The Nitrogen Requirement of Sugar Beets[1]

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A decade ago the typical fertilizer recommended for sugar beets in the northern Great Plains and Intermountain areas was 6 to 10 tons of barnyard manure disked into the soil and 100 to 150 pounds of treble superphosphate broadcast before planting (9) (6)[3]. Such recommendations were based upon the results of field observations and experimental study.

Recent experiments by Tolman (10), Gardner and Robertson (3), Haddock and Kelley (4), and Swift (8) among others have emphasized the value of commercial nitrogen as a fertilizer constituent for sugar beets in addition to that supplied by crop residues and manure in these areas. These experimenters have noted also the harmful effects of excess available soil nitrogen on depressing the sucrose percentage of beets. Sugar beet yields and quality are so markedly influenced by available soil nitrogen (2) (11) (5) (3) that neither a deficiency nor large excess should be permitted where this crop is grown.

Nitrogen Required to Produce a Sugar Beet Crop

Since the nature of the sugar beet crop is such that its nitrogen requirement should be known and supplied with precision, one should first determine how much nitrogen a sugar beet crop requires. In most sugar beet growing areas a 20-ton crop of beets is frequently grown and 30 ton is an attainable goal.

How much nitrogen does a 20-ton crop of sugar beets need? Chemical analysis of both tops and roots at the Utah Agricultural Experiment Station indicates that such a crop removes from the soil approximately 200 pounds of nitrogen per acre. Since recovery of available plant nutrients from the soil is not complete, somewhat more than 200 pounds per acre must be made available in the soil. This is particularly true of nitrogen which is subject to heavy deep percolation losses under irrigation.

Adequate Nitrogen Fertilization

The intelligent sugar beet grower is anxious to know how much of the 200-pound nitrogen requirement his soil will supply and how much supplementary nitrogen he should provide. As stated by Brown (1), "The fertilizer application should depend upon the soil content of available plant food and the particular crop needs."

The present fertility status of most sugar beet soils necessitates the addition of only a fraction, but a highly important fraction, of the total nitrogen requirements for sugar beets, especially nitrogen, are rough and frequently soil test has been developed and standardized to provide an estimate of the seasonal nitrogen-supplying power of a soil. Recommendations on fertilizer requirements for sugar beets, especially nitrogen, are rough and frequently in serious error. Many beet growers and field men agree with the observations of Brown (1) who says:

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[3] Numbers in parentheses refer to literature cited.

> The farmers' cropping system, if he used clover crops in good rotation series have marked effects upon the fertility level and modify the fertilizer recommendations . . . We feel that much still remains to be done in persuading farmers to stop burning straw, to adopt better rotations and apply more fertilizer for this special cash crop. The general production can be raised much higher . . . if the proper fertilizer analyses are used in the proper quantities and put in the right place.

At the present time those charged with the responsibility of advising farmers do not have adequate facilities and information to direct wisely efficient nitrogen fertilizer practice. This fact is emphasized in the following statement by Walker et al (13) :

> It might also be concluded that use of an average fertilizer requirement for the area, even if known accurately, could result in fairly frequent losses to the grower of as much as $50 per acre through missing the actual optimum for his particular field. Obviously, much of the difference in nitrogen requirement was caused by differences in fertility before the application of fertilizer.

Nitrogen Nutritional Status of Sugar Beets

How can the nitrogen fertilizer requirement be determined?

One obvious answer to this question is: by applying known graduated quantities of barnyard manure, green manure, crop residues and commercial nitrogen fertilizer, alone and in various combinations in carefully controlled field experiments, and observing the effects on yield and quality of crop.

This approach is generally thought to be too slow and expensive to be used on a wide scale. Various research workers have found approximate answers to this question. Robertson's (7) answer is to make current green tissue field tests for available nitrogen and side-dress the indicated fertilizer requirements. Gardner and Robertson (3) recommend the application of 10 to 15 ton of manure per acre. If manure is not available, maintain a comparatively high nitrogen level in the soil with commercial nitrogen even though a slight reduction in percentage of sugar may result.

Ulrich (12) suggests that chemical analysis of plant samples be made at regular intervals from the same field and used as a guide in adjusting the fertilizer program for succeeding beet crops. Walker et al (13) indicate that possibly the glutamic acid content of sugar beet roots may be the best guide to most efficient nitrogen applications. Brown (1) determines total and active organic matter in the soil and obtains the ratio A:T but does not indicate how this is used in fertilizer recommendations.

Experimental Results

A series of experiments was conducted at the Utah Agricultural Experiment Station in 1946, 1947 and 1948 in which some observations were made on the nitrogen requirement of sugar beets grown on typical soils of northern Utah. Some of the tests suggested above were applied to crops grown in order to have some basis for evaluating the effectiveness of the several treatments used.

The data presented in Table 1 show the effect of too little and too much nitrogen on the yield of beets, quality of beets and yield of gross sugar. It is not difficult to see that on soils with a nitrogen-supplying power sim-

ilar to these soils that 80 pounds of nitrogen increases yields of beets and gross sugar without decreasing sucrose percentage. There is evidence that the coefficient of apparent purity is decreased slightly. While an additinal 80 pounds of nitrogen further increased the yield in 1946, it simultaneously depressed the sucrose percentage to such an extent that gross sugar was not increased. In 1947 and 1948 yields were not increased by a second 80-pound nitrogen application. Although the yield of beets was not increased in 1948 the sucrose percentage and purity were markedly depressed, so that actually less sugar was produced from the additional nitrogen.

Table 1.—Yield of Sugar Beets, Sucrose Percentage and Sugar Production as Influenced by Nitrogen Fertilization.

Nitrogen Applied lbs./A	1946 Yield T/A	1946 Sucrose Percent	1946 Coeff. App. Purity	1946 Sugar T/A	1947 Yield T/A	1948 Yield T/A	1948 Sucrose Percent	1948 Coeff. App. Purity	1948 Sugar T/A
0	16.8	17.0	91.1	2.85	23.3	14.1	16.4	91.7	2.31
80	20.5	17.0	90.6	3.49	27.6	17.6	16.6	90.5	2.92
160	22.0	15.9	87.8	3.50	27.0	17.1	14.5	87.7	2.48
L.S.D. at .05	0.51	0.15	0.40	0.092	0.88	0.73	0.384	0.65	0.15

What effects from fertilizer application can be observed in the chemical composition of plant tissue? The data in Table 2 show that the nitrogen applied as fertilizer had a marked effect on the nitrate-nitrogen content of the beet petioles. It appears from these data that the nitrogen content in the plant should be kept above 1,000 ppm. until mid-September for best yields.

The relatively low nitrogen content of petioles in August and September of 1946 for the 80-pound nitrogen plots may be the answer as to why the 160-pound nitrogen plots gave still higher yields that year. It will be noted that high concentrations of soluble nitrates in beet petioles in October are associated with low sucrose percentages and purity. It is easy to see from the data in Tables 1 and 2 the close relationship among nitrogen fertilization, yield, sucrose percentage, coefficient of apparent purity, yield of gross sugar and nitrate-nitrogen content of beet petioles.

Table 2.—Seasonal Nitrate-nitrogen Content of Sugarbeet Petioles as Influenced by Nitrogen Fertilization. (ppm)

Nitrogen Applied lbs./A	1946 July	1946 Aug.	1946 Sept.	1947 July	1947 Sept.	1947 Oct.	1948 July	1948 Sept.	1948 Oct.
0	1,122	294	112	2,660	534	42	6,750	123	320
80	1,972	500	88	14,800	1,136	276	8,500	1,291	280
160	2,317	2,336	1,140	15,750	2,362	1,719	9,300	5,300	1,440
L.S.D. at .05	243	116	92	1,913	496	714	1,821	1,916	540

It has been observed by sugar beet growers and research workers that frequently, when barnyard manure is applied in the spring of the year in which beets are grown, beet plants do not appear to obtain sufficient nitrogen for rapid growth until about August. This phenomenon was observed during the course of the experiments reported herein. This effect was not as

pronounced in 1948 as in 1946 and 1947. Only on those plots which received nitrogen fertilizer with or without manure did the beet plants appear to be adequately supplied with nitrogen during July and early August.

The data presented in Table 3 are typical of those obtained for other years. It will be seen that yields were increased in response to both nitrogen fertilizer and manure. Sucrose percentage was not affected by 80 pounds of nitrogen in presence or absence of manure. Fifteen tons of manure did not depress sucrose or purity. Eight pounds of nitrogen depressed purity slightly. One hundred sixty pounds of nitrogen with manure did not increase yields over the 80-pound nitrogen rate but this relatively high rate markedly depressed sucrose percentage, coefficient of apparent purity and gross sugar. It will be noted that the nitrate-nitrogen content of beet petioles

Table 3.—Influence of Manure and Nitrogen Fertilizer on Yield and Quality of Beets and Seasonal Nitrate-nitrogen Content of Petioles. (1948)

Fert. Nitrogen lbs./A	Beets T/A	Sucrose Percent	Coeff. App. Purity	Gross Sugar T/A	Nitrate-nitrogen in petioles (ppm)				
					July 15	Aug. 2	Aug. 28	Sept. 18	Oct. 9
No 0	13.03	16.42	92.12	2.09	5,460	2,580	530	180	240
Manure 80	15.64	16.23	90.20	2.51	8,500	7,080	4,660	990	650
Manure 100	14.12	16.37	91.67	2.25	6,750	2,710	820	120	320
15 T/A 80	17.63	16.56	90.47	2.92	8,500	9,600	5,080	1,290	280
160	17.14	14.53	87.70	2.58	9,950	9,000	11,000	5,950	1,445
L.S.D. at .05	0.73	0.38	0.65	0.15	1,621	1,111	1,560	916	540

was similar regardless of manure treatment. Eighty and 160 pounds of nirogen fertilizer had a pronounced influence on the nitrogen content of beet petioles.

These data do not establish 80 pounds as the most profitable rate of supplemental nitrogen on these soils. In 1946, 120 pounds of nitrogen may not have been too much. In 1947 and 1948, 40 pounds may have been sufficient for most efficient use of nitrogen. In order to obtain more detailed information on the effects of supplemental nitrogen on quality and yield of sugar beets, eight nitrogen fertilizer treatments were studied in 1948. The soil used had received 15 tons of manure, 80 pounds of nitrogen, 100 pounds of phosphoric acid and 60 pounds of potash per acre in 1947 previous to planting beets. Beet tops were left on the soil in the fall of 1947. Following this treatment it was not expected that a marked response for nitrogen fertilizer would result. The data in Table 4 show the effect of nitrogen supplement on the 1948 crop.

It will be observed in the second column of Table 4 that significant yield increases were obtained over unfertilized plots in all instances where 40 or more pounds of nitrogen were applied. Significant depressions in sucrose percentage and purity occurred where more than 80 pounds of nitrogen were applied. When 80 pounds of nitrogen were applied in a split application a similar depression occurred. A large excess of nitrogen gave no adverse affect on yield but sucrose percentage was so noticeably lowered that the highest rate of nitrogen tended to produce less sugar than was

obtained from untreated plots. The most profitable returns on this soil were obtained from 40 pounds of nitrogen. It is interesting to observe that yield, sucrose percentage and purity were not affected appreciably by an additional 40 pounds unless applied late in the season. It was definitely a waste of fertilizer to apply more than 40 pounds of nitrogen per acre and it was unprofitable to apply as little as 20 pounds.

It can be seen that when the nitrate-nitrogen content of beet petioles falls below 1,000 ppm. in August yields tend to be adversely affected. When more than 1,000 ppm. are present in petioles in October, quality is lowered. It appears as though the nitrate-nitrogen content of beet petioles should fall below 1,000 ppm. by mid-September. From August to harvest time the nitrate-nitrogen content of sugar beet petioles was roughly in the same order as the quantity of nitrogen fertilizer applied.

Table 4.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. (1948)

Nitrogen Applied lbs./A	Yield Beets T/A	Sucrose Percent	Coeff. App. Purity	Gross Sugar T/A	Nitrate-nitrogen in beet petioles (ppm)				
					7/13	8/2	8/23	9/18	10/9
0	17.61	16.72	92.27	2.94	4,725	2,975	962	220	132
20	18.87	16.75	90.63	3.16	6,850	5,550	947	238	56
40	19.73	16.39	91.35	3.23	8,100	9,850	2,230	224	48
80	19.69	16.28	90.54	3.21	8,200	10,650	3,581	232	456
80 (½ in Aug.)	20.10	14.93	88.37	3.00	8,100	9,850	3,370	2,740	1,536
160	19.79	15.15	87.09	3.00	8,850	13,100	9,775	1,780	792
160 (½ in Aug.)	21.57	13.25	83.97	2.86	8,200	10,650	4,925	5,830	2,476
320	19.45	12.96	83.93	2.52	8,850	15,300	14,050	4,790	1,848
L.S.D. at .05	1.72	0.85	1.29	N.S.	0,918	2,388	2,734	1,687	688

Discussion

It is evident from the data given here and from other work cited that either a deficiency or an excess of available soil and fertilizer nitrogen may have important economic consequences in sugar beet production. It is, therefore, important that a farmer know as precisely as possible the amount of nitrogen fertilizer he should apply to supplement other nitrogen available to his sugar beet crop.

The recommendations coming from various sources indicating ways of testing soils or plants as a basis for determining supplementary nitrogen requirements are helpful and serve an important need. However, it is difficult to see how plant tissue tests either on green or dry material can bring satisfaction to beet farmers generally. It is evident from the data presented herein that plant tissue analyses are useful in appraising the nutritional status of sugar beet plants. The effect of various field treatments on the uptake of nitrogen can be determined with confidence. Frequently, the information obtained from plant tissue analysis may be useful to commercial growers. But information on the nitrogen-supplying power of a soil would be much more useful to a sugar beet grower if it were available before planting time.

If a direct soil test could be developed which would supply sugar beet growers with a good estimate of supplemental nitrogen requirement, better yield and sucrose percentages would result. Furthermore, sugar beet growing would become more profitable. It would seem that greenhouse pot tests or soil incubation tests or a combination of these may have good possibilities.

Until some more useful measure of the nitrogen-supplying power of a soil is standardized, petiole analyses in conjunction with yield and quality data may be employed to furnish an approximation of supplemental nitrogen requirement. On the basis of such data presented above it appears as though 40 to 100 pounds of commercial nitrogen per acre should be applied on typical soils of northern Utah. Barnyard manure applied in the spring of the year in which beets are grown should be supplemented with commercial nitrogen.

What then is the nitrogen requirements of sugar beets?

The nitrogen requirement depends upon the season and the ability of a farmer to get the best growth of sugar beets by good farming practices. If a 20-ton per acre crop can be grown, the nitrogen requirement is approximately 200 pounds per acre. Of this total requirement the soil may supply from one-half to four-fifths or from 100 to 160 pounds of nitrogen per acre. The farmer should supplement this with 40 to 100 pounds of nitrogen fertilizer per acre.

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