Method of Phosphorus Fertilization for Sugarbeets in the Red River Valley*

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INTRODUCTION

Most studies involving rates and methods of phosphorus (P) fertilization of sugarbeets in the United States have been conducted under irrigated conditions. The sugarbeet crop in the Red River Valley of North Dakota, Minnesota and Manitoba is grown largely under dryland conditions where topsoils, after an effective leaf canopy has been established, often have low quantities of available soil moisture. Successful sugarbeet production is dependent upon utilization of stored subsoil moisture (10). Sugarbeets usually responded to row applications of superphosphate in the early years of the industry in the region (12).

Low soil temperatures increase the likelihood of P deficiency in sugarbeets (15). Etchevers (6) found that higher rates of P fertilizer were needed to optimize early sugarbeet growth as soil temperatures were reduced from 16 to 7° C. According to Sample (13) band or seed application of P fertilizer may be beneficial in regions where cold or wet springs affect early growth.

Sugarbeets utilized more ^{32}P-tagged fertilizer during the first four weeks of a greenhouse study when the fertilizer was placed either 5.1 or 10.2 cm below the seed as compared to a sideband application 5.1 cm to the side and 5.1 cm below the seed (1). Results of field experiments with sugarbeets in Michigan supported this finding (4). Sidebanded or row applications, however, are sometimes still preferred since disturbance of the soil at a depth near the line of seed sowing may affect emergence (5); this is especially relevant since precision planting is becoming

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of increasing importance to producers.

A great deal of work has been conducted on method of placement of P fertilizer, particularly under irrigated conditions. Results have been variable and in many cases yield differences were small (14). Cope and Hunter (3) suggested that small responses both to application and placement of P fertilizer under British conditions were due to the extensive nature of the sugarbeet root system.

Irrigated sugarbeets reportedly are unlikely to respond to P fertilizer in Washington (9) and Idaho (17) when soil $NaHCO_3$-extractable P (11) levels in the surface soil are greater than 10 ppm. The critical value for irrigated sugarbeets in Utah was given as 12.5 ppm $NaHCO_3$-extractable P (8). The relationship between reponses to broadcast and incorporated fertilizer by dryland sugarbeets in the Red River Valley and $NaHCO_3$-extractable P was studied by Etchevers (6) and is illustrated in Figure 1; sugarbeets growing in soils containing over 10 ppm extractable P seem unlikely to respond to broadcast fertilizer.

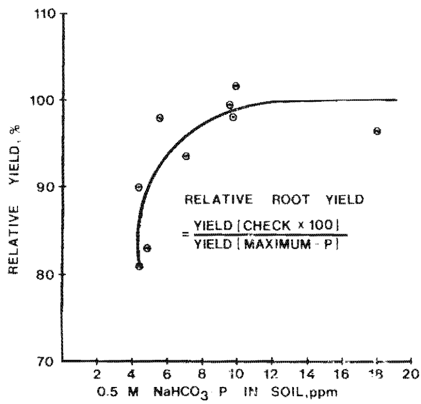

Figure 1. - Relationship between relative responses of sugarbeets to P fertilizer under field conditions and $NaHCO_3$-extractable P.

Recent data pertaining to responses to P fertilizer and method of application for sugarbeet production in the Red River Valley are sparse. The objective of the present study was to compare the efficacy of banded triple superphosphate with broadcast and incorporated application of the same material on soils with selected levels of $NaHCO_3$-extractable P.

MATERIALS AND METHODS

Four field experiments, one in 1975 and three in 1976, were established at sites with $NaHCO_3$-P levels (11) as given in Table 1. The experimental design was a randomized block with a split-plot arrangement of treatments. Broadcast and incorporated P fertilizer (0, 11, 22, 45, and 90 kg P/ha or 0, 10, 20, 40, and 80 lbs P/A) and banded fertilizer (0 and 11 kg P/ha) were the whole- and split-plot treatments, respectively. Each treatment was replicated six times. The experimental plot at Site 1 consisted of six 9.2-m rows spaced 75 cm apart; the plots at Sites 2, 3 and 4 were eight 13.6-m rows spaced 56 cm apart.

Table 1. - Selected properties of the soils at the sites of the rate and method of phosphorus fertilizer experiments.

Site	Soil	pH	0.5 M $NaHCO_3$-P
			ppm
1	Glyndon	8.1	4
2	Fargo	7.4	10
3	Overly	8.2	10
4	Glyndon	7.8	12

The broadcast P treatments were applied to the soil surface in the fall of the year prior to the experiment. The fertilizer was incorporated up to a depth of approximately 10 cm by use of a cultivator. The banded treatment was applied 5 cm to the side and 5 cm below the seed at planting by means of belt attachments to the planter and separate disc openings. A population of 58,000 plants per ha was established in all plots by thinning. A basal dressing of nitrogen, based on soil nitrate contents in the upper 61 cm of soil, was applied to the soil at all sites.

Petioles from recently mature leaves were sampled several times during the growing season, dried at 60°C, ground to pass a sieve with 0.5-mm openings, and analyzed for acetic acid extractable phosphate (7, 16). For root yield determinations at Sites 1, 2 and 3, two 5.0-m sections of the center rows were harvested and weighed. A subsample of 20 roots was taken and analyzed for percentage sugar and impurities. The final root yields at Site 4 were obtained similarly except that the lengths of the harvested rows were 7.6 m. Sugar losses were determined by the impurity approach of Carruthers and Oldfield (2). The impurity index ratio was defined as:

$$\text{Impurity Index} = \frac{3.5\text{xppm Na} + 2.5\text{xppm K} + 10\text{xppm amino-N}}{\%\text{sugar}}$$

RESULTS AND DISCUSSION

GROWING SEASON CONDITIONS

Precipitation during the growing season was 9.7, 15.0, 8.1 and 14.0 cm at Sites 1, 2, 3 and 4, respectively. During most of July and August total soil moisture in the 0 to 15-cm depth increment, the zone where the fertilizer was located, at Sites 1 and 3 below the 15-bar matric potential.

ROOT AND SUGAR YIELDS

The influence of method of application of P fertilizer on yield of sugar and roots is given in Table 2. Phosphorus fertilizer significantly increased yields of both roots and sugar only at Site 1, the site with the lowest value, 4 ppm, of $NaHCO_3$-extractable P. Percentage sugar and the impurity index were not affected by P treatment at any site.

Table 2. - Influence of rate and method of phosphorus fertilization on yield and related characteristics of sugarbeets at four sites.

		Broadcast P, kg/ha[a]								
		0		11		45		90		LSD
Site	Parameter	x	y	x	y	x	y	x	y	(0.05)
1	Yield, T/ha	32.7	37.6	36.5	39.7	36.7	40.5	40.3	40.5	2.9
	Sugar, %	18.4	18.4	18.4	18.2	18.4	18.0	18.1	18.5	NS
	Rec. sugar, kg/ha	5660	6690	6250	6720	6380	6900	6940	7011	392
2	Yield, T/ha	28.9	30.5	30.2	31.8	30.5	32.7	30.5	32.0	NS
	Sugar, %	16.3	16.8	16.8	16.8	17.1	16.6	16.8	16.7	NS
	Rec. sugar, kg/ha	4140	4510	4570	4780	4640	4860	4540	4730	NS
3	Yield, T/ha	37.9	39.0	37.4	37.6	38.3	39.0	39.0	40.0	NS
	Sugar, %	20.0	20.1	19.8	20.0	19.8	19.7	19.8	19.9	NS
	Rec. sugar, kg/ha	7070	7460	6930	7070	7090	7160	7220	7390	NS
4	Yield, T/ha	36.5	37.6	36.3	37.0	39.0	38.5	38.1	37.6	NS
	Sugar, %	19.0	18.9	19.3	19.2	18.7	19.0	19.0	19.0	NS
	Rec. sugar, kg/ha	6600	6680	6630	6640	6880	6830	6810	6720	NS

[a] "x" and "y" denote that either 0 or 11 kg P per ha, respectively, was applied 5 cm to the side and 5 cm below the seed. To convert from metric tons (T)/ha to tons/acre multiply T/ha by 0.446.

Side-banded application of 11 kg P per ha at Site 1 significantly increased recoverable sugar yields at the 0, 11 and 45 kg P per ha broadcast levels; the banded application had no significant effect on sugar yield at the highest rate of broadcast P. The banded application of 11 kg P per ha was significantly more effective than the same quantity broadcast at this site. In fact, this banded rate was equivalent or superior to the 45 kg P per ha rate.

There was a tendency for P fertilizer to increase root and sugar yields at Site 2, where the $NaHCO_3$-extractable P was 10 ppm. The effect of banded P fertilizer averaged over broadcast rates on root yields was significant at this site. Data showing the influence of banded phosphorus fertilizer averaged over the broadcast rates are given in Table 3.

Table 3. - Influence of a banded phosphorus fertilizer treatment averaged over several broadcast phosphorus fertilizer treatments on the yield of sugar and related characteristics at four sites.

Band P	Root yield	Sugar	Impurity index	Rec. sugar
kg/ha	T/ha	%		kg/ha
		Site 1		
0	37.0	18.4	375	6310
11	39.0	18.3	364	6830
LSD (0.01)	1.3	NS	NS	340
		Site 2		
0	30.0	16.8	732	4470
11	31.8	16.6	782	4720
LSD (0.01)	1.1	NS	NS	NS
		Site 3		
0	38.1	19.9	412	7110
11	38.5	19.9	411	7180
LSD (0.05)	NS	NS	NS	NS
		Site 4		
0	37.2	19.1	367	6710
11	27.4	19.1	393	6640
LSD (0.05)	NS	NS	NS	NS

PLANT ANALYSIS DATA

The effect of fertilizer treatments on acetic acid extractable phosphate in recently mature sugarbeet petioles during the growing season is illustrated in Table 4. Principal Conclusions from these data were:

Table 4. Influence of rate and method of phosphorus fertilization on acetic acid soluble phosphorus (AcOH-P) in petioles of recently mature sugarbeet leaves during the growing season at four sites.

P fert.[a]		Site 1			Site 2			Site 3			Site 4		
I	II	7/16	8/10	8/30	8/5	8/17	9/2	7/14	8/9	8/25	7/15	8/4	9/11
kg/ha		AcOH-P, ppm											
0	0	740	260	240	630	590	550	1660	1070	650	1780	1130	500
	11	1440	530	380	780	760	730	1750	1100	740	1840	1380	700
1	0	870	350	240	650	650	650	1820	1140	760	1850	1190	660
	11	1540	630	500	760	830	770	1640	1080	700	1810	1200	680
45	0	1470	490	430	800	900	820	1890	1310	790	2090	1400	820
	11	1770	830	620	850	1000	1000	1780	1160	840	2190	1460	860
90	0	2040	770	620	910	1110	1150	1840	1230	910	2270	1620	940
	11	2090	890	720	1020	1220	1230	1980	1280	930	2350	1640	950
LSD (0.05)		300	70	110	210	234	270	210	190	190	270	304	220

[a] "I" and "II" represent broadcast and incorporated phosphorus fertilizer, and banded 5 cm to the side and 5 cm below the seed, phosphorus fertilizer, respectively.

a. Extractable phosphate values were higher in petioles from Sites 3 and 4 where no response to phosphate fertilizer was obtained.

b. Banded P fertilizer was particularly effective at increasing plant phosphate at Site 1, the low soil phosphate site. The banded treatment was more effective in increasing plant phosphate than was up to 45 kg P per ha applied broadcast and incorporated.

c. Acetic acid extractable plant phosphate decreased during the growing season at all four sites. Phosphate values below 750 ppm P, the reported critical value for this element (16), were found at all sites during portions of the growing season. Data from the four experiments suggest that the critical value for plant phosphate-P decreased during the growing season under the given conditions. The critical value at Site 1 appeared to be between 1470 and 1770 ppm in mid-July, soon after the establishment of a complete leaf canopy; in contrast, the value dropped to between 430 and 620 ppm P late in the growing season. The plant analysis data from the other sites generally support these conclusions.

Westerman et al. (17) recently provided extensive plant analysis data for sugarbeets grown under irrigated conditions in Idaho where acetic-acid extractable phosphate contents of petioles of recently mature leaves also decreased during the growing season. Sugarbeets did not respond to P fertilization in the irrigated study if the petioles contained more than 1200 ppm phosphate-P in early July and 700 ppm phosphate-P in late August. Decreases in petiole P values in the dryland Red River Valley studies were larger than those for the irrigated study. This was probably due to shortages of available topsoil moisture detrimentally affecting the availability of native and fertilizer P during the latter part of the growing season. Luxury uptake of P early in the growing season may be needed under some conditions in the Red River Valley in order to insure adequate plant P later, when soil moisture shortages restrict P uptake from the topsoil.

SUMMARY

The influence of method of application on the response of sugarbeets to P fertilizer, triple superphosphate, was studied in four field experiments on soils containing 4, 10, 10 and 12 ppm

$NaHCO_3$-extractable P. Yield of recoverable sugar was increased by P fertilization of the soil with the lowest test value. On this latter soil 11 kg P per ha banded 5 cm to the side and 5 cm below the seed was equal or superior to the application of 45 kg P per ha broadcast and incorporated in the upper 10 cm of soil. Acetic acid extractable phosphate-P in petioles from recently mature leaves decreased during the growing season. The levels of petiole phosphate-P above which sugarbeets did not respond to fertilizer were approximately 1500 ppm and 500 ppm for leaves samples soon after establishment of a complete leaf canopy in mid-July and in late August or early September, respectively. Lack of available soil water in soil zones where P fertilizer is located probably influence critical plant P values in the Red River Valley. Banding some of the P fertilizer would appear to be agronomically efficient on soils in the region with relatively low levels of $NaHCO_3$-extractable P. The alternative in such cases is to apply larger quantities, up to 90 kg P per ha, of broadcast and incorporated fertilizer.

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