

A Survey of the Nutrient Status of Soils in the North Platte Valley of Nebraska for Sugar Beet Production¹

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A survey was undertaken in 1963 to more clearly define the problem of sugar beet nutrition in the North Platte Valley of Nebraska, a major beet-producing area. The survey was prompted by the common occurrence of trace element deficiencies in various crop species grown in the Valley, especially in crops following sugar beets. Results of the study would then be used in planning future detailed soil fertility investigations in the area.

Proponents of plant analysis as a means of estimating a given soil's nutrient delivery power recognize the establishment of a critical nutrient concentration as the key to the procedure (7)³. This value unfortunately varies among plant species, with maturity, within varieties of a given species and even among plant parts of a given species (1,7). Therefore, any specified value is subject to several qualifications. Moreover, adequacy of a nutrient in some cases hinges upon the concentration of another element in the plant tissue (7,4). The critical concentration of some of the elements is not known for sugar beets; in fact, few concentration values for these elements have been reported in the literature.

Specific objectives of this survey were: (A) to ascertain nutrient element status of typical soils of the area by soil and plant analyses; (B) to attempt correlation of soil testing procedures with nutrient element concentrations in plant parts; and (C) to study interactions between nutrient element concentrations in the sugar beet plant. Hopefully, the concentration values reported herein will be a useful addition to the sugar beet plant analysis data presently in the literature.

Experimental Procedure

Seventy sampling sites representing two each of thirty-five irrigated soil types and phases were chosen for the survey of sugar beet nutrient status. These included the predominant cultivated soil types of the North Platte Valley of Nebraska. Soil samples were obtained at the time of site selection in June

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³ Numbers in parentheses refer to literature cited.

1963, followed by collection of plant samples during the last week in July and again in early September. A sample consisted of 20 of the youngest fully matured leaves. The leaf samples were immersed in detergent solution and rinsed in distilled water, after which the blade and petiole portions were separated as described by Ulrich (7). After drying at 75°C the plant samples were crushed within polyethylene bags in preference to mill grinding to avoid possible heavy metal contamination.

Soil measurements included pH by glass electrode in a 2.5:1 water to soil suspension; soil phosphorus by Bray and Kurtz No. 1 extraction; nitrate production rate by incubation of soil for 10 days at 75°F and measurement of nitrate produced by phenoldisulfonic acid procedure; soluble and exchangeable potassium, sodium, calcium, magnesium and manganese by extraction with neutral 1.0 N ammonium acetate and flame photometry in the case of sodium and potassium, atomic absorption spectroscopy with calcium, magnesium and manganese; zinc, copper and iron by extraction with 0.1 N HCl and atomic absorption spectroscopy; and sulfate sulfur by monocalcium phosphate extraction and turbidimetric analysis.

Plant analysis involved extraction of nitrate-nitrogen by the method of Johnson *et al.* (5) and wet digestion in nitric-perchloric acids for the remaining elements. Phosphorus was measured in the digestion solution by the metavanadate yellow procedure; potassium and sodium by flame photometry; calcium, magnesium, manganese, zinc, copper, and iron by atomic absorption spectroscopy; and sulfur by turbidimetric procedure. Sugar content of beet roots from the sampled areas was determined in the laboratory of The Great Western Sugar Company at Mitchell.

Results and Discussion

Beet roots for sugar analysis were collected on an area basis such that approximate yields could be determined for the sampled area. Values ranged from 10 to 45 tons per acre, with mean of 23.6 tons. Sugar percentage ranged from 12.5 to 18.0 with mean of 15.6.

Status of soil and plant nitrate is indicated in Figure 1, which shows a small decline in the mean nitrate content of leaf petioles between July and September. The problem of maintaining an adequate level without excess to suppress sugar production is clearly apparent in the data for individual locations. Whereas thirteen locations were deficient throughout the season and certainly lost yield as a consequence, only thirty-five locations were down to a deficiency level in September, a necessity for optimum sugar production. From the economic standpoint,

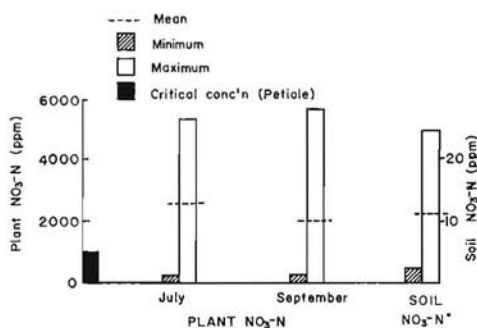


Figure 1.—Ranges in nitrate-nitrogen content in petioles of mature sugar beet leaves at two sampling dates in relation to soil nitrate (*Mean of initial soil nitrate and nitrate production rate).

it would appear advantageous for sugar beet growers in the North Platte Valley to use more discretion in nitrogen fertilization of sugar beets and also on crops preceding beets in the rotation. Correlations of Table 1 (No. 2) and Table 3 complement this observation in showing a highly significant negative relationship between sucrose percentage of the roots and petiole nitrate contents at both sampling dates, *i.e.*, lower sugar percent with increasing nitrate.

Soil and plant phosphorus data of Figure 2 suggest that phosphorus levels are being maintained at adequate to excessive levels in the Valley. The frequency distribution of soil test values for phosphorus is shown in Table 2. A median value of 28 ppm

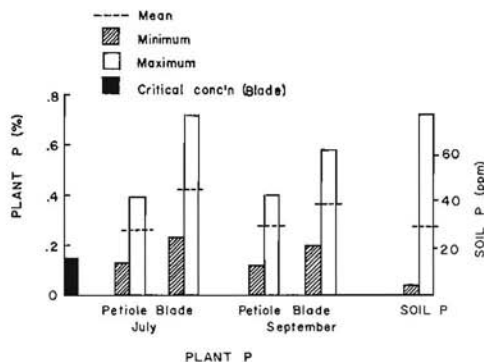


Figure 2.—Ranges in total phosphorus content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil P.

soil phosphorus was in evidence. Forty-nine of the survey sites had phosphorus levels above the 20 ppm level which is categorized as "high" in calcareous soils. Plant phosphorus con-

centrations were higher in the blade than petiole, and both were down somewhat with advancing maturity but still remained at high levels. The correlation data (No. 3 of Table 1) indicate that the soil testing procedure employed is predicting phosphorus availability for the sugar beet plant reasonably well, also that plant phosphorus and nitrate contents were rather closely related in a positive way (No. 4 of Table 1). Phosphorus did not decrease the negative effect of nitrogen on sugar percentage (Table 3).

Considering the soil and plant data jointly it appears that phosphorus fertilizer rates have been in excess of the amount required by the sugar beet crop. Plant phosphorus levels greatly exceeded the proposed critical concentration for sugar beet leaf

Table 1.—Simple correlations relating concentrations of soil and plant nutrients.

Correlation factors	Plant part	Correlation coefficients according to sampling time	
		"r"	
		1st	2nd
1. Nitrification rate \times Plant $\text{NO}_3\text{-N}$	Petiole	-.070	-.016
2. Sucrose % \times Plant $\text{NO}_3\text{-N}$	Petiole	-.46**	-.57**
3. Soil P \times Plant P	Petiole	.26	.46**
	Blade	.34**	.39**
4. Plant P \times Plant $\text{NO}_3\text{-N}$	Petiole	.26	.50**
5. Sucrose % \times Plant Na	Petiole	-.12	-.32
6. Plant $\text{NO}_3\text{-N}$ \times Plant Na	Petiole	.68**	.60**
7. Soil Ca \times Plant Ca	Petiole	-.12	-.027
	Blade	-.046	-.088
8. Soil Mg \times Plant Mg	Petiole	-.13	-.093
	Blade	-.14	-.15
9. Soil K/Mg \times Plant Mg	Blade	-.081	-.037
10. Soil S \times Plant S	Blade	-.025	-.15
11. Plant S \times Plant $\text{NO}_3\text{-N}$	Petiole	.45**	.27
12. Plant S \times Sucrose %	Petiole	-.24	-.14
13. Soil Cu \times Plant Cu	Blade	-.17	.020
14. Plant Zn \times Plant Cu	Blade	-.11	.41**
15. Plant P \times Plant Cu	Blade	.030	.39**
16. Soil Zn \times Plant Zn	Blade	.42**	.20
17. Soil P \times Plant Zn	Blade	.089	.061
18. Plant P \times Plant Zn	Blade	.43**	.51**
19. Soil Mn \times Plant Mn	Blade	.28*	.28*
20. Plant P \times Plant Mn	Blade	-.12	-.061
21. Soil Fe \times Plant Fe	Blade	-.061	.25
22. Plant Mn \times Plant Fe	Blade	.17	.054
23. Plant P \times Plant Fe	Petiole		-.27
	Blade		-.23

* Significant at the 5% level.

** Significant at the 1% level.

blade tissue. Although these excessive phosphorus levels did not appear to affect the sugar beet plants adversely, such luxuriant uptake does not prove profitable to the grower. No yield

increase or increase in sugar content results from the overabundance of phosphorus in the plant tissue. In addition continued application of excessive amounts of phosphorus fertilizers on sugar beets creates micronutrient antagonisms in subsequent crops of the rotation. The apparent buildup of soil phosphorus supply as indicated by the survey data (Table 2) undoubtedly is contributing to the increased incidence of zinc and iron deficiencies in bean and corn fields of the survey area (6).

Table 2.—Frequency distribution of soil phosphorus levels over the 70 sampling sites.

ppm P (Bray & Kurtz No. 1)	Number of sites
0-10	6
11-20	15
21-30	19
31-40	16
41-50	7
>50	7
Median = 28 ppm.	

Sugar beets grown in the North Platte Valley take up large to very large quantities of sodium, evidenced by the range of 2 to 8% in Figure 3, and the mean value of about 4%. The fact that sodium is absorbed in large quantities may substantiate

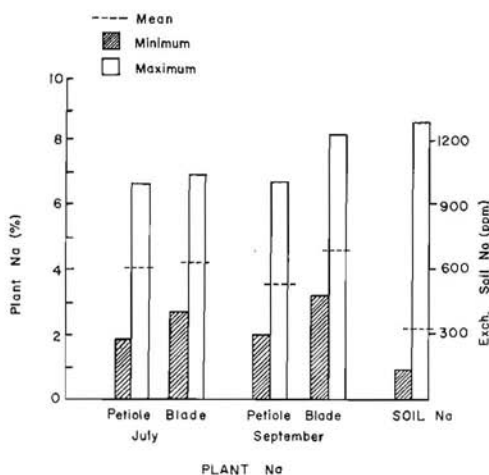


Figure 3.—Ranges in total sodium content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Na.

the requirement of sugar beets for sodium as postulated by Harmer and Benne (4), although at present no positive evidence exists that sodium is an essential element for any plant species.

Table 3.—Multiple correlations relating certain within-plant variables.

Correlation factors	Correlation coefficients, R ² according to sampling time					
	1st			2nd		
	Var.	Coeff.	t Ratio	Var.	Coeff.	t Ratio
1. Sucrose % × Petiole NO ₃ -N × Petiole P	R ² = .21			R ² = .34		
	2	-0.00034	-3.96**	2	-0.00035	-4.41**
	3	-0.43622	-0.15	3	-2.08762	-0.95
2. Sucrose % × Petiole NO ₃ -N × Petiole Na	R ² = .28			R ² = .34		
	2	-0.00054	-4.85**	2	-0.00040	-4.57
	3	+0.44656	2.53**	3	+0.03556	0.24

** Significant at the 1% level.

Correlation No. 5 of Table 1 suggests a direct negative effect of sodium content on sugar percentage. Since plant nitrate and plant sodium are positively related, however (No. 6 of Table 1), and sodium effect is not additive to nitrate effect in the multiple correlation of Table 3, it is probable that sodium and sugar contents are only indirectly related.

Luxury consumption of potassium apparently is the rule for the area in consideration of the mean leaf concentration of 7% and the very high mean soil value of 550 ppm, where approximately 75 ppm would be considered low by the testing procedure (Figure 4). There was little if any seasonal effect on potassium concentrations of the plant parts studied, just as with the companion element sodium. The extremely high potassium and sodium levels portend no likely nutritional needs for potassium, but possibly some indirect problems with magnesium could arise if its concentrations are not correspondingly high.

Calcium, too, appears to be bountifully available to the sugar beet plant in the North Platte Valley (Figure 5). In no case did plant concentration approach a critical level and the average concentration of about 1.5% seems to be high by any standards. The poor correlation between soil and plant calcium concentrations (No. 7 of Table 1) is undoubtedly related to the variable degree of calcareousness of the soils involved, the ammonium acetate extract having dissolved from some of the more calcareous soils a large quantity of calcium that was not plant-available.

Depending on whether 0.04 or 0.10% is a critical level for magnesium, there may or may not be magnesium problem situa-

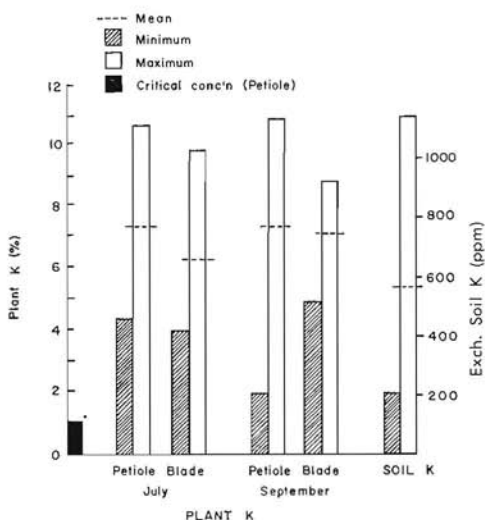


Figure 4.—Ranges in total potassium content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil K (*When Na > 1.5%).

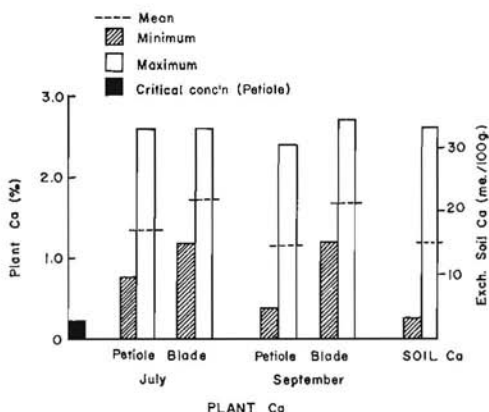


Figure 5.—Ranges in total calcium content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Ca.

tions indicated (Figure 6). In consideration of known antagonistic effects of excess potassium on magnesium nutrition (8,9) and the high levels of plant potassium already described, magnesium needs will bear watching.

A ratio of soil potassium to soil magnesium has been used as a criterion for judging the adequacy of soil magnesium supplies. If it is indeed essential that there be no more available soil potassium than magnesium on an equivalence basis, then

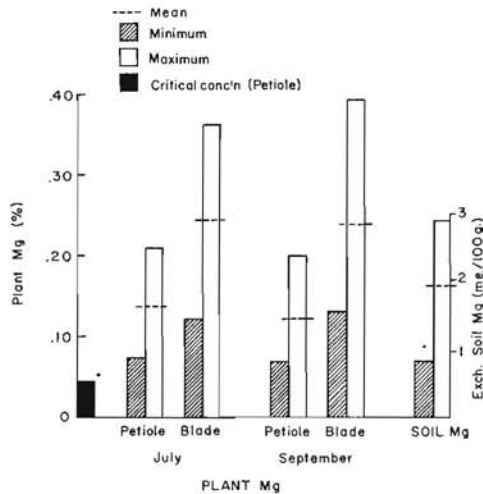


Figure 6.—Ranges in total magnesium content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Mg (*This value not well established).

the average value of soil potassium in Figure 4 would be quite excessive if associated with the lowest values of soil magnesium in Figure 6. In this survey only 10 of the sites had potassium to magnesium ratios that exceeded 1.0, none of which was greater than 1.4:1. Correlation No. 9 in Table 1 indicates no relationship of the soil potassium to magnesium ratio with plant magnesium content at either sampling date. Potassium to magnesium ratio of the soil may be misleading with respect to magnesium supply in the North Platte Valley area because of the large amounts of magnesium being supplied in the irrigation water each season. A report published by the Geological Survey (3) on the chemical composition of irrigation waters used in the survey area indicates that larger amounts of magnesium than potassium are present in the water on a chemical equivalence basis. For example, from the mean values of water composition for the years 1949-51 an acre foot of irrigation water supplied approximately 60 lbs of magnesium and 15 lbs of potassium. It does not seem reasonable that magnesium deficiencies should occur in the immediate future with such large additions being made annually via the irrigation water.

Ammonium acetate extracted soil magnesium was statistically unrelated to plant magnesium concentration (No. 8 of Table 1) and probably for the same reason as expressed for calcium. In addition, the large increment of magnesium supplied through the irrigation water annually would tend to invalidate the singu-

lar effect of soil concentration on plant availability of the nutrient. As with calcium, there was little seasonal change in concentration of the element in plant parts.

Plant sulfur concentrations appeared to be high and remained relatively constant throughout the growth period studied.

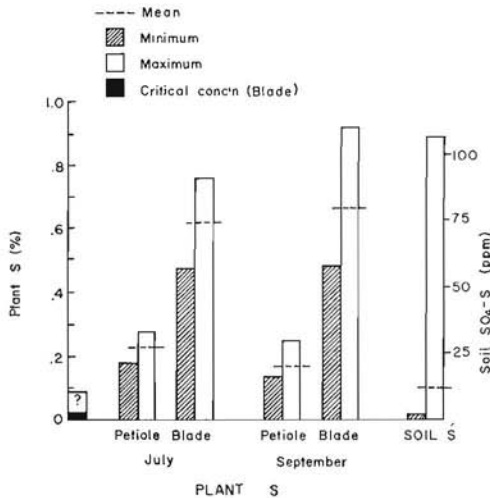


Figure 7.—Ranges in total sulfur content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil S.

This would be expected in consideration of the high sulfate levels in the soil (4-6 ppm being low by this test) and the usual substantial quantity of sulfate in irrigation water of the Valley. The poor correlation between soil and plant sulfur concentrations is probably a consequence of larger concentrations of sulfate in lower soil horizons and irrigation water sulfate which contribute to plant sulfur concentration but which quantities are not measured in a surface soil sample. The apparent negative effect of sulfur on sugar content may have been due to the positive relationship existing between sulfur and nitrate, just as between sodium and nitrate (Nos. 11 and 12 of Table 1).

There can be no certainty of the adequacy of copper in beet nutrition from this study since the literature gives no indication of deficiency levels. If 6 ppm copper is indeed a representative concentration for sugar beet leaves (2), then the crop was well supplied with the element at most locations (Figure 8). A synergistic effect of plant phosphorus on plant copper is expressed at the later sampling date, likewise of plant zinc on copper concentration (Nos. 14 and 15 of Table 1).

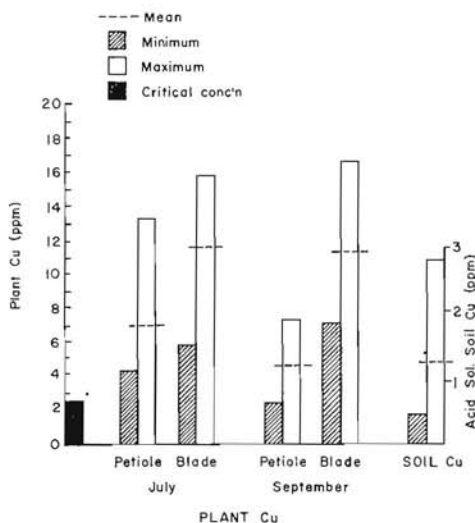


Figure 8.—Ranges in total copper content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Cu (*This value not well established).

Concentration of plant zinc appeared adequate in most cases (Figure 9). The level of this element was notably lower in the petiole at the late sampling date than at the earlier date with little change in blade concentrations. A similar situation was evident with copper. Soil zinc by the extraction method used was significantly related to plant zinc concentration, while plant phosphorus was correlated in a positive way with zinc uptake (Nos. 16 and 18 of Table 1). The latter observation is contrary to that observed with several other crops in which zinc and phosphorus concentrations are inversely related (6). Although no beet leaf tissue fell below the 9-10 ppm critical concentration for zinc in the leaf blades, it was observed that several soil test values lay in the "low" category. In fact over 50% of the sampling sites were classified as zinc deficient for corn production. This would indicate a need for separate soil test evaluation criteria for zinc fertilizer recommendations on the sugar beet crop.

Manganese concentration in the beet leaves appeared to be more than adequate at all seventy locations (Figure 10), and manganese level remained nearly constant throughout the growth period involved. Exchangeable soil manganese was significantly related by positive correlation with plant uptake of the element (No. 19 of Table 1). Since the manganese content of the leaf blade tissue was well above the critical concentration in all cases, it is improbable that manganese limits crop production

of any type on the vast majority of soils in the North Platte Valley.

Iron content of beet leaves in this survey appeared adequate (Figure 11), although not with certainty in view of the unknown critical concentration of this element in beets. A wide range of total iron contents was observed in the sugar beet leaves and advancing maturity did not appear to influence these levels

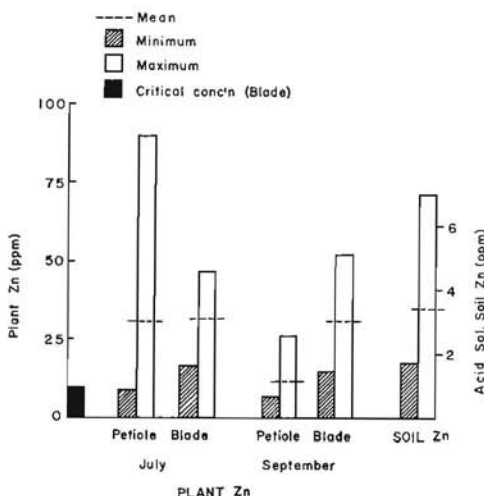


Figure 9.—Ranges in total zinc content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Zn.

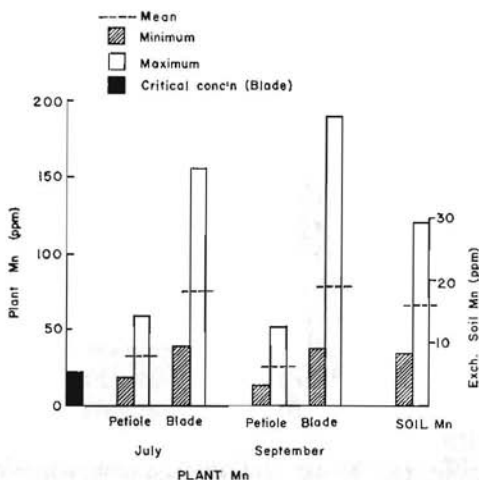


Figure 10.—Ranges in total manganese content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Mn.

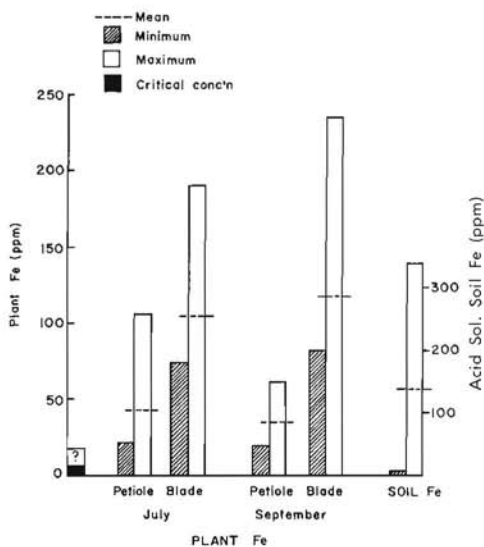


Figure 11.—Ranges in total iron content of petioles and blades of mature sugar beet leaves at two sampling dates in relation to soil Fe.

appreciably. Levels of soil iron as extracted by 0.1 N HCl were not related to plant uptake in this survey. There was no consistent indication of antagonism between iron and manganese concentrations of the leaf blades (No. 22 of Table 1), but plant phosphorus was negatively correlated with iron in both blade and petiole at the final sampling (No. 23 of Table 1, both values barely missing significance). The generally inconsistent correlations concerning iron in soil and plants may result from the fact that total iron content is a poor measure of a plant's iron status.

Conclusions

The survey suggests that the majority of nutrient elements are plentifully available in the important soils of the North Platte Valley for optimum growth of sugar beets. Cautioning words need be expressed with respect to excessive use of fertilizer phosphate and its deleterious effects on trace element nutrition of crops following beets, which antagonisms do not seem to appear in the beet crop itself.

High plant phosphate concentration does not alleviate the effects of excessive nitrate on root sugar percentage. High sodium and sulfur concentrations as they complement nitrate concentration of the leaf tissue appear to be equally nonbeneficial.

Magnesium nutrition of the sugar beets in this area does not seem to be affected by the extremely high potassium concentrations found in the plant material. Irrigation water of relatively high magnesium content may be the reason why serious magnesium deficiencies do not arise, since potassium to magnesium ratios of the soil would indicate a critical point with respect to magnesium is near for some soils.

Sugar beets are notably different from other crops in expressing results of nutrient interactions. Indications here are that plant phosphorus is synergistic to copper and zinc uptake rather than depressive, but phosphorus does not promote manganese uptake as in other crops. Manganese and iron do not give evidence of being mutually antagonistic as noted in so many other species.

Literature Cited

- (1) ALEXANDER, J. T., CLYDE C. SCHMER, LOUIS P. ORLEANS, and R. H. COTTON. 1954. The effect of fertilizer applications on leaf analysis and yield of sugar beets. Proc. of Am. Soc. of Sugar Beet Technol. 8: 370-379.
 - (2) BEESON, K. C. 1941. The mineral composition of crops with particular reference to the soils on which they were grown. USDA Misc. Publ. 369.
 - (3) GEOLOGICAL SURVEY. WATER RESOURCES DIVISION. 1953. Chemical analysis of surface waters in the Platte River Basin, Colorado, Wyoming, and Nebraska. December 1943 to December 1953.
 - (4) HARMER, PAUL M. and ERWIN J. BENNE. 1945. Sodium as a crop nutrient. Soil Sci. 60: 137-148.
 - (5) JOHNSON, C. M. and ALBERT ULRICH. 1950. Determination of nitrate in plant material. Anal. Chem. 22: 1526-29.
 - (6) LANGIN, E. J., R. C. WARD, R. A. OLSON and H. F. RHOADES. 1962. Factors responsible for poor response of corn and grain sorghum to phosphorus fertilization: II. Lime and P placement effects on P-Zn relations. Soil Sci. Soc. of Am. Proc. 26: 574-578.
 - (7) ULRICH, ALBERT and CLARENCE M. JOHNSON. 1959. Plant analysis a guide for sugar beet fertilization. Calif. Agr. Expt. Sta. Bull. 766.
 - (8) WALSH, T. and T. C. O'DONOHUE. 1945. Magnesium deficiency in some crop plants in relation to the level of potassium nutrition. J. of Agr. Sci. 35: 254-263.
 - (9) ZIMMERMAN, M. 1947. Magnesium in plants. Soil Sci. 63: 1-12.
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