Table V. An analysis of variance for these data reveals a significant response to K but not to N or to P (Table VIII). The mean marketable yield due to each element is given in Table IX. When the level was increased from K_0 to K_2, yield increased from 337.3 to 349.7 bushels per acre (Table IX). This significant increase is shown in Figure 4 as a solid line. A dotted line joins the yield of K_1 with the yields of K_0 and K_2. The increase in yield from K_1 to K_2 is large in comparison to the increase from K_0 to K_1. Thus, K applied at the rate of approximately 100 pounds of muriate of potash (0-0-60) gave the highest yield.

Total yield did not respond to K treatment (Table VI) but marketable yield did respond (Table VIII). This would indicate that either the size or the number of marketable tubers was increased by K treatment.

As with the total yield analysis there was a P x year interaction for marketable yields. This indicates that yield responded differently to P in each year (Figure 5).

TABLE VIII

ANALYSIS OF VARIANCE
OF MARKETABLE TUBER YIELD SHOWING CALCULATED F VALUE
FOR LINEAR REGRESSION AND DEVIATION FROM REGRESSION,
1946 AND 1947

Variance due to	D.F.	Calculated F value	F value at 5% point	F value at 1% point
N regression	1	1.25	3.91	
deviation	1	3.34	3.91	
P regression	1	2.17	3.91	
deviation	1	.03		
K regression	1	4.13*	3.19	6.81
deviation	1	.68		
N x P				
Nr x Pr	1	.18		
Nr x Pd	1	.10		
Nd x Pr	1	.59		
Nd x Pd	1	.17		
N x K				
Nr x Kr	1	2.78	3.91	
Nr x Kd	1	.10		
Nd x Kr	1	.14		
Nd x Kd	1	.07		
P x K				
Pr x Kr	1	.16		
Pr x Kd	1	.52		
Pd x Kr	1	.40		
Pd x Kd	1	.21		
Nr x year	1	1.02		
Nd x year	1	.20		
Pr x year	1	5.98*	3.91	6.81
Pd x year	1	.05		
Kr x year	1	.35		
Kd x year	1	.81		
Error	140			

* significant

TABLE IX

MEAN MARKETABLE YIELD
IN BUSHELS PER ACRE FOR EACH ELEMENT
AND TREATMENT LEVEL, 1946 AND 1947 COMBINED

Level	Element		
	N	P	K
0	335.5	337.9	337.3
1	348.5	341.5	339.2
2	342.3	346.9	349.7*

* significant

Necessary difference = 12.1 at the 5 per cent point.

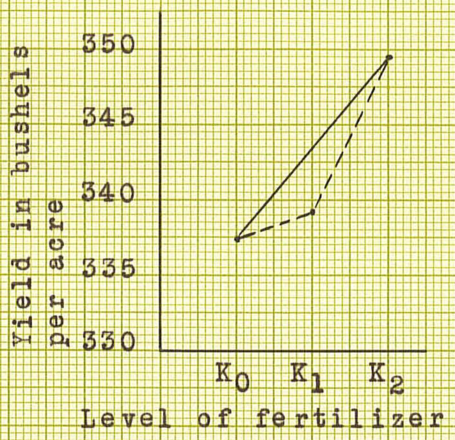

FIGURE 4 - MARKETABLE YIELD RESPONSE TO POTASSIUM, 1946 AND 1947 COMBINED

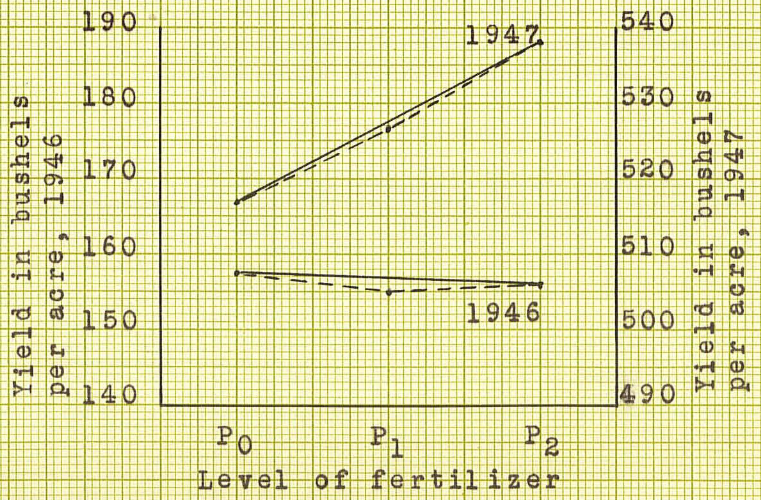

FIGURE 5 - PHOSPHORUS-YEAR INTERACTION

III Effect of fertilizers on the quality of potatoes

The mean specific gravity of tubers for each treatment combination is given in Table X. An analysis of variance for these data reveals a significant response of marketable tubers to N and to K but not to P (Table XI). The mean specific gravity due to each element is given in Table XII. When application of N was increased from N_0 to N_2, specific gravity increased from 1.0861 to 1.0886. This highly significant increase is shown in Figure 6 as a solid line. A dotted line joins the specific gravity value of N_1 with the values at N_0 and N_2. This intermediate point lies close to the solid line. Thus in 1947 in the Red River Valley of Manitoba an increase in N application increased the specific gravity of potatoes. This result, though contrary to the results of some workers (27, 37), is nevertheless similar to the results obtained by Smith and Nash (35), who found that high nitrogen together with some potassium resulted in the highest specific gravity values.

Increase in level of K from K_0 to K_1 resulted in a significant decrease in specific gravity values from 1.0881 to 1.0867. Increasing the level from K_1 to K_2 resulted in a slight increase in specific gravity values from 1.0867 to 1.0877 (Table XII). The curve is shown in Figure 7 where the general trend is downward with the lowest specific gravity value being found at K_1. Though values beyond K_2 are not known, the general trend with increase in K treatments is a decrease in specific gravity values. This result is in agreement with the results of some workers (2, 13, 14) who found that an increase in K decreased the specific gravity.

TABLE X

SPECIFIC GRAVITY VALUES
FOR EACH TREATMENT COMBINATION

		K_0	K_1	K_2
N_0	P_0	1.0875	1.0868	1.0855
	P_1	1.0855	1.0858	1.0875
	P_2	1.0862	1.0842*	1.0862
N_1	P_0	1.0892	1.0880	1.0870
	P_1	1.0892	1.0848	1.0880
	P_2	1.0870	1.0875	1.0888
N_2	P_0	1.0890	1.0895	1.0880
	P_1	1.0897	1.0860	1.0882
	P_2	1.0892	1.0875	1.0898

*significant at the 5 per cent point.

Necessary difference = .0031 at the 5 per cent point.

TABLE XI

ANALYSIS OF VARIANCE
OF SPECIFIC GRAVITY OF TUBERS SHOWING VARIANCE
FOR LINEAR REGRESSION AND DEVIATION FROM REGRESSION

Variation due to	D.F.	Calculated F value	F value at 5% point	F value at 1% point
N regression	1	15.2**	3.98	7.01
deviation	1	0.5		
P regression	1	0.5		
deviation	1	0.6		
K regression	1	0.4		
deviation	1	5.1*	3.98	7.01

* significant   ** highly significant

TABLE XII

MEAN SPECIFIC GRAVITY VALUE OF TUBERS
FOR EACH ELEMENT AND TREATMENT LEVEL

	Element		
Level	N	P	K
0	1.0861	1.0878	1.0881
1	1.0877**	1.0872	1.0867*
2	1.0886**	1.0874	1.0877

* significant at the 5 per cent point.
** significant at the 1 per cent point.

Necessary difference = .0012 at the 5 per cent point.
Necessary difference = .0016 at the 1 per cent point.

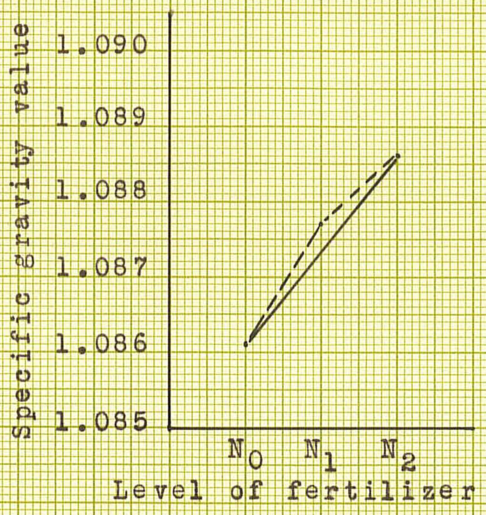

FIGURE 6 - SPECIFIC GRAVITY RESPONSE TO NITROGEN

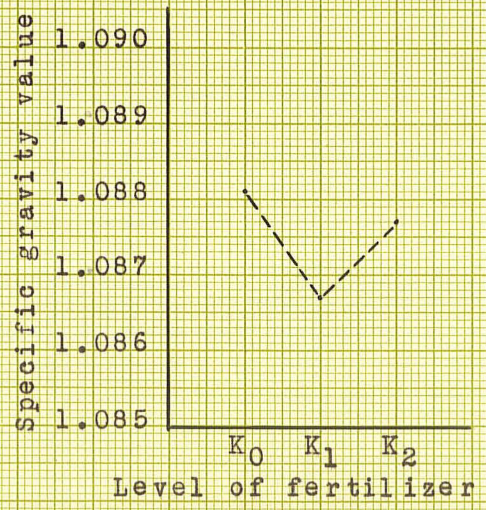

FIGURE 7 - SPECIFIC GRAVITY RESPONSE TO POTASSIUM

IV Nutritional deficiency symptoms

1. Nitrogen deficiency

Growth in the plants ceased three weeks after planting. The foliage turned to a light green and as the deficiency became acute the leaves turned yellow. The leaves were small. The stems and branches were also small. The plants seemed less succulent than those receiving a complete solution. The foliar diagnosis of the nitrogen deficiency may be seen in Plate 3.

2. Phosphorus deficiency

The plants tended to be smaller in size than those receiving a complete solution. The leaves and leaflets were proportionately smaller. The leaves were as dark or darker green in color than those on plants receiving a complete solution. Irregular brown spots appeared over the surface of the leaves six weeks after planting when the plants were eight to ten inches high. There was no pattern as to size or position of these spots. The foliar diagnosis of the phosphorus deficiency may be seen in Plate 4.

3. Potassium deficiency

At first the plants developed much like those receiving a complete solution. The leaves were slightly darker green in color. Eight weeks after planting when the plants were twelve to fifteen inches high the older leaves became yellowish to bronze in color along the margins while the areas close to the veins remained green. The leaflets lost the smooth surface and became crinkled and curled. The foliar diagnosis of the potassium deficiency may be seen in Plate 5.

4. Magnesium deficiency

The affected plants were slightly smaller than those receiving a complete solution. The leaves too were smaller and slightly chlorotic on these affected plants. Brown colored necrotic areas appeared in the interveinal regions near the midrib five weeks after planting when the plants were about eight to ten inches high. The foliar diagnosis of the magnesium deficiency may be seen in Plate 6.

5. Calcium deficiency

The plants receiving the calcium deficient solution were stunted and poorly developed in contrast to those receiving a complete solution. The leaves were chlorotic and small. The symptoms began to appear three to four weeks after planting when the plants were about four inches high. Maturity and flowering was hastened by the lack of calcium. The chlorotic leaves soon began to die. The foliar diagnosis of the calcium deficiency may be seen in Plate 7.

6. Boron deficiency

The growing tips of the plants were killed three weeks after planting when the plants were two to three inches high. This stimulated the development of the lateral buds into side shoots, the apices of which then died. This gave the plant a squat bushy appearance. The leaves were thick and the margins were rolled. The petioles were generally very brittle as were the midribs and veins. Frequently the leaves became twisted. The foliar diagnosis of the boron deficiency may be seen in Plate 8.

7. Sulphur deficiency

The plants treated with a sulphur deficient solution did not differ greatly from the plants receiving a complete solution. Slight chlorosis of the plants deficient in sulphur appeared about two weeks after planting. Except for this slight chlorotic condition, no differences were seen when compared to plants receiving a complete solution. The foliar diagnosis of the sulphur deficiency may be seen in Plate 9.

8. Manganese deficiency

No differences were observed between plants receiving a manganese deficient solution and those receiving a complete solution.

9. Iron deficiency

No differences were observed between plants receiving an iron deficient solution and those receiving a complete solution. Chlorosis normally accompanies iron deficiency (29). This condition did not appear on plants receiving an iron deficient solution. Since Pyrex distilling apparatus had not been used, it is possible that minute quantities of iron were present in the distilled water.

A summary of the deficiency symptoms is found in Table XIII.

TABLE XIII

SUMMARY OF NUTRITIONAL DEFICIENCY SYMPTOMS

Element deficiency	Chlorosis	Growth (size)	Foliar necrosis	Other remarks
N	severe	severely stunted	none observed	plants less succulent than normal.
P	none apparent	normal	irregular, marginal	necrotic areas located along the leaflet margins.
K	none apparent	normal	none observed	marginal bronzing and curling of older leaves.
Mg	slight	normal	rounded, interveinal	necrotic areas adjacent to mid-rib of leaflets to form a pattern.
Ca	severe	stunted	none observed	early maturity and flowering
B	none apparent	bushy and stunted	necrosis of branch tips	bushy appearance due to death of apical buds.
S	slight	normal	none observed	
Mn	none apparent	normal	none observed	
Fe	none apparent	normal	none observed	

PLATE 3 Nitrogen deficiency

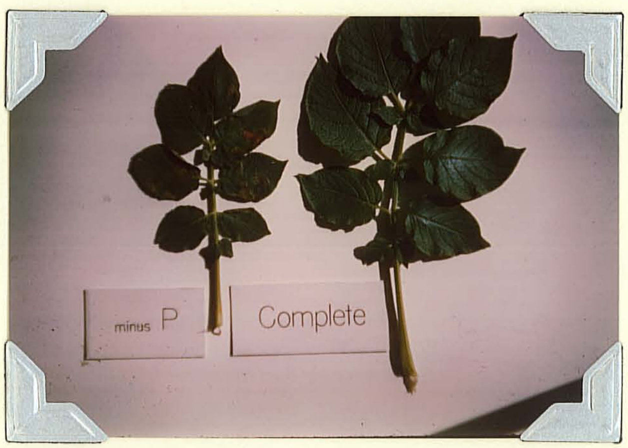

PLATE 4 Phosphorus deficiency

PLATE 5 Potassium deficiency

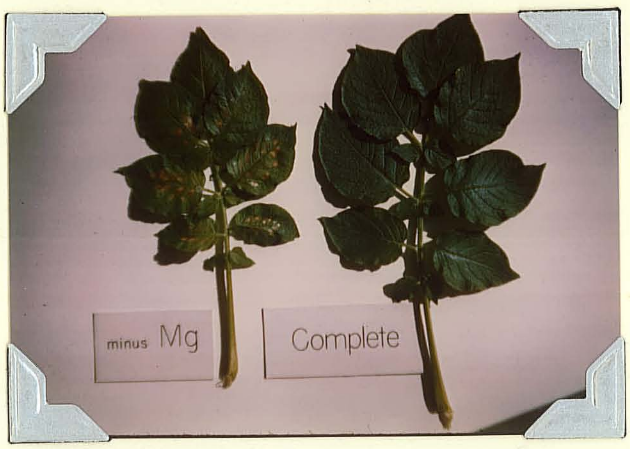

PLATE 6 Magnesium deficiency

PLATE 7 Calcium deficiency

PLATE 8 Boron deficiency

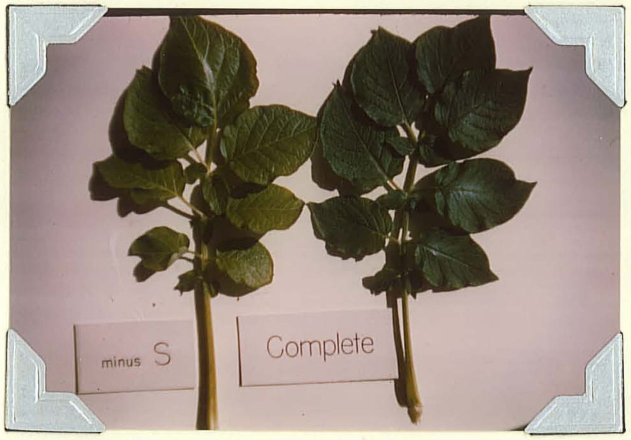

PLATE 9 Sulphur deficiency

SUMMARY

A potato fertilizer experiment was conducted in 1946 and in 1947 at the University of Manitoba to determine the effects of fertilizer on yield. Three levels (one of which was zero) of N, of P_2O_5, and of K_2O were used in all possible combinations. The plots were located on fairly well drained clay textured black earth soils typical for the Red River Valley. The varieties used were Warba in 1946 and Irish Cobbler in 1947. For both years the 111 treatment or the basic rate per acre was 28 pounds of nitrogen (N) from 20 per cent ammonium sulphate, 90 pounds of phosphorus (P_2O_5) from 38 per cent triple superphosphate, and 30 pounds of potassium (K_2O) from 60 per cent muriate of potash. This rate was equivalent to approximately 333 pounds of 9:27:9 per acre. Data as to marketable and total yields were taken.

Total yield responded to N and to P but not to K. Ammonium sulphate (20-0-0) at the rate of 140 pounds per acre and triple superphosphate (0-38-0) at the rate of 474 pounds per acre applied together gave the highest total yield. Marketable yield responded to K but not to either N or P. Muriate of potash (0-0-60) applied at the rate of 100 pounds per acre gave the highest marketable yield. Since total yield did not respond to K, this would indicate that the size or the number of marketable tubers

was affected by K. Yield responded to P in the normal season of 1947 but not in the drier season of 1946.

The two highest yields resulted from treatments 122 and 112 both of which yielded approximately 14 per cent more than the 000 treatment.

An experiment to determine the effects of fertilizer on the quality of potatoes was conducted in 1947. Random samples of marketable tubers selected at the time of harvest were used. Data revealed that increase in N increased the specific gravity values of potatoes. Nitrogen applied at the rate of 280 pounds of 20 per cent ammonium sulphate gave the highest value. No response resulted from P. Increase in K decreased the specific gravity of potatoes. The highest specific gravity values resulted from treatments 201, 210, and 222, indicating that N was most significant.

A related study was set up to establish symptoms of some of the nutritional disorders in potato plants. Nutrient solutions, each in turn deficient in one of nitrogen, phosphorus, potassium, boron, calcium, iron, magnesium, manganese, and sulphur, were used. In all cases, except manganese and iron, the deficient nutrient solutions induced symptoms sufficient to provide valuable information. The symptoms were recorded in Kodachrome prints and have been included in the results.

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