Phosphorus Fertilization of Sugarbeets[1]

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Sugarbeets (*Beta vulgaris* L.) have been fertilized with phosphorus (P) in the U.S.A. for the past 30 to 40 years. During this period, numerous studies on P fertilization rates and application methods have been conducted. Much of this information has been summarized (12, 14, 15, 4).[3]

Recent soil test data from England and the U.S.A. suggest that the available P levels in many soils are sufficient for maximum root and sucrose production without P fertilization. Detrimental effects of P fertilization at excessive soil P levels have been reported (6, 5) but not all data support these conclusions (12). Increasing fertilizer costs have also made it essential that growers have adequate guidelines upon which to base fertilizer applications. Information has been limited in Idaho for establishing an adequate soil test P level for optimum sugarbeet production. With this as background, we conducted two field experiments evaluating 1) the P fertilizer requirements of sugarbeets at different soil test P levels, and 2) the effects of P fertilization on soils already containing adequate available P levels.

Methods and Materials

Field experiments were conducted in 1972 and 1973 on the Portneuf silt loam (Xerollic Calciorthid) soil. This soil has a weakly cemented hardpan beginning at the 16- to 18-in depth which restricts downward root growth but not water movement. The residual soil P levels (Table 1) in 1972 resulted from a P fertilization experiment conducted on dry beans in 1971, whereas those in 1973 were established by rototilling into the soil various P fertilizer rates in the fall of 1972 after the harvest of a spring wheat crop. The bean straw residue from 1971 and the wheat straw residue from 1972 were plowed down in the spring, prior to the 1972 and 1973 experiments, respectively. The spring applications of N (34-0-0) and P (CSP, 0-45-0) fertilizers were incorporated into the seedbed before planting. The amount of N fertilizer applied was determined by the method outlined by Carter, *et al.* (3).

Soil samples were taken from each residual P treatment in 9-in increments to the 18-in depth before the spring fertilizer application. The samples were air-dried and the soil test P level (STPL) was measured by the

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[3] Numbers in parentheses refer to literature cited.

Table 1.—Effect of P level on root and sucrose yields, impurity indexes, and P uptake by sugarbeets.

Experiment	Residual soil test P level (0-9 in)	P fertilizer rate	Root yield	Sucrose	Sucrose yield	Impurity* index	P uptake at harvest	
							Tops and crowns	Storage roots
	ppm	lb/A	T/A	%	lb/A		lb/A	
1972	3.8	0	25.5	16.5	8450	450	8.6	10.4
		20	27.9	16.3	9120	435	10.1	13.3
		60	30.4	16.2	9860	494	12.3	16.3
		120	29.2	16.4	9520	528	11.3	15.8
	6.5	0	27.4	16.3	8900	481	10.0	11.6
		60	29.3	16.2	9510	454	9.9	13.7
	13.1	0	28.9	16.6	9290	496	10.3	15.0
		60	29.0	16.1	9320	491	11.8	16.5
LSD 1% level			3.0	N.S.	N.S.	N.S.	—	—
5% level			2.3	N.S.	1080	N.S.	—	—
1973	6.6	0	23.1	18.0	8320	527	10.9	7.6
		20	25.7	18.5	9510	487	12.6	10.6
		60	25.6	18.2	9318	505	13.3	12.3
	10.8	0	24.4	17.9	8735	521	12.0	10.3
		20	25.8	18.6	9600	539	14.8	11.5
		60	25.8	18.0	9290	522	13.8	13.2
	30.6	0	26.2	18.6	9750	465	13.3	13.4
		20	26.4	18.4	9720	481	13.9	13.9
		60	26.6	18.3	9740	480	15.0	14.4
	106.3	0	26.4	18.2	9610	506	16.5	15.4
		20	26.5	18.0	9540	542	16.6	16.1
		60	26.6	18.6	9895	496	16.0	15.7
Within a soil test P level:								
LSD 1%			2.1	N.S.	670	N.S.	—	—
5%			1.6	N.S.	500	N.S.	—	—
Within a P fertilizer rate:								
LSD 1%			2.2	N.S.	800	N.S.	—	—
5%			1.7	N.S.	700	N.S.	—	—

*Impurity Index = $$\frac{10\,(\text{ppm amino N}) + 2.5\,(\text{ppm K}) + 3.5\,(\text{ppm Na})}{\%\ \text{sucrose}}$$

$NaHCO_3$ method (11). Initial soil and beet petiole NO_3-N levels were determined by the NO_3-N specific-ion electrode method (10).

Sugarbeets were planted in 24-in rows in early April and hand-thinned to a within-row plant spacing of 8- to 10-in in late May. The experimental areas were furrow-irrigated when tensiometers installed in the row at the 18-in depth indicated that approximately 55% of the available soil moisture had been used.

Twenty petioles from the most recently matured blades were taken randomly from each plot near July 1, 15, and 30, and again near September 1. The petioles were separated from the blades and cut into 0.5-in sections. In 1973, whole plants (tops and storage roots) were also randomly sampled at thinning for dry-weight determinations. All plant samples were dried at 65°C and ground to pass a 40-mesh sieve. The petioles were extracted with 2% acetic acid for soluble PO_4-P (19, 1). Total-P concentrations were determined after wet-ashing plant samples with a mixture of $HC1O_4$ and HNO_3. Both P forms were determined by the vanadomolybdate method (8).

Root yields were estimated by hand-harvesting four 10-ft row sections from each plot in the 1972 experiment and by machine-harvesting four 35-ft row sections from each plot in the 1973 experiment. Samples of sugarbeet tops and crowns from two uniform 10-ft row sections were harvested from each plot in both experiments immediately prior to root harvest for determining total-P uptake. The impurity index (2) and sucrose content were determined on two randomly selected root samples (approximately 25 lb each) from each plot by a sugar company. The root pulp (collected during the sucrose analysis) and the top and crown samples were dried at 65°C, ground to pass a 40-mesh sieve, and analyzed for total P. The crown's P content has been added to that of the tops for this discussion.

Results and Discussion

Soil test phosphorus levels

Significant ($P \leq 0.01$) root yield responses to P fertilization were observed at the lowest STPL each year (Table 1). Root yields were maximum when 60 lb P/A were applied at the 3.8 ppm STPL in 1972, whereas only 20 lb P/A were necessary at 6.6 ppm in 1973. In both experiments, root yields were not significantly increased by P fertilization when the STPL was greater than 10 ppm. However, yields increased significantly when the STPL increased from 10.8 to 30.6 in 1973 without P fertilization. The STPL in the 9- to 18-in soil layer was 2 to 3 ppm P in both experiments (data not shown). A higher STPL in this lower soil layer would probably decrease the STPL at which sugarbeets would respond to P fertilization but we did not confirm this in these experiments. Our results verify an earlier reported experiment on this same soil series (9). Similar data for other calcareous soils have been reported in Washington (7, 6), England (5), and in the western U.S. and Canada (11). However, some yield responses to P fertilization have been reported when the STPL was above 10 ppm (18, 13).

The sucrose yields increased linearly with root yields since neither the initial STPL nor P fertilization significantly affected the sucrose concentration or impurity index (Table 1). The P fertilization treatments that significantly increased root yields also significantly increased sucrose yields. One anomaly did occur in the 1973 experiment where P fertilization at the 10.8 ppm STPL increased the sucrose yield but not the root yield. Higher sucrose concentrations in 1973 as compared with 1972 compensated for the lower root yields in 1973 so that the amounts of sucrose produced both years were nearly equal.

We did not observe any detrimental effects of P fertilization on root yields, sucrose concentrations, sucrose yields, or impurity indexes at STPLs from 3.8 to 106.3 ppm. Other published data have suggested that P fertilization decreases sucrose production at STPLs above adequacy (6, 5, 4). Perhaps other non-nutritional or nutritional factors were involved that may account for these differences.

Plant analyses

Plant analysis can identify and confirm visual deficiency symptoms and be used to supplement soil testing in developing a fertilizer management program. However, plant nutrient levels must be established that are sufficient for maximum yields. Figure 1 shows the petiole PO_4-P concentrations that resulted from different P fertilization rates at the lowest STPL in each experiment from early July to end of August. The petiole PO_4-P concentration reached a maximum in early July and then decreased until late August. Previous findings have shown that yield is reduced when the

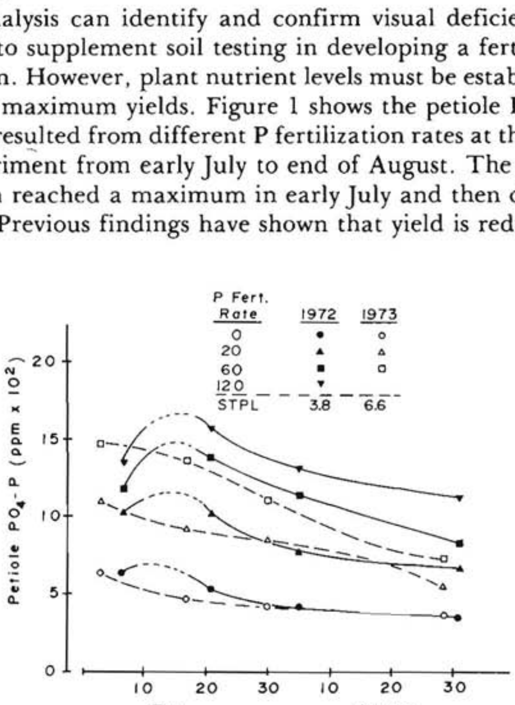

Figure 1.—Effect of P fertilization on petiole PO_4—P concentrations. Dashed sections of 1972 lines are estimated.

petiole PO_4-P concentration decreases below 750 ppm between thinning and harvest (19, 15). Our data showed that a petiole PO_4-P concentration of 750 ppm early in the growing season may still limit yields if the decrease in petiole PO_4-P concentration during the season is not considered. In general, we found that petiole PO_4-P concentrations should be greater than 1200 ppm in early July and 700 ppm in late August to insure maximum yields (Figure 1). We also found agreement was good between the petiole PO_4-P concentration and the STPL (Figure 2). At a 10 ppm STPL, the petiole PO_4-P concentrations were approximately 1200 ppm in early July and 700 ppm in late August.

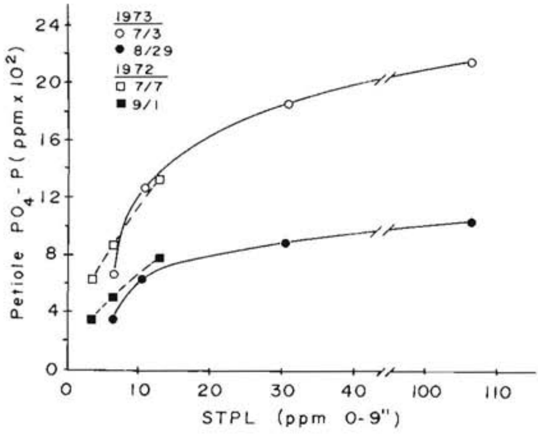

Figure 2.—Relationships between different STPLs and petiole PO_4-P concentrations.

The relationships between the total P concentration in the blades and root yields are shown in Figure 3. Using the same root yield criteria as in Table 1 to separate significant root yield differences, P concentrations above 0.24% in early July and 0.21% in late August were adequate. Very little information is available relating the total P concentration of blades to root yields, but petiole P concentrations from 0.25 to 0.27% have been reported necessary for maximum root yields (7, 6). Critical P concentrations in young seedling blades have been given as 0.42% total P (16); however, photosynthesis has been shown to decrease at P levels below 0.60% (17).

Total P uptake ranged from a low of 18.5 to over 30 lb P/A (Table 1). Approximately 50% of this remains on the field in the tops and crowns after the sugarbeet roots are harvested. Total P uptake was lower in 1972 compared with 1973 at equivalent sugarbeet root yields. The P uptake per ton of sugarbeet roots varied from 0.7 to 1.2 lb P/A under deficient and excessive levels of P, respectively.

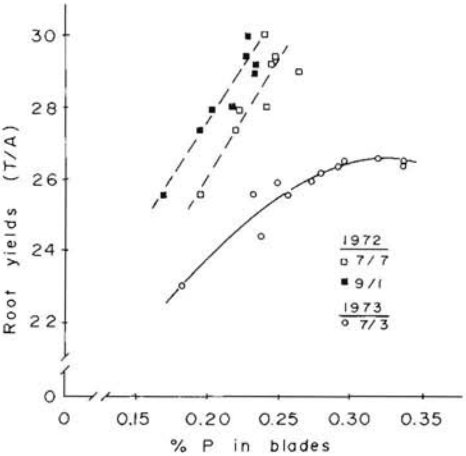

Figure 3.—Relationship between total P in the most recently matured blade and root yields.

Petiole NO_3-N levels in late August averaged 3900 and 1900 ppm in the 1972 and 1973 experiments, respectively. This indicates that the N level did not limit root yields in either experiment but may have been slightly high for maximum sucrose production (3). We found that all the other nutritive elements in the blades were at sufficient concentrations.

Early plant growth

We observed a visual top growth response to P fertilization early in the growing season in each experiment, but many of these differences had disappeared by early August. Early plant weight was related to P fertilization, particularly at the 6.6 ppm STPL (Figure 4). Phosphorus fertilization had very little effect on plant weights above a 10.8 ppm STPL. Plants were still larger at higher STPLs, but these did not significantly increase final root yields. Other researchers have reported that root yield improvements from P fertilization occurred early in the growing season (15, 5). This early growth effect was confirmed in 1973 by relating plant weights at thinning to final root yields (Figure 4). Increasing the early plant size by P fertilization or with higher STPLs increased the final root yields; however, no significant root or sucrose yield increases occurred when the plants were larger than 11 g/25 plants at thinning.

Summary

Phosphorus fertilizer applications did not significantly increase sugarbeet root yields when the $NaHCO_3$-soil test P level was greater than 10 ppm in the 0- to 9-in plow layer. Neither P fertilization nor soil test P level influenced the sucrose concentration or impurity indexes. Thus, sucrose yields increased linearly with root yields.

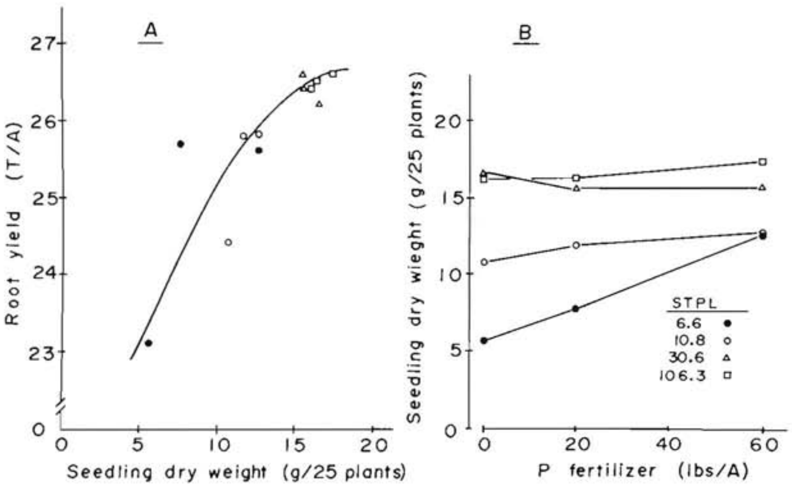

Figure 4.—Relationship between seedling dry weights at thinning (31 May 1973) and root yields (A) and P levels (B) in the 1973 experiment.

Sugarbeets did not respond to P fertilization if the petioles from the most recently matured blades contained more than 1200 ppm PO_4-P in early July and 700 ppm PO_4-P in late August. Under similar conditions, the blades contained 0.24 and 0.21% total P. The whole plant dry weights at thinning were related to final root yields, indicating that the yield potential resulting from P fertilization is established early in the growing season.

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