The Application of Petiole Analyses to Sugar Beet Fertilization

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Nitrogen has been demonstrated to be the principal limiting fertilizer element in sugar beet production on most California soils (5)[2]. Phosphorus and potash have been shown to be insufficient for sugar beet needs on a lesser number of soils (5). A number of investigators (1, 2, 4, 7, 10, 11) have emphasized the critical aspects of nitrogen fertilization with respect to yield and sugar content of the crop. Through their work the reduction of yield resulting from an inadequate supply and the lowering of sugar content accompanying an oversupply has been demonstrated. It is essential then that time and rate of nitrogen application should be such that a good yield results with a minimal sucrose concentration reduction. The problem is further complicated by the fact that field needs vary widely in limited areas (1, 11) . It has also been observed that the nitrogen fertilizer requirement of a single field may vary considerably in different seasons (6).

In answer to the problem of efficiently fertilizing sugar beets, with special reference to notrogen, Ulrich has proposed and refined techniques utilizing petiole analysis (7, 8, 9). The method consists of following the status of labile fractions of various essential plant nutrients by chemical analyses of dried petioles, plotting such data to obtain curves showing concentration changes with time, and fertilizing according to the interpretation of such curves. By means of pot and field tests critical concentration levels were found, below which plants werc observed to develop deficiency symptoms and suffer yield reductions (7, 8, 9). It was suggested and demonstrated that the time for fertilization could be indicated by the rate at which the concentration of nutrients in the samples taken approached the established critical ranges (1, 8).

The purpose of the more recently completed experiments was to test and extend the usefulness of such techniques under field conditions.

Methods and Procedure

Replicated field tests were set up with nitrogen rates varying over a rather wide range. Each plot consisted of four 2-row beds or six single-row beds, which were 60 feet long. Two hundred feet of row were harvested from each plot for yield determinations. Except for the check plots, a basic nitrogen rate was applied to all plots at thinning time or as a preplant application. As the need for supplemental applications was indicated by petiole analysis, more fertilizer was added by sidedressing at predetermined amounts. Whenever no approaching deficiencies were indicated by the analytical results, the supplemental applications were added at the latest practical date.

In one of the tests additional treatments were included in which all the nitrogen was applied at thinning time in amounts equivalent to that applied to corresponding plots receiving basic plus supplemental applica-

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[2] Numbers in parentheses refer to literature cited.

tions. The nitrogen was supplied as NH_4NO_3 or as $(NH_4)^2S0_4$. In addition to the plots receiving only nitrogen fertilizer, four tests included plots treated with phosphorus or both phosphorus and potassium, which were applied with a high rate of nitrogen. The rates applied are given in tables which follow. Both the P_2O_5 and K_2O were applied before planting or at thinning time by sidedressing as treble superphosphate and K_2SO_4.

Petiole samples w're collected periodically from each plot throughout the season and analyzed for NO_3-N. Certain of the samples were also analyzed for PO_4-P and K, but only for selected sampling times. At harvest time the beets were dug and yield and sucrose determinations made.

Results

Test 1

The harvest data for Trial 1 are given in Table 1 and three of the curves for petiole analyses are shown in Figure 1.

Table 1.—Harvest Results. Trial No. 1, Davis, Yolo County, 1952.

Lbs. of N, P_2O_5 or K_2O per acre		Tons beets per acre	% sugar	Cwts. sugar per acre
May 31[1]	July 24			
0	0	21.1	15.9	66.8
80N	0	23.6	15.6	72.8
80N	40N	25.9	15.1	78.2
80N	80N	28.5	14.7	84.0
80N	160N	30.4	14.0	84.8
200 P_2O_5, 80N	160N	29.7	13.6	80.6
200 P_2O_5, 200 K_2O and 80N	160N	28.4	14.1	80.2
Significant difference	(19:1)	2.3	0.7	10.0
	(99:1)	3.1	0.9	13.4

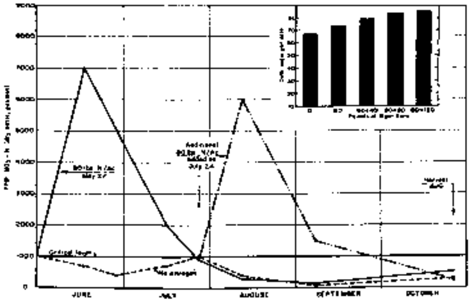

Figure 1.—Effects fertilization on the nitrate-nitrogen content of sugar beet petioles. Trial No. 1, Davis, Yolo County, 1952.

The curve indicated by the lower dashed line represents the check plots. In the case of this field the nitrogen level of the plants was below the critical concentration practically all season long when no fertilizer was applied. The NO_3-N content of the plants which received the 80-pound per acre rate, as can be seen from the solid line curve, increased considerably after the nitrogen application, but declined rapidly as the season progressed and fell below the critical concentration three months prior to harvest. Both of these treatments resulted in lowered yields, which was anticipated from the petiole data. The remaining curve represents the analytical results from beets of the plots to which supplementary 80-pound nitrogen applications were made when petiole analysis showed an impending deficiency. From the data collected the best time for supplemental nitrogen application could have been predicted but not the amount to apply. At the highest supplemental rate no further significant yield increase was observed, nor was there any yield increase from phosphorus or potassium. The petiole P and K values were well above critical levels and no response was expected.

Test 2

In 1952-53 an experiment was conducted at the Meloland Field Station, Imperial County, California. The treatments, application dates, and yield data are reported in Table 2 and the petiole analysis curves for certain key treatments are found in Figure 2.

Table 2.—Harvest Results. Trial No. 2, Meloland, 1952-53.

Lbs. of N per acre		Tons beets per acre	% sugar	Cwts. sugar per acre
Nov. 5[1]	Jan. 29			
0	0	15.0	18.5	55.6
80	0	23.6	18.5	86.8
160	0	29.6	18.3	108.6
240	0	32.7	17.8	116.0
80	40	28.6	18.5	105.4
80	80	30.9	18.2	113.4
80	160	33.5	17.8	118.8
Significant	(19:1)	2.5	0.5	10.2
difference	(99:1)	3.4	0.6	13.6

[1] Thinning time. Planted September 25.

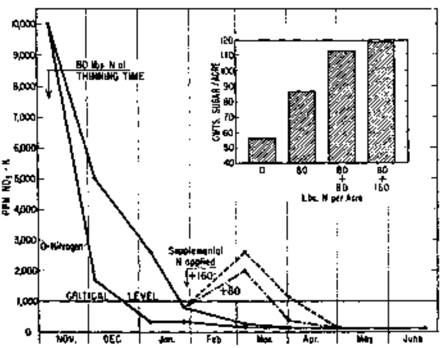

Figure 2.—Effects of fertilization on NO_3-N content of sugar beet petioles. Trial No. 2, Meloland, Imperial County, 1952-53.

In this test the beets responded to nitrogen rates up to 240 pounds per acre. There were no significant differences between the single and split applications at corresponding total nitrogen rates. The long periods of short nitrogen supply of those plots receiving no nitrogen or 80 pounds per acre at thinning time accounted for the yield reduction. When 80 and 160 pounds of nitrogen were applied as a supplement, the period of sufficient supply was extended 2 and 3 months respectively, resulting in yield increases.

Test 3

One of the tests was located on a field of very high nitrogen fertility. The yields of all plots, including check plots, were high and even at harvest time the NO_3-N concentration of the petioles was in excess of the critical level regardless of treatment. Consequently, there were no significant differences in yield due to nitrogen applications. Although petioles of beets which received supplemental nitrogen showed more nitrogen uptake, the difference between such treatments and the check was relatively small at all sampling dates. The data for this test are summarized in Table 3.

Table 3.—Harvest Results. Trial No. 3, Santa Barbara County, 1953.

Lbs. of N, P_2O_5 or K_2O per acre		Tons beets per acre	% sugar	Cwts. sugar per acre[2]	NO_3-N content at harvest p.p.m.
Feb.[1]	May 30				
0	0	30.8	15.2	93.6	5,750
80N	0	33.8	14.9	100.6	5,460
80N	80N	33.8	14.2	96.8	6,530
80N	160N	30.6	14.5	88.8	7,150
80N, 200 P_2O_5	160N	32.0	14.4	92.2	5,610
80N, 200 P_2O_5, 200 K_2O	160N	33.0	14.3	94.4	6,180
Significant difference	(19:1)	N.S.	N.S.	N.S.	N.S.
	(99:1)	N.S.	N.S.	N.S.	N.S.

[1] Planting time.
[2] Calculated using treatment averages for tons beets per acre and percent sugar.

Test 4

Experiment 4 illustrates a case in which no response to added nitrogen was measured, even though such appeared likely. At the time of supplemental application the concentration of NO_3-N in the petioles was approaching the critical concentration. Even though supplemental nitrogen was applied June 5 and the field irrigated June 13 the NO_3-N content of the petioles did not increase appreciably. The petiole analyses correlated with the yield data, as indicated in Figure 3 and Table 4.

Test 5

In Tests 1, 2, 3, and 4 no response to phosphorus was observed. In Test 5, however, both nitrogen and phosphorus applications stimulated yields. The yield data, as reported in Table 5, show that nitrogen alone increased root yields about 7 tons per acre and when combined with adequate phosphorus another 7 ton per acre increase was measured.

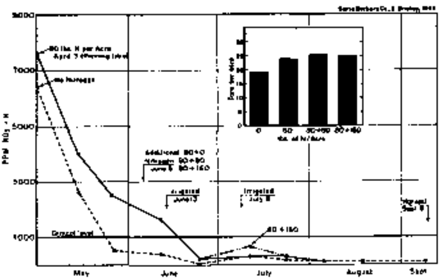

Figure 3.—Effect of fertilization on NO_3-N content of sugar beet petioles. Trial No. 4, Santa Barbara County, 1952.

Table 4.—Harvest Results. Trial No. 4, Santa Barbara County, 1952.

Lbs. N, P_2O_5 and K_2O per acre April 3[1]		Tons beets per acre	% sugar	Cwts. sugar per acre	Beets harvest per 100' of row
0	0	19.0	18.6	73.2	131
80N	0	24.1	18.5	89.4	130
80N	80N	25.4	18.5	93.6	131
80N	160N	25.0	18.2	91.2	125
200 P_2O_5, 80N	160N	26.0	18.2	94.4	130
200 K_2O, 200 P_2O_5, 80N	160N	25.6	18.3	94.0	130
Significant difference	(19:1)	1.4	N.S.	4.6	
	(99:1)	1.9	N.S.	6.4	

[1] Thinning time.

Table 5.—Harvest Results. Trial No. 5, Tulare County, 1952.

Lbs. N, P_2O_5 or K_2O per acre March 28[1]	June 27	Tons beets per acre	% sugar	Cwts. sugar per acre	Beets harvested per 100' of row
0	0	14.5	17.8	51.4	230
80N	0	18.1	17.2	62.4	235
80N	40N	20.3	17.0	68.8	256
80N	80N	19.4[2]	15.8	61.2	250
80N	160N	22.0	15.3	67.4	242
80N, 200 P_2O_5	160N	29.6	15.2	89.8	228
80N, 200 P_2O_5, 200 K_2O	160N	27.6	15.3	85.0	239
Significant difference	(19:1)	2.4	0.9	8.8	
	(99:1)	3.2	1.2	11.8	

[1] Planting time. Fertilizer side-dressed 6 inches S inches from row and about 4 inches deep.
[2] This value is low because the yield of one of the plots in this treatment was exceptionally low (11.5 tons/acre).

Figure 4 shows the petiole analyses curves for NO_3-N and indicates an interesting effect of phosphorus on nitrate absorption. On May 30 the NO_3-N concentration was found to be higher on the plots which received nitrogen plus phosphorus at planting time than those which received the same amount of nitrogen alone. On July 18 this appeared again in the samples taken soon after the supplementary nitrogen had been added. The converse phenomenon had been observed by Lorenz and Johnson (3) in which additions of ammonium sulfate increased the PO_4-P content of tomato foliage. In the latter case ammonium sulfate, because of its acid reaction in the soil, made more phosphorus available to the plants. In Trial 5 the greater absorption of nitrate in the presence of phosphorus may be due to faster root development or to increased root activity or to factors not now known.

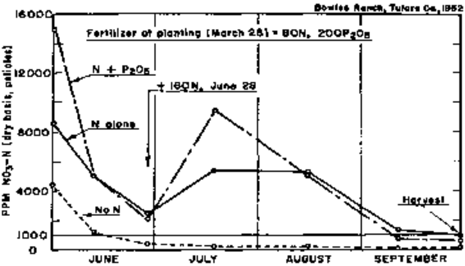

Figure 4.—Effect of phosphorus fertilization of sugar beet petioles. Trial No. 5, Tulare County, 1952.

Figure 5 shows the effect of phosphorus fertilization on the PO_4-P concentration of petioles. Both treatments plotted in this figure received the same amount of nitrogen (240 lbs. N/acre). The phosphate level of the plants which received no fertilizer phosphate ranged from 680 to 440 p.p.m. PO_4-P throughout the season, whereas the phosphate-fertilized plants always had a concentration of 1,600 p.p.m. PO_4-P or more. This difference accounted for the yield differences measured.

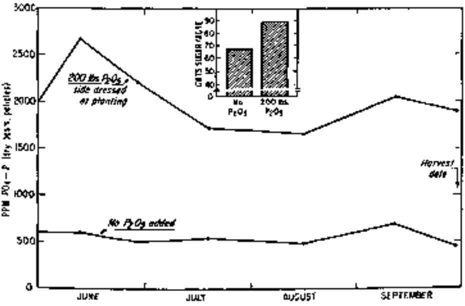

Figure 5.—Effect of phosphorus fertilization on the PO_4-P concentration of sugar beet petioles. Trial No. 5, Tulare County, 1952.

Diagnosis of Sulfur Deficiency

During the summer of 1953 a field was observed in which there was a large area of chlorotic sugar beets having symptoms indistinguishable from those produced by a nitrogen deficiency. Petiole analysis, however, showed that the affected beets were higher in nitrate-nitrogen than the more vigorous green beets. It was determined that there was no appreciable difference between good and poor beets in potassium or phosphate content, but that the sulfate content of the two varied widely as reported in Table 6. Although wide differences in the concentration of SO_4-S occurred in petioles as well as leaf blades, the latter appear to be better for diagnosis of possible sulfur deficiencies.

Table 6.—Sugar Beet Leaf Analyses, Butte County, July 7, 1953.

	Leaf Analyses				
	(petioles)			(blades)	(petioles)
Growth of sugar beets	NO_3-N (ppm)	PO_4-P (ppm)	K (%)	SO_4-S (ppm)	SO_4-S (ppm)
Vigorous	2,520	2,120	3.15	1,880	530
Poor	9,000	2,900	3.30	155	85

After the analyses had been made, small strips of soil with the deficient beets were treated with ammonium nitrate, gypsum, and ammonium sulfate. The results of subsequent leaf analyses are found in Table 7.

Table 7.—Sugar Beet Leaf Analyses, Butte County, August 11, 1953.

Treatments[1]			Leaf Analyses	
	Lbs. per acre		ppm NO_3-N	ppm SO_4-S
Material	N	S	(petioles)	(blades)
Check	0	0	640	750
Am. nitrate	200	0	7,600	295
Gypsum	0	484	580	13,600
Am. Sulfate	200	242	1,350	11,000

[1] Applied to single 4-row strips, July 20, 1953.

There was a great improvement in the appearance of sugar beets treated with $(NH_4)_2SO_4$. The deficiency symptoms disappeared, the leaves turned dark green, and there was a visible growth response. Petioles collected from these plants indicated that this growth response was associated with the absorption of SO_4-S. The addition of NH_4NO_3 did not correct the deficiency symptoms and the plants did not make the thrifty growth made by those receiving $(NH_4)_2SO_4$. When gypsum alone was added the plants readily absorbed SO_4-S but made no growth response; in fact, they made less growth than plants receiving NH_4NO_3.

Reasons for these divergent growth responses can be seen in the data presented in Table 7. When gypsum was added the sulfur deficiency was readily corrected, but almost immediately the plants became deficient in nitrogen and therefore little or no growth response would be expected. The addition of NH_4NO_3 kept the plants well supplied with nitrates but they continued to be deficient in sulfur. $(NH_4)_2SO_4$ corrected the sulfur deficiency and also supplied the plants with sufficient nitrogen for good growth.

These observations illustrate that in many instances leaf analysis can be a very effective tool for rapid diagnoses of field problems.

Discussion

These trials have provided case histories showing how leaf analysis might be used to improve practices in sugar beet fertilization. In each instance it was felt that such a technique could have led to better fertilization and a better understanding of the fertility problems of the fields studied.

Tests 1 and 2 illustrated that petiole analysis can be used to demonstrate impending nitrogen deficiencies and thereby act as a guide to time of application. In Test 2 there was apparently no advantage to applying the fertilizer in two applications rather than one. The point is raised, however, that at the beginning of the season there was no satisfactory way to predict with accuracy which of the rates applied would have been best. In fact, at mid-season petiole analysis could not be used to tell how much nitrogen to apply as indicated by the maximum response to 80 pounds of supplemental nitrogen in Test 1, whereas Test 2 required 160 pounds for best results. For such fields addition of an amount somewhat less than that considered adequate, with supplemental nitrogen applied when indicated by the analytical data, would appear most efficient. The amount of supplemental fertilizer to be added would depend on the length of growing season remaining and past experience with the field.

Test 3 represented a field in which certainly no supplemental nitrogen was needed or indicated by petiole analvsis. In such fields, *i.e.*, those which may be judged to be high *in* fertility due to past history or the nature of the soil, it would probably be best to refrain from applying fertilizer until such time as the analyses indicated a need. In the particular field cited any fertilizer expenditure was wasted during that particular crop season.

If petiole analysis had not been used in Trial 4, a false conclusion might have been drawn due to the failure of beets to respond to supplemental nitrogen applications. The conclusion that the beets did not need more nitrogen would have been suggested from the yield data alone. Petiole analysis, however, showed that the plants did not absorb the supplementary nitrogen in amounts sufficient to affect the yields appreciably. Therefore, it may still be possible to obtain yield responses to nitrogen on this field if ways can be found to get supplementary nitrogen into the beets.

Test 5 demonstrated the relationship between both NO_2-N and PO_4-P concentration in sugar beet petioles and the growth of the plants. Leaf analyses of such a field would indicate the possibility of improving subsequent crops by phosphate fertilization. In all trials, except Number 5, phosphate and potassium analysis showed no indications of deficient supplies and, since no yield differences arose, the analytical data are not included.

Summary

The use of petiole analysis as a guide to sugar beet production was studied through a series of tests conducted in several California beet-growing districts. Petiole samples were taken periodically from check plots and from plots treated with predetermined basic fertilizer rates. Certain of the samples were "analyzed for NO_3-N, PO_4-P, and K, and curves representing changes in plant content of the nutrients with time were constructed. In the case of nitrogen, supplemental applications were made when the curves indicated an approaching deficiency. When experiments were conducted on high fertility fields, in which no need of supplemental treatments was indicated, the same treatments were applied at the latest practical date.

The experiments demonstrated that petiole analysis can be a valuable aid in sugar beet fertilization on fields of high or low fertility. It was possible to predict from curves cases in which nitrogen responses could or could not be expected, and the time when supplemental applications should be made. It was also possible to use leaf analysis in improving phosphorus fertilization practices, and, as was pointed out in a case where a sulfur deficiency was found, to diagnose still other nutrient deficiencies.

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