

Yield and Zinc Content of Sugar Beets as Affected by Nitrogen Source, Rate of Nitrogen, and Zinc Application¹

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Introduction

An experiment in which field plots were treated with a factorial combination of three nitrogen sources, three rates of nitrogen, and five rates of zinc was started at Prosser, Washington, in 1953. The cropping sequence on these plots included grain sorghum in 1953, potatoes in 1954, and sugar beets in 1955. The interest in sugar beets was concerned primarily with the influence of the treatments on zinc nutrition. At the same time, however, it was convenient to observe the effect of nitrogen rate and nitrogen source on such things as yield, sugar content, and petiole nitrate.

Apparently little work has been done to determine the zinc requirements of sugar beets. In a previous paper Boawn and Viets (1)³ published data for a number of experiments showing levels of zinc in leaf blades, and concluded that 10 ppm. zinc in young, fully developed leaves at mid-season is adequate for above average yields. They did not report zinc levels in other parts of the plant nor the total zinc requirement. Lingle and Holmberg (5) have reported increased growth of sugar beets in Yolo County of California from applications of zinc but did not show levels of zinc in the plant associated with this response.

In the present experiment it was hoped that unfertilized plants would be sufficiently low in zinc that a growth response to additions of zinc would be obtained. This did not occur, and therefore the data do not establish "critical" levels for zinc in the tissues analyzed. On the other hand, since additional zinc did not increase growth, the levels of zinc found in plants from plots which did not receive zinc fertilization are shown to be adequate.

Procedure

Complete details of the experiment—procedure, objectives, and complete experimental results—have been given in two previ-

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³ Numbers in parentheses refer to literature cited.

ous publications (2) (3). Only that portion of the procedure pertinent to the growing of sugar beets will be repeated here.

The soil at the experimental site was a Ritzville fine sandy loam, a Brown soil which is noncalcareous to a depth of 18 inches and is essentially neutral at the surface. Total nitrogen is low, about 0.04 percent in the surface, and decreases gradually with depth. The area had not been cropped previously and was taken out of sagebrush and bunchgrass just prior to application of the treatments.

Treatments consisted of three nitrogen carriers, three rates of nitrogen, and five rates of zinc applied in factorial combination. Nitrogen carriers were $(\text{NH}_4)_2\text{SO}_4$, NH_4NO_3 , and $\text{Ca}(\text{NO}_3)_2$; nitrogen rates 40, 80, and 160 pounds N per acre; and Zn rates 0, 2, 4, 8, and 16 pounds per acre as ZnSO_4 . The treatments were replicated twice in a randomized block design on 20 x 33 foot plots. In addition to these treatments, data were taken from plots which received neither N nor Zn. These plots were located among the other plots but were not randomized.

ZnSO_4 was applied only once, at the initiation of the experiment in 1953. Sugar beets, which were grown on the plots in 1955, therefore measured effectiveness of zinc fertilizer after contact with the soil for two years. Nitrogen treatments were made annually at the initial rates. All materials were broadcast on the surface and rototilled to a depth of eight inches the first year. In subsequent years the nitrogen materials were broadcast and plowed down.

The beets were furrow-irrigated and all cultural operations were done according to standard grower practice.

Leaf blades for analysis were taken on August 24 and consisted of 20 young, fully-developed leaves without petioles from each plot. Total top samples were taken August 25 and 26 from two 10-foot sections of row from each plot. Yield data are based on hand-topped beets from two 10-foot sections of row from each plot. The harvest date was October 24. Subsamples of roots for chemical analysis were obtained from the harvested beets using a Spreckels saw.

Zinc was determined by the dithizonate procedure essentially according to Holmes (4) using nitric-perchloric digests. Samples for sugar analysis were taken according to the procedure of the Utah-Idaho Sugar Company and the analysis was made by them along with samples from farmers' beets. Sugar analyses are expressed on a fresh weight basis; zinc and nitrate analysis on an oven-dry basis.

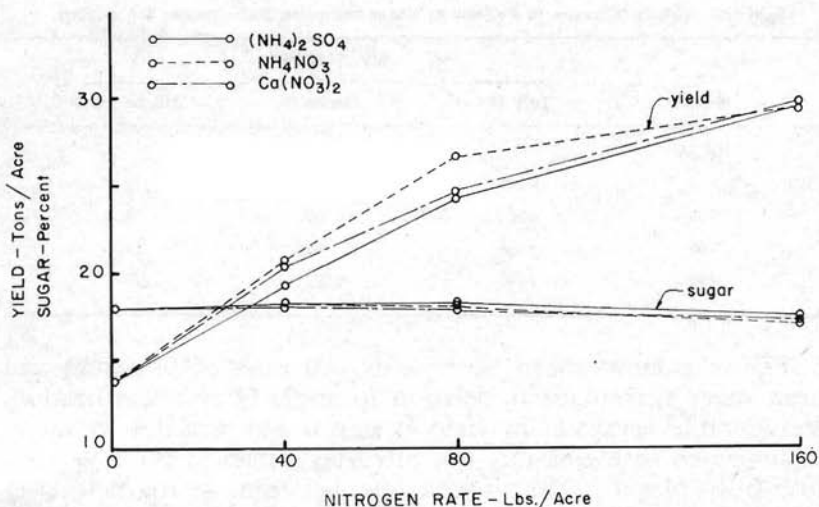


Figure 1.—Tared yield and sugar percentage of beets as affected by nitrogen rate and nitrogen carrier. (L.S.D. for nitrogen rate at the 1 percent level: yield—1.85 tons/acre, sugar—0.68 percent. Nitrogen carrier differences not significant at the 5 percent level.)

Results and Discussion

Yield and Sugar Percentage

Figure 1 shows the effect of nitrogen rate and carrier on beet yield and sugar percentage. Without nitrogen fertilization the yield of beets was slightly more than 14 tons per acre and increased sharply with each rate of nitrogen to just slightly less than 30 tons when the N rate was 160 pounds per acre. As shown by Table 1 the petiole nitrate-nitrogen even in those plots receiving 160 pounds of nitrogen per acre had dropped to 210 ppm. nitrogen as early as August 24, far below Ulrich's critical concentration of 1000 ppm. (6). It is evident that higher yields could have been obtained had an adequate supply of nitrogen been available during the early part of September. There was a tendency for $\text{Ca}(\text{NO}_3)_2$ and NH_4NO_3 to result in higher yields than were obtained with $(\text{NH}_4)_2\text{SO}_4$ but the differences are not statistically significant at the 5 percent level.

Sugar percentage in harvested beets decreased from 18.13 percent to 17.11 percent as the rate of nitrogen fertilization was increased from 40 pounds per acre to 160 pounds per acre. This occurred even though the petiole nitrate-nitrogen had dropped to 210 ppm. as early as August 24 (Table 1), and the beets were not harvested until two months later on October 24.

Table 1.—Nitrate Nitrogen in Petioles at Three Sampling Dates (ppm. dry weight).

N Rate lbs./A.	Sampling Date		
	July 14	August 5	August 24
0	140	35	75
40	320	70	98
80	1530	96	58
160	6440	2120	210

Figure 2 shows mean beet yields (all rates of nitrogen) and mean sugar percentage in relation to levels of zinc fertilization. Considerable variation in yield is shown but was not found to be associated with zinc rate nor nitrogen carrier at the 5 percent probability level. The interaction between nitrogen carrier and zinc rate and between nitrogen rate and zinc rate were not significant either. Since the highest average yield of beets was obtained at the 0 level of zinc it can be concluded that these plants had adequate zinc to satisfy their growth requirements. Indeed, as shown by Figure 3, the leaf blades from these plants averaged about 20 ppm. zinc, which is much higher than the critical level of 10 ppm. previously reported (1).

Sugar percentage in harvested beets was unaffected by the level of zinc fertilization.

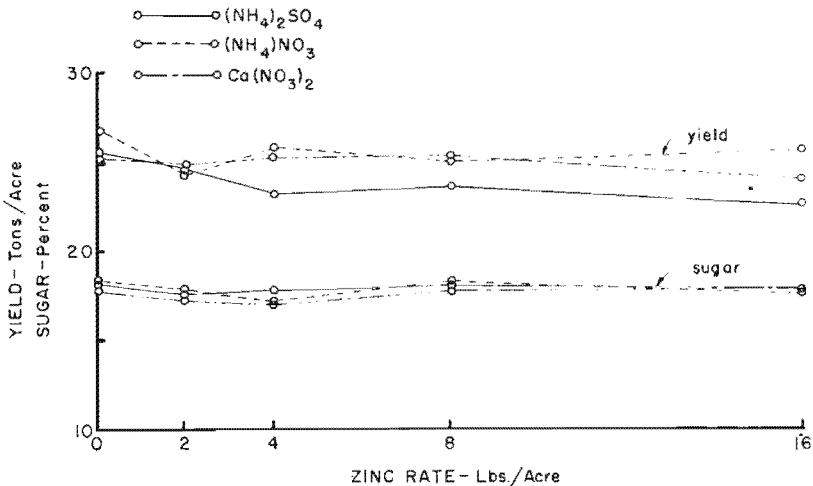


Figure 2.—Tared yield and sugar percentage of beets as affected by zinc rate and nitrogen carrier. Means of three nitrogen rates. (No significant differences at the 5 percent level.)

Zinc Concentration in Total Tops, Leaf Blades, and Roots

Figures 3 and 4 show the levels of zinc found in total tops, leaf blades, and roots as affected by different rates of zinc fertilization, nitrogen rate, and nitrogen carrier. Where 16 pounds zinc per acre was applied, the zinc concentration in leaf blades was increased by approximately 50 percent, from about 20 ppm. to a little over 30 ppm. In comparison, zinc concentration in total tops was increased from 12.5 ppm. to an average of 22 ppm., an increase of around 75 percent. Since zinc concentration in the total top is more responsive to the zinc status of the soil than leaf blades, further separation and analysis of the beet top would probably reveal a tissue which is more sensitive than either of these two.

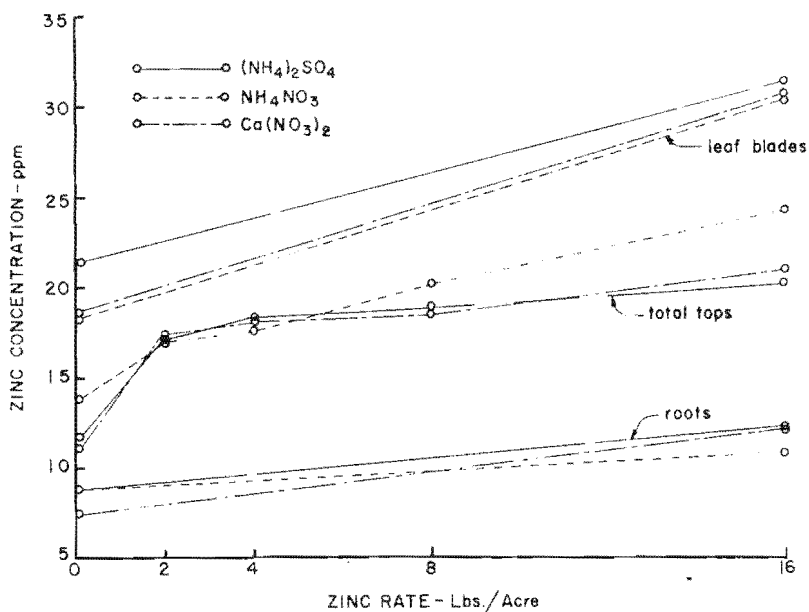


Figure 3.—Effect of zinc and nitrogen carrier on zinc concentration of total tops, leaf blades, and roots of sugar beets. Means of three nitrogen rates. (L.S.D. for zinc rate at the 1 percent level: total tops—2.3 ppm., leaf blades—2.4 ppm., roots—1.6 ppm. Nitrogen carrier differences not significant at the 5 percent level.)

As was expected, the zinc uptake response to zinc rates was curvilinear, the major increase occurring with the first increment of 2 pounds per acre.

Zinc levels in beet roots were found to be much lower than in tops and to be less responsive to changes in zinc levels in the soil.

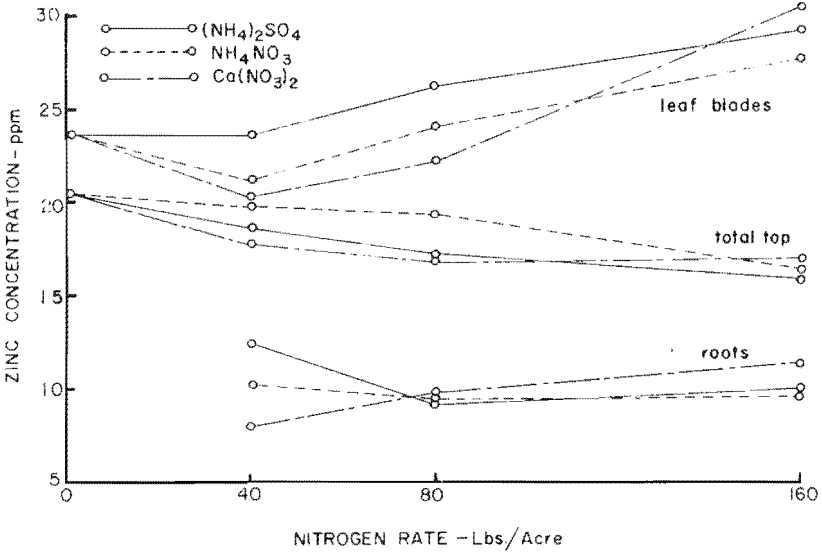


Figure 4.—Effect of nitrogen rate and nitrogen carrier on zinc concentration of total tops, leaf blades, and roots of sugar beets. Means of all zinc rates for total tops, and two zinc rates for leaf blades and roots. (L.S.D. for nitrogen rate at the 1 percent level: total top—1.8 ppm., leaf blades—3.0 ppm., roots—2.0 ppm. Nitrogen carrier differences not significant at the 5 percent level.)

Nitrogen carrier appears to have had some effect on the zinc concentration of the various plant parts, but in general it was not consistent and is not statistically significant at the 5 percent level.

Nitrogen fertilization increased the zinc concentration of leaf blades but decreased the zinc concentration of total tops. Apparently, as plant size was increased through nitrogen fertilization there was a substantial increase in the ratio of total top to leaf blades. That such a phenomenon does occur has been previously reported by Ulrich (7).

There would seem to be evidence that increasing rates of nitrogen actually increased the availability of zinc, as has been reported previously by the authors (2), but that in the case of total tops the increase in dry matter overshadowed the increased uptake of zinc.

Nitrogen rates did not change the concentration of zinc in roots.

The total zinc contained in sugar beet plants grown with two levels of zinc and three rates of nitrogen is given in Table 2.

Table 2.—Average Pounds Zinc Per Acre Contained in Sugar Beet Tops and Roots Grown with Three Rates of Ammonium Nitrate and Two Rates of Zinc.

Zn Rate	N Rate	Zinc Content		
		Tops	Roots	Sum
lbs./A.	lbs./A.		lbs./A.	
0	40	.044	.108	.152
	80	.063	.100	.163
	160	.069	.114	.183
16	40	.073	.108	.181
	80	.090	.142	.232
	160	.140	.128	.268

In comparison to other crops sugar beets remove fairly large amounts of zinc from the soil. This is especially true if tops as well as roots are removed. The amount of zinc removed by sugar beets may well be a factor in the common observation that corn planted on ground which has grown sugar beets continuously for several years will usually show severe zinc deficiency symptoms.

Summary and Conclusions

Sugar beets were grown the third year of a cropping sequence on plots treated with a factorial combination of three nitrogen carriers, three rates of nitrogen, and five rates of zinc. Increasing the nitrogen rate from 0 to 160 pounds per acre increased the beet yields from 14 tons per acre to about 30 tons per acre. Nitrogen carrier had no effect on yield. The rates of nitrogen applied caused the average sugar percentage to decrease from 18.13 percent to 17.11 percent. Zinc rates from 0 to 16 pounds per acre had no effect on either yield or sugar percentage.

Nitrogen rate and nitrogen carrier had no effect on the zinc content of various plant parts. Sixteen pounds zinc per acre, applied 2 years earlier, increased the zinc content of leaf blades from 20 ppm. to slightly over 30 ppm., of total tops from 12 ppm. to 22 ppm., and of roots from 8 ppm. to 12 ppm. These increases in the level of zinc in the plant did not produce a measurable increase in beet yield.

The total zinc contained in a beet crop yielding 30 tons per acre varied from 0.183 pounds per acre to 0.268 pounds per acre depending on the level of zinc fertilization.

Literature Cited

- (1) BOAWN, LOUIS C., and VIETS, FRANK G., JR. 1956. Zinc fertilizer tests on sugar beets in Washington. *Jour. Amer. Soc. Sugar Beet Tech.* 9(3): 212-216.
 - (2) BOAWN, LOUIS C., VIETS, FRANK G., JR., CRAWFORD, C. L. and NELSON, J. L. 1960. Effect of nitrogen carrier, nitrogen rate, zinc rate, and induced soil changes on zinc uptake by sorghum, potatoes, and sugar beets. *Soil Sci.* 90: 329-337.
 - (3) BOAWN, LOUIS C., NELSON, C. E., VIETS, FRANK G., JR., and CRAWFORD, C. L. 1960. Nitrogen carrier and nitrogen rate influence on soil properties and nutrient uptake by crops. *Wash. State University, Agr. Exp. Sta. Bul.* 614.
 - (4) HOLMES, R. S. 1945. Determination of total copper, zinc, cobalt, and lead in soils and soil solutions. *Soil Sci.* 59: 77-84.
 - (5) LINGLE, JOHN C., and HOLMBERG, D. M. 1956. Zinc-deficient crops. *Calif. Agr.* 10(2): 13-14.
 - (6) ULRICH, A. 1950. Critical nitrate levels of sugar beets established from analysis of petioles and blades, with special reference to yields and sucrose concentrations. *Soil Sci.* 69: 291-309.
 - (7) ULRICH, A. 1955. Influence of night temperature and nitrogen nutrition on growth, sucrose accumulation, and leaf minerals of sugar beet plants. *Plant Physio.* 30: 250-257.
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