Predicting Sugar Content and Petiole Nitrate of Sugarbeets from Soil Measurements Of Nitrate and Mineralizable Nitrogen[1]

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Soil analysis for initial NO₃-N provides a preseason estimate of plant-available N on which to base N fertilizer recommendations for cultivated crops including sugarbeets (6,7,8,10,11)[4]. In addition to any NO₃-N in the root zone at the beginning of the growing season, some soil organic N mineralizes to plant-available form and serves as an added source of N for growing crops (5,17). If plants utilize substantial quantities of mineralizable organic N, then soil tests for both NO₃-N and mineralizable N may be required as a basis for fertilizer recommendations rather than following the common practice of using only soil NO₃-N. Besides soil N measurements, the levels of NO₃-N in plant petioles during the season and the percentage of sugar in sugarbeets at harvest are regarded as sensitive indicators of the actual available-N supply for the crop (2,3,5,13). Of course diagnostic tests on soil or plant petioles early in the season are useful for determining the need for supplemental fertilization, while harvest measurements are of limited value in this regard.

Bremner (1) reviewed recent progress in the development and application of soil tests for inorganic and mineralizable organic N. Hills and Ulrich (5) prepared a summary on soil testing, primarily for NO₃-N as a guide to N fertilization of sugarbeets. Unfortunately, tests for mineralizable soil N have been used on a very limited scale in connection with sugarbeets or any other crop, perhaps because of the inability to interpret or calibrate these tests adequately with field crop response.

Measurement of total N in soil, as an index of soil N availability, has been of little value in most studies. Even so, Spencer *et al.* (15) found that total soil N combined with initial NO₃-N in regression analysis gave some improvement in the prediction of N uptake by sugarbeets, compared to regression analysis based entirely on NO₃-N. Total soil N is usually closely associated with soil organic matter, but organic matter was shown by correlation analysis to explain only about 50% of the variation in N release values obtained for a selected group

of soil samples (6). Others demonstrated a significant correlation between N response parameters for spring-seeded barley and an estimate of mineralizable organic N which was released following treatment of the soil with alkali, CO_2, or after a period of anerobic incubation (4,12).

Stanford and Demar (16) studied the extraction of soil organic N by autoclaving in water and suggested the use of the NaOH-distillable fraction for use as an index of N availability. Values for N mineralized from soil during a 13-week incubation, usually regarded as a reliable indication of N release, were more closely correlated with autoclave-distillable N than was evident for results obtained by any of the other procedures studied. Release of N on incubation was closely correlated with N uptake from soil organic N, evaluated by N^{15} tagged fertilizer, in a previous greenhouse pot study (16). The autoclaving-distillation procedure, although it has some promising aspects, has received limited study for predicting organic N release for field crops. Research is needed on this aspect of indexing N availability in soil.

This report covers the results obtained from field experiments to determine the levels of autoclave-distillable N in sugarbeet-producing soils of central Washington, and to study the relationship of estimated mineralizable soil N to beet sugar percentage and petiole NO_3-N concentrations in sugarbeets as indicators of N availability to the crop.

Additional field experiments are in progress to calibrate the combined test values for atoclave-distillable N and soil NO_3-N as a basis for predicting the response of sugarbeets to N fertilization.

Procedure

The utilization of residual soil N by sugarbeets was studied in the unfertilized control plots of N-rate studies, which were conducted at 10 locations in central Washington. The soils at the experimental sites, representing nine different soil mapping units, were developed from alluvial or loessial parent materials in an area of 7 to 10 inches of annual precipitation.

Individual plots were four rows spaced 22 inches apart and 50 feet long. At thinning time in May, each plot received a sidedress fertilizer application consisting of 80 pounds of P per acre as treble superphosphate, 100 pounds of K as muriate of potash, and 10 pounds of Zn as ZnMNS. The cooperating growers did the seeding, weed control, thinning, and irrigating of the plots.

Soil samples were collected in May by the three-point group sampling technique (7) which consists of taking cores from the soil profile of individual plots in a series of three holes equally spaced along a line perpendicular to the irrigation furrow. Soil samples were collected by 1-ft increments to a depth of 6 ft or to the depth of sampling barrier, which was less than 6 ft in some cases. The soil samples for

NO_3-N were dried in a forced-draft oven at 50°C soon after sampling, passed through a 2 mm sieve, and extracted with a saturated solution of $Ca(OH)_2$ for NO_3-N determination with phenoldisulfonic acid. The initial NO_3-N (N_i) in the soil was expressed as an index numerically equivalent to the sum of parts per million NO_3-N in successive 1-ft increments of the soil profile. Soil samples from the surface 1-ft layer were analyzed for mineralizable N (N_m) by the standard procedure (16), following three successive extractions with .01 M $CaCl_2$ to remove any inorganic ammonium-N initially present. Ammonium-N was not determined, but it is usually low in soil not fertilized with N since the previous season.

Plant samples consiting of 25 recently matured petioles were collected from each plot on four different sampling dates. The petioles were oven-dried at 70°C, ground through a 20 mesh screen and analyzed for NO_3-N by the phenoldisulfonic acid method (9).

Yield of sugarbeets was determined by either hand harvesting 30 ft of row per plot or by machine harvesting the entire plot. Sugar percentages in subsamples of sugarbeets were determined in the Utah-Idaho Sugar company laboratory.

Multiple regression analysis was used to study the combined relationship between initial soil NO_3-N (N_i) and mineralizable N (N_m) in beet sugar percentage and petiole NO_3-N in sugarbeets. Snedecor's methods and notations (14) were used in the statistical analysis.

Results and Discussion
Soil Nitrogen

The initial NO_3-N (N_i for the experimental sites when expressed as an index ranged from 14 to 197, and the mineralizable organic N (N_m) determined by autoclave-distillation ranged from 19 to 50 ppm in the surface 1-ft soil layer (Table 1). For practical purposes NO_3-N in the 6-ft soil profile is presumed equivalent to N fertilizer for sugarbeets, but the equivalent availability of N_m is presently unknown for these central Washington soils. A group of soil samples analyzed by Stanford and Demar (16) ranged from 28 to 162 ppm N_m, which was higher on the average than the values obtained here. Higher levels of total N and organic matter might be expected in the soil samples studied by Stanford and Demar than in some of our samples from the semiarid area of central Washington.

Yield of Sugarbeets and Sugar

Sugarbeet yields for the control plots, without N fertilizer, ranged from 20.6 to 34.3 tons per acre (Table 1). Significant root yield responses to N occurred at only four out of ten experimental sites, and N significantly increased the yield of beet sugar at only two sites (Table 1). The calculated sugar yields on the control plots ranged from 3.36 to 5.50 tons per acre.

Table 1.—Soil nitrogen and sugarbeet data collected from unfertilized plots at experimental sites in three different districts.

Exp. no.	Soil classi- fication	$N_i{}^1$	$N_m{}^2$ ppm	Root yield t/A	Sugar conc. %	Sugar yield t/A
		Yakima Valley				
1	Warden sil	49	28	25.7*	16.4	4.19
2	Sagemoor l	14	50	20.6	16.0	3.31
3	Beverly sil	62	31	25.4	14.8	3.76
4	Sagemoor l	94	46	30.2	14.6	4.43
		Columbia Basin				
5	Ephrata l	20	31	23.8*	16.3	3.86+
6	Shano sil	37	18	27.8*	15.9	4.42
7	Sagehill fsl	34	23	25.8	15.2	3.92
8	Haywood sil	71	25	34.3	16.0	5.50
		Walla Walla District				
9	Adkins-Quincy lfs	21	19	29.8*	17.7	5.25+
10	Onyx l	197	35	26.6	12.7	3.38

[1]Index for sum of initial NO_3-N (Ni) in the soil profile.
[2]Parts per million mineralizable N (Nm) in the surface 1-ft layer.
l +Confirmed responses to N applied at rates of from 50 to 100 lb/acre were significant at .05 and .10 level respectively, based on data from N rate study.

Site 1 had an N_i index of 49, which was the highest for any of the N responsive sites. In previous field calibration research, N_i of 50 approximated the upper limit of the range for N response by sugarbeets in our area (8). Sites with N_i below 50 were expected to benefit from N fertilizer, but not all sites in this category responded to N fertilization. Perhaps the availability of mineralizable N at some sites compensated for low levels of N_i present and partially accounted for the lack of response to N fertilizer. Experimental sites with N_i above 50 are not likely to respond to N fertilization.

The wide range of sugarbeet yields, even with adequate N, clearly indicated that factors in addition to available N were affecting the actual yields obtained. Additional sugarbeet experiments are in progress where measurable responses to N are anticipated. The purpose of these is to study the possibility for more precise calibrations of soil N indexes for predicting field response to N fertilizer.

Correlation Analysis

In the present study, beet sugar ranged from 12.6% at site 10 to 17.7% at site 9 (Table 1). The well-documented available N-percent sugar relationship (6,7,8,13) explains the differences in sugar percentage observed in the study. Based on regression analysis of field data, for example, Reuss and Rao (13) indicated a 0.97% reduction in sugar content for each additional 100 pounds of N per acre.

A significant multiple correlation was found for the multiple regression of sugar percentage on soil Ni and Nm indexes in these experiments (Table 2). The two soil N variables were not significantly

Table 2.—Standard partial regression coefficients, and linear and multiple correlation coefficients for relating variable Y in terms of beet sugar percentage in one case and percent nitrate-N in petioles at two dates in the second case with mineralizable organic nitrogen (Nm) and soil nitrate-nitrogen (Ni).

| | Coefficients[b] | | |
| | | Y as percent petiole NO_3^1N | |
Statistic[a]	Y as percent beet sugar	6/23	7/26
r_{YN_m}	-.3655*	.0134	.4301**
r_{YN_i}	-.7753**	.7251**	.5050**
$b^1 YN_m . N_i$	.2991	.0513	.5883
$b^1 YN_i . N_m$	.7478	.7297	.4705
$R_{Y.N_m N_i}$	.8306**	.7269**	.6361**

[a]Based on measurements from each replication of ten experiments, n=40; $r_{N_m N_i}$=.0888; significance at .01 level (**) and .05 level (*).

Regression equations for predicted values (Y): % Beet sugar, $Y = 16.998 - .0462$ ppm n_m; $Y = 16.587 - .0168$ ppm N_i; $Y = 17.715 - .0378$ ppm $N_m - .0162$ n_i expressed as index; % Petiole NO_3-N on 7/26, $Y = .1467 + .0206$ ppm $N_m + .0042$ N_i.

correlated with each other as indicated by the low correlation coefficient (r = .088). There was a significant negative correlation of sugar percentage on the soil N variables considered individually (Table 2), but the multiple regression function gave the highest correlation coefficient.

Based on standard partial regression coefficients the relative importance of Nm was 40% that of Ni in predicting beet sugar percentage from multiple regression analysis (Table 2). By an alternate approach using only the relative simple correlation coefficients, r^2 values would indicate the contribution of N_m at 22% of N_i. Therefore the significance of N_m must not be overlooked in correlating the N response of sugarbeets to soil tests for N in central Washington.

Values for petiole nitrate-N were higher on the average for all sites at the earliest sampling date, June 23, than on subsequent sampling dates (Figure 1 and Table 3). On July 26, sites 2, 3 and 4 showed higher levels of petiole NO_3-N than had been observed on July 7 (Figure 1 and Table 3), and none of these sites produced yield responses to N. The highest value for petiole NO_3-N on July 26 was recorded at site 2 (Table 3) which also had the highest level of mineralizable N (Table 1). The petiole data in Table 3 were compiled for all sites where the NO_3-N in the petioles dropped below 0.1% on August 30, and four out of six of these sites produced responses to N fertilization. Previous research on diagnostic testing for sugarbeets has pinpointed 0.1% NO_3-N in the petiole as a critical level for sugarbeets (5).

Multiple correlation analysis (Table 2) indicated levels of petiole NO_3-N were significantly correlated with soil NO_3-N (Ni) on June
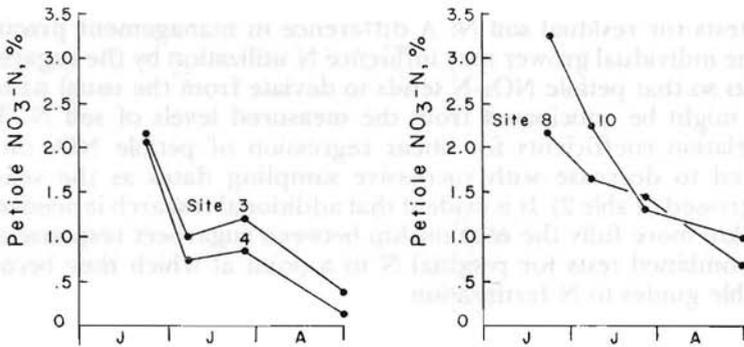
Figure 1.—Changes in sugarbeet petiole NO_3-N with sampling time in plots untreated with N at four experimental sites.

Table 3.—Nitrate nitrogen in sugarbeet petioles from unfertilized control plots for all sites testing below the suggest critical level of 0.1% petiole NO_3-N on August 30.

Exp.	Petiole NO_3-N, %			
No.	June 23	July 7	July 26	August 30
1	.77	.41	.21	.040
2	.46	.25	.96	.063
5	.93	.13	.08	.018
6	1.67	1.04	.45	.067
7	.77	.29	.08	.020
9	1.22	.33	.19	.065

23, and as expected, very little of the correlation was explained by the values for Nm this early in the season. On July 26, at a time when some petiole. NO_3-N values were higher than at the previous sampling period about 2 weeks earlier, multiple correlation analysis indicated a significant correlation of petiole NO_3-N with both Ni in the soil profile and Nm (Table 2). Considerable microbial activity in the soil, including mineralization of organic N, normally occurs when the soil temperature reaches a favorable range, and growing crops should respond to the increased N availability.

Conclusions on the importance of the two N soil test values for predicting petiole NO_3-N were based on the relative values for the standard partial regression coefficients. On July 26, the relative importance of Nm was 80% that of Ni for predicting petiole NO_3-N based on multiple regression analysis (Table 2), and using the alternate approach based only on the simple correlation coefficients, r^2 values, Nm was 73% as important as Ni. The multiple correlation coefficient (R) was .6361 on July 26 for the relationship between petiole NO_3-N and the soil test for N (Table 2). Considerable unexplained variation exists in petiole NO_3-N that is not fully accounted for by the two

soil tests for residual soil N. A difference in management practices by the individual grower may influence N utilization by the sugarbeet plants so that petiole NO_3-N tends to deviate from the usual pattern that might be anticipated from the measured levels of soil N. The correlation coefficients for linear regression of petiole NO_3 on N_i tended to decrease with successive sampling dates as the season progressed (Table 2). It is evident that additional research is needed to develop more fully the relationship between sugarbeet response and the combined tests for residual N to a point at which they become reliable guides to N fertilization.

Summary

The utilization of residual soil N by sugarbeets was studied at ten different locations in central Washington. Measurements of residual soil N were based on initial NO_3-N in the soil profile (N_i) and on mineralizable organic N (N_m). Values for N_i expressed as an index ranged from 14 to 197, and N_m ranged from 18 to 50 ppm in the surface 1-ft layer. Measurements of N_m were by Stanford's procedure (16) which is the NaOH-distillable N obtained after autoclaving the soil sample for 16 hours.

Beet sugar percentage at harvest and plant petiole NO_3-N, both regarded as sensitive idicators of the general level of N availability to the growing crop, were each significantly correlated to soil N_i and N_m in multiple regression analysis. Multiple correlation analysis indicated that late season increases in petiole NO_3 which heretofore were unexplained could be predicted from the multiple regression response function based on preseason values for soil N_i and N_m. Standard partial regression coefficients for predicting beet sugar percentage and late season levels of petiole NO_3 indicated that N_m was on the order of 40 to 80% as important as N_i, and based only on relative correlation coefficients (r^2 values) for simple regression, the importance of N_m was somewhat lower. The study suggests that tests for both N_i and N_m may be required as a basis for N fertilizer recommendations on sugarbeets, and additional studies are in progress to obtain calibration of soil N_i and N_m with sugarbeet response to N.

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