REPRINTED FROM JOURNAL OF THE
AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS

Predicting Nitrogen Fertilizer Needs for Sugarbeets from Residual Nitrate and Mineralizable Nitrogen[1]

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Received for publication July 8, 1974

Nitrogen (N) fertilizer management for sugarbeet (*Beta vulgaris* L.) production requires more precise information than for most crops. Inadequate N limits plant growth and root yield, but excess N may reduce both sucrose percentage and recoverable sucrose (7).[3] Also, excess N may stimulate more leaf growth than necessary. The rate and timing of N fertilizer applications are not only important in supplying crop N needs, but can influence the amount of N lost by leaching and denitrification. Soil and plant tissue tests can provide essential data for decision-making for efficient and economical use of N fertilizer.

Recent studies have shown that the NO_3-N level in the soil before planting is closely related to sucrose production when N is limiting (8, 12). Inclusion of the N mineralization capacity of the soils would be expected to improve the relationship. Stanford and Smith (14) showed that the mineralization capacity varies with soil type and location. Therefore, a soil test for N that would have general applicability should include the mineralization capacity of the soil, and the interpretation of these tests should include some knowledge of expected irrigation practices. A soil test for NO_3-N may suffice as an index of N fertilizer needs for a given soil and irrigation level.

Recently, Carter *et al.* (5) showed that sucrose production was closely related to available soil N, as indicated by a soil test that included both mineralizable N and NO_3-N. The objective of our study was to evaluate the soil test-yield relationship, developed from experimental data at one location in south central Idaho, for predicting N fertilizer needs throughout southern Idaho under various irrigation management practices.

Theory and Basic Relations

Previous investigations showed that N in the soil, measured as NO_3-N and mineralizable N, may not represent all of the N taken up by the sugarbeet crop (5). Although NO_3-N in the sampling zone can be measured, the plants may take up additional NO_3-N from a hardpan

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[3]Numbers in parentheses refer to literature cited.

or from below the sampling depth. Mineralizable N in the sampling zone, as determined in the laboratory, is an index of the supply from this source, but more or less N may be mineralized in the field, and N may be taken up from below the sampling zone. N uptake (N_{up}) by the crop from various sources is the best measure of N availability and can be expressed as:

$$N_{up} = E_f N_f + \alpha_n N_n + \alpha_m N_m \qquad [1]$$

where E_f = the efficiency of applied N fertilizer (N_f),

$$\alpha_n = \frac{\text{crop extractable } NO_3\text{-N}}{NO_3\text{-N in the soil depth sampled}},$$

N_n = soil NO_3-N in the soil depth sampled,

$$\alpha_m = \frac{\text{crop extractable mineralizable N}}{\text{field mineralizable N in soil depth sampled}} \times \frac{\text{field min. N},}{\text{lab. min. N}}$$

N_m = mineralizable N in the soil depth sampled, as determined by the laboratory mineralization tests.

The more difficult parameters in equation [1] to determine are E_f, α_n, and α_m. E_f can be evaluated by determining total N uptake from about 4 rates of N_f (0, 0.5, 1.0, and 1.5 to 2 times the rate needed for optimum production) or by assuming a value between 0.5 to 0.7 (13). When evaluating E_f, the method and time of fertilizer application normally used by the growers should be used. Determining α_n is more difficult, since $\alpha_m N_m$ is not easily separated from $\alpha_n N_n + \alpha_m N_m$. At least two levels of N_n are needed. These may be approximated for a soil type by applying two excessive N fertilizer treatments for the crop grown before sugarbeets to give two levels of residual N_n. After determining the total N uptake by sugarbeets on these two treatments, and assuming N_m to be the same on both, α_n and α_m can be approximated by a trial-and-error procedure (assuming a value for α_m, calculating α_n, and solving for α_m, etc.). The sampling depth for determining N_n and N_m should represent normal sampling depths for the area involved and be consistent with expected future sampling and analyses.

If the entire rooting depth is sampled, and if all of the NO_3-N in this zone is taken up by the crop, α_n will be 1.0. If the entire rooting depth is sampled, but not all of the NO_3-N is taken up, α_n will be less than 1.0. If only part of the rooting depth is sampled and some NO_3-N is taken up from below the sampling depth, α_n will be greater than 1.0.

Previous investigations indicated that when sampling to the cemented zone on a Portneuf silt loam soil in south central Idaho near Twin Falls, $E_f = 0.65$, $\alpha_n = 1.2$, and $\alpha_m = 0.95$ (5). In this study, only E_f could be evaluated because of the lack of different N_n levels.

Previous studies have shown that for maximum sucrose yields, the N requirements per ton of beet roots is 11 ± 1 lbs (5). Less N is required for root production at low levels of available soil and fertilizer N, and more N is used when the N levels exceed the plant needs for maximum sucrose production.

If 11 ± 1 lbs of N are needed to produce a ton of fresh roots, then the potential yield, Y, for a sugarbeet field, if limited by N, will be:

$$Y = N_T/(11 \pm 1),\ N_T/(11 \pm 1) \leq Y_E \qquad [2a]$$

$$\text{or} \quad \frac{Y}{Y_E} = \frac{N_T}{Y_E\,(11 \pm 1)};N_T \leq Y_E \quad (11 \pm 1) \qquad [2b]$$

where Y_E is the expected maximum yield under a given management level, when N is not limiting (obtained from farm records), N_T is the total "net" N available to the crop ($N_T = E_f N_f + \alpha_n N_n + \alpha_m N_m$). If maximum yields expected from a farmer's management are desired and $(\alpha_n N_n + \alpha_m N_m) \leq (11 \pm 1)\ Y_E$, the N fertilizer needed to make up the deficit, $(11 \pm 1)\ (Y_E - Y)$, will be:

$$N_f = \frac{Y_E\,(11 \pm 1) - (\alpha_n N_n + \alpha_m N_m)}{E_f} \qquad [3]$$

where N_f is the needed N fertilizer, and E_f is the N fertilizer efficiency, expressed as a fraction. The E_f value can be expected to range from 0.5 to 0.7, depending on management practices (13), and was previously found to be 0.65 in this area (5). After harvest, the yield response to N can be evaluated by substituting Y_{max} for Y_E in Equation [2b].

Materials and Methods

During 1971, 32 experiments, involving four N fertilizer treatments, were established throughout southern Idaho. The results from 24 were usable (Table 1). The experimental sites, each 60 × 100 feet, were located midway between the upper and lower end of irrigated sugarbeet fields. Nutrients, other than N, were applied to the sites at the level used by the farm managers. All other nutrients, except N, were considered adequate from soil and irrigation water sources.

Each experimental site was divided into four 30- × 50-foot plots, and ammonium nitrate applied at rates 0, 0.5, 1, and 2 times the recommended amount for each site. The recommended amount of N fertilizer was obtained from fertilizer and sugarbeet company fieldmen, based on past fertilizer and cropping histories. In all tests, the recommended N fertilizer rate was applied to the surrounding sugarbeet field by the farm managers. The fertilizer was broadcast and disked into the surface 3 to 4 inches of soil on each site. All cultural operations and irrigations were uniform for the entire field.

Each site was sampled to a depth of 60 inches or to the hardpan in the spring of 1971, before applying fertilizer. Twenty-four cores per

Table 1.—Classification and soil properties of experimental sites used in the nitrogen study in southern Idaho.

Area No.	Soil Classification: Designation, Subgroup, and Family	Root Zone[1]	Previous Crop	Surface soil properties (0–6″) pH	O.M.%	N%
		Southwestern				
1	Scism sil, Haplorexollic Durorthid[3]	20	Beans	7.80	2.88	0.073
2	Garbutt sil, Typic Torriorthent[4]	60	Beets	7.80	3.92	0.102
4	Greenleaf sil, Xerollic Haplargid[5]	30	Onions	7.50	4.23	0.107
6	Elijah sil, Mollic Durargid[5]	14	Fallow	7.90	3.76	0.100
7	Power sil, Xerollic Haplargid[5]	30	Sweet Corn	7.80	2.88	0.052
8	sicl	24	Onions	7.20	3.56	0.099
		South Central				
101	Declo sil, Xerollic Calciorthid[6]	21	Corn	7.90	3.24	0.085
103	Portneuf sil, Xerollic Calciorthid[6]	24	Potatoes	7.55	0.89	0.085
104	Portneuf sil, Xerollic Calciorthid[6]	23	Beans	7.65	0.74	0.085
105	Portneuf sil, Xerollic Calciorthid[6]	24	Potatoes	7.50	1.84	0.079
106	Portneuf sil, Xerollic Calciorthid[6]	20	Wheat[2]	7.55	0.89	0.101
151	Portneuf sil, Xerollic Calciorthid[6]	17	Potatoes	7.55	1.74	0.108
152	Decker l, Aquic Calciorthid[7]	24	Beets	7.50	1.32	0.099
156	Kimama sil, Aridic Calcic Aryixeroll[5]	24	Wheat	7.75	1.26	0.087
157	Portneuf sil, Xerollic Calciorthid[6]	18	Wheat	7.60	0.89	0.094
		Southeastern				
201	Portneuf sil, Xerollic Calciorthid[6]	17	Potatoes	7.95	1.00	0.068
202	Neeley sil, Calciorthidic Haploreroll[3]	60	Potatoes	7.45	0.74	0.077
204	Broncho l, Xerollic Camborthid[8]	16	Beets	7.75	1.05	0.102
205	Portneuf sil, Xerollic Calciorthid[6]	23	Potatoes	7.60	1.53	0.088
206	Portneuf sil, Xerollic Calciorthid[6]	18	Potatoes	7.50	0.68	0.081
207	Declo sil, Xerollic Calciorthid[6]	21	Potatoes	7.35	1.95	0.133
208	Ammon sil, Calciorthidic Haploxeroll[9]	60	Beets	7.45	1.11	0.103
210	Pancheri sil, Xerollic Calciorthid[9]	14	Potatoes	7.75	1.53	0.110
211	Bannock l, Aridic Calcixeroll[10]	23	Beets	7.70	1.32	0.097

[1]Soil depth to hardpan or 60 inches
[2]Straw burned
[3]Coarse-silty, mixed, mesic
[4]Coarse-silty, mixed, calcareous, mesic
[5]Fine-silty, mixed, mesic
[6]Coarse-loamy, mixed, mesic
[7]Fine-loamy, mixed, mesic
[8]Sandy-skeletal, mixed, mesic
[9]Coarse-silty, mixed, frigid
[10]Coarse-loamy over sand or sandy skeletal, mixed, frigid

site were composited by 6-inch depth increments to the 24-inch depth and by 12-inch increments below that depth. The soil samples were air-dried, ground, and stored until analyzed.

The potential available soil N was determined by extracting NO_3-N from air-dried soil and from 50 g of soil incubated in a 500-ml Erlenmeyer flask for 21 days at 30°C with moisture maintained at approximately 1/3 atm. Moisture loss was minimized by using a one-hole rubber stopper in the flask for aeration during the incubation. The NO_3-N was extracted with a $CuSO_4 \cdot 5H_2O$ (2.5 g/l) and Ag_2SO_4 (0.167 g/l) solution. The 50-g soil sample was shaken for 10 minutes with 200 ml of extractant, then 1.2 g precipitating mixture, composed of 10 parts of $MgCO_3$ and 4 parts $Ca(OH)_2$, were added and the sample shaken again for 5 minutes. Samples were then filtered through Whatman[4] No.2 filter paper, and an aliquot taken for NO_3-N determination by the phenoldisulfonic acid method essentially as described by Bremner (1).

The difference between the NO_3-N concentrations found in the incubated and air-dried samples was considered the mineralizable N. Small amounts of ammonium-N normally found in these soils were assumed to be oxidized to NO_3-N during incubation and, therefore, were included in the mineralizable N fraction.

Samples of 24 of the youngest fully mature petioles were selected at random from each plot (two in July, two in August, and one in the first part of September). The petioles were cut into ¼-inch sections, dried at 65°C, ground to pass through a 40-mesh sieve, subsampled, and analyzed for NO_3-N, using a nitrate specific ion electrode (11).

The beet tops, crowns, and roots from six uniform 10-foot sections of row were harvested from each treatment at the end of the season to determine root yield, sucrose percentage, sucrose yield, impurity index, and total N uptake. Impurity index (2) and sucrose content were determined on two samples, 30 lbs each, of randomly selected roots from each plot by the Amalgamated Sugar Company, using their standard procedures. The beet pulp (collected during sucrose analysis,) tops, and crowns were dried at 65°C and dry matter determined. The dried samples were ground to pass a 40-mesh sieve, and total N in the samples was determined by the semimicro-Kjeldahl procedure modified to include nitrate (1). Nitrogen uptake was determined by assuming that the percentage N was the same in the fibrous and storage roots, and that the fibrous roots make up 25% of the total harvested root weight (10).

The field numbers, locations, soil classifications, previous crop, and surface soil properties of the 24 experimental sites are given in Table 1. Soil pH was determined using a glass electrode measurement in a soil-water saturated paste, organic matter by a modified method of Walkley and Black (15), and total soil N by the Kjeldahl procedure modified to include nitrates (3).

[4]Mention of trade names or companies is for the benefit of the reader and does not imply endorsement by the U. S. Department of Agriculture.

Results and Discussion

The initial NO_3-N (N_n), mineralizable N (N_m), and total available N (N_T) varied widely between sites and were not consistent within soil series or types (Table 2). A range of 123-236, 127-223, and 104-195 lbs of mineralizable N were released during incubation for the southwestern, south central and southeastern Idaho areas, respectively. The mineralizable N and/or the NO_3-N from below the depth sampled comprised 49 to 81% and averaged 63% of the total N available for plant growth where no N fertilizer was applied. These data indicated that the mineralizable N in the higher organic matter soils of southwestern Idaho could be roughly estimated from their organic matter content, but the lower organic matter soils in south central and southeastern Idaho released 1.5 to 3.0 times more N than would be expected (assuming 5-6% of O.M. is N and 1-2% of this N is released yearly). However, the total N content of the higher and lower organic matter soils were comparable, indicating the N fractions mineralized were similar. Past cropping and management practices over an extended period of years apparently had a pronounced effect on the total N available for plant growth from the mineralization process.

Equation [2a] was evaluated for southern Idaho in 1971 by assuming $E_f = 0.65$, $\alpha_n = 1.2$, and $\alpha_m = 0.95$ (Figure 1). The root yield predicted from N levels generally agreed with yields of the harvested beets. However, on some sites, yields were below those expected, based on available soil N (sites 157, 202), which is apparently due to production difficulties other than those under study (Figure 1a). Yields on four of the sites were higher than those expected from the available soil N (6, 7, 101, 201). The sugarbeet plant becomes much more efficient in the use of N for root production at lower levels of available N, as shown by sites 101 and 201. Yields on both of these sites were predictable from soil N levels, after adequate N fertilizer was applied to get maximum yields (Figure 1b). Site 6 had been fallowed for 2 years before this study and had accumulated large amounts of NO_3-N just above or in the hardpan. The assumed α_n value of 1.2 probably was too low, and yields indicated that α_n should have been near 1.6 for this site. Yields from the check plot on site 7 cannot be explained from either the amount of N available from soil sources or from the amount of N taken up by the plants per ton of beet roots (Table 2). The sugarbeet plants apparently used the soil N much more efficiently on this site. Yield was predictable, however, when adequate N was present for maximum root and sucrose yield.

If the root yield potential for any sugarbeet field is known and other factors are not limiting, then the amount of N fertilizer necessary for maximum yields can be predicted, using equation [3] as shown in Table 2. The predicted N required for site 6 exceeded the N necessary for maximum sucrose yields enough to significantly reduce the sucrose percentage and sucrose yield. Fertilizer predictions based on soil test $\alpha_n N_n + \alpha_m N_m$ were superior in southern Idaho to procedures used

Table 2.—Available N, root yield, N fertilizer recommendations, and N uptake on sugarbeet experimental sites used in 1971.

Exp. Area No.	Soil N_n	Soil N_m	Soil N_T[1]	Yield Measured Y min.	Yield Measured Y max.	N Fertilizer Needed N_T[1]	Recommendations based on NO_3-N[2]	Recommendations based on $NO_3-N \times 1.47$[3]	Recommendations based on Fieldmen	Max. Yield	N uptake Check plot	N uptake Max. Yield	N_T[1] Check plot	N_T[1] Max. Yield
	lbs N/A			T/A		lbs N/A					lbs N/T			
1	101	171	349[4]	28.3	28.3	0-0	81	41	90	0	11.2	11.2	12.3	12.3
2	81	236	321	20.4	20.4	0-0	107	116	150	0	8.3	8.3	15.7	15.7
4	165	210	398	28.4	28.4	0-0	118	185	200	0	11.0	11.0	14.0	14.0
6	101	153	267	28.5	28.5	28-115[5]	183	175	180	0	10.0	10.0	9.4	9.4
7	96	123	232	26.3	30.4	111-205	207	225	150	150	4.9	8.7	8.8	10.9
8	135	148	303	25.5	29.9	0-86	163	225	230	115	9.0	10.2	11.9	12.6
101	41	132	175	20.6	27.4	152-237	232	242	160	160	5.4	9.3	8.5	10.2
103	79	201	286	25.5	25.5	0-31	175	203	140	0	6.3	6.3	11.2	11.2
104	79	159	276[4]	24.7	25.8	0-52	148	160	175	87	6.4	9.3	11.2	12.9
105	104	127	245	20.1	20.1	0-0	96	140	150	0	9.6	9.6	12.2	12.2
106	77	187	270	24.3	26.7	0-77	189	216	100	50	8.1	8.1	11.1	11.3
151	130	189	336	22.8	22.8	0-0	97	124	150	0	11.0	11.0	14.7	14.7
152	122	223	358	21.2	21.2	0-0	89	102	160	0	12.4	12.4	16.9	16.9
156	34	144	178	14.1	14.1	0-0	106	115	200	0	5.8	5.8	12.6	12.6
157	88	157	255	18.3	20.8	0-0	119	116	150	75	11.8	11.9	13.9	14.6
201	62	104	173	19.3	22.0	72-140	157	170	120	120	8.8	11.4	9.0	11.4
202	134	129	283	20.9	25.1	0-28	86	178	120	60	6.2	10.9	13.5	12.8
204	50	128	182	17.7	17.7	0-46	126	130	130	0	12.4	12.4	10.3	10.3
205	116	141	273	22.4	26.7	0-72	150	206	180	90	11.1	12.7	12.2	12.4
206	117	116	251	21.6	23.8	0-54	120	159	120	60	12.0	13.5	11.6	12.2
207	171	168	365	25.7	25.7	0-0	85	59	100	0	10.7	10.7	14.2	14.2
208	145	195	359	28.7	28.7	0-0	69	207	130	0	10.0	10.0	12.5	12.5
210	140	194	352	23.5	23.5	0-0	94	71	130	0	12.0	12.0	15.0	15.0
211	50	183	234	21.0	21.0	0-28	159	156	120	0	7.8	7.8	11.1	11.1
Avg.	101	163	280	22.9	24.4	15-49	132	155	147	40	9.3	10.2	12.2	12.6

[1]Total available soil and fertilizer N ($\alpha_n N_n + \alpha_m N_m + E_f N_f$) in the top 36 inches or to the hardpan.
[2]Calculated N fertilizer needs from residual NO_3-N to the 60-inch soil depth or hardpan by methods of Reuss and Rao (12).
[3]Calculated N fertilizer needs from residual NO_3-N in the top 12 inches × 1.47 by methods of Reuss and Rao (12).
[4]N fertilizer applied to experimental area by farm manager.
[5]Calculated N fertilizer need for maximum yield (Y_{max}) if 10 to 12 lbs N/T of beet roots is required.

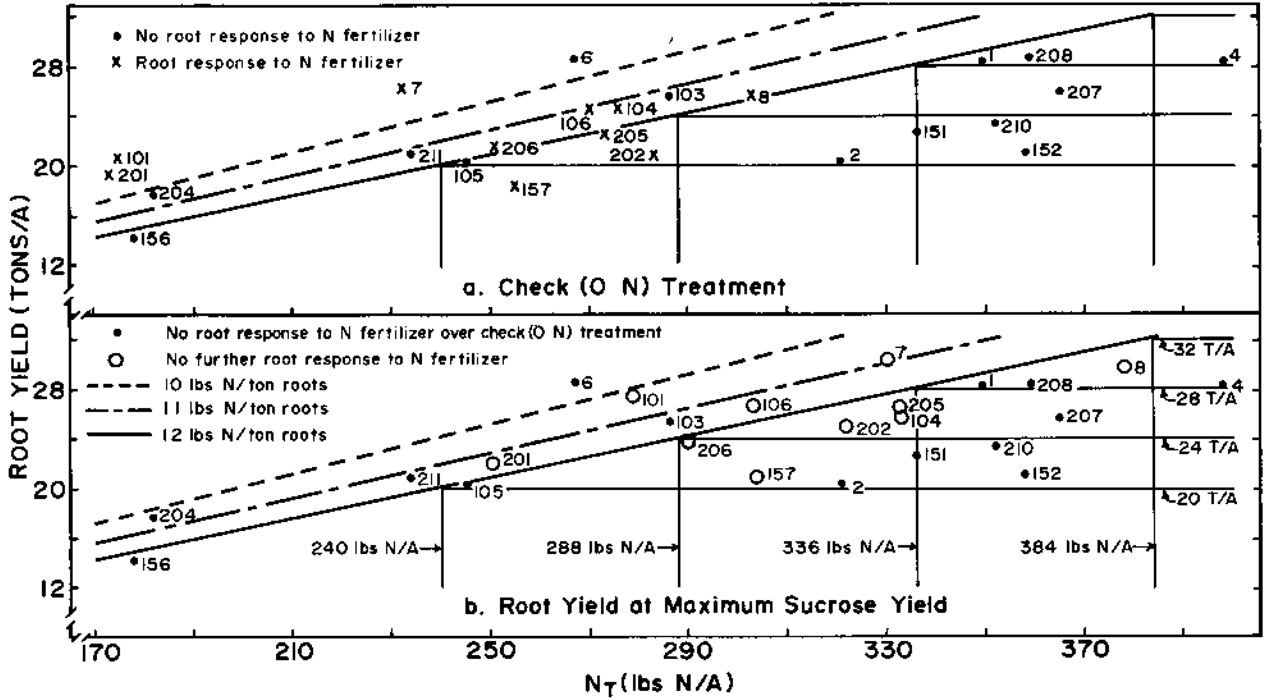

Figure 1a and 1b.—Effect of available N on the root yield of sugarbeet. (Root yields should be near the 10 to 12 lbs N/ton of roots lines until sufficient N is available for maximum root yield. Excess N for the root yield potential of the sugarbeet field will maintain root yield while increasing the total available soil and fertilizer N (N_T) per ton of roots. Solid vertical and horizontal lines represent the N level necessary to produce a given yield level if 12 lbs of N is required to produce a ton of beet roots.)

by fieldmen based on past fertilization and cropping histories and predictions based only on available NO_3-N (Table 2). However, if cultural practices, irrigations, disease, or insects limit yields, then predicted required N, from all procedures, will probably exceed the sugarbeet needs and may further reduce sucrose yields.

The total N uptake by the sugarbeet plant was linearly related to the available soil N ($\alpha_n N_n + \alpha_m N_m$) on the check (O N) treatment ($\hat{Y} = 8.60 + 0.73\ N_T$, r = 0.72), available soil and fertilizer N ($\alpha_n N_n + \alpha_m N_m + E_f N_f$) at maximum sucrose yield ($\hat{Y} = 33.37 + 0.70\ N_T$, r = 0.67), and available soil and fertilizer N on all treatments ($\hat{Y} = 47.88 + 0.67\ N_T$, r = 0.75). However, the results were quite variable, because of variations in climate, different sugarbeet varieties, and large variations in available N that probably affected the efficiency of both soil and fertilizer N utilization. The linear relationships were improved when each experimental site was considered separately (average $\hat{Y} = 18.03 + 0.78\ N_T$, r = 0.88). The correlation coefficient was highest on soils initially deficient in available soil N for maximum sugarbeet production.

The sucrose percentage was inversely related to both N_T and the average NO_3-N concentration in the petioles from 7/6 to 9/2 (Table 3). The sucrose percentage at O N and the amount of decrease with N fertilizer varied with sites, probably as a result of climatic conditions or factors other than those under study. However, the average rate of decrease in sucrose percentage with available N and average petiole NO_3-N concentration were similar to those previously found in a detailed study at one site (6).

The impurity index (Impurity Index = [10 (amino N) + 3.5 (Na) + 2.5 (K)]/sucrose %), as expected, was inversely related to the sucrose percentage ($\hat{Y} = 2441 - 115 \times$ % sucrose, r = 0.85) (Table 3). Beet roots with the higher impurity indexes had a moderate sucrose percentage when no N fertilizer was applied, and the sucrose percentage decreased as N fertilizer increased. The reason for the moderate sucrose percentage at comparatively low available N values at certain sites is unknown, but is probably due to climatic effects.

If the experimental sites used in this study were representative of the sugarbeet fields in southern Idaho, then these results indicate that excess N fertilizer is being recommended and applied on most sugarbeet fields (Figure 2). Of the 24 fields, 29.5% had ample N fertilizer applied to obtain near maximum sucrose yields, whereas 70.5% of the fields had excess N fertilizer applied which decreased sucrose percentage and sucrose yield. Preplant soil tests, based on total available N from residual and mineralizable sources, would have enabled predicting optimum needs for sugarbeet production. This emphasizes the need for an adequate testing program for maximum sucrose production and overall profits. However, as long as the payment to an individual grower is based on root tonnage and average sucrose percentage for the district, controlling N fertilizer to maximize sucrose

Table 3.—Effect of available N and average petiole NO_3-N on the sucrose percentage and impurity index of sugarbeets.

Area	% Sucrose		Imp. Index		Regression Analysis			
No.	Check	2 × Rec.	Check	2 × Rec.	Available $N(N_T)$[1]	r	Avg. petiole NO_3-N[2]	r
1	17.0	16.0	526	710	$\hat{Y} = 18.8 - 4.1 \times 10^{-3} X$	−0.67	$\hat{Y} = 19.5 - 2.1 \times 10^{-4} X$	−0.71
2	17.0	14.8	319	644	$\hat{Y} = 19.8 - 9.7 \times 10^{-3} X$	−0.89	$\hat{Y} = 17.3 - 1.8 \times 10^{-4} X$	−0.88
4	15.0	13.5	496	934	$\hat{Y} = 17.1 - 5.7 \times 10^{-3} X$	−0.95	$\hat{Y} = 15.7 - 1.3 \times 10^{-4} X$	−0.92
6	16.8	14.8	459	875	$\hat{Y} = 17.6 - 5.9 \times 10^{-3} X$	−0.57	$\hat{Y} = 18.8 - 3.4 \times 10^{-4} X$	−0.94
7	17.7	16.5	293	382	$\hat{Y} = 19.4 - 6.5 \times 10^{-3} X$	−0.97	$\hat{Y} = 18.0 - 2.3 \times 10^{-4} X$	−0.96
8	16.4	12.4	436	1,069	$\hat{Y} = 20.9 - 14.4 \times 10^{-3} X$	−0.95	$\hat{Y} = 19.2 - 3.7 \times 10^{-4} X$	−0.96
101	17.9	16.2	298	577	$\hat{Y} = 19.9 - 9.1 \times 10^{-3} X$	−0.91	$\hat{Y} = 18.4 - 1.0 \times 10^{-4} X$	−0.93
103	18.0	16.2	378	670	$\hat{Y} = 21.4 - 10.8 \times 10^{-3} X$	−0.94	$\hat{Y} = 18.9 - 1.3 \times 10^{-4} X$	−0.92
104	18.4	16.3	275	599	$\hat{Y} = 21.3 - 10.0 \times 10^{-3} X$	−0.95	$\hat{Y} = 18.9 - 1.6 \times 10^{-4} X$	−0.95
105	18.7	16.3	430	725	$\hat{Y} = 21.5 - 11.8 \times 10^{-3} X$	−0.99	$\hat{Y} = 20.2 - 1.6 \times 10^{-4} X$	−0.98
106	17.8	17.1	267	442	$\hat{Y} = 19.4 - 5.9 \times 10^{-3} X$	−0.93	$\hat{Y} = 18.0 - 0.9 \times 10^{-4} X$	−0.99
151	16.1	14.4	645	721	$\hat{Y} = 19.1 - 8.9 \times 10^{-3} X$	−0.99	$\hat{Y} = 17.4 - 1.5 \times 10^{-4} X$	−0.84
152	16.0	15.6	603	731	$\hat{Y} = 16.4 - 1.8 \times 10^{-3} X$	−0.44	$\hat{Y} = 17.0 - 0.9 \times 10^{-4} X$	−0.52
156	18.9	16.6	402	603	$\hat{Y} = 21.3 - 10.4 \times 10^{-3} X$	−0.89	$\hat{Y} = 19.9 - 1.4 \times 10^{-4} X$	−0.80
157	16.1	13.2	737	1,159	$\hat{Y} = 19.5 - 14.8 \times 10^{-3} X$	−0.93	$\hat{Y} = 24.2 - 5.4 \times 10^{-4} X$	−0.99
201	17.1	16.8	491	602	$\hat{Y} = 17.5 - 2.3 \times 10^{-3} X$	−0.64	$\hat{Y} = 17.2 - 0.5 \times 10^{-4} X$	−0.67
202	18.9	16.9	—	—	$\hat{Y} = 21.4 - 11.7 \times 10^{-3} X$	−0.66	$\hat{Y} = 19.7 - 2.1 \times 10^{-4} X$	−0.95
204	18.0	15.5	—	—	$\hat{Y} = 21.1 - 15.6 \times 10^{-3} X$	−0.98	$\hat{Y} = 22.4 - 3.4 \times 10^{-4} X$	−0.99
205	15.7	15.2	—	—	$\hat{Y} = 16.1 - 2.1 \times 10^{-3} X$	−0.70	$\hat{Y} = 16.5 - 0.9 \times 10^{-4} X$	−0.82
206	17.4	15.1	—	—	$\hat{Y} = 20.2 - 13.1 \times 10^{-3} X$	−0.89	$\hat{Y} = 22.0 - 3.9 \times 10^{-4} X$	−0.89
207	15.9	16.1	—	—	$\hat{Y} = 14.5 + 2.7 \times 10^{-3} X$	+0.39	$\hat{Y} = 16.8 - 1.0 \times 10^{-4} X$	−0.37
208	16.3	15.6	—	—	$\hat{Y} = 17.2 - 3.7 \times 10^{-3} X$	−0.53	$\hat{Y} = 19.2 - 2.5 \times 10^{-4} X$	−0.93
210	17.4	14.9	—	—	$\hat{Y} = 23.0 - 15.9 \times 10^{-3} X$	−0.95	$\hat{Y} = 23.8 - 4.4 \times 10^{-4} X$	−0.93
211	17.9	15.7	—	—	$\hat{Y} = 21.3 - 14.4 \times 10^{-3} X$	−0.99	$\hat{Y} = 17.4 - 1.5 \times 10^{-4} X$	−0.84
Avg.	17.2	15.5	441	715	$\hat{Y} = 19.4 - 8.6 \times 10^{-3} X$	−0.82	$\hat{Y} = 19.0 - 2.1 \times 10^{-4} X$	−0.86
For all points					$\hat{Y} = 19.8 - 9.4 \times 10^{-3} X$	−0.69	$\hat{Y} = 18.0 - 1.5 \times 10^{-4} X$	−0.57

[1] $\hat{Y}$ = % sucrose, X = available $N(N_T)$

[2] $\hat{Y}$ = % sucrose, X = average petiole NO_3-N concentration from 7/6 to 9/2.

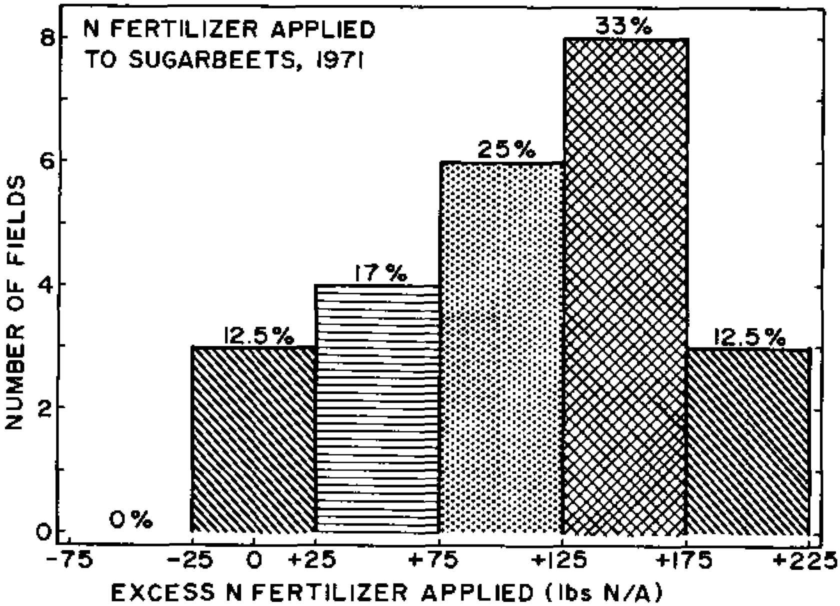

Figure 2.—Distribution of excess N fertilizer recommended and applied to sugarbeet fields in southern Idaho in 1971.

production has no economic advantage over maximizing yield of beets per acre.

In conclusion, the NO_3-N level in the soil has been shown in these and other studies (5, 8, 12) to be an excellent indicator of the N fertilizer needs of sugarbeets for maximum sucrose production, provided that the mineralization capacity of the soil and the yield potential of the field are known. The amount of N supplied from mineralizable sources in a uniformly cropped and fertilized field is expected to remain reasonably constant from one year to the next, if adequate but not excess N fertilizer is supplied yearly for the crop grown (5). Once the mineralization capacity of a soil has been determined, this test need not be repeated yearly. Soil sampling and laboratory analyses, to determine the amount of NO_3-N in the rooting zone, when combined with the predetermined mineralizable N, would enable accurate N fertilizer recommendations. Mineralizable N should be redetermined every few years, particularly following forage legumes or unusual fertilizer practices.

The use of this soil test should indicate the optimum N levels for maximum refined sucrose production, provided that proper irrigation levels are used (9). Excessive irrigations, particularly early in the season before the period of maximum N uptake by the crop, will move part of the N supply out of the root zone and make it unavailable to the sugarbeets. Although the testing for and the application of proper amounts of N fertilizer before the period of maximum plant N uptake are important, a mid-season verification of the N status of the crop by petiole analysis (4) would help to determine the accuracy of N fertilizer application recommendations in relation to the irrigation levels, and should permit fertilizer and irrigation adjustments during the current and future years for maximum refined sucrose production.

Summary

Sugarbeets (*Beta vulgaris* L.) were grown at four N fertilizer levels on 24 sites throughout southern Idaho to determine root yield, sucrose percentage, sucrose yield, impurity index, and plant N uptake in relation to the residual, mineralizable, fertilizer N, and petiole NO_3-N. A soil test to measure both mineralizable and nitrate-nitrogen level of a soil serves as a valuable guide in recommending nitrogen fertilizer for sugarbeets over a wide area of southern Idaho. The use of this test will enable the optimum application of nitrogen fertilizer before planting or side-dressing early in the season, before the period of highest nitrogen uptake by the plant, to obtain maximum refinable sucrose production and profits to both the producer, when paid on a refined sucrose basis, and processor.

Acknowledgment

The authors express appreciation to Mr. Darrell L. Gallup, State Soil Scientist, Soil Conservation Service and his staff for their assistance in the soil classification.

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