Relationships of Potato Yields and Quality to Soil Test Values and Fertilizer Applications

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The use of soil tests to accurately predict nutrient needs is dependent on (1) having a soil test procedure that accurately predicts when a nutrient is lacking, and (2) on the calibration of that soil test. Potatoes were grown at 17 sites in the Red River Valley over a 5-year period to determine the influence of N-P-K fertilizer on yield at various soil test levels.

It is generally accepted that the application of mineral nutrients is required for maximum production of potatoes in North Dakota. Early trials (1,2) established the need for nutrients and were the basis for fertilizer recommendations for many years. Since these earlier fertility trials, large quantities of N-P-K have been applied to some Red River Valley soils. The application of excess fertilizer on some fields has resulted in large variations in soil fertility from farm to farm, and even from field to field on the same farm. Therefore, it becomes necessary to turn from general fertilizer recommendations to applications based on soil test results and projected yield goals for each field.

The use of soil tests to accurately predict nutrient needs is dependent on (1) having a soil test procedure that accurately predicts when a nutrient is lacking, and (2) on the calibration of that soil test.

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The soil test calibration trials reported here were conducted by the Departments of Soils and Horticulture at North Dakota State University over a five-year period at 17 sites. In five trials where two potato varieties were used, each variety was considered a separate site.

Procedure

Trials were conducted at the Red River Valley Potato Growers Research Farm (PGRF) near Grand Forks and on farms near Minto, Hoople, Park River and Hillsboro. An effort was made to select sites that tested low in nitrate-nitrogen (NO_3-N) and/or phosphorus (P). The soil tests used were the nitrate electrode procedure (3) for nitrogen, the Olson sodium bicarbonate procedure (4) for phosphorus, and the neutral normal ammonium acetate procedure for potassium. The site locations, cooperators, varieties, planting dates and harvest dates are given in Table 1.

The potatoes were planted in 38-inch (96.5 cm) rows with a two-row planter that placed the fertilizer in bands two inches (5 cm) on each side of

Table 1. Location and other information about the potato plots established from 1971 thru 1975.

Site		Year	Location	Cooperator	Variety	Planted	Harvested
1.	PRF1	1971	T150N-R50W-Sec 5	Potato Res. Farm	Kennebec	May 7	Sept. 21
2.	PRF2	1971	T150N-R50W-Sec 5	Potato Res. Farm	Norchip	May 7	Sept. 21
3.	Hoople	1972	T159N-R54W-Sec 15	Paul Midgarden	Norchip	May 18	Sept. 12
4.	Minto	1972	T156N-R52W-Sec 19	Dean Bjorneby	Chieftain	May 17	Sept. 13
5.	PRF3	1972	T150N-R50W-Sec 5	Potato Res. Farm	Kennebec	May 19	Sept. 14
6.	PRF4	1972	T150N-R50W-Sec 5	Potato Res. Farm	Norchip	May 19	Sept. 14
7.	Hillsboro 1	1973	T146N-R50W-Sec 27	Obed Tweten	Kennebec	May 18	Sept. 17
8.	Park River	1973	T158N-R50W-Sec 35	Earl Marifjeren	Chieftain	May 14	Sept. 14
9.	PRF5	1973	T150N-R50W-Sec 5	Potato Res. Farm	Kennebec	May 21	Sept. 20
10.	PRF6	1973	T150N-R50W-Sec 5	Potato Res. Farm	Norchip	May 21	Sept. 20
11.	Hillsboro 2	1974	T146N-R50W-Sec 27	Obed Tweten	Kennebec	June 3	Sept. 16
12.	Hillsboro 3	1974	T146N-R49W-Sec 20	Harold Letnes	Norchip	May 24	Sept. 13
13.	PRF7	1974	T150N-R50W-Sec 5	Potato Res. Farm	Kennebec	May 22	Sept. 24
14.	PRF8	1974	T150N-R50W-Sec 5	Potato Res. Farm	Norchip	May 22	Sept. 15
15.	Hillsboro 4	1975	T145N-R49W-Sec 6	Roger Anderson	Norchip	May 29	Sept. 15
16.	PRF9	1975	T150N-R50W-Sec 5	Potato Res. Farm	Kennebec	May 22	Sept. 29
17.	PRF10	1975	T150N-R50W-Sec 5	Potato Res. Farm	Norchip	May 22	Sept. 29

Table 2. Total yield of potatoes as influenced by nitrogen, phosphorus and potassium fertilizer and soil test data on 10 sites for the years 1971, 1972, and 1973.

Treatments					Total Yield					
					Site No.					
$N + P_2O_5 + K_2O$	1	2	3	4	5	6	7	8	9	10
lb/a					cwt/acre					
[Kg/ha]					[quintal/ha]					
1. 0+0+0	204	201	146	131	221	188	154	125	153	153
[0+0+0]	[228]	[225]	[164]	[147]	[248]	[211]	[172]	[140]	[171]	[171]
2. 50+0+0	230	248	128	136	265	233	168	162	135	156
[56+0+0]	[258]	[278]	[143]	[152]	[297]	[261]	[188]	[181]	[151]	[175]
3. 50+50+0	268	288	—	—	—	—	—	—	—	—
[56+56+0]	[300]	[322]								
4. 50+0+50	239	237	155	138	274	237	174	175	118	131
[56+0+56]	[268]	[265]	[174]	[154]	[307]	[265]	[195]	[196]	[132]	[147]
5. 50+50+50	262	261	140	130	306	231	188	172	154	159
[56+56+56]	[293]	[292]	[157]	[146]	[343]	[259]	[210]	[193]	[172]	[178]
6. 50+100+50	261	249	127	143	275	228	176	197	106	133
[56+112+56]	[292]	[279]	[142]	[160]	[308]	[255]	[197]	[221]	[119]	[149]
7. 50+200+50	264	264	125	149	299	257	185	198	143	157
[56+224+56]	[296]	[296]	[140]	[167]	[335]	[288]	[207]	[222]	[160]	[176]
8. 100+0+50	231	261	135	142	301	246	178	153	127	150
[112+0+56]	[259]	[292]	[151]	[159]	[337]	[275]	[199]	[171]	[142]	[168]
9. 100+50+50	236	257	133	159	314	231	181	169	115	137
[112+56+56]	[264]	[288]	[149]	[178]	[352]	[259]	[203]	[189]	[129]	[153]
10. 100+100+50	270	309	117	145	311	261	178	190	119	140
[112+112+56]	[302]	[346]	[131]	[162]	[348]	[292]	[199]	[213]	[133]	[157]
11. 100+200+50	247	280	134	159	281	243	183	216	138	172
[112+224+56]	[277]	[314]	[150]	[178]	[315]	[272]	[205]	[242]	[154]	[193]
12. 100+200+100	—	—	139	—	—	—	—	—	—	—
[112+224+112]			[156]							
13. 200+200+50	—	—	140	—	—	—	—	—	—	—
[224+224+56]			[157]							
14. 100+400+50	323	322	146	153	293	255	185	218	102	126
[112+448+56]	[362]	[361]	[163]	[171]	[328]	[286]	[207]	[244]	[114]	[141]
LSDO5	31	31	—	20	52	52	—	30	—	—
	[35]	[35]		[22]	[58]	[58]		[34]		
LSDO1	42	42	—	—	69	69	—	40	—	—
	[47]	[47]			[77]	[77]		[45]		
				Soil Test Data						
pH	8.0	8.0	8.3	7.9	8.0	8.0	8.2	8.0	8.0	8.0
Nitrate-nitrogen	56	56	197	112	38	38	91	40	121	121
lb/acre-2'	[63]	[63]	[221]	[125]	[42]	[42]	[102]	[45]	[135]	[135]
[kg/ha-61 cm]										
Phosphorus	10	10	16	31	22	22	31	25	30	30
lb/acre	[11]	[11]	[18]	[35]	[25]	[25]	[35]	[28]	[34]	[34]
[kg/ha]										
Potassium	320	320	162	342	182	182	528	305	332	332
lb/acre	[358]	[358]	[181]	[383]	[204]	[204]	[591]	[342]	[372]	[372]
[kg/ha]										
Electrical cond.	—	—	0.30	0.61	0.38	0.38	0.94	1.50	2.93	2.93
mmhos/cm										

the seed pieces. Spacing between hills was approximately 12 inches (30.5 cm). Plants were sprayed and cultivated during the season by the cooperator to control insects, diseases and weeds. Vines were usually removed with a rotobeater several days before harvest. After digging, potatoes from 40 feet (12.2 m) of row were picked by hand from each plot. The potatoes were taken to Fargo for grading and sizing.

Tubers from 12 sites were taken at the time of grading and stored for later chipping tests. Storage conditions varied from year to year, but temperatures ranged from 40° to 65°F (4° to 18°C) and storage periods ranged from 70 to 120 days. In some instances tubers were subjected to unfavorable storage temperatures to enhance possible differences between treatments. Chipping tests were conducted at the Processing Laboratory, East Grand Forks, MN, to evaluate the effect of various fertilizer treatments on potato chip color.

Table 3. Total yield of potatoes as influenced by nitrogen, phosphorus and potassium fertilizer and soil test data on 7 sites for the years 1974 and 1975.

Treatment $N + P_2O_5 + K_2O$		Total Yield Site No. 11	12	13	14	15	16	17
	lb/a [kg/ha]	cwt/acre [quintal/ha]						
1.	0+0+0	196	300	182	217	128	228	265
	[0+0+0]	[219]	[336]	[204]	[243]	[143]	[255]	[297]
2.	0+50+50	186	296	186	220	149	252	280
	[0+56+56]	[208]	[331]	[208]	[246]	[167]	[282]	[314]
3.	25+50+50	205	299	220	242	163	257	286
	[28+56+56]	[230]	[335]	[246]	[271]	[182]	[288]	[320]
4.	50+50+0	189	301	192	227	175	247	291
	[56+56+0]	[212]	[337]	[215]	[254]	[196]	[277]	[326]
5.	50+0+50	187	315	196	228	175	257	280
	[56+0+56]	[209]	[353]	[219]	[255]	[196]	[288]	[314]
6.	50+25+50	194	317	218	236	174	264	309
	[56+28+56]	[217]	[355]	[244]	[264]	[195]	[296]	[346]
7.	50+50+25	185	304	208	244	187	255	290
	[56+56+28]	[207]	[340]	[233]	[273]	[209]	[286]	[325]
8.	50+50+50	200	304	218	239	198	271	314
	[56+56+56]	[224]	[340]	[244]	[268]	[222]	[304]	[352]
9.	50+100+50	191	322	221	249	184	278	294
	[56+112+56]	[214]	[361]	[248]	[279]	[206]	[311]	[329]
10.	50+200+50	193	288	213	253	211	259	303
	[56+224+56]	[216]	[323]	[239]	[283]	[236]	[290]	[339]
11.	100+50+50	179	312	196	234	200	259	298
	[112+56+56]	[200]	[349]	[220]	[262]	[224]	[290]	[334]
	LSDO5	—	26	17	17	31	23	23
			[29]	[19]	[19]	[35]	[26]	[26]
	LSDO1	—	—	23	23	41	31	31
				[26]	[26]	[46]	[35]	[35]
				Soil Test Data				
pH		8.0	7.4	8.0	8.0	7.8	8.0	8.0
Nitrate-nitrogen		52	67	50	50	28	50	50
lb/acre-2'		[58]	[75]	[56]	[56]	[31]	[56]	[56]
[Kg/ha-61 cm]								
Phosphorus		22	78	20	20	13	17	17
lb/acre		[25]	[87]	[22]	[22]	[15]	[19]	[19]
[Kg/ha]								
Potassium		457	820	265	265	360	257	257
lb/acre		[512]	[918]	[297]	[297]	[403]	[288]	[288]
[Kg/ha]								
Electrical cond. mmhos/cm		0.88	0.60	1.12	1.12	0.21	0.18	0.18

Table 4. Influence of fertilizer treatments on average total yield, percent marketable yield, percent culls and specific gravity of potatoes, 1971-1975.

Treatment $N + P_2O_5 + K_2O$ lb/acre [Kg-ha]	Total yield cwt/acre [quintal/ha]	Percent marketable weight	Percent culls weight	Specific gravity
	Average for Sites 1-10			
1. 0+0+0 [0+0+0]	168 [188]	87	2.3	1.087
2. 50+0+0 [56+0+0]	186 [208]	87	2.7	1.087
3. 50+0+50 [56+0+56]	188 [211]	86	2.4	1.085
4. 50+50+50 [56+56+56]	200 [224]	86	2.3	1.086
5. 50+100+50 [56+112+56]	190 [213]	87	1.5	1.085
6. 50+200+50 [56+224+56]	204 [228]	86	2.6	1.087
7. 100+0+50 [112+0+56]	192 [215]	84	2.6	1.085
8. 100+50+50 [112+56+56]	193 [216]	84	2.8	1.085
9. 100+100+50 [112+112+56]	204 [228]	85	3.1	1.084
10. 100+200+50 [112+224+56]	205 [230]	85	3.4	1.084
11. 100+400+50 [112+448+56]	212 [237]	84	3.2	1.085
	Average for Sites 11-17			
1. 0+0+0 [0+0+0]	217 [243]	85	7.3	1.083
2. 0+50+50 [0+56+56]	224 [251]	87	6.0	1.083
3. 25+50+50 [28+56+56]	239 [268]	85	7.0	1.083
4. 50+50+0 [56+56+0]	232 [260]	85	7.4	1.082
5. 50+0+50 [56+0+56]	234 [262]	86	7.3	1.081
6. 50+25+50 [56+28+56]	245 [274]	86	6.0	1.081
7. 50+50+25 [56+56+28]	239 [268]	85	7.1	1.081
8. 50+50+50 [56+56+56]	249 [279]	86	6.7	1.082
9. 50+100+50 [56+112+56]	248 [278]	85	6.7	1.082
10. 50+200+50 [56+224+56]	246 [276]	84	7.0	1.081
11. 100+50+50 [112+56+56]	240 [269]	87	6.3	1.079

Table 5. Effect of fertilizer treatments on color of potato chips.

	Treatment $N + P_2O_5 + K_2O$	Agtron readings* Site No.								
	[lb/acre]	1	2	3	5	6	7	9	10	Average
1.	0+0+0	26.3	38.3	32.4	28.2	29.6	33.8	34.8	44.8	33.5
2.	50+50+50	31.1	37.6	32.3	29.8	31.4	33.2	35.2	43.5	34.3
3.	100+0+50	28.0	38.5	28.6	25.0	30.6	33.5	34.2	43.0	32.7
4.	100+50+50	30.1	40.3	32.3	27.2	31.6	33.5	33.0	45.5	34.2
5.	100+100+50	32.0	36.6	30.6	27.2	31.6	33.5	29.0	42.0	32.8
6.	100+400+50	33.3	40.0	29.6	27.6	29.2	31.8	31.5	43.2	33.3
		Site No.								
		11	12	13	14					Average
1.	0+0+0	27.5	41.3	28.2	42.0					34.8
2.	0+50+50	26.8	44.2	29.2	43.8					36.0
3.	50+0+50	26.0	41.8	30.5	43.0					35.3
4.	50+50+0	29.0	40.7	30.0	43.5					35.8
5.	50+50+50	30.5	42.8	31.0	43.2					36.9
6.	100+50+50	27.5	41.7	31.0	42.5					35.7

*Higher values indicate lighter colored chips. Processors prefer readings over 40.
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Results and Discussion

Precipitation and temperatures were normal at the experimental sites in 1971, 1973 and 1975. In 1972, Site 3 at Hoople and Site 4 at Minto were dry, resulting in low yields. In 1974, Site 12 near Hillsboro became wet after a long dry spell, which resulted in a high percentage of culls.

The primary objective at sites 1 to 10 was to determine the response of potatoes to phosphorus, with secondary emphasis on nitrogen. At sites 11 to 17, the primary emphasis was on nitrogen. Soil test nitrate-nitrogen levels ranged from 28 to 197 pounds/acre (31 to 221 kg/ha), and phosphorus from 10 to 78 pounds/acre (11 to 87 kg/ha) at planting time.

The fertilizer rates, total yields and soil test data at sites 1 to 10 are shown in Table 2. Since little response was obtained at these sites to high rates of phosphorus, some of the phosphorus treatments were replaced by nitrogen treatments in 1974 and 1975 (sites 11 to 17 in Table 3). Total yields include all sound potatoes over 1½ inches (3.8 cm) in diameter. Total yields on the check plots ranged from 125 cwt/acre (140 quintal/ha) on Site 8 in 1973 to 300 cwt/acre (336 quintal/ha) on Site 12 in 1974.

Average yields and specific gravity for the various fertilizer treatments are summarized in Table 4. Average total yield for the check plots was 188 cwt/acre (211 quintal/ha) of which 86 per cent was marketable. The non-marketable tubers were the culls plus those under 1⅞" or over 3½" (under 4.75 cm or over 8.9 cm) in diameter. No definite trend was evident between the type or amount of fertilizer and per cent marketable yield (Table 4). The specific gravity of tubers tended to be slightly lower with heavy nitrogen fertilization (Table 4).

Fertilizer treatments had no measureable effect on chip color after storage and reconditioning (Table 5). Cultural and storage conditions were the same for sites 1 and 2, 5 and 6, 9 and 10, and 13 and 14. Kennebec was grown in the first of each pair of these sites and Norchip was grown on the other site. Norchip was consistently higher in color than Kennebec after chipping.

As stated earlier, the main purpose of this project was to relate soil test values with potato response to fertilizer, or, in other words, to use soil tests to predict the probability of getting a profitable response to the application of fertilizer. Data can be analyzed in several ways to show the relationship between the soil test and the response of crops to fertilizer, but one of the best and simplest is the method of Cate and Nelson (5).

In this method a scatter diagram of percentage yield (Y-axis) vs. soil test value (X-axis) is plotted as shown in Figure 1. Percentage yield is determined by dividing the yield obtained when a nutrient is lacking by the yield obtained when an adequate level of that nutrient is present. A low percentage yield indicates a large response to a nutrient and a high percentage yield indicates little or no response. The critical soil test level (point on the X-axis) below which the probability of a response to added fertilizer is high and above which the probability of such a response is low

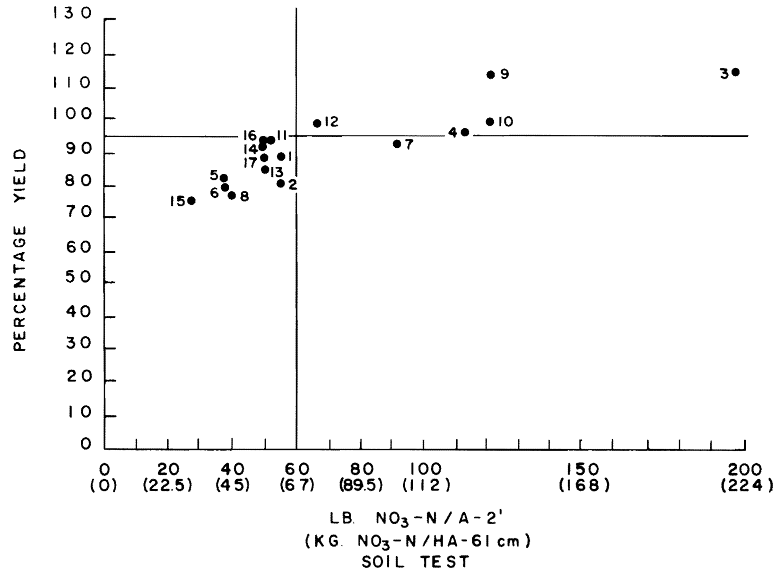

Figure 1. Scatter diagram of percentage yield vs. NO_3-N soil test value for 17 potato trials, 1971-1975.

can be obtained readily if it is assumed the points on the diagram belong to two groups. One group of points represents those sites where there was a low soil test and a good response to fertilizer (low percentage yield), and the other group represents the sites where there was a high soil test and a small or no response to fertilizer (high percentage yield).

Two solid lines have been drawn on Figure 1 in such a way that the maximum number of points fall into these two groups. The top-right quadrant formed by these two lines contains those points where there was a high soil test value and a small response to nitrogen fertilizer and the bottom-left quadrant contains these points where there was a low soil test value and a larger response to nitrogen fertilizer. From these data it can be concluded that below a soil test level of 60 lbs NO_3-N/acre-2' (67 kg NO_3-N/ha-67 cm) the probability of a response to nitrogen fertilizer was good, while above this soil test level there was a small chance of obtaining a large response to nitrogen fertilizer.

It was expected that there would be a large response by potatoes to nitrogen fertilizer on soils testing less than 50 lbs NO_3-N/A-2' (56 kg NO_3-N/ha-67 cm). This was expected because potatoes are shallow rooted, with most or all of the roots in the top 2 feet (67 cm) of soil, which is the soil depth normally tested for NO_3-N. The small response to nitrogen that we found was probably due to the fact that much of the NO_3-N that potatoes use forms in the soil during the long growing

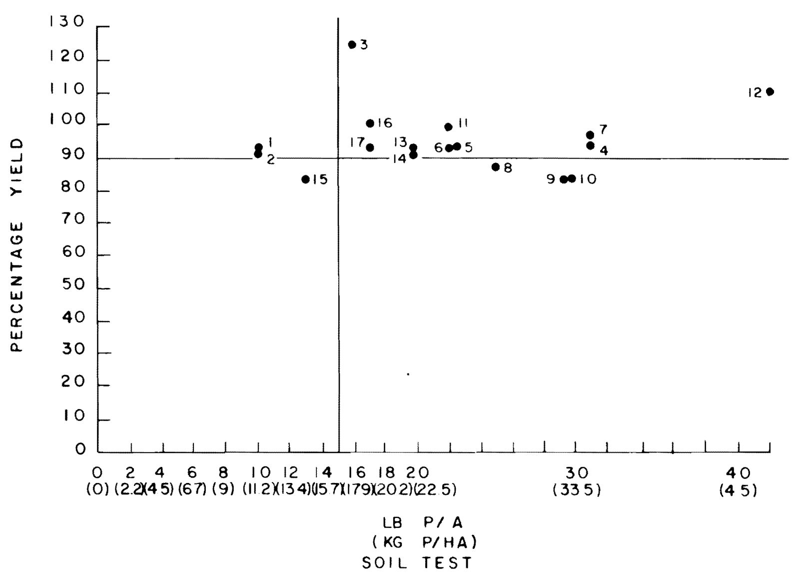

Figure 2. Scatter diagram of percentage yield vs. bicarbonate extractable soil P for 17 potato trials, 1971-1975.

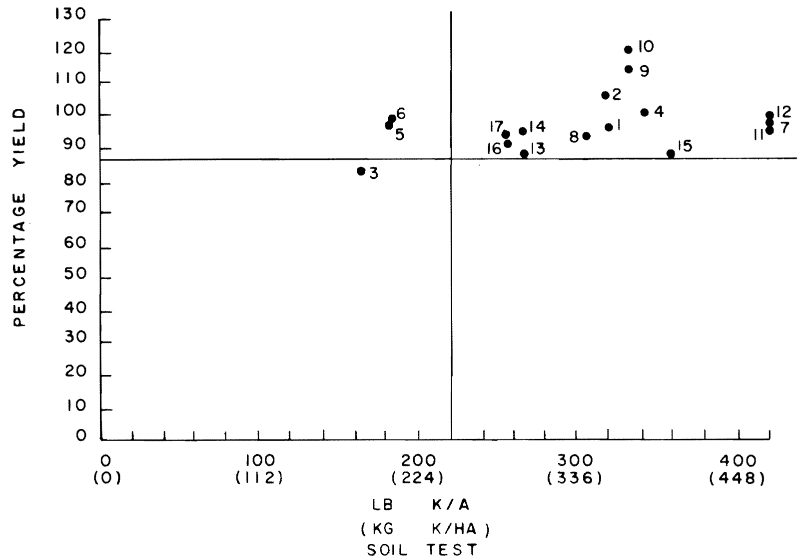

Figure 3. Scatter diagram of percentage yield vs. ammonium acetate extractable soil K for 17 potato trials 1971-1975.

period of this crop. Small grains, on the other hand, have a relatively short growing season and, therefore, depend heavily on the NO_3-N present at planting time. These data indicate that the present nitrogen fertilizer recommendations for potatoes should be reduced.

A scatter diagram of the percentage yield vs. phosphorus soil test values (Figure 2) shows there was very little response (high percentage yield) to phosphorus fertilizer at any of the sites. If sites 9 and 10 are left out (no significant response to fertilizer at the 5 per cent level), a line can be drawn at the 90 per cent yield level and at 15 lbs P/acre (17 kg P/ha) soil test level to get most of the points in the top-right and bottom-left quadrants. Based on these data, it can be said that below the critical phosphorus soil test level of 15 lbs P/acre (17 kg P/ha) the probability of a response to phosphorus fertilizer was good, while above this level there is only a small chance of obtaining a response. As with nitrogen, these data indicate that the phosphorus fertilizer recommendations for potatoes also should be reduced.

Figure 3 is a scatter diagram of the percentage yield vs. potassium soil test values. On site 3 which tested 162 lbs K/acre (181 kg K/ha), the lowest potassium test for any of the sites, there was a small response to potassium. Use of the Cate and Nelson method placed the critical potassium soil test value at about 220 lbs K/acre (246 kg K/ha), which is somewhat lower than the presently used critical value of 300 (336). Based on the data, potassium fertilizer recommendations should be reduced, but not to the extent of the nitrogen and phosphorus recommendations.

Summary

Potatoes were grown at 17 sites in the Red River Valley over a 5-year period to determine the influence of N-P-K fertilizer on yield at various soil test levels. It was found that there was very little response to fertilizer nitrogen when the NO_3-N soil test level was more than 60 lbs NO_3-N/acre - 2' (67 kg NO_3-N/ha-67 cm). There was very little response to phosphorus fertilizer when the soil tested over 15 lbs P/acre (17 kg P/ha) (bicarbonate extractable). At only one site was there a response to potassium fertilizer. High rates of nitrogen tended to decrease specific gravity. Fertilizer did not affect the color of potato chips.

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