Table 5. Minimum soil temperatures at 2, 4 and 12 inches in sugarbeet beds, 1980 and 81

Date	Soil Depth - inches 2	4	12
	- - - - - - - - - - ^{o} F - - - - - - - - - - - -		
Jan. 6	50	53	55
Jan. 16	52	55	56
Jan. 22	44	49	52
Feb. 6	43	47	50
Mar. 12	--	58	59
Mar. 24	52	52	59

Table 6. Effect of foliar N and P treatments and N fertility level on NO_3-N content of petioles sampled on 21 January in low residual P soil.

Foliar Treatment[1/]	N Fertility Level N1	N2	N3
		NO_3-N (ppm)	
1A	2,900	7,430	9,000
1B	2,600	8,500	9,600
2A	3,200	8,200	8,200
2B	4,000	9,050	8,300
3A	3,100	8,600	7,900
3B	6,000	8,800	9,000
4A	3,350	8,050	9,100
4B	4,600	9,200	8,800
5A (N)	3,200	9,750	8,600
5B (N)	1,630	8,300	9,400
6A (N + P)	2,000	7,950	9,100
6B (N + P)	3,300	8,600	8,050
7 Check	5,000	8,100	8,850

[1/]For a description of foliar treatments see Table 1.

Phosphorus Fertilization of Fall-Planted Sugarbeets

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Summary

Data presented indicates that P availability plays a significant role in production of fall-planted sugarbeets, as both root yield and percent sucrose may be affected. Analyzing petioles for soluble P as well as nitrate concentration should aid in evaluating a P fertilization program, although the P concentration values may vary from year to year, depending on the climatic conditions. This is more practical than analyzing leaf blades, because the same petiole samples collected for nitrate analysis can also be analyzed for soluble P.

Application of P fertilizer would be recommended if soil tests indicate low to marginal available P. Soil P extracted by $NaHCO_3$ should not be below 10 ppm. Soil with test values from 5 to 10 ppm would be adequate for the seedling growing in warm soil, but in the December through February cold soil period, petiole soluble P concentration may drop to around 1,000 ppm, with inadequate growth and sucrose concentration the result.

Introduction

The sugarbeet grower in southwestern irrigated desert areas is sometimes doubtful of results to be expected from the application of phosphorus (P) fertilizer. Consequently, P is routinely applied with nitrogen (N) fertilizer at planting time as "insurance" against a possible soil P deficiency. Because of a number of factors that affect P utilization, there is little assurance that P fertilizer will be worth the cost. Some of the more important factors influencing P uptake are: the concentration of available and organic P in the soil; placement of P fertilizer; soil temperature -- low temperatures reduce P uptake; pH of the soil; and water and N content of the soil.

In a survey conducted by Dennis et al. (1), summarizing practices of 52 growers and 62 fields in Arizona, higher rates of P fertilizer were positively and significantly correlated with sucrose percentages and yield of sugar. Higher P rates were also apparently related to earlier maturity.

Westermann et al. (5) found in Idaho that whole plant dry weights at thinning time were related to root yields and that the yield potential from P fertilization was established in the early stages of growth. In central Arizona, sugarbeets are planted in the fall at about the same time as harvest in Idaho.

It is expected that differences might be found in P utilization between the two climates and soils. Beets in Arizona reach about the same growth stage in January and February as that at which Westermann et al. found petiole P concentration to be related to yield response. However, in Arizona, beets at that stage are usually growing slowly in cold soil, while in Idaho growth is rapid in warm soil.

Experiments were conducted at Mesa, Arizona, in 1970-71 and 1971-72 to provide growers with information on N and P nutrition. The response of fall-planted sugarbeets to residual and applied N in these experiments was reported earlier (3). Presented here are the effects of P fertilization on sugarbeet production and the relationships between P levels in tissue and yield factors for the same experiments.

Results of this study have been published in the Journal of the American Society of Sugar Beet Technologists, Vol. 20, No. 5, pp 439-448, 1980.

Materials and Methods

Cultural and harvest procedures were described in the earlier report on N effects by Johnson et al. (3), and were essentially the same for both experiments. However, conditions for the two seasons were dissimilar in that the average air temperature of the growing period after mid-February 1971-72 was about 5^{o} F warmer than the 1970-71 season. Another difference was that small grains preceded the 1970-71 crop and potatoes preceded the 1971-72 crop. Residual N and P levels were relatively high for the 1971-72 season (3). Soil for extractible P measurement was sampled to a depth of one foot, before P fertilizer application, on September 7 for the 1970-71 crop, and on August 13 for the 1971-72 crop. Soil P was extracted by 0.02 N NaCl at 1:5 ratio, soil:extractant, a method then in use for studying changes in inorganic and organic forms of soil P.

Sugarbeet cultivar 'US H9B' was planted on September 12, 1970 and September 17, 1971 on Laveen loam (typic calciorthid), on 40-inch double row beds, and furrow irrigated. Four replications of treatments were located on pairs of larger plots maintained at low P (no P applied for eight years) and high P (phosphate fertilized annually). The P treatment plots were split by four N fertilizer rates of 0, 80, 160 and 240 lb N/A as urea, in 1970-71; and by rates of 0, 100, 200 and 300 lb N/A in 1971-72. Only the high P plots received 40 lbs P/A in a preplant band application six inches below and one inch to the side of the seed row each season. Potatoes preceding the 1971-72 crop received 90 lbs P/A. A 183 ft^2 area was harvested from each subplot June 15, 1971 and June 8, 1972. Tissue P concentration data were not obtained for the 0-N and highest N rates; consequently yield data for these N treatments are not reported here.

In the 1970-71 season, leaf blades and petioles were collected on six dates for the lower N rate and on four dates for the higher N rate (Tables 2 and 3). Only NO_3-N was measured in petioles in the 1970-71 season. In 1971-72, leaf blades were collected on six dates, and petioles, collected for NO_3-N analysis, were also analyzed for P content on four dates.

Etchevers et al. (2) reported that two variables affecting soluble P values obtained from sugarbeet petioles are drying temperature and leaf selection for sampling. In these experiments the drying temperature for tissue samples did not exceed 75^{o} C, and entire replications were sampled by a single operator to minimize sampling error. Samples were dried in a forced-draft oven and ground to pass a 40-mesh screen.

Soil P was determined in NaCl extracts by the procedure of Watanabe and Olsen (4). Concentration of total P in leaf tissue was determined after ashing at 500^{o} C, and soluble P in leaf blades and petioles after extracting with 2% acetic acid, by adapting the same procedure.

Results and Discussion

Yield data obtained for the two experiments are summarized in Table 1. Root yields for the two seasons were not greatly different, but in 1971-72 more residual N was available, resulting in lower sucrose percentages and sugar yields. Warmer temperatures in the 1971-72 season undoubtedly influenced growth and nutrient absorption. Nearly all of the tissue P levels that are comparable by date for the two seasons were higher in 1971-72 than in 1970-71 (Table 3).

Table 1. Effect of soil P level on sugarbeet yield parameters at two N fertility levels in 1970-71 and 1971-72.

		1970-71			1971-72		
N Fertilizer 1/ Increment	P 2/ Level	Yield Root	Yield Sugar	Sucrose Concn	Yield Root	Yield Sugar	Sucrose Concn
		T/A	T/A	%	T/A	T/A	%
First	Low	24.2	3.97	16.38	29.0	4.04	14.78
	High	27.1	4.53	16.78	28.9	4.40	15.22
	LSD (0.05)	2.6	0.22	NS	NS	NS	NS
Second	Low	29.2	4.65	15.92	30.4	3.91	12.85
	High	31.4	5.19	16.50	29.3	3.91	13.35
	LSD (0.05)	NS	0.18	0.36	NS	NS	NS

1/ First N fertilizer increment was 80 lb/A in 1970-71 and 100 lb/A in 1971-72; second N fertilizer increment was 160 lb/A in 1970-71 and 200 lb/A in 1971-72.

2/ Low P level, no P applied in last 10 years; high P level, P fertilizer applied annually.

Soil P extracted by 0.02 N NaCl solution indicated approximate $NaHCO_3$- available P values for the 1970-71 crop of from 3 to 4 ppm for the low P, and 9 to 11 ppm for the high P soil; for the 1971-72 crop, values were about 10 to 13 ppm for the low P, and 13 to 16 ppm for high P soil.

1970-71 Season

The high P treatment resulted in increased root yields (Table 1) at the lower N rate (80 lb/A), but not at the higher rate (160 lb/A). Sugar yields were significantly increased by yearly additions of P fertilizer at both N levels. When 160 lbs of N/A were supplied, P fertilizer increased the sucrose percentage. Both total and soluble P in leaf blades were higher with the high P treatment for the first four sampling dates at the lower N rate (Table 2). There was no significant difference in P levels in blades between P treatments just before harvest.

Table 2. Effect of soil P level on sugarbeet tissue P concentration at the first increment of N fertilizer, 1970-71 and 1971-72.

Sampling Date	Tissue	P Form	1970-71 P Level High	1970-71 P Level Low	1971-72 P Level High	1971-72 P Level Low
			- - - - - - - - -	ppm-p	- - - - - - - - -	
Nov. 13	Leaf	Total	4350	2690*	-	-
		Soluble	2790	1610*	-	-
Dec. 2	Leaf	Total	3470	2410*	-	-
		Soluble	1960	1280*	-	-
Dec. 21	Leaf	Total	3660	2990*	-	-
		Soluble	1900	1410*	-	-
	Petiole	Soluble	-	-	2130	1540*
Feb. 5	Leaf	Total	3580	2910*	-	-
		Soluble	1980	1430*	-	-
	Petiole	Soluble	-	-	1650	1060*
Apr. 8	Leaf	Total	3430	2900*	-	-
		Soluble	2240	1760 NS	-	-
	Petiole	Soluble	-	-	2060	1550*
Jun. 11	Leaf	Total	3020	2580 NS	-	-
		Soluble	2250	1720 NS	-	-

*Difference between P levels within a season is statistically significant at the 5% level; NS, not significant at the 5% level.

At the 160 lb/A N rate, only total P in blades sampled in February was increased by the addition of P fertilizer (Table 3). When total P values for either early or late sampling dates within the higher N rate were averaged, blade P concentration was significantly increased by the high P treatment. Soluble P was increased by P fertilization only in the late sampling period.

Table 3. Effect of soil P level on sugarbeet tissue P concentration at the second increment of N fertilizer, 1970-71 and 1971-72.

Sampling Date	Tissue	P Form	1970-71 High	1970-71 Low	1971-72 High	1971-72 Low
			ppm-p			
Nov. 13	Leaf	Total	-	-	5280	4380*
		Soluble	-	-	2840	2140*
Dec. 21	Leaf	Total	3640	3040 NS	3890	3270*
		Soluble	1860	1480 NS	2150	1720*
	Petiole	Soluble	-	-	1700	1710 NS
Feb. 5	Leaf	Total	3580	2820*	2940	2370*
		Soluble	2040	1520 NS	1340	1190 NS
	Petiole	Total	-	-	2520	1790*
		Soluble	-	-	1570	940*
Mar. 8	Leaf	Total	-	-	4630	3200*
		Soluble	-	-	3090	2160*
	Petiole	Soluble	-	-	2660	1840*
Apr. 8	Leaf	Total	3500	3120 NS	3890	2940 NS
		Soluble	2300	1990 NS	2830	2120 NS
	Petiole	Soluble	-	-	2130	1320*
Jun. 5	Leaf	Total	2810	2520 NS	3550	2750*
		Soluble	1940	1760 NS	2580	1880 NS
Average Dec. 21 & Feb. 5	Leaf	Total	3610	2930*	-	-
		Soluble	1950	1490 NS	-	-
Average Apr. 8 & Jun. 5	Leaf	Total	3160	2820*	-	-
		Soluble	2120	1880*	-	-

*Difference between P levels within a season is statistically significant at the 5% level; NS, not significant at the 5% level.

The relationships between yield parameters and P levels in tissue are summarized in Table 4. Some correlations were significant both seasons for data obtained at the lower N rate, but none were significant for data from the higher N rate. Soluble P levels in blades on December 21 and on February 5 were best correlated with root yields in June, 1971 (R^2 = 0.63), and total P in blades was so related in April 8 samples (R^2 = 0.77). Only the soluble P levels in blades sampled April 8 were significantly related to sucrose concentration. Yield of sugar was significantly correlated with both total and soluble P levels in blades on all sampling dates except Dec. 2.

Table 4. Correlation coefficients for regression of yield parameters on P concentration in sugarbeet leaf blades for the first increment of N fertilizer, 1970-71.

Sampling Date	P Form	Root Yield	Sucrose Concn	Sugar Yield
		- - - - - - - -	r	- - - - - - - -
Nov. 13	Total	.600	.602	.739*
	Soluble	.662*	.291	.699*
Dec. 2	Total	.444	.161	.459
	Soluble	.415	.082	.404
Dec. 21	Total	.611	.371	.678*
	Soluble	.796**	.365	.843**
Feb. 5	Total	.588	.367	.657*
	Soluble	.791**	.398	.848**
Apr. 8	Total	.876**	.527	.961**
	Soluble	.642*	.720*	.809**

*,**Coefficients significant at the 5 and 1% levels, respectively.

1971-72 Season

None of the yield parameters measured were affected by P treatment (Table 1). Soluble P in petioles in plots receiving the lower N rate (100 lb/A) was significantly increased by the high P treatment on all sampling dates (Table 2). At the higher N rate (200 lb/A), the effect of the high P treatment on soluble P level in petioles was similar to that at the lower N rate except that an increase was not obtained in December (Table 3). Conversely, total and soluble P levels in blades were increased by P fertilizer in December, but not in April.

The only significant relationship between yield data and P levels in tissue was between soluble P concentration in petioles sampled in April and sugar yield ($R^2 = 0.50$, 100 lbs N/A). Higher temperatures and greater N and P availability in 1971-72 were probably responsible for the low correlations obtained.

Westermann et al. (5) reported that yields were likely to be reduced when soluble P levels in petioles were lower than 750 to 1200 ppm and that total P concentration in leaf blades should be approximately 0.24% in July or at midseason. Based on these criteria, the tissue P levels indicated the P supply was marginal in 1970-71 and that adequate P was available in the low P treatment in 1971-72.

Phosphate fertilizer applied in a band near and below the seed at planting time may not be as effective for fall-planted sugarbeets as if disked into the surface and listed into the bed, or applied in a wide band below the seed, since seedling root contact with the fertilizer is not as important as having many roots in contact with fertilizer when soil temperatures are low. Maintaining a high available P in soil planted to other crops preceding sugarbeets may be more effective than applying P fertilizer at the time sugarbeets are planted. The management objective, then, would be to plant sugarbeets on land high in residual P. Should tissue analysis indicate that in winter months P is low, and sucrose concentration likely to be adversely affected, the only practical way to get P into the plant immediately appears to be by foliar application.

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