The Response of Sugar Beets to Fertilizers in Western South Dakota[1]

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The yields of sugar beets on the Belle Fourche irrigation project in western South Dakota usually average about 10 tons per acre. In order to increase these yields, the Utah-Idaho Sugar Company has conducted numerous field trials with fertilizers (1) (2)[3].

Data from these have shown that applications of nitrogen and phosphate frequently increase the yields. In addition to the field trials, the Utah-Idaho Sugar Company conducted a soil sampling survey of fields where beets were grown to determine the levels of available phosphorus (3). The results of this study show that 68 percent of the samples contained only zero to five ppm. of CO_2-soluble PO_4. This level is considered very low. Other data obtained on the Newell Irrigation and Dryland Field Station tend to support these observations (4).

In order to study more intensively the nutrient needs of sugar beets in the area, six experiments on farmers' fields were conducted in 1950 and 1951. It is the purpose here to present the results from these experiments and to attempt to explain the observed responses in light of supporting data from soil and plant analyses.

The Belle Fourche irrigation project consists of approximately 50,000 acres. Part of the soils are sandy. These lie along the Belle Fourche river and range in textures from sandy loams to loams. Included in this category are the soils of the Vale and Nisland areas. Row crops such as corn, sugar beets and beans are more frequently grown on the sandy soils than on the finer-textured soils occurring elsewhere on the project. Clay soils occur over much of the remainder of the project. These include the Orman clay on the Arpan flats laid down in an old lake bed, and the Pierre clay in the vicinity of Newell which developed from weathering of Pierre shale. The clay soils are difficult to till and irrigate and stands of beets usually are poor. The clay soils are better adapted for small grains and alfalfa although considerable acreages of beets are grown on them. Beet yields on the clay soils over the past eleven years averaged only eight and one-tenth tons per acre as compared with 10.4 tons on the sandy soils.

Experimental Procedure

The six fertilizer experiments were conducted on six separate commercial sugar beet fields. The preparation of the land, planting, cultivation and irrigation were done by the farmer. The placement of the fertilizer, supervision of thinning and harvesting were done by Station personnel.

Four of the experiments were conducted in 1950 and two in 1951. Locations of the experiments, soil types, past management information and

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supplementary soil and plant data are given in Table 1. Nitrogen and phosphate rates and combinations used are shown in Table 2 for the 1950 experiments and in Table 3 for the 1951. Double superphosphate was used as the source of phosphate and ammonium nitrate as the source of nitrogen. The phosphate was banded two inches deep and two inches to the side of the row with a belt-fertilizer machine soon after planting. The nitrogen was side-dressed at thinning.

The fertilizer treatments were replicated five times in a randomized block design. Each plot was four or six beet rows wide and 50 feet long. Two of the center rows were used for yield determinations while 15 beets from the harvest area were selected for sugar determination. Gypsum blocks were placed at each location for the purpose of obtaining moisture records and as a guide in advising the farmer when to irrigate. Soil samples were taken at zero-eight-inch depths from each location and the CO_2-soluble phosphorus, nitrifiable-nitrogen, percent organic matter, percent free lime, base exchange capacity, pH, electrical conductivity and percent water at

Table 1.—Location, Soil Type, Management History, and Soil and Petiole Analyses for Each of the Six Sugar Beet Experiments.

	1950 Experiments				1951 Experiments	
Location	Newell	Arpan	Vale	Nisland	Vale	Nisland
Soil type	Pierre clay	Oman clay	Vale f.sa.l.	sa.l.	Vale sa.l.	gravelly l.
Past management						
1950	----------	----------	----------	----------	Beans	Wheat
1949	Barley	Beets (M)	Corn	Beets (M, F)	Beans	Barley
1948	Barley	Beets (F)	Alfalfa	Beets	Beets (F)	Beets (M)
1947	Alfalfa	Barley	Alfalfa	Alfalfa	Beets	----------
Beets per 100 ft.	72	81	81	74	95	91
Avail. PO_4, ppm.	1	23	6	14	2	13
Nitrifiable N, ppm.	84	50	82.5	54.8	----	
Organic matter, %	1.9	1.8	1.5	1.7		
Free lime, %	3.1	0.5	0.1	1.2		
Base exch. cap., m. e/100 gms	26.4	16.0	9.0	8.7		
Conductivity, millimhos	1.5	1.9	0.9	1.3	1.5	1.8
% water, 1/3 atmos.	44.4	32.8	16.0	20.6		
Petioles—Check plots						
Organic N, ppm.	6,900	3,050	5,250	4,400	3,970	3,440
Nitrate N, ppm.	15,000	1,650	4,500	3,500	910	620
Total soluble N, ppm.	21,900	4,700	9,750	7,900	4,880	4,060
Phosphorus, ppm.	1,060	2,520	560	870	380	2,200

M—Barnyard manure applied.
F—Commercial fertilizer usually about 250 pounds 16-20-0 per acre.

one-third atmosphere tension were determined either at the Newell Irrigation and Dryland Field Station laboratory or by Dr. W. E. Larson at Bozeman, Montana, using standard procedures. The sucrose content of the beets was determined by the Utah-Idaho Sugar Company. Petiole samples were collected in late August and the soluble nitrogen and phosphorus contents determined by Dr. J. L. Haddock at Logan, Utah, in 1950 and at Newell in 1951.

In 1951, in addition to the normal field topping procedure, the tops were cut flush with the crowns and green weights for tops, crowns and roots were determined at harvest time. The percent dry matter was determined on samples of the beet raspings and of the tops.

Results and Discussion

The root yields for the experiments conducted in 1950 are given in Table 2 and for 1951 in Table 3. Fertilizer significantly increased the yield in four of the six locations although some increases were obtained at all locations. Yields of the unfertilized plots ranged from 7.1 to 19.2 tons per acre. Yield increases from fertilizers ranged from 1.9 to 8.0 tons per acre, and there appears to be a wide range in fertility needs from field to field.

The responses by locations are summarized as follows:

1. At Arpan, nitrogen increased the yields but phosphate had no beneficial effect. The yields increased with each increasing rate of nitrogen.
2. At Newell, phosphate increased the yields but nitrogen had no effect. Largest increases per pound of applied P_2O_5 were obtained from the 40-pound rate of P_2O_5, although yields increased slightly up through the 160-pound rate of P_2O_5.
3. At Nisland in 1950, a combination of nitrogen and phosphate appeared most effective—with 80 pounds of N and 80 pounds of P_2O_5 giving near maximum response.
4. At Nisland in 1951, nitrogen markedly increased the yields, while phosphate had little effect. The 40-pound rate of nitrogen gave by far the largest increase per pound of applied N.
5. At Vale in 1950, no significant increases were obtained from either nitrogen or phosphorus, singly or in combination.
6. At Vale in 1951, very slight but not significant increases apparently exist. Most of the increases may be ascribed to phosphate.

Table 2.—1950 Data Comparing Root Yields and Sugar Percentage from Various Nitrogen and Phosphate Applications at Four Locations.

Treatment Lbs. per acre		Newell		Arpan		Vale		Nisland	
N	P_2O_5	Roots T/A.	% Sugar	Roots T/A.	% Sugar	Roots T/A.	% Sugar	Roots T/A.	% Sugar
0	0	10.1	16.3	7.1	18.3	19.2	15.1	16.2	17.4
0	160	12.2	16.6	7.3	18.2	20.3	15.0	17.7	17.1
40	160	12.5	16.1	8.9	18.5	20.5	14.8	18.5	16.5
80	160	12.2	16.2	9.5	18.9	19.7	14.6	19.2	16.7
160	160	12.3	16.1	10.2	18.5	21.1	14.4	19.6	14.9
80	0	8.6	16.3	10.2	17.9	19.3	14.8	16.4	15.4
80	40	11.8	16.2	9.1	18.0	19.8	14.7	18.1	16.2
80	80	11.5	16.2	8.5	18.5	19.7	15.0	19.3	15.5
LSD	.05	1.9	N.S.	1.7	N.S.	N.S.	N.S.	2.1	1.2

Although the yields on most of the low-producing fields were improved through fertilizers, really high yield increases were obtained only at Nisland in 1951. Apparently factors other than a deficiency of nitrogen and phosphorus are responsible such as poor stands, disease injury and poor physical condition of the soil.

Table 3.—1951 Data Comparing Root Yield, Sugar Percentage and Top Yields from Various Nitrogen and Phosphate Applications at Two Locations.

Treatment Lbs. per acre N	P_2O_5	Vale Roots T/A.	Vale % Sugar	Vale Tops[1] T/A.	Vale Root/Top[2] Ratio	Nisland Roots T/A.	Nisland % Sugar	Nisland Tops T/A.	Nisland Root/Top Ratio
0	0	11.4	18.4	4.5	2.53	10.0	18.7	3.8	2.63
0	80	13.8	18.2	5.4	2.56	9.8	18.9	4.0	2.45
40	80	13.0	18.7	4.8	2.71	16.0	18.2	7.1	2.25
80	80	15.1	18.5	6.5	2.02	15.9	18.5	8.6	1.85
120	80	13.4	17.7	6.8	1.97	18.0	18.2	10.9	1.65
80	0	12.1	18.0	6.4	1.89	15.5	18.0	8.9	1.74
80	40	13.1	17.8	6.7	1.96	17.4	18.6	9.5	1.83
LSD	.05	N.S.	N.S.	1.8		2.1	N.S.	2.8	

[1] Green tops, does not include the crown. The average yield of the crowns was approximately 7 percent of the roots.
[2] Tons roots divided by tons tops.

Percent sugar

A linear regression was computed between root yields and percent sugars from the data for the four sandy soil locations. Preliminary regressions indicated that the data from the two clay soil locations behaved entirely differently from those of the sandy soils, and since only 16 pairs of values were available for the clays, regressions for the latter were not computed. The regression line for the 30 pairs of values for the sandy soils is shown in Figure 1.

For this set of data, the regression equation was Y = 23.45 — .4008x and the regression coefficient was r = —.83, a highly significant value. For the sandy soils, each ton increase in beet yield was associated with an 0.4 percent decrease in the sugar content. Insufficient data existed for the preparation of a valid regression line on the clay soils; nevertheless, it is interesting to point out that, for a given yield, the percent sugars are lower on the clays than on the sands. This is apparent in Tables 2 and 3 by comparing certain of the yields and sugar percentages from Newell with the 1951 Nisland data, and from Arpan with the 1951 Vale data.

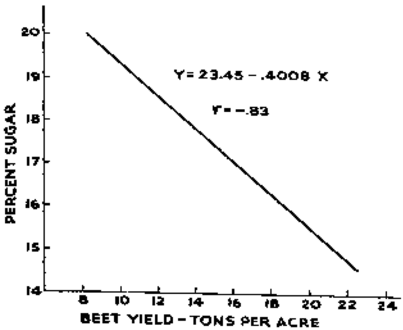

Figure 1. Average regression of percent sugar on beet yield in four field experiments located on sandy soils.

At most locations, applications of nitrogen tended to reduce the sugar percentage. This reduction was great enough to be significant only at Nisland in 1950. Here the 160-pound nitrogen rate decreased the sugar contents by two and two-tenths percent below that of the phosphated check. This resulted in an actual decrease of 230 pounds of sugar per acre even though the nitrogen increased the root yield by one and nine-tenths tons. In the same experiment, the 40- and 80-pound nitrogen rates resulted in an average depression in sugar content of five-tenths percent below that of the phosphated check.

At Arpan, on the other hand, nitrogen in the presence of 80 or 160 pounds of P_2O_5 apparently had no deleterious effect on the sugar content even though the beet yields were increased by as much as two and nine-tenths tons. It is interesting, however, that 80 pounds of nitrogen either alone or in the presence of 40 pounds of P_2O_5 appear to have decreased the sugar content.

Phosphate appears to have exerted but little depressive influence upon the sugar percentage. In fact, a combination of nitrogen and phosphate generally showed smaller depressive effect than where the same amount of nitrogen was used alone.

Production of Tops

The 1951 yields of green tops and the corresponding root/top ratios point out some interesting comparisons (Table 3) .

At both locations, increasing the rate of nitrogen in the presence of phosphate decreased the root/top ratio, i. e., increased the proportion by weight of tops to roots. Increasing the rate of phosphate in the presence of nitrogen, on the other hand, slightly increased the root/top ratio, i.e., decreased the proportion of tops to roots. Nitrogen alone decreased the root/top ratio to a greater extent than the same rate of nitrogen in the presence of phosphate, thus indicating that nitrogen alone produced more tops in proportion to the roots than did a combination of nitrogen and phosphate.

Representative samples of root raspings and green tops were oven dried for the determination of the percent dry matter. The dry matter content of the roots did not vary more than one percent between treatments. However, in the case of the tops, there was as much as five percent less dry matter per unit of green material in the large green tops from the nitrogen plots as from small yellow-green tops collected from the no-nitrogen plots.

General Relationships

The foregoing data show that root yields, sugar percentages and growth of tops vary considerably between locations. Can reasons for these variations be accounted for?

At Arpan, on the Orman clay, large root response to nitrogen was obtained; however, nitrogen in the presence of high rates of phosphate had no depressing effect upon the sugar percentage. Table 1 shows that the soil samples collected from this location contained 23 ppm. of $C0_2$-soluble $P0_4$, the highest at any location, and 50 ppm. of nitrifiable nitrogen—the lowest reported. The analysis of the beet petioles taken from check plots confirms the soil analysis, i.e., high in soluble phosphorus and low in the soluble nitrogen fractions. From the soil and petiole analysis, one would expect the large response to nitrogen and the lack of response to phosphate. Although manure and fertilizer were applied to the field during the three-year period preceding the experiment, no legume crops were grown during these years. Earlier history indicates that the field was poorly managed and received no manure or fertilizers. Apparently, however, the level of available soil nitrogen was so low that even 80 or 160 pounds of fertilizer nitrogen per acre when applied with 80 or 160 pounds of P_2O_5 were insufficient to cause depression in sugar content of the beets. Why some depression in sugar content resulted when 80 pounds of nitrogen were applied either alone or with 40 pounds of P_2O_5 is not explainable from the data available.

At Newell, on the Pierre clay, phosphate increased the yields but nitrogen had no effect. Table 1 shows that the soil contained only one ppm. of CO_2-soluble PO_4, while the petioles contained 1,000 ppm. of soluble phosphorus, much lower than at Arpan on a soil having somewhat similar texture. Nitrifiable nitrogen, however, was high (84 ppm.) , and the soluble nitrogen fractions in the petioles were extremely high. This field had been in alfalfa from 1947 and for several years previously and phosphate or manure had not been applied. These observations indicate a low level of available phosphorus and a high level of available nitrogen in the soil which correlate well with the observed yield response. One would expect, however, that the sugar percentage of the beets would have been decreased to a greater extent from the application of nitrogen.

At Nisland on a sandy loam in 1950, a combination of nitrogen and phosphate fertilizer was most effective, while nitrogen greatly depressed the sugar content. The soil analysis shows that the soil contained a moderate supply of 14 ppm. of available PO_4; the nitrifiable nitrogen, however, was 54.8 ppm., considerable lower than on the clay soil at Newell but slightly higher than at Arpan. Petiole analyses showed a comparatively low level of both soluble phosphorus and soluble nitrogen. This field had been in alfalfa three years previously and had received manure and fertilizer in 1949. While these observations would lead one to expect a response to nitrogen and phosphate, it is by no means as clear-cut as the nitrogen at Arpan or the phosphate at Newell. However, the check yield at Nisland was 16.2 tons as compared to seven and one-tenth and 10.1 tons at Arpan and Newell, respectively.

At Vale in 1950, significant yield responses were not obtained; however, the yield of the check plots averaged 19.2 tons per acre. Phosphorus analysis of both the soil and the petioles indicate a low level of available phosphorus. Why phosphate response was not obtained is not known. Nitrogen analysis of the soil and petioles indicates that the nitrogen level was quite high.

At Vale in 1951, no significant yield responses were obtained, although there was a tendency for phosphate to increase the yields by about one ton per acre. Observations made early in the season also indicated a vegetative response to phosphate. The top yields were significantly increased from

80 pounds of nitrogen alone and from the 80- and 120-pound rates of nitrogen in combination with phosphate. The available PO_4 level in the soil was only two ppm. while the petiole phosphorus also was extremely low. The soluble nitrogen fractions in the petioles were low. The lack of legumes on the field in the past would tend to support the low levels of soluble nitrogen in the petioles. Why final yield responses were not obtained from nitrogen and phosphate cannot be explained.

At Nisland in 1951, a very large response to nitrogen of both roots and tops was obtained. Phosphate had no effect. The CO_2-soluble PO_4 content of the soil was 13 ppm. while the soluble phosphorus in the petioles was high. The soluble nitrogen fractions in the petioles were very low, equalled only at Arpan. No legumes were grown on the field for several years in the past. Thus, all indications point to a moderate to good supply of available phosphorus and a very low supply of available nitrogen in the soil, which explains satisfactorily the type of yield response obtained. Although nitrogen fertilizer did not significantly reduce the sugar content of the beets, the reduction nevertheless was considerable.

Summary

Results presented from six fertilizer experiments conducted on the Belle Fourche irrigation project in western South Dakota show that response to nitrogen and phosphate varies greatly from field to field.

These responses correlated well with soil and petiole analyses in four instances but not in two.

Nitrogen fertilizer at some locations lowered the sugar content of the beets. This was particularly serious at only one location. Increase in yield was closely associated with a reduction in sugar content.

Root/top ratios indicate that nitrogen fertilizer increased the proportion by weight of tops to roots while phosphate slightly decreased the proportion of tops to roots. Nitrogen alone increased proportion tops to roots to a greater extent than did a combination of nitrogen and phosphate.

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