THE EFFECT OF DIFFERENT RATES OF NITROGEN, PHOSPHORUS AND POTASSIUM ON YIELD, SPECIFIC GRAVITY, COOKING QUALITY CHIPPING QUALITY AND ASCORBIC ACID CONTENT OF POTATO TUBERS

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ABSTRACT

A potato fertilizer experiment was conducted in 1960 and 1961 at three locations to determine the effect of various rates of nitrogen, phosphorus and potassium on yield, specific gravity, ascorbic acid, texture and chip color of potato tubers. The locations included three typical soils on which potatoes are grown in Manitoba.

Yield response to nitrogen was apparent on all three soils, to phosphate on the lightest and heaviest, and to potassium on the lightest. Nitrogen requirements for potatoes were shown to be quite modest, as optimum yields were generally obtained with thirty pounds of applied nitrogen per acre on second crop land.

Specific gravity was reduced by nitrogen and potassium in most cases. In general, chip color intensity was reduced by potassium and increased by nitrogen, but no treatment affected color intensity sufficiently to result in unacceptable chips. Texture was impaired by nitrogen and by potassium, but on one occasion was markedly improved by the latter. This was construed to be due to an increase in amylose content. Ascorbic acid was inconsistently reduced by nitrogen and potassium. Evidence was found of a close association between ascorbic acid and specific gravity. This was taken as an indication that some of the response in ascorbic acid concentration of the tubers was due to change in total dry matter, as distinct from change in ascorbic acid proportion to other dry matter constituents. Phosphorus had little or no effect on specific gravity, ascorbic acid, chip color intensity or texture of the tubers.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Professor J. A. Menzies and to Professor A. C. Ferguson for their guidance and assistance in the preparation of this manuscript.

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INTRODUCTION

The Irish potato, Solanum tuberosum L. is an important crop in Manitoba. In the period from 1957 to 1960 the average annual potato production was over 2,000,000 bushels (5). This production is sufficient to supply local needs in most years, yet Manitoba imports annually over 134,000 cwt. from the United States. This situation is cause for concern.

One of the major reasons for this situation is the poor quality of local potatoes. In order to fully exploit the local market, Manitoba growers must produce a product more acceptable for processing and fresh consumption. Among the qualities which should be improved are specific gravity, cooking quality, chipping quality and ascorbic acid content. This improvement of quality must not be accompanied by a reduction in yield of sufficient magnitude to reduce profits.

High specific gravity is associated with high dry matter content and high starch content, which is of benefit both to the consumer of fresh potatoes and to processors. Because potatoes are sold by weight rather than by dry matter, processors purchasing low specific gravity potatoes are buying water at potato prices. In addition to this economic factor, tubers of low specific gravity are less palatable for fresh consumption and are less attractive when chipped.

The importance of producing potatoes suitable for chip production must not be underestimated. The market for chipping potatoes has been substantially more lucrative than the fresh potato market, and in addition has been on a contract basis. In recent years, increasingly large quantities of potatoes have been chipped in Manitoba but Manitoba growers have not fully exploited this market because of their ineffective control over the quality of their potatoes.

The qualities which most interest chip processors are chip color and yield. Chip color is unfavorably affected by high content of reducing sugars and amino acids, and by low specific gravity. The latter is also associated with an unfavorable ratio of raw potato to end product (29).

Ascorbic acid, commonly known as vitamin C, is found in relatively low concentrations in potato tubers. In spite of this, potatoes are considered to be an important source of ascorbic acid for people in the low income category, who generally consume large quantities of this food.

Fertilizer practices which are consistent with the production of high quality potatoes are necessary to increase the demand for Manitoba grown potatoes. This study was concerned with investigating the effects of the common fertilizer elements, nitrogen, phosphorus and potassium, on yield, specific gravity, cooking quality, chipping quality and ascorbic acid content of potato tubers.

LITERATURE REVIEW

There is abundant experimental evidence indicating that substantial increases in yields of potatoes can be obtained by the use of chemical fertilizers in soils deficient in available nutrients. Response is inversely related to the presence of available nutrients.

Evidence concerning the effect of chemical fertilizers on cooking quality and specific gravity of potatoes is less conclusive. Hill (17) reported that potash fertilizers reduced specific gravity when used at rates which allow luxury absorption. Odland and Sheehan (22) at Rhode Island, found no consistent increase or decrease in specific gravity when nitrogen was increased from 130 to 190 pounds per acre. Increased phosphate, however, tended to increase specific gravity whereas increased potash reduced it. Murphy and Goven (20) at Maine found a definite increase in specific gravity when nitrogen was increased from 90 to 210 pounds per acre. The weight of evidence supports the findings of Sheard and Johnston (25) at Guelph and Terman and coworkers (30, 31, 32) at Maine, that nitrogen and potash tend to reduce specific gravity, while phosphorus tends to increase it.

The most common criterion of mealiness is specific gravity, although it is recognized as an imperfect one. Two samples of potatoes having identical specific gravity may differ in mealiness. Sheard and Johnston found some improvement in mealiness due to potash, which was not accompanied by an increase in specific gravity (25). Although tests on mealiness, as such, are generally based on taste panels, Barrios et al (7) reported that many workers and food processors have used specific gravity as a measure of mealiness.

Low levels of available potash in the soil accompanied by high nitrogen has been reported to contribute to blackening of tubers after boiling (26, 33).

Reports on the effects of nitrogen, phosphorus and potash on potato chip color are inconsistent in their conclusions. Eastwood and Watts (9) observed a lighter chip color with higher levels of nitrogen when applied with sulphate of potash, and the opposite trend when applied with muriate of potash. In agreement with these findings are the reports of Habib (16), Sawyer and Dallyn (24). Smith (27), Murphy and Goven (20) reported trends towards darker chip color with higher rates of nitrogen application.

The process by which chips darken, the Maillard reaction (28), requires two main substrates, reducing sugars and amino acids. The percentage of reducing sugars is not altered to any appreciable extent by nitrogen application (10). This would indicate that nitrogen fertilizer affects chip color by increasing the amino acid content of the tubers. This supposition is supported by the report of Hope et al (18), who found that potatoes fertilized with high rates of nitrogen had higher concentrations of amino acids and produced darker chips.

The few reports available on the effects of fertilizers on ascorbic acid content of tubers generally agree that nitrogen is associated with low ascorbic acid content. There is no agreement on the effect of phosphorus or potassium on ascorbic acid content of potato tubers (4).

MATERIALS AND METHODS

The design was a 3 x 4 x 2 factorial incomplete block with PK and NPK confounded and with three replications at each of three locations. The entire experiment was carried out in the summer of 1960 and again the summer of 1961. The three levels of nitrogen were 0, 30 and 60 pounds of N per acre; the four levels of P were 0, 30, 60 and 90 pounds of P_2O_5 per acre and the two levels of potassium were 0 and 30 pounds of K_2O per acre. Sources of these nutrients were nitrogen from ammonium nitrate, phosphorus from triple superphosphate and potassium from potassium chloride.

For purposes of convenience, nitrogen, phosphate and potash will be referred to by the symbols N, P and K, and the levels of treatment by means of numerical subscripts.

Three locations were chosen to include soil types representative of the major potato growing areas in Manitoba; St. Andrews on Red River clay (11), St. Eustache on the Oakville soil association (11), a medium textured soil, and Carman on almasippi fine sandy loam (12). In all cases the land had been planted to cereal crops the previous year.

Norland, a general purpose variety suitable for chip manufacture, boiling and baking was planted at Carman and St. Eustache. Pontiac, a low starch variety which is unsuitable for chipping, was planted at St. Andrews.

Single row plots were 55 feet long with rows spaced 40 inches apart and seed pieces spaced 14.6 inches apart within the rows, at a depth of 2 inches. Fertilizer was applied at the same depth as the seed piece, in bands, 2 inches on either side of the row for a length of 50 feet, using a V-belt attachment on an assisted feed, single row, commercial planter.

The data collected included yield, specific gravity, ascorbic acid concentration in the tubers, texture of the boiled potato, and chip color.

Yields were calculated by dividing total plot yields by number of hills per plot and multiplying by the appropriate factor to give yields in terms of 75 pound bags per acre. Marketable yields as distinct from gross yields were determined by running the gross yields through a commercial grader with openings of 2.25 inches in the grader chain. Yield data are presented in terms of marketable yields, with the exceptions of St. Andrews 1961 and St. Eustache 1961 which are given as gross yields. These exceptions were deemed prudent because drought conditions in 1961 caused a large proportion of the crop to be just under 2.25 inches in size. In these cases gross yield was more indicative of yield response than was marketable yield.

The method used to determine specific gravity was the one outlined by various workers (2, 8). Sodium chloride solutions ranging in specific gravity from 1.060 to 1.115 at intervals of .005 were used. Fifteen pound samples picked at random from each plot were used in each determination.

The modal class as isolated by the specific gravity method was retained for ascorbic acid analysis, chipping tests and boiling tests.

Ascorbic acid analysis was carried out by the Franke method (14).

Norland potatoes were chipped and fried by the method of Hyde and Shewfelt (17) and evaluated as to chip color by means of the color chart of the Potato Chip Institute International (3).

Boiling tests were performed by placing two peeled potatoes from each sample into boiling water for thirty minutes. These were then placed on white identical plates bearing code numbers and evaluated by several judges for texture. The mean values of the several judges were used in analysis of variance. Visual observations of after-cooking blackening were also made.

RESULTS AND DISCUSSION

Carman

Yield data for Norland potatoes grown at Carman in 1960 and 1961 are presented in Table 1.

Table 1. Marketable yields, in 75 lb. bags per acre of Norland potatoes at different rates of N, P_2O_5 and K_2O at Carman.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		163	155	187
30		215	212	207
60		212	205	
90			215	
L.S.D. 5%		19	22	16
L.S.D. 1%		25	30	
	1961			
0		122	117	132
30		143	147	143
60		148	141	
90			146	
L.S.D. 5%		12	14	10
L.S.D. 1%		17	19	

In 1960 and 1961 there was a significant yield response to nitrogen ($p = .01$), phosphorus ($p = .01$) and potash ($p = .05$). Although the effects of nitrogen and phosphorus were linear in both years, there were also significant quadratic effects. Relatively low rates of the three nutrients, i.e. 30 to sixty pounds of N, 30 pounds of P_2O_5 and 30 pounds of K_2O were required to obtain maximum yields.

In 1960 there was a significant ($p = .01$) interaction between nitrogen and phosphorus. The data are presented graphically in Fig. 1.

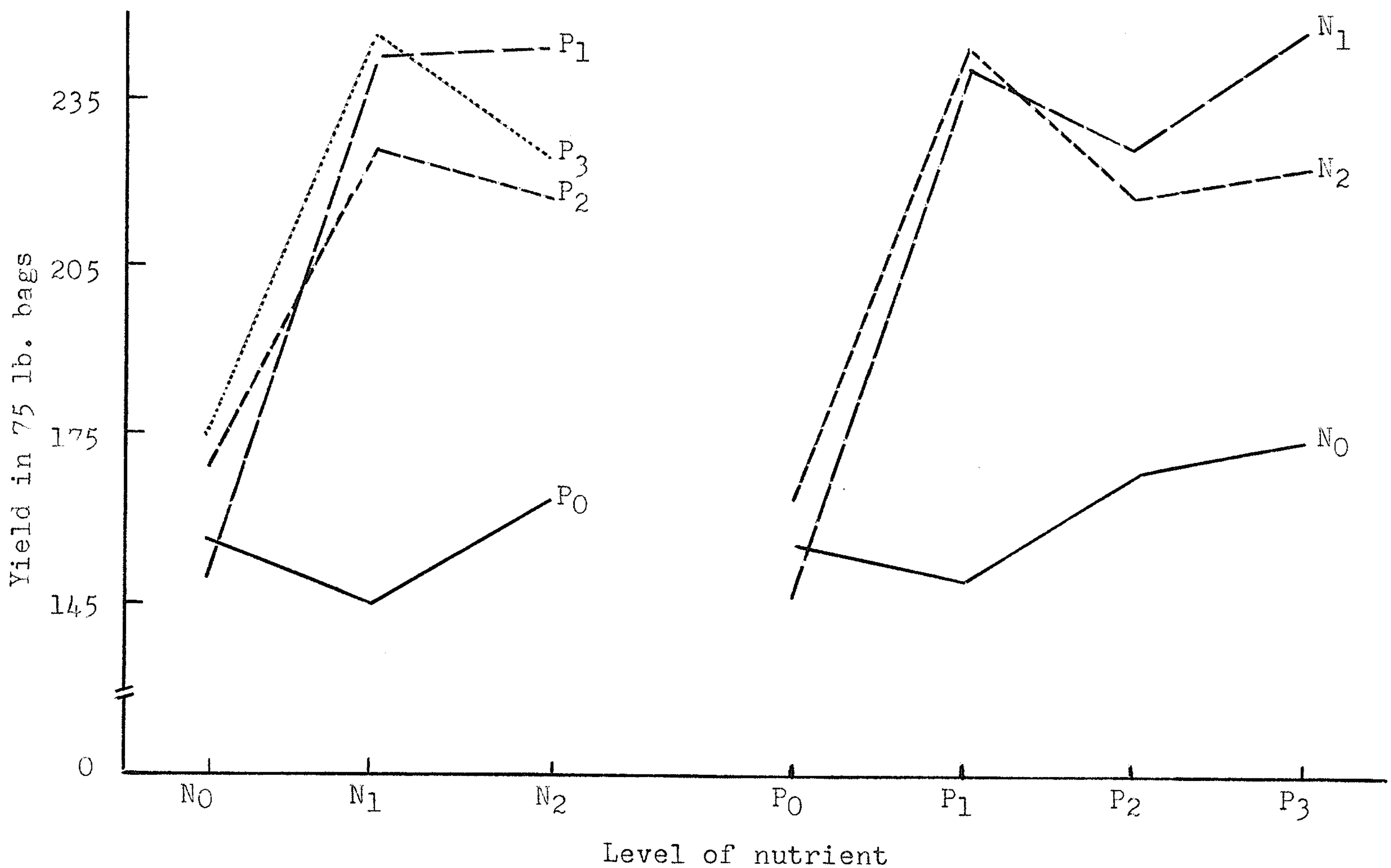

Figure 1. N x P interaction on marketable yield of Norland potatoes at Carman 1960.

At 0 level of nitrogen there is much less response to phosphorus than at the second or third level of nitrogen. At the second and third level of N there is a strong response to the first increment of P, but none to further increments. At the first level of P there is little or no response to N, but with 30 pounds of P response to N reaches its maximum.

Specific gravity data for Norland potatoes grown at Carman are presented in Table 2.

Table 2. Specific gravity of Norland potatoes at different rates of N, P_2O_5 and K_2O at Carman.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		1.0867	1.0843	1.0870
30		1.0863	1.0862	1.0851
60		1.0851	1.0863	
90			1.0872	
L.S.D. 5%		.0013	.0015	.0011
L.S.D. 1%			.0020	.0014
	1961			
0		1.1022	1.1012	1.1020
30		1.1006	1.1017	1.1005
60		1.1011	1.1012	
90			1.1011	
L.S.D. 5%		.0012	n.s.	.0010
L.S.D. 1%				.0013

Specific gravity was reduced by nitrogen and potash in both years and increased by phosphorus in 1960. The 1960 responses were linear. The large differences in specific gravity between the two years were probably due to differences in available moisture.

Data for ascorbic acid concentration in Norland tubers grown at Carman are presented in Table 3.

Table 3. Ascorbic acid content in mg./100 gm. fresh weight, of Norland potatoes at different rates of N, P_2O_5 and K_2O at Carman.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		13.1	13.0	13.5
30		12.1	13.4	12.7
60		14.1	13.2	
90			13.0	
L.S.D. 5%		.6		.5
L.S.D. 1%		.8		.7
	1961			
0		25.2	26.2	26.2
30		26.4	25.7	25.5
60		26.0	25.8	
90			25.7	

In 1960 there was a significant (p = .01) reduction in ascorbic acid with treatments of thirty pounds per acre of nitrogen and potassium. The second increment of nitrogen increased ascorbic acid content. There were no significant effects of treatments in 1961.

Data on the texture of Norland potatoes grown at Carman are presented in Table 4.

These data were obtained by comparing the various levels of a single nutrient, holding the other nutrients constant in all possible combinations. This method was not successful in detecting texture differences.

A second method of comparison was successful in detecting differ-

Table 4. Texture[1] of Norland potatoes at different rates of N, P_2O_5 and K_2O at Carman.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		3.44	3.39	3.44
30		3.46	3.54	3.44
60		3.45	3.42	
90			3.46	
	1961			
0		3.40	3.22	3.36
30		3.32	3.57	3.33
60		3.31	3.44	
90			3.35	

[1]Texture is rated on a scale from 0 to 5, with the lower end of the scale representing a less mealy texture.

ences due to potassium treatment. Potash vs. no potash was compared in every possible combination of the other nutrients. No numerical scale was used, instead, one of the two samples was judged mealier than the other. The data from these tests are presented in Table 5.

These data indicate that potassium affected texture and that the effect was dependent on the levels of applied nitrogen and phosphorus. Depending on these levels potassium either improved or impaired texture. At N_0, potassium improved texture, at N_1, potassium had no effect at the low levels of phosphorus, but at the higher levels of phosphorus, potassium impaired texture. At N_2 and the lowest level of phosphorus, K_1 again impaired texture, at P_1 potassium improved texture and at the higher levels of phosphorus potassium had no effect.

It is a widely accepted fact, and it has been demonstrated in this experiment, that specific gravity, a measure of dry matter content, is reduced by potassium fertilization. Because amylose is a dry matter

Table 5. Comparison of texture of Norland potatoes fertilized with K_2O vs. unfertilized with K_2O, at various levels of nitrogen and phosphorus, from Carman 1960.

Level of nutrient N P K	Number of times K_0 judged to be mealier	Number of times K_1 judged to be mealier	X^2
0 0 0 0 0 1	0	4	
0 1 0 0 1 1	0	5	
0 2 0 0 2 1	0	5	
0 3 0 0 3 1	0	2	
Total	0	16	X^2 1d.f.= 16**
1 0 0 1 0 1	7	5	.33
1 1 0 1 1 1	3	9	3.00
1 2 0 1 2 1	10	2	5.33*
1 3 0 1 3 1	10	2	5.33*
2 0 0 2 0 1	11	1	8.33**
2 1 0 2 1 1	1	11	8.33**
2 2 0 2 2 1	4	8	1.33
2 3 0 2 3 1	4	8	1.33

* significant at the 5% level
** significant at the 1% level

fraction, reduction in dry matter is a reduction in amylose, if dry matter fractions remain in constant proportion. Because an improvement in texture, which is an increase in amylose content, was accompanied by a reduction in dry matter, it was concluded that the amylose content had increased in proportion to the other dry matter constituents. The sum effect depended on the balance which was attained between the decrease in total dry matter and the increase in amylose proportion.

At N_0, potassium increased mealiness, but at higher levels of nitrogen the balance was altered such that the specific gravity effect of potassium was as great, or greater than the effect on amylose proportion. An interaction between nitrogen and phosphorus also affected this balance. In the presence of N_1P_0 or N_1P_1, the dry matter reduction was equivalent to the amylose increase. When N_1P_2, N_1P_3 or N_2P_0 was present, the balance was such that K_1 impaired texture.

Chip color data on Norland potatoes grown at Carman are presented in Table 6.

Potassium caused a highly significant reduction in chip color both years, while nitrogen increased it only in 1960. Although the lighter colors are more preferable, the dark color caused by the nitrogen was not enough to disqualify the potatoes for chipping.

The effect of potassium in reducing chip color intensity may be caused by the effect of altering the potassium/calcium uptake. It has been reported that a more proteinaceous plant results when the potassium/calcium ratio is in favor of the latter element (15), and dark chip color has been associated with amino nitrogen content in tubers (18).

Table 6. Chip color[1] in National Potato Chip Institute International color units, of Norland potatoes, at different rates of N, P_2O_5 and K_2O at Carman.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		4.46	5.11	5.60
30		5.21	5.16	4.89
60		6.08	5.22	
90			5.50	
L.S.D. 5%		.68	n.s.	.53
L.S.D. 1%		.91		.71
	1961			
0		5.12	5.56	5.61
30		5.58	5.11	5.02
60		5.25	5.39	
90			5.22	
L.S.D. 5%		n.s.	n.s.	.56

[1]Low numbers refer to lighter color.

St. Eustache

Yield data for Norland potatoes grown at St. Eustache are presented in Table 7.

Yield response to 30 and 60 pounds of nitrogen was significant ($p = .01$) and linear in both years, indicating that higher yields might be obtained with further increases in nitrogen.

Data on specific gravity of Norland potatoes grown at St. Eustache are presented in Table 8.

In 1960 and 1961 nitrogen had a significant ($p = .01$) effect in reducing specific gravity. This effect was linear, indicating that increased rates of nitrogen might have caused further reductions in specific gravity. Although no significant effects due to potassium

Table 7. Yield in 75 lb. bags per acre, of Norland potatoes at different rates of N, P_2O_5 and K_2O at St. Eustache.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
Marketable yield	1960			
0		259	286	291
30		289	290	295
60		331	301	
90			295	
L.S.D. 5%		17	n.s.	n.s.
L.S.D. 1%		23		
Gross yield	1961			
0		75	86	86
30		88	87	87
60		98	87	
90			86	
L.S.D. 5%		7	n.s.	n.s.
L.S.D. 1%		9		

Table 8. Specific gravity of Norland potatoes at different rates of N, P_2O_5 and K_2O at St. Eustache.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		1.0922	1.0907	1.0912
30		1.0914	1.0911	1.0906
60		1.0891	1.0909	
90			1.0909	
L.S.D. 5%		.0016		
L.S.D. 1%		.0021		
	1961			
0		1.0979	1.0964	1.0968
30		1.0967	1.0969	1.0963
60		1.0950	1.0971	
90			1.0958	
L.S.D. 5%		.0022	n.s.	n.s.
L.S.D. 1%		.0030		

could be detected, the trends were not inconsistent with the results at other locations, there being a tendency for potassium to be associated with lower specific gravity. There was no apparent effect of phosphorus on specific gravity.

Ascorbic acid concentrations in tubers from St. Eustache are presented in Table 9.

Table 9. Ascorbic acid concentration in mg. per 100 gm. fresh weight, in Norland potatoes at different rates of N, P_2O_5 and K_2O at St. Eustache.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		14.8	14.6	14.6
30		14.6	14.8	14.5
60		14.2	14.2	
90			14.5	
		n.s.	n.s.	n.s.
	1961			
0		21.7	22.0	21.8
30		21.4	20.8	20.9
60		21.0	21.2	
90			21.5	
		n.s.	n.s.	n.s.

In neither year did treatments have any significant effect on ascorbic acid, but there appeared to be trends in both years for reductions with higher rates of nitrogen and potash.

Results for tests of texture on Norland potatoes from St. Eustache are presented in Table 10.

In 1960, nitrogen significantly ($p = .01$) impaired texture when applied at 30 and 60 lbs., but in 1961, 30 lbs. improved texture, while

Table 10. Texture[1] of Norland potatoes at different rates of N, P_2O_5 and K_2O at St. Eustache.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		2.36	1.98	1.99
30		2.07	1.99	2.00
60		1.55	2.00	
90			2.01	
L.S.D. 5%		.11	n.s.	n.s.
L.S.D. 1%		.15		
	1961			
0		3.28	3.22	3.24
30		3.52	3.28	3.40
60		3.15	3.47	
90			3.32	
L.S.D. 5%		.37	n.s.	n.s.

[1]Evaluation is made on a scale from 0 to 5, with 0 representing a wet, non mealy texture and 5 representing a dry, mealy texture.

60 lbs. impaired it. There was a significant ($p = .05$) interaction between phosphorus and potash in 1961. This is illustrated in Fig. 2. At K_0 there was a continuous positive response to increments of phosphorus. At K_1 there was a positive response from P_0 to P_2 and a negative response from P_2 to P_3. Potassium improved texture in the presence of P_0, P_1 and P_2, but impaired it in the presence of P_3. This is somewhat similar to the results of Carman 1960, where potassium improved texture at N_0 and N_2P_1.

Chip color data on Norland potatoes grown at St. Eustache are presented in Table 11.

In 1960 there were no significant treatment effects, but in 1961 nitrogen significantly ($p = .05$) reduced chip color intensity. Phos-

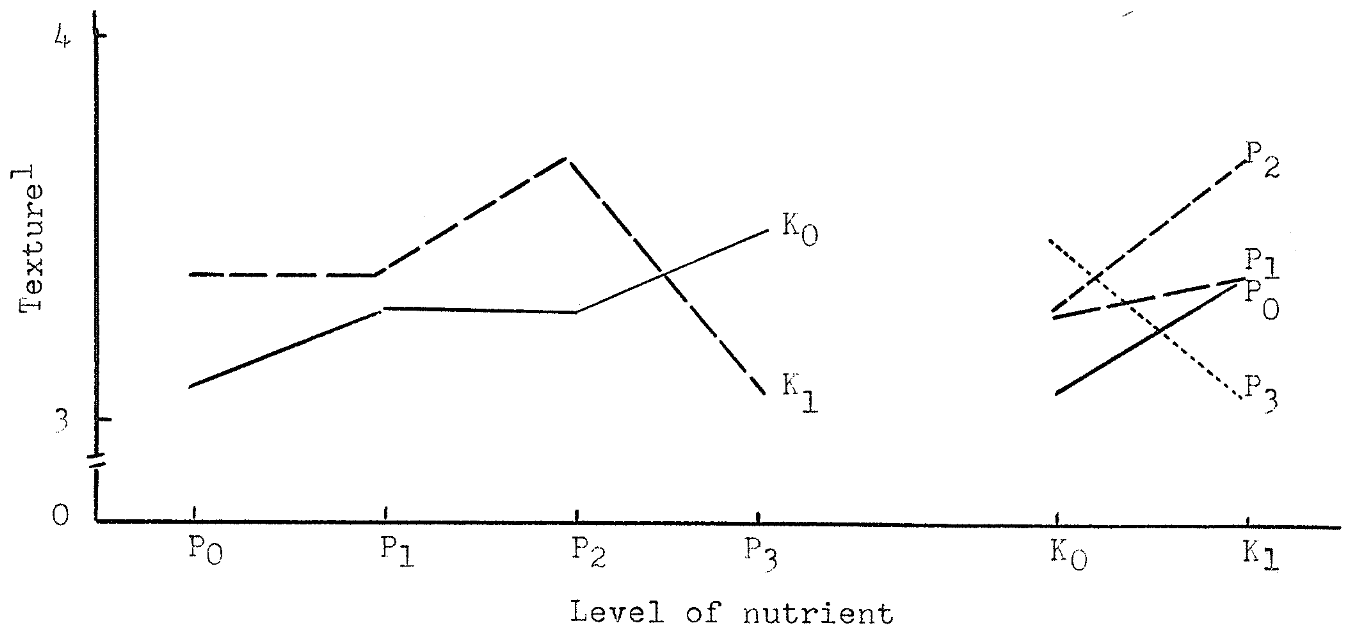

Figure 2. P x K interaction on texture of Norland potatoes from St. Eustache 1961.

[1]Higher values represent a more mealy texture.

Table 11. Chip color, in National Potato Chip Institute International color units, of Norland potatoes at different rates of N, P_2O_5 and K_2O at St. Eustache.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		5.12	4.44	4.92
30		4.88	5.11	5.02
60		4.92	5.27	
90			5.05	
		n.s.	n.s.	n.s.
	1961			
0		5.45	4.60	5.11
30		4.74	5.66	5.14
60		5.16	5.50	
90			4.72	
L.S.D. 5%		.58	.69	n.s.
L.S.D. 1%			.89	

N.B. Low numbers refer to lighter color.

phorus, at 30 and 60 pounds darkened chip color in 1961. In 1961 an interaction between nitrogen and potassium became apparent. At K_0, N_1 caused a lighter colored chip while N_2 caused a darker chip color. At K_1 however, both increments of nitrogen lightened chip color. Potassium caused lighter color at N_0 and N_2 but a darker at N_1.

St. Andrews

Yield data for Pontiac potatoes grown at St. Andrews are presented in Table 12.

Yield responded to nitrogen and phosphorus in 1960 ($p = .01$) and to phosphorus in 1961 ($p = .01$). In each case linear components were significant. In 1960 the data indicated that higher yields might be obtained with further increases in nitrogen and phosphorus. There was

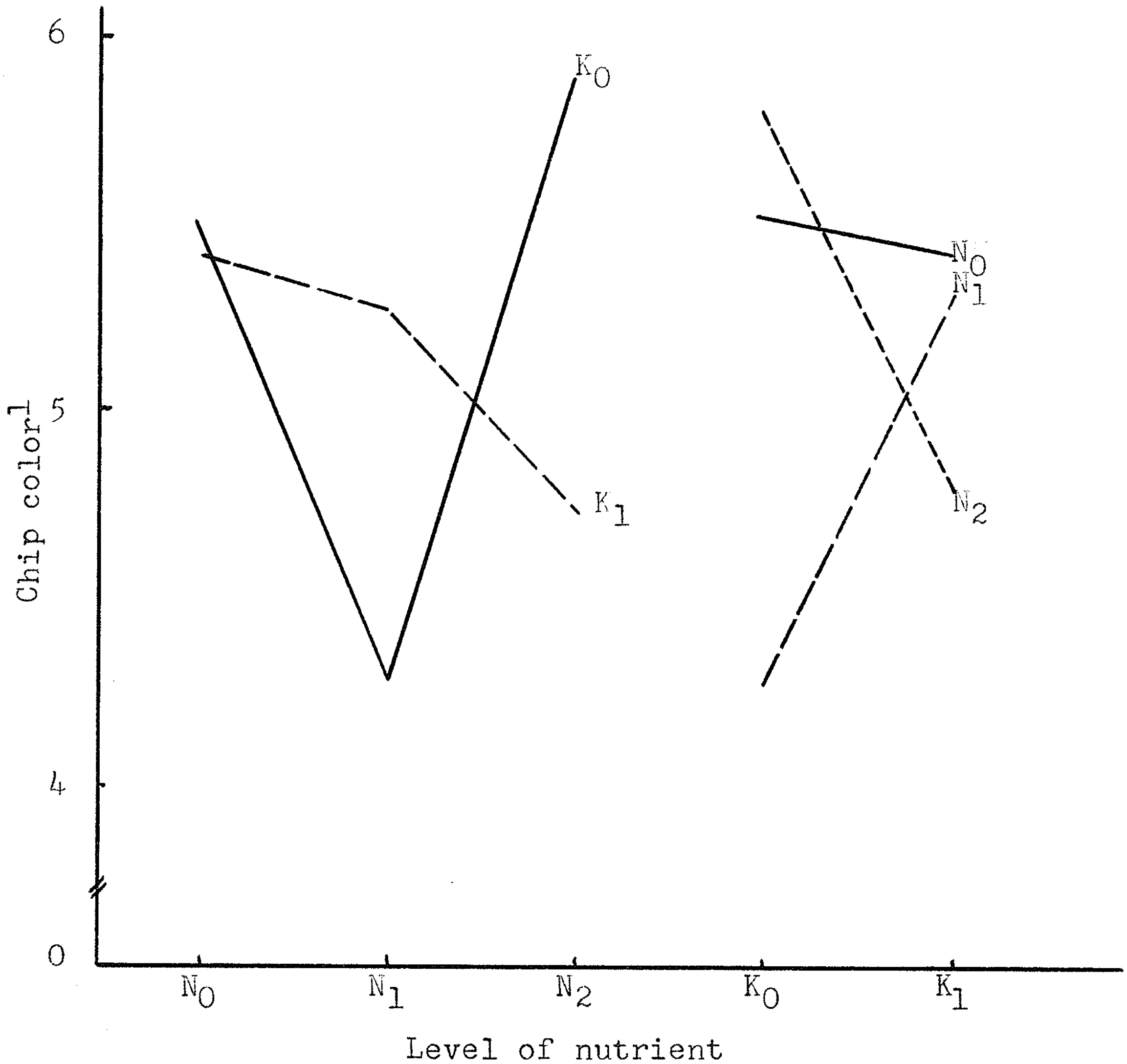

Figure 3. N x K interaction on chip color of Norland potatoes from St. Eustache 1961.

[1]National Potato Chip Institute color units

Table 12. Yield in 75 lb. bags per acre of Pontiac potatoes at different rates of N, P_2O_5 and K_2O at St. Andrews.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
Marketable yield 1960				
0		141	137	154
30		160	157	160
60		171	163	
90			172	
L.S.D. 5%		12	14	n.s.
L.S.D. 1%		16	19	
Gross Yield 1961				
0		124	112	122
30		119	120	121
60		121	130	
90			125	
L.S.D. 5%		n.s.	10	n.s.
L.S.D. 1%			13	

no significant yield response to potassium in St. Andrews.

Specific gravity data on the Pontiac potatoes grown at St. Andrews are presented in Table 13. In 1960 potassium and in 1961 nitrogen significantly ($p = .01$) reduced specific gravity. Phosphorus had no effect on specific gravity which is consistent with the results from St. Eustache and from Carman in 1961.

Data from ascorbic acid analysis of Pontiac potatoes grown at St. Andrews are presented in Table 14. In 1960 there were no significant responses of ascorbic acid to treatments, but in 1961 N, P, NP, PK and NPK all had highly significant effects: N linear and P cubic.

In view of these significant interactions, it appears to be the case, that response to N, P or K was fixed, not by any of these nutrients independently, but by the relative levels of each. The question is, not how N affects ascorbic acid content, but how N affects ascorbic acid

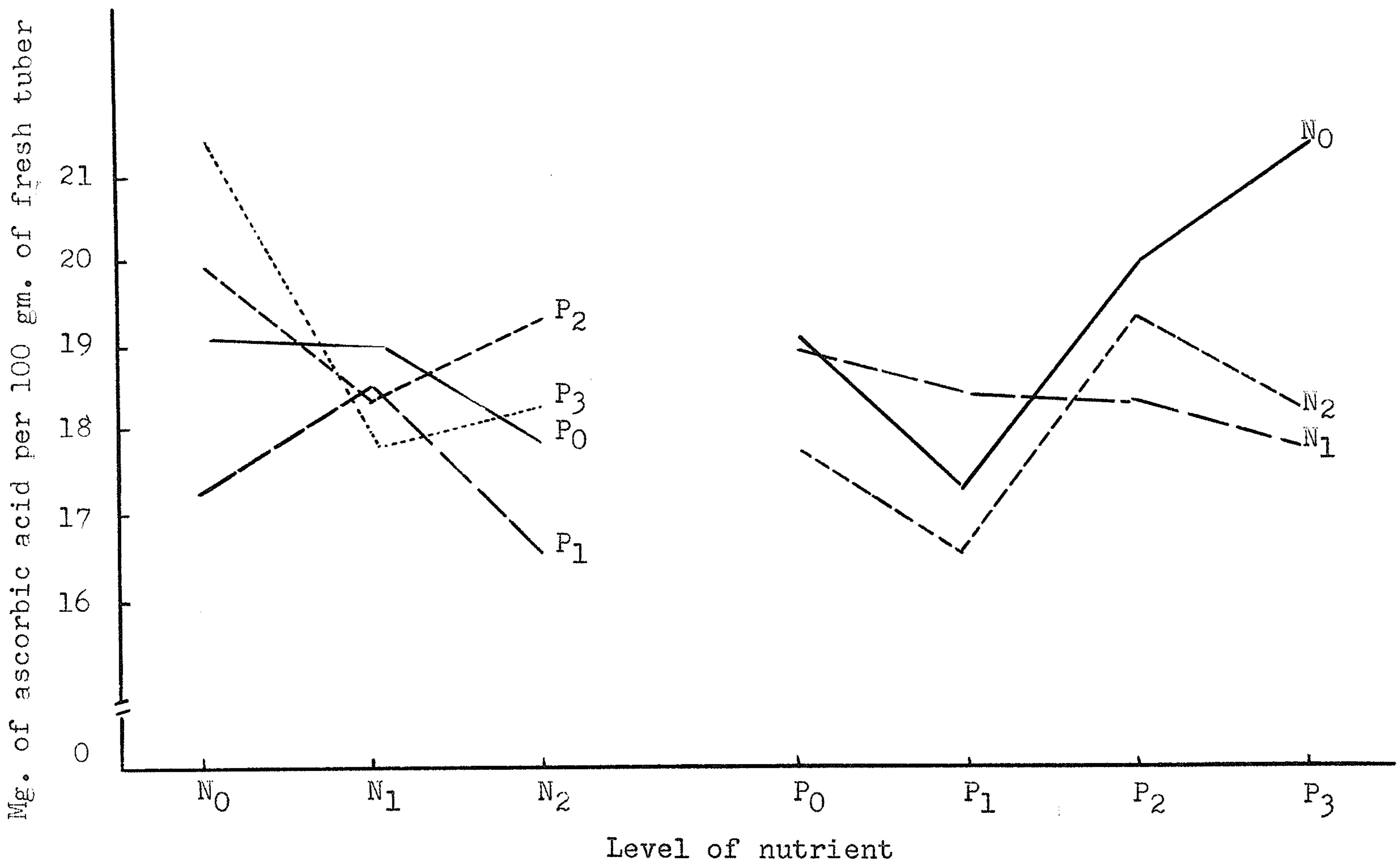

Figure 4. N x P interaction on ascorbic acid concentration in Pontiac potatoes from St. Andrews 1961.

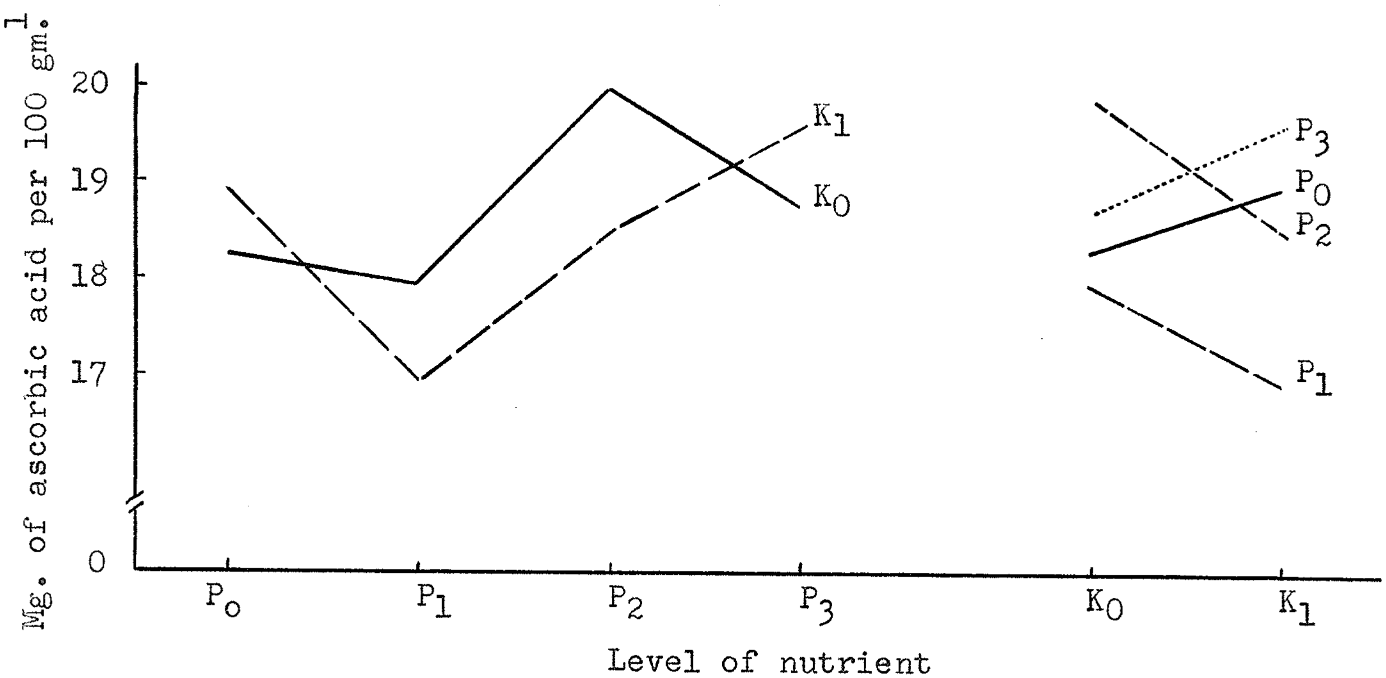

Figure 5. P x K interaction on ascorbic acid concentration in Pontiac potatoes from St. Andrews 1961.

[1]Fresh tuber weight

Table 13. Specific gravity of Pontiac potatoes at different rates of N, P_2O_5 and K_2O at St. Andrews.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		1.0778	1.0780	1.0795
30		1.0780	1.0780	1.0765
60		1.0780	1.0770	
90			1.0781	
L.S.D. 5%		n.s.	n.s.	.0010
L.S.D. 1%				.0013
	1961			
0		1.0883	1.0876	1.0874
30		1.0870	1.0863	1.0860
60		1.0849	1.0870	
90			1.0859	
L.S.D. 5%		.0020	n.s.	n.s.
L.S.D. 1%		.0026		

Table 14. Ascorbic acid content in mg./100 gm. fresh weight of Pontiac potatoes at different rates of N, P_2O_5 and K_2O at St. Andrews.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		17.3	16.6	17.0
30		17.0	16.9	17.0
60		16.7	17.5	
90			17.0	
		n.s.	n.s.	n.s.
	1961			
0		19.5	18.7	18.8
30		18.4	17.5	18.5
60		18.0	19.3	
90			19.2	
L.S.D. 5%		.8	.9	n.s.
L.S.D. 1%		1.0	1.2	

content at some particular level of P or K. Generalities concerning the effect of one of these nutrients were therefore valid only under some given fixed quantities of the other two nutrients.

Data for tests of texture from tubers grown at St. Andrews are presented in Table 15.

Table 15. Texture[1] of Pontiac potatoes at different rates of N, P_2O_5 and K_2O grown at St. Andrews.

Rate of nutrient lbs./acre	Year	N	P_2O_5	K_2O
	1960			
0		2.27	2.15	2.16
30		2.20	2.00	2.00
60		1.76	2.04	
90			2.00	
L.S.D. 5%		.35	n.s.	n.s.
L.S.D. 1%		.47		
	1961			
0		2.58	2.52	2.60
30		2.48	2.39	2.36
60		2.38	2.44	
90			2.57	
L.S.D. 5%		n.s.	n.s.	.21
	1961[2]			
0		2.75	2.56	2.58
30		2.56	2.44	2.50
60		2.29	2.56	
90			2.61	
L.S.D. 5%		.22	n.s.	n.s.
L.S.D. 1%		.32		

[1]Texture is rated on a scale from 0 to 5, with the lower end of the scale representing a less mealy texture.
[2]Data obtained from a single judge (P.B.).

The usual procedure for detection of treatment effects on texture was to average the ratings of the several judges, and to perform an analysis of variance on these values. By this method it was found that nitrogen impaired texture in 1960 ($p = .01$) and potash impaired it in 1961 ($p = .05$).

In the course of analysis it became clear that one of the judges (P.B.) was more adept at tasting differences in texture due to nitrogen, and when his data were analyzed separately it was shown that there was a significant ($p = .01$) impairment of texture with both increments of nitrogen, in 1961.

After-Cooking Darkening

In 1960, Norland tubers from all locations and with all treatments turned black after boiling. In 1961 only tubers from Carman were seriously affected by this fault. In neither year did Pontiac exhibit this phenomenon. Because no method is yet available for evaluating intensity, only general appearance was noted. Discoloration was so severe in 1961 as to make the tubers unacceptable for consumption as boiled or mashed potatoes. Objection to the color is based on appearance rather than on taste. It is interesting to note that chips from such tubers produced excellent, light colored chips.

Ascorbic Acid and Specific Gravity

In the course of this experiment a close relationship between ascorbic acid and specific gravity appeared. Specific gravity is a measure of dry matter and ascorbic acid is a fraction of the total dry matter content. This seems to account for the relationship.

The effect of treatment on ascorbic acid content can be due to an increase in dry matter with dry matter fractions remaining in constant proportion; or a change in the ascorbic acid fraction of the dry matter. The latter would be directly due to treatment while the former would be indirectly due to treatment i.e. the treatment would affect the dry matter content which in turn would affect the ascorbic acid content. To measure the strength of this latter effect, a simple regression of block mean ascorbic acid by block mean specific gravity was computed for Carman and St. Eustache, for both years. The coefficient of correlation was determined to be .926 with 22 degrees of freedom. This was highly significant, indicating an exceedingly close relationship existing between ascorbic acid and specific gravity.

SUMMARY AND CONCLUSIONS

Yield response to nitrogen was apparent on all three soils, to phosphate on the lightest and heaviest and to potassium on the lightest. Nitrogen requirements for potatoes were shown to be quite modest, in that optimum yields were generally obtained with thirty pounds of applied nitrogen on second crop land. Had this experiment been carried out on summerfallow, it is likely that response to nitrogen would have been less. Where yield responded to phosphorus, rates above thirty pounds per acre did not result in significantly higher yields. Potassium increased yields both years at Carman but had no significant yield effects at the other two locations.

Specific gravity was reduced by applications of nitrogen and potassium with a fair degree of consistency. Only at St. Andrews in 1961 was there an exception. In this instance all levels of nitrogen resulted in tubers of equal specific gravity. There was no effective specific gravity response to phosphorus.

A fertilizer program for chipping potatoes on almasippi fine sandy loam or on the Oakville soil association should involve application of nitrogen to the level of highest economic yield, namely thirty pounds of nitrogen per acre. Although chip color was darkened by nitrogen at these locations, in no instance was the effect sufficient to result in chips of unacceptable color. At Carman, potassium at thirty pounds per acre was not only consistent in enhancing yield, but was also consistent in reducing chip color.

Texture was not affected by phosphorus, but was adversely affected by nitrogen and potassium. Although the general effect of potassium was to impair texture by reducing specific gravity, there appeared to be a compensating effect of increasing amylose concentration. The failure of potassium to consistently affect texture at Carman, where the soil is deficient in this nutrient, supports the hypothesis of Hill (17) that potassium affects texture only when used at rates which allow luxury absorption.

After-cooking blackening was apparent in the variety Norland at both locations in 1960 and at Carman in 1961. Pontiac did not blacken in either year. Although fertilizer treatments may have some minor effect, varieties like Norland which are extremely susceptible to after-cooking blackening, cannot be protected by any simple fertilizer program.

There was a general trend for ascorbic acid to be reduced with increasing rates of nitrogen and potassium. Phosphorus appeared to have no consistent effect on this quality. Ascorbic acid was found to be closely associated with specific gravity. In view of this association it follows that some of the ascorbic acid response to treatment is due to change in total dry matter as distinct from change in proportion of ascorbic acid to other dry matter fractions.

Variation due to treatments was much less than variation between locations, years and varieties. It follows therefore, that locations and varieties must be selected with discrimination in order to achieve major changes in any of the qualities studied.

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Appendix 1.

Analysis of variance for the effect of fertilizer on the marketable yield of Norland potatoes at Carman.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	1,085	5,252**
N	2	20,933**	3,403**
P	3	14,187**	3,593**
K	1	7,100*	2,188*
NP	6	3,523*	262
NK	2	775	355
PK	3	350	624
NPK	6	582	881
Error	43	1,120	468
Total	71		
C.V.		16.9%	15.7%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 2.

Analysis of variance for the effect of fertilizer on the specific gravity of Norland potatoes at Carman.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	1,895.46*	40.15**
N	2	1,753.62*	17.23*
P	3	2,646.56**	1.38
K	1	6,422.22**	40.20**
NP	6	705.29	3.37
NK	2	307.93	.10
PK	3	426.94	1.49
NPK	6	618.76	3.25
Error	43	546.99	4.40
Total	71		
C.V.		2.71%	2.82%

** 1.00 percent level of significance
* 5.00 " " " "

Appendix 3.

Analysis of variance for the effect of fertilizer on the ascorbic acid content of Norland potatoes at Carman.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	1.11	14.35
N	2	23.70**	7.92
P	3	.44	1.06
K	1	11.84**	9.68
NP	6	1.34	8.91
NK	2	.87	3.18
PK	3	2.31	1.96
NPK	6	1.69	4.10
Error	43	1.17	6.90
Total	71		
C.V.		8.25%	10.1%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 4.

Analysis of variance for the effect of fertilizer on the texture of Norland potatoes at Carman.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	.146	.068
N	2	.003	.065
P	3	.079	.140
K	1	.000	.017
NP	6	.346	.184
NK	2	.052	.015
PK	3	.174	.058
NPK	6	.156	.148
Error	43	.161	.184
Total	71		
C.V.		11.6%	12.8%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 5.

Analysis of variance for the effect of fertilizer on the intensity of chip color of Norland potatoes at Carman.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	2.93	21.75**
N	2	15.88**	1.35
P	3	.54	.68
K	1	9.39**	6.12*
NP	6	1.13	.85
NK	2	1.51	.37
PK	3	.58	1.51
NPK	6	.79	1.81
Error	43	1.34	1.37
Total	71		
C.V.		22.0%	22.0%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 6.

Analysis of variance for the effect of fertilizer on the yield of Norland potatoes at St. Eustache.

Source of Variance	D.F.	Marketable yield M.S. 1960	Gross yield M.S. 1961
Blocks	5	2,211*	899**
N	2	31,429**	3,165**
P	3	787	6
K	1	397	37
NP	6	1,087	42
NK	2	37	81
PK	3	1,283	58
NPK	6	178	198
Error	43	901	125
Total	71		
C.V.		10.2%	12.9%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 7.

Analysis of variance for the effect of fertilizer on the specific gravity of Norland potatoes at St. Eustache

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	140.96	27.46
N	2	6,332.04**	51.59*
P	3	29.05	5.62
K	1	616.69	3.21
NP	6	302.60	16.56
NK	2	196.05	9.87
PK	3	31.35	5.08
NPK	6	454.67	16.56
Error	43	729.10	14.05
Total	71		
C.V.		2.97%	.393%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 8.

Analysis of variance for the effect of fertilizer on the ascorbic acid content of Norland potatoes at St. Eustache.

Source of Variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	7.96**	21.21
N	2	2.03	2.51
P	3	1.27	4.14
K	1	.37	13.09
NP	6	.69	2.59
NK	2	.27	6.61
PK	3	1.28	1.72
NPK	6	.44	2.27
Error	43	.86	5.09
Total	71		
C.V.		6.38%	11.7%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 9.

Analysis of variance for the effect of fertilizer on the texture of Norland potatoes at St. Eustache.

Source of variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	.10	.27
N	2	4.07**	.82*
P	3	.00	.21
K	1	.00	.53
NP	6	.40	.19
NK	2	.01	.22
PK	3	.02	.69*
NPK	6	.53	.17
Error	43	.36	.20
Total	71		
C.V.		30.1%	12.4%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 10.

Analysis of variance for the effect of fertilizer on the chip color of Norland potatoes at St. Eustache.

Source of variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	1.70	9.858**
N	2	.46	3.041*
P	3	2.61	5.162**
K	1	.27	.013
NP	6	1.64	2.468
NK	2	.15	5.098**
PK	3	1.11	1.261
NPK	6	1.49	2.051
Error	43	1.13	1.069
Total	71		
C.V.		21.3%	20.1%

** 1.00 percent level of significance
* 5.00 " " " "

Appendix 11.

Analysis of variance for the effect of fertilizer on the yield of Pontiac potatoes at St. Andrews.

Source of variance	D.F.	Marketable yield M.S. 1960	Gross yield M.S. 1961
Blocks	5	431.92	365.18
N	2	5,544.35**	156.02
P	3	4,146.28**	1,052.83**
K	1	747.55	.02
NP	6	518.29	135.92
NK	2	1,384.19	158.00
PK	3	51.02	133.83
NPK	6	178.90	294.15
Error	43	435.76	212.96
Total	71		
C.V.		13.3%	12.4%

** 1.00 percent level of significance
* 5.00 " " " "

Appendix 12.

Analysis of variance for the effect of fertilizer on the specific gravity of Pontiac potatoes at St. Andrews.

Source of variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	3,685.29**	9,478.96**
N	2	84.43	7,161.10**
P	3	67.15	943.59
K	1	15,901.39**	3,945.70
NP	6	175.53	693.70
NK	2	112.68	134.45
PK	3	347.86	1,557.01
NPK	6	412.47	653.75
Error	43	339.88	1,132.70
Total	71		
C.V.		2.36%	3.92%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 13.

Analysis of variance for the effect of fertilizer on the ascorbic acid content of Pontiac potatoes at St. Andrews.

Source of variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	62.39**	15.84**
N	2	2.66	13.09**
P	3	2.32	12.50**
K	1	.09	.68
NP	6	7.20	7.51**
NK	2	3.51	.81
PK	3	2.25	8.36**
NPK	6	2.34	8.69**
Error	43	10.85	1.71
Total	71		
C.V.		19.3%	7.01%

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 14.

Analysis of variance for the effect of fertilizer on the texture of Pontiac potatoes at St. Andrews.

Source of variance	D.F.	M.S. 1960	M.S. 1961
Blocks	5	.09	.52
N	2	1.81*	.22
P	3	.30	.12
K	1	.48	1.03*
NP	6	.71	.20
NK	2	.59	.08
PK	3	.09	.02
NPK	6	.43	.09
Error	43	.37	.20
Total	71		
C.V.		29.2%	18.1%

** 1.00 percent level of significance
* 5.00 " " " "

Appendix 15.

Analysis of Nitrogen Regression .

	D.F.	M.S. for Marketable yield	Specific gravity	Ascorbic acid	Texture	Chip Color
Carman 1960						
Linear	1	29,452.52**	3,267.00**	11.90**	31.69**	
Quadratic	1	12,413.67**	240.25	35.50**	.06	
Error	46	1,374.68	617.16	1.40	1.44	
Carman 1961						
Linear	1	12,852.88**	14.96			
Quadratic	1	380.25	19.51			
Error	46	742.65	6.52			
St. Eustache 1960						
Linear	1	62,208**	11,687.52**		7.92**	
Quadratic	1	975	976.56		.21	
Error	46	1,303	524.00		.47	
St. Eustache 1961		(Total yield)				
Linear	1	6,308.96**	102.67**		.23	1.02
Quadratic	1	21.71	.51		1.42**	2.27
Error	46	190.11	16.43		.22	

(Continued)

Appendix 15 (Continued)

	D.F.	M.S. for Marketable yield	Specific gravity	Ascorbic acid	Texture	Chip Color
<u>St. Andrews 1960</u>						
Linear	1	10,830.02**			3.05*	
Quadratic	1	258.67			.57	
Error	46	890.79			.50	
<u>St. Andrews 1961</u>						
Linear	1		14,076.75**	25.81*		
Quadratic	1		245.44	1.36		
Error	46		1,509.00	4.66		

** 1.00 percent level of significance
 * 5.00 " " " "

Appendix 16.

Analysis of Phosphorus Regression.

	D.F.	M.S. for Yield	Specific gravity	Ascorbic acid	Chip color
Carman 1960					
Linear	1	26,988.02**	6,952.01**		
Quadratic	1	9,499.01**	440.05		
Cubic	1	6,076.22**	547.60		
Error	51	1,269.29	544.87		
Carman 1961					
Linear	1	5,775.21**			
Quadratic	1	3,045.90*			
Cubic	1	1,956.73			
Error	51	694.50			
St. Eustache 1961					
Linear	1				.02
Quadratic	1				7.69*
Cubic	1				.34
Error	51				1.97
St. Andrews 1960					
Linear	1	11,628.10**			
Quadratic	1	522.72			
Cubic	1	288.01			
Error	51	409.54			
St. Andrews 1961		Total yield			
Linear	1	2,185.47**		10.54	
Quadratic	1	744.98		5.55	
Cubic	1	227.21		21.41*	
Error	51	216.45		4.88	

** 1.00 percent level of significance
 * 5.00 " " " "