Plant Analysis as a Guide in the Fertilization of Sugar Beets [1]

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The need for better methods of determining the fertilizer requirements of sugar beets is emphasized whenever a fertilizer program is proposed for a field of beets. While soil analyses conducted either through chemical or biological means are helpful in estimating the concentrations of nutrients in the soil that are available to plants, they do not indicate what the crop is actually getting from the soil under the prevailing climatic conditions. In contrast to soil analysis, analyses of plant samples properly collected from the field will indicate what the plant is getting from the soil in relation to its environment. When the analytical values from the plant samples are compared with the critical levels for each nutrient, conclusions may be drawn with respect to the adequacy or inadequacy of the nutrients at the time of taking the sample. By collecting plant samples from the same field at regular intervals, the relative importance of the deficiency can be estimated from its duration and from the time of its occurence during the growing season. It is obvious that the longer the plant is deficient, in a given nutrient, and the earlier in the growing season the deficiency takes place, the greater the chance of getting an increase in yield from adding the required nutrient to the soil.

Tn order to interpret the results of plant analysis, the values must be compared with the critical level for each nutrient as estimated from previous experimentation. For practical purposes the critical nutrient level may be defined as "that narrow range of concentrations in which the growth rate or yield first begins to decrease in comparison with plants at a higher nutrient level" *(3)*[3]. Thus, plants with nutrient concentrations well above the critical level are likely to be adequately supplied with nutrients at the time of collecting the samples, while plants with nutrient concentrations at or below the critical level are likely to be deficient in nutrients.

[1]In conducting the surveys in 1943 through 1945, aid from many sources was obtained. Field men of the Spreckels, Holly, and American Crystal Sugar Companies and of the California Packing Corporation collected the leaf samples and supplied the crop and fertilizer data for each field sampled. Grants-in-aid for analytical assistance were received from the American Potash Institute, the Barrett Division of the Allied Chemical & Dye Corporation, California Fertilizer Association. Chilean Nitrate Sales Corporation, and National Fertilizer Association.

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[3]Italic numbers in parentheses refer to literature cited.

When plant samples are collected at regular intervals the analytical results may be helpful in at least three ways, first by disclosing nutrient deficiencies which may be corrected when detected early in the growing season; second by observing changes in the nutrient composition of the beets produced from additions of fertilizers or from changes in cropping practices, and third by indicating adjustments to be made in subsequent fertilizer and cropping practices on the field which has been sampled. In order to correct nutrient deficiencies arising during the current season, speed is essential, both in reporting the analytical results and in making the fertilizer applications in the field. However, as more experience is gained, emergency applications of fertilizers on beet fields should become less important and more emphasis placed upon maintaining a high level of soil fertility in relation to the nitrogen, phosphorus, and potassium requirements of sugar beets. By keeping a record of the nutrient status of each crop of beets, and if possible of all other crops grown on the field, the general trend in the fertility level of the field can be observed and changes in the cultural practices introduced in time to counteract decreases in fertility of the soil.

Procedure of Sampling

Success in the use of plant analysis as a means of determining the nutrient status of sugar beets depends largely upon the technique adopted in the sampling of beet plants. Preliminary studies in our laboratories *(2)* and by Brown (*1*) have indicated that the petiole of the youngest "mature" leaf reflects satisfactorily the nitrogen and phosphorus status of sugar beets. Recent studies have also indicated that the same part of the plant may be used for estimating the potassium status of sugar beets.

The procedure usually followed in collecting petiole samples *(4, 5)* is to divide a field into approximately four equal parts. A sample from each part is collected by walking across the planting rows and taking the petiole of the one leaf selected from each of the 30 to 40 locations uniformly spaced across the center of each quarter of the field. Thus, four samples are collected from each field for individual laboratory analysis. The petioles arc then cut into sections of 2 to 5 millimeters in length. A representative sample of 50 or 100 grams of freshly sliced material is dried rapidly in an oven with air circulating at temperatures from 70° to 80° C. The dried plant material is ground in a Wiley mill to pass a 40-mesh sieve and stored in bottles until analyzed for nitrate, phosphate, and potassium. Samples collected every 2 to 4 weeks, starting shortly after thinning and ending at harvest time, are sufficient to show the trends in the nutrient status of sugar beets under field conditions.

Plant Nutrient Surveys

In 1943 and 1944 seventy fields of sugar beets located in the Monterev, San Benito, and Santa Clara counties and in the Sacramento and San Joaquin valleys were sampled at intervals of 3 to 5 weeks during the growing season *(4, 5)*. Each field in the survey was selected on the basis of its productivity. As a rule each field man in a given district sampled one field that was considered by him to be either average or above average and another field that was considered to be below[7] average in productivity. In no case were fields selected that were suspected of being seriously affected by diseases or pests or by any other known factor, with the possible exception of a plant nutrient deficiency.

The analytical results obtained for the leaf samples from each field in the survey were compared with the critical levels for each nutrient which, expressed on the dry basis, are tentatively as follows: 1,000 p.p.m. of nitrate nitrogen for nitrogen, 1.000 p.p.m. of phosphate-phosphorus extracted by 2 percent acetic acid for phosphorus, and 2 percent total potassium for potassium. By making these comparisons for the 70 fields sampled during the 2-year period it was found that 70 percent of the fields were beiow the critical nitrogen level long enough to warrant experiments with nitrogen, 28 percent in the case of phosphorus, and 6 percent for potassium. When fields below the critical level for a short time only are included as being suitable for experimentation, the percentages would be 88 percent for nitrogen, 41 percent for phosphorus, and 14 percent for potassium. Whether or not the fields which were indicated as being deficient by plant analysis would actually respond to the fertilizers must, of course, be determined by experiments on these fields.

Demonstration Experiments

In order to evaluate the effectiveness of plant analysis as an aid in determining the fertilizer requirements of sugar beets, many field experiments or demonstration trials must be established in each sugar beet district. When conducting these experiments, nutrient content comparisons should be made between plants that, are deficient and those in adjacent plots that have been fertilized adequately with the required nutrient. These comparisons should result in a satisfactory correlation between the nutrient content of the plant and yield response, providing that the fundamental concept of the critical nutrient level is valid. However, when making the comparisons between nutrient levels and yields, it should be noted at the beginning that there will be a number of instances in which the nutrient concentrations of the unfertilized beets will be at the critical level, and yet, after fertilization there will be no significant increases in yield even though the nutrient concentrations of the beets have been increased above the critical level. In these instances the increases in yield will be relatively small and unless the design of the experiment is efficient they will not be detected.

Table 1.—Nitrate concentration below the critical level in sugar beet petitoles from the untreated demonstration plot on Salinas clay located near King City, Calif.*

		Plant analyses		
Sampled	Treatment**	NOs - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 28	None	300	2,690	7.52
	N	200	2,440	6.84
	2 N	1,100	2,600	7.94
July 25	None	280	1,690	7.16
	N	10,500	1,530	6.49
	2 N	12,800	1,700	6.51
August 25	None	20	1,610	6.87
	N	390	1,570	5.30
	2 N	1,470	1,580	5.30

*The leaf samples and yields were obtained by Mr. Harold Voth of the Spreckels Sugar Company.

** N = 400 — 500 pounds ammonium sulfate per acre.
2 N = 800 — 1000 pounds ammonium sulfate per acre.

The fertilizers were applied June 17, and thereafter the field was irrigated on July 5 and August 3. The beets were harvested on November 21, 1944. The yields for the untreated, N, and 2 N plots were 12.2, 20.3, and 20.9 tons of beets per acre, respectively, while the corresponding sugar concentrations were 17.8, 17.3, and 17.1 percent.

During 1944 and 1945 a number of demonstration plots were established by the fieldmen of the Spreckels Sugar Company. Six trials were conducted, and in all cases the results were in accord with the leaf analyses that were made during the course of the experiment. The results of 3 of these trials are reported in tables 1 to 3. The data of tables 1. and 2 indicate that when beets from unfertilized plots have nitrogen concentrations well below the critical level, the addition of nitrogen increases the nitrate concentration of the beets considerably during part of the growing season. In the plots near King City, Calif., (table 1) the addition of nitrogen increased the yields from 12 tons per acre for the untreated plots to 20 tons per acre for the N treatment and to 21 tons per acre for the 2N treatment. At Grimes, Calif., (table 2) the yields were increased from 14.4 tons per acre to 16.7 tons per acre by the addition of 335 pounds of ammonium nitrate per acre. In contrast to the plots in which yield increases were obtained when the beets reached the critical nitrogen level, the results given in table 3 for a field of beets near Ryde, Calif., indicate that when the beets have nitrogen concentrations well above the critical level on all sampling dates, the addition of nitrogen fails to give a response. However, an inspection of the analyses for phosphorus and potassium of this field suggests that the beets were

Table 2.- Nitrate concentrations below the critical level in sugar beet petioles from the untreated demonstration plots on Sacramento clay located near Grimes, Calif.*

		Plant analyses		
Sampled	Treatment **	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 19	None West	3,940	1,050	3.91
	None East	5,100	990	3.68
	N West	4,310	640	4.25
	N East	4,200	880	4.40
July 2	None West	2,580	1,160	3.29
	None East	1,850	1,410	3.14
	N West	12,000	1,170	3.34
	N East	7,700	1,200	3.14
July 31	None West	490	1,370	2.77
	None East	259	1,700	2.97
	N West	2,700	1,180	2.39
	N Kast	4,880	1,560	2.51
Sept. 25	None West	0	575	2.35
	None West	8	850	2.66
	N West	25	652	0.88
	N East	210	927	1.24

*The leaf samples and yields were obtained by Mr. M. G. Raney of the Spreckels Sugar Company.

** N = 335 pounds ammonium nitrate per acre drilled into center of irrigrat ion furrows on June 5, 1945. Thereafter the field was irrigated on June 19 after taking the first plant samples.

The average yields from the unfertilized and fertilized plots on October 17 were 14.4 and 16.7 tons of beets per acre, respectively, while the corresponding sugar concentrations were 18.9 and 19.0 percent.

deficient in phosphorus and possibly in potassium, and therefore phosphorus alone and in combination with potassium should have been tried on this field. After phosphorus is added, the changes in the nitrogen and potassium concentration of the beets should be followed carefully because the increased growth caused by the phosphorus application should draw more heavily on the nitrogen and potassium reserves of the soil.

Field History

The importance of keeping a record of the nutrient levels of crops grown on the same field is shown in tables 4 and 5 for beet leaves sampled in 1943 and again in 1945. Prior to leaf sampling the field had been in beets in 1942, barley in 1941, oats in 1940, and asparagus in 1939 and for many yours preceding this date. No fertilizer was used on this field until 1942 when 400 pounds of 30-20-0 per acre was applied. In 1943 when plant samples were first collected, the beets were fertilized with 400 pounds of nitrate of soda per acre. The results of

Table 3.—Nitrate concentrations above the critical level in sugar beet petioles from the demonstration plots on Ryde clay loam located near Ryde, Calif.*

		Plant analyses		
Sampled	Treatment**	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 20	None	8,000	1,230	3.08
	N	11,000	1,080	3.02
July 18	None	8,100	840	2.17
	N	8,200	840	2.50
August 23,	None	5,300	540	1.71
	N	5,500	740	2.01
September 28	None	7,600	520	1.69
	N	5,900	410	1.90

*The leaf samples and visual observations were taken by Mr. G. W. Zellinger of the Spreckels Sugar Company.

**200 pounds ammonium nitrate drilled into the soil on May 22. Thereafter the field was first irrigated on June 10. The average yield for the entire field on January 15, 1945, was 21.9 tons of beets per acre, while the sugar concentration was 11.5 percent.

All figures for the N treatment are averages from three sections of the field.

There was no visible response to the nitrogen application.

the leaf sampling for four sections of the field are given in table 4. The chemical analyses presented in the table indicate that the beets were primarily deficient in nitrogen, although at times they were somewhat low in phosphorus throughout the field.

In 1944 the field was planted to carrots, which were grown for seed, and during this period no fertilizer was applied. In 1945 the field was again planted to beets, and it received 480 pounds of nitrate of soda per acre on April 15 as a side dressing and 150 pounds of ammonium nitrate per acre applied through the sprinkling system on June 24. On each sampling date two samples were collected from Sections A and 13 and three at intervals from Section 0. The analytical results from these sections are reported in table 5 as averages for each section. The chemical analyses of these samples indicate that the beets were well supplied with nitrogen throughout, all the growing season and that phosphorus was low in mid-July, through August, and at the time of harvest in September. Therefore the use of phosphorus in addition to nitrogen should now be considered for this field, particularly when it is planted to sugar beets. Potassium was apparently adequate, as shown by the potassium analyses for the 2 years.

Table 4,—Plant nutrient status of sugar beets on Egbert muck located near Rio Vista, Calif., for 1943*

		Plant analyses		
Sampled	Section	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 7	A	5,400	1,190	6.42
	B	7,400	1,120	6.52
	C	8,200	980	6.23
	D	3,240	1,370	4.98
June 28	A	2,450	850	5.91
	B	1,590	893	5.77
	C	1,330	1,090	5.21
	D	1,130	1,160	4.30
July 26	A	720	670	6.19
	B	70	880	6.99
	C	182	900	6.09
	D	46	960	5.68
Sept. 9	A	99	670	6.90
	B	38	1,060	7.89
	C	38	1,230	6.68
	D	23	890	7.17
Oct. 4	A	30	830	6.73
	B	23	1,340	6.51
	C	15	1,620	6.10
	D	38	1,340	6.16

*The leaf samples were collected by Mr. L. A. Kloor of the Holly Sugar Company. On October 9, 1943, the field produced 17.1 tons of beets per acre with an average sugar concent ration of 19.1 percent.

Table 5.—Plant nutrient status of sugar beets on Egbert muck located near Rio Vista, Calif., for 1945* (same field as in table 4).

		Plant analyses		
Sampled	Section	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent.
June 21	A	10,150	1,230	3.58
	B	11,800	1,100	3.86
July 5	A	7,000	1,070	3.73
	B	7,900	1,025	2.96
	C	7,000	1,000	2.81
Aug. 6	A	4,490	670	3.71
	B	7,600	700	3.59
	C	4,800	730	3.73
Aug. 22	A	1,620	610	5.59
	B	3,800	640	4.35
	C	2,770	800	5.14
Sept. 6	A	1,070	525	5.14
	B	1,300	510	5.37
	C	2,050	620	4.99

*The leaf samples were collected by Mr. J. W. Coover of the California Packing Corporation.

On September 11, 1945, the field produced 20.3 tons of beets per acre with an average sugar concentration of 15.5 percent.

Summary

Plant nutrient surveys of sugar beet fields were made by analyzing petioles of leaves collected from 70 fields in the Salinas, San Joaquin, and Sacramento Valleys of California during 1943 and 1944. Four samples were taken from each field three to five times during the growing season of each year. After the samples were dried at 70 to 80° C. analyses were made for nitrate, soluble phosphate, and potassium. The analytical values for each sample were expressed on the dry basis and were then compared with the critical values for each nutrient. The critical values are approximately 1,000 p.p.m. of nitrate nitrogen; 1,000 p.p.m. of phosphate-phosphorus, soluble in 2 percent acetic acid ; and 2 percent total potassium.

Of the 70 fields sampled during the 2-year period 70 percent were below the critical level for a long enough time to warrant experiments with nitrogen, 28 percent with phosphorus, and 6 percent with potassium. When fields below the critical level for only a short time are included as being suitable for experimentation, the corresponding figures are 88 percent for nitrogen, 41 percent for phosphorus, and 14 percent for potassium.

The yields and growth responses observed in six fertilizer demonstration trials conducted during 1944 and 1945 were in accord with petiole analyses. The results of three of these trials are reported in this paper.

Plant samples taken at regular intervals from the same field planted to heels in 1943 and 1945 indicate that plant analysis may serve as a guide in adjusting the fertilizer program for the next crop of beets on the field.

Literature Cited

1. Brown, Robt. J. Sampling Sugar Beet Petioles for Measurement of Soil Fertility. Soil Sci., 56: 213-222. 1943.

2. Ulrieh, Albert. The Relationship of Nitrogen to the Formation of Sugar in Sugar Beets. Proc. Amer. Soc. Sug. Beet Tech. 66-80. 1942.

3. Ulrieh, Albert. Plant Analysis as a Diagnostic Procedure. Soil Sci. 55: 101-112. 1943.

4. Ulrieh, Albert. Plant Nutrient Survey of Sugar Beets. Mimeographed Report, Div. of Plant Nutrition, Univ. of Calif., Berkeley. 1943.

5. Ulrich, Albert. Plant Nutrient Survey of Sugar Beets. Mimeographed Report, Div. of Plant Nutrition, Univ. oC Calif., Berkeley. 1944.