Nutritional Conditions in Sugarbeet Fields of Western United States and Chemical Composition of Leaf and Petiole Tissue, Including Minor Elements[1]

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Ulrich *et al.* (12)[3] concluded from a national study on the effects of climate on sugarbeet yield, that plants receiving ample supplies of nutrients and water, and kept free of plant diseases, produce as much in Michigan as in the best beet growing areas of the United States. It appears appropriate to inquire if high producing sugarbeet fields in various sugarbeet areas have acquired a common nutritional status for the growing of sugarbeets. Furthermore, Ulrich (11) and Haddock and Stuart (4) have proposed techniques for diagnosing well nourished sugarbeet plants. A number of diagnostic soil fertility tests have been proposed (7, 8, 10) for crop plants in general, without specific reference to sugarbeets.

Research on sugarbeet nutritional requirements could be directed more intelligently if the present nutritional status of the more productive sugarbeet fields were known. During the past 20 years the percentage of sugar in sugarbeets grown in the United States has shown a persistent decline while yields have increased significantly (3). Even with this increase in yield, production of high quality sugarbeets is far below desirable and attainable goals. The production of high yields of high quality beets results from a combination of many cultural practices. Adequate plant nutrition has been one of the most influential in bringing about past advances. It promises great hope for future improvement in both yield and quality of sugarbeets. In each sugarbeet growing district there are farmers who consistently produce good yields of high quality beets. It was hoped that an examination of the soils used and plants produced by farmers may demonstrate the nutritional conditions of the soils which are conducive to high yields. This study was undertaken to indicate weaknesses or strengths inherent in natural soils and farmer practices of the Western United States.

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[3] Numbers in parentheses refer to literature cited.

Methods and Procedure

The five sugarbeet companies which cooperated in this study selected three highly productive farms in one or more of their respective districts. A 5-acre area was selected on each farm for soil uniformity, accessibility and high yielding ability.

Soil samples were collected by the authors or their colleagues before fertilization and before seeding. They were obtained from two depths, 0 to 6 and 6 to 12 inches, and from 20 borings. Each depth was composited separately, air dried promptly near the sampling site and mailed to Logan, Utah, for chemical and physical study.

Leaf-blade and petiole samples (30 leaves per sample) were obtained at three seasonal sampling dates. These were carefully washed in deionized water and dried at 70° C near the sampling area. All samples were packaged dry and sent to Logan for chemical analysis. Yield of roots and tops and sugar analysis were obtained by each cooperating company. Standard laboratory chemical procedures were used for both soil and plant tissues.

The authors wish to present a broad general understanding of the nutritional conditions of only the most productive sugarbeet fields in Western United States. Since the observations were restricted to a small segment of the sugarbeet producing area, conclusions which seem to apply to this limited segment of sugarbeet production must be applied with extreme caution to the broader area and with some caution to all high producing farms because of the sampling limitations.

The authors desire to present this broad appraisal of nutritional conditions in productive sugarbeet fields from four points of view, viz. (A) soil analysis, (B) petiole analysis, (C) leaf-blade nitrogen-potassium ratios, and (D) minor element status.

Experimental Results

Soil Characteristics of Farms Studied

Location—Cooperating sugar companies selected three presumably high producing fields in each district. Figure 1 and Table 1 show the distribution of farms brought under observation in this study. It will be noticed that there are 13 in Idaho, 2 in Oregon, 6 in Washington, 4 in Colorado, 1 in Montana, 1 in Nebraska, 15 in Utah and 6 in California.

Incubated Available Nitrogen—Few data are published on the desirable level of available soil nitrogen needed for the production of a good sugarbeet crop. Stanford and Hanway (10) proposed the use of a soil incubation technique for appraising nitrogen availability. The senior author modified this technique using 25 grams of soil and found after several years of study

Table 1.—Distribution of farms used in sugarbeet field study 1961.

State	Factory District	Farm
Idaho	Burley	Mai
		Bowen
		Stanger
	Twin Falls	Glenn
		Parrish
		Newberry
		Harrison
		Denney
	Nampa	Carlson
		Watanabe
		Christensen
	Idaho Falls	DeKay
Oregon		Itania
		Hart
	Nyssa	Walkayawa
Utah		Goodwin
		Amalgamated
	Lewiston	Jensen
		Maw
		East
	Ogden	Wayment
	Garland	Wiedman
		Fukue
		Firth
	Gunnison	Sorensen
		Hansen
		Hawley
	West Jordan	Marcusen
		Gammon
		Hamilton
Washington	Moses Lake	Bingham
	Moses Lake	Lybbert
	Othello	Hirasawa
	Toppenish	Bauchey
	Toppenish	Benz
	Prosser	Willard
Nebraska	Mitchell	S. C. D.
Montana	Huntley	Gabel
Colorado	Grand Junction	Long
	Grand Junction	Matchett
	Fort Collins	Johnson
	Fruita	Schlauger
California	Fresno	Cardwell
	Mendota	V. D. L.
	Firebaugh	Schimer & Frazier
	Gonzales	Oreggia
	Spreckles	Spreckles
	New Watsonville	Crossetti

that 60 ppm of incubated nitrate-nitrogen is ample under Utah conditions for at least 20 tons of sugarbeets. This may or may not be an adequate level for soils used in the wide range of

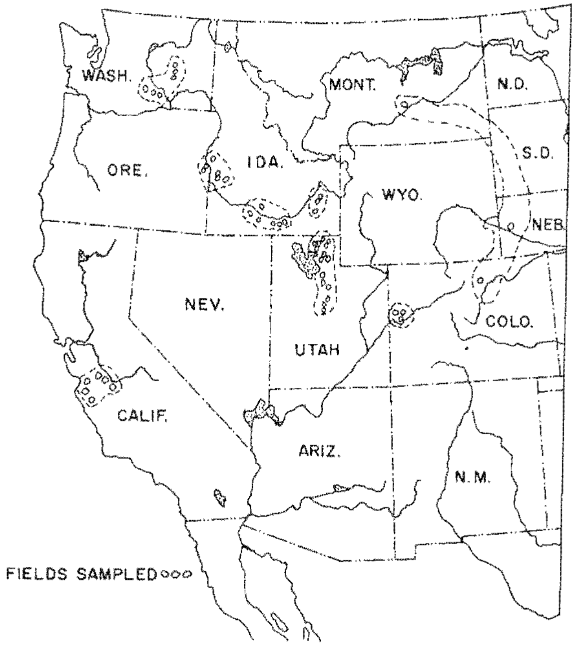


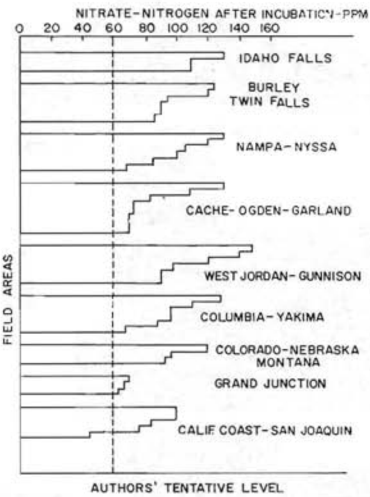
Figure 1.—Location of sample areas in the Western United States.

climatic conditions found in this study. Nevertheless, the authors have placed this value as a tentative reference point in Figure 2.[4] This reference value is shown as a broken vertical line.

Two important conclusions appear obvious from the data shown in Figure 2. First, the range of available nitrogen from farm to farm is very wide; and second, based on the tentative adequate level, there are excessive quantities of available nitrogen in most of the sugarbeet fields under study.

Sodium Bicarbonate Soluble Phosphorus—There is no standard soil test value for $NaHCO_3$-soluble phosphorus for the sugarbeet crop which is generally accepted. Olsen *et al.* (6) have suggested 22 pounds per acre or 11 ppm as a phosphorus level above which a response is unlikely for wheat, oats, alfalfa and similar crops. They recognize that values may be higher for potatoes and other crops. This value is plotted at 15 ppm to accommodate for higher requirement of sugarbeets for phosphorus. The Utah Agricultural Experiment Station has recently revised soil test recommendations for sugarbeets. This value is placed at 22 ppm above which sugarbeets are unlikely to benefit

[4] Fields in each district are arranged graphically in descending order. Each field is allotted the same vertical space. Variation in soil composition within each district and between districts can be readily appraised.



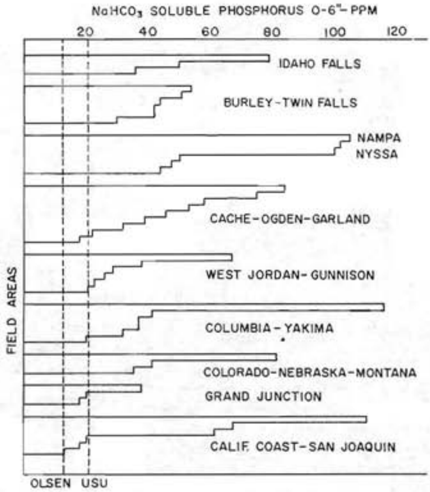


Figure 2.—(left) Incubated nitrate-nitrogen in 48 soils of Western United States. 1961.

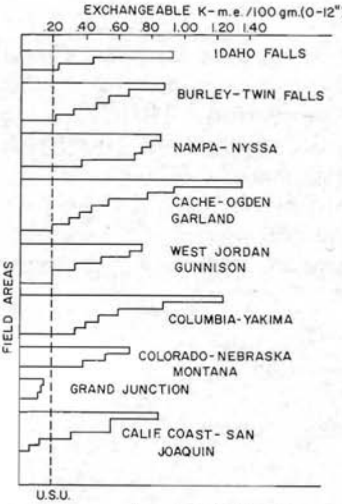
Figure 3.—(right) Sodium bicarbonate soluble phosphorus in 48 sugarbeet fields of Western United States. 1961.

from additional phosphorus. These values are shown by vertical dotted lines in Figure 3 for reference.

Two significant conclusions are justified from the graphical data in Figure 3. First, the soils under observation exhibit a wide variation in the quantity of available phosphorus; and second, the soils are heavily weighted on the side of excess phosphorus.

Exchangeable Potassium—There are few available data to support a soil test value in terms of available potassium. The authors have selected the recent recommendation of the Utah Agricultural Experiment Station of 0.2 of a me. exchangeable potassium per 100 grams of soil, as the value above which a soil is unlikely to show visible signs of potassium deficiency in sugarbeets. Only five of the fields studied in this survey showed less than 0.2 me. of exchangeable potassium or 156 pounds potassium per acre 6 inches. As with phosphorus and nitrogen, the soils showed a wide range of exchangeable potassium and generally an adequate supply relative to the standard reference (see Figure 4).

Exchangeable Sodium—The sugarbeet plant is thought to be tolerant and in many cases benefited by sodium in the nutrient solution. There was only one farm in California which was obviously too high in exchangeable sodium for sugarbeets. It is not known with any degree of certainty what concentration of



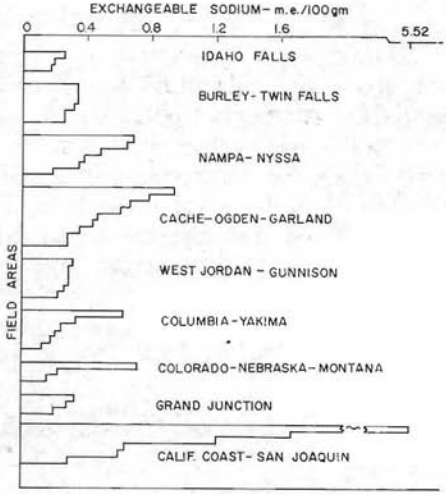


Figure 4.—(left) Exchangeable potassium in soils from 48 sugarbeet fields in Western United States. 1961.

Figure 5.—(right) Exchangeable sodium content of 48 sugarbeet field soils in Western United States. 1961.

sodium in the soil solution or in the exchange complex is optimum for the growth of sugarbeets. At least sodium is present in all western sugarbeet soils in rather high concentrations and exhibits considerable variation from field to field in all areas (see Figure 5).

Conclusions Based on Soil Analysis

Soil analysis methods now available for western soils are in need of refinement. Nevertheless, they show positively that, as a group, the 48 sugarbeet soils sampled in this study are well supplied with available phosphorus, nitrogen, and potassium. The very interesting feature shown in Figures 2, 3 and 4 is the wide range of available nutrients shown in most of the sugarbeet-growing districts. Few of the soils show any indication of insufficient major nutrients. The question might well be raised: Is it beneficial or harmful to have a soil highly charged with one particular plant nutrient and at the same time poorly provided with another nutrient?

Large quantities of sodium are present in all soils studied. Heimann and Ratner (5) lay great stress on the need of a high K:Na ratio in the sugarbeet plant for high yield, sucrose percentage, and sugar extraction percentage. The average exchangeable sodium and potassium in the 48 sugar beet fields studied were nearly identical, but the average soluble sodium concentration in the saturated extract was 3.47 times the potassium concentration (data not shown).

Petiole Analysis

Data from petiole analysis are given in Figures 6 to 17. These are given by individual farms and show a seasonal trend for available nitrogen, phosphorus and potassium. Ulrich's (11) "critical level" value is shown as a solid horizontal line with each figure for comparison of nutritional status.

Nitrogen—It is apparent from Figure 6 that only in the case of the Parrish and Dennie farms did the nitrogen level approach the critical level during the growing season. None of the farms

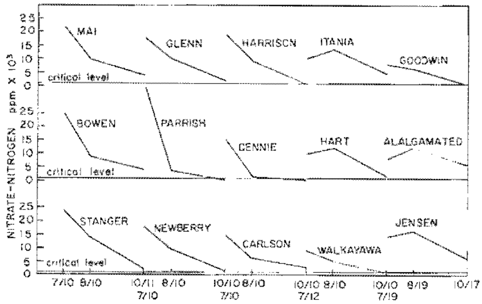


Figure 6.—Seasonal nitrate-nitrogen concentration in sugarbeet petioles from commercial fields in Idaho and Utah. 1961.

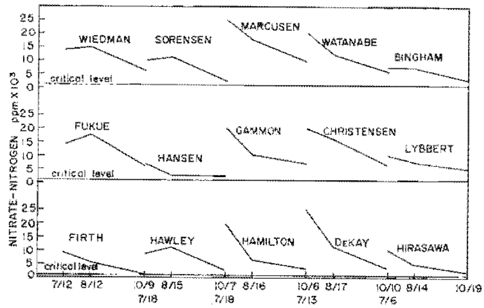


Figure 7.—Seasonal nitrate-nitrogen concentration in sugarbeet petioles from commercial fields in Utah, Idaho and Washington. 1961.

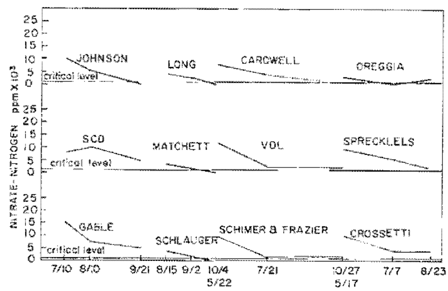


Figure 8.—Seasonal nitrate-nitrogen concentration in sugarbeet petioles from commercial fields in Colorado and California. 1961.

shown in Figure 7 indicated a nitrogen deficiency. In Figure 8 the three farms in Grand Junction showed a weakness in supplying available nitrogen as did the Oreggia farm in California. Figure 2 should be studied in this connection since it shows an agreement with data in Figures 6, 7 and 8 with respect to nitrogen availability. Three farms in the Ogden area, viz. Maw, East and Wayment show a low nitrogen content in petioles after mid season (Figure 9). The six line drawings on the right half of Figure 9 were obtained from pot culture studies and local fields with varying known levels of available nitrogen. These are presented for comparison with high producing farms. Check-N

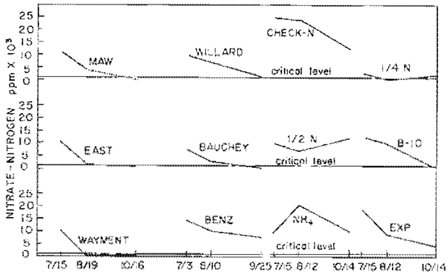


Figure 9.—Seasonal nitrate-nitrogen concentration in sugarbeet petioles from commercial fields in Utah and Washington and nutrient cultures. 1961.

represents a sugarbeet plant with well-balanced nutrition for optimum growth. ½ N represents a plant slightly deficient in nitrogen. NH_4 represents a plant with ample nitrogen in the ammonia form but with high phosphorus. ¼ N represents a sugarbeet plant deficient in nitrogen all season. B-10 represents a sugarbeet plant grown in a field with ample phosphorus and potassium but deficient in nitrogen. Exp. represents a plant grown on a soil with ample nitrogen but low in phosphorus and potassium.

Phosphorus—Data shown graphically in Figures 10, 11, 12 and 13 for seasonal phosphorus content in sugarbeet petioles indicate that there were no fields deficient in phosphorus. Ulrich's (11) "critical level" of 750 ppm of soluble phosphorus is shown for reference. These petiole values are in good agreement with Olsen's (6) soil test values. The broken vertical line is placed at 15 ppm available soil phosphorus (Figure 3). The six line drawings on the right half of Figure 13 are given for comparison with plant tissue composition from commercial fields. OK represents plant tissue sufficiently low in potassium to result in depressed yields. Nitrogen and phosphorus composition are adequate.

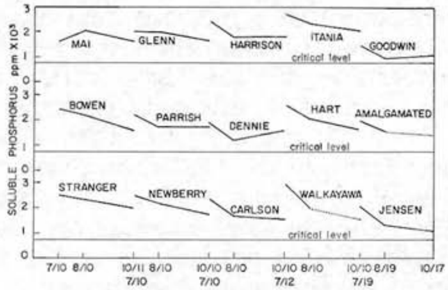


Figure 10.—Seasonal soluble phosphorus concentration in sugarbeet petioles from commercial fields in Idaho and Utah. 1961.

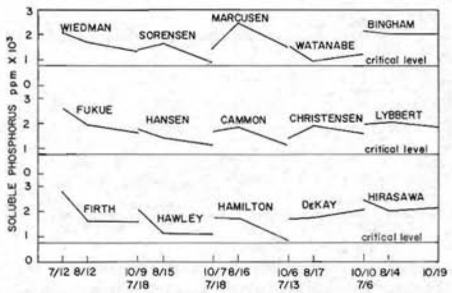


Figure 11.—Seasonal soluble phosphorus concentration in sugarbeet petioles from commercial fields in Utah, Idaho and Washington. 1961.

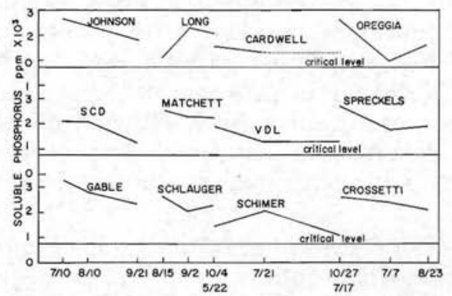


Figure 12.—Seasonal soluble phosphorus concentration in sugarbeet petioles from commercial fields in Colorado, Nebraska, Montana and California. 1961.

Potassium—Figures 14 to 17 show all petiole samples from commercial farms to be well above the critical level set for these tissues. Data in Figures 4 and 16 disagree with respect to the ability of the three soils at Grand Junction (Long, Matchett, Schlauger) and two in the San Joaquin area (Cardwell, Schimer) to supply potassium. Otherwise, the soil tests and petiole tests

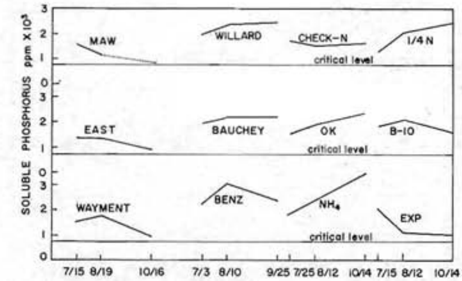


Figure 13.—Seasonal soluble phosphorus concentration in sugarbeet petioles from commercial fields in Utah and Washington and nutrient cultures. 1961.

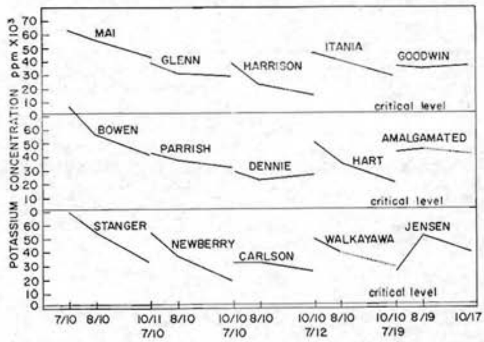


Figure 14.—Seasonal soluble potassium concentration in sugarbeet petioles from commercial fields in Idaho and Utah. 1961.

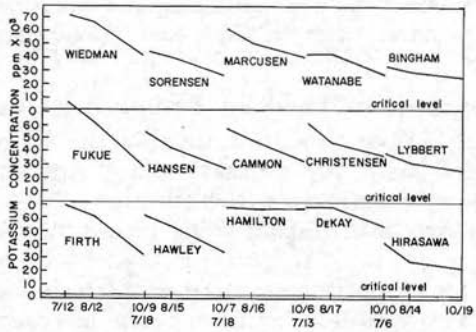


Figure 15.—Seasonal soluble potassium concentration in sugarbeet petioles from commercial fields in Utah, Idaho and Washington. 1961.

are in good agreement, indicating an ample supply of available potassium for sugarbeets. The six line drawings on the right half of Figure 17 with the possible exception of Exp. show petioles with adequate supplies of potassium.

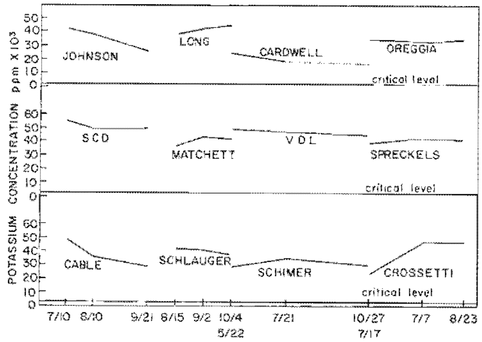


Figure 16.—Seasonal soluble potassium concentration in sugarbeet petioles from commercial fields in Colorado, Nebraska, Montana and California. 1961.

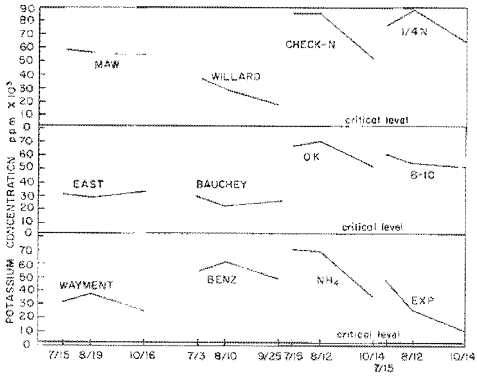


Figure 17.—Seasonal soluble potassium concentration in sugarbeet petioles from commercial fields in Utah and Washington and nutrient cultures. 1961.

Conclusions Based on Petiole Analysis

The seasonal petiole data indicate that the 48 selected farms are well supplied with the primary plant nutrients with few exceptions. One might well raise the question: Is there likelihood of injury from over-fertilization with either nitrogen or phosphorus? The use of "critical level" as used by Ulrich (1) makes weak provision for appraising excessive fertilization with nitrogen. On this basis beet petioles should contain less than 1,000 ppm NO_3-N several weeks before harvest. Also, on this basis two-thirds of the high producing sugarbeet farms are applying excessive quantities of nitrogen. Only one-third of the farms approached the critical level of 1,000 ppm NO_3-N on or before harvest time. It is well known that excessive nitrogen fertilizers are associated with low sugar content of sugarbeet roots. This may well explain the low sugar percentage shown in Figure 30.

Leaf-Blade Composition

Nitrogen-Potassium Ratio—It has been shown by the authors (4) that the N:K ratio in the leaf-blade is a good, sensitive indication of nutritional status of the sugarbeet plant, particularly if the phosphorus nutrition is adequate. Muller *et al.* (6) have laid great stress upon the necessity of having a wide N:K_2O ratio (1:3) in fertilizer used for sugarbeets, especially when available soil nitrogen is high. It is obvious from the data in Figures 18, 19 and 20 that all of the high producing fields studied in Western United States produce plants with a high nitrogen-potassium ratio.

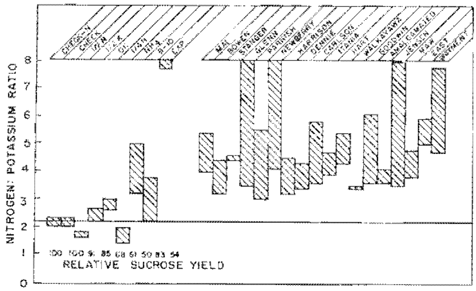


Figure 18.—Seasonal nitrogen-potassium ratio in sugarbeet leaf-blades grown in nutrient solutions and commercial fields. 1961.

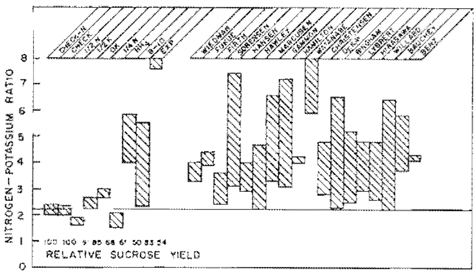


Figure 19.—Seasonal nitrogen-potassium ratio in sugarbeet leaf-blades grown in nutrient solutions and commercial fields. 1961.

We (4) have found in sugarbeet nutrient culture studies conducted over several years strong support for Muller *et al.* (6) claim that available potassium must be high when available nitrogen is high. The relative sucrose yield obtained from sugarbeets with varying N:K ratios are shown graphically in Figure 19 for reference with N:K ratios found in sugar beets from commercial fields under study. The seasonal range in N:K ratios

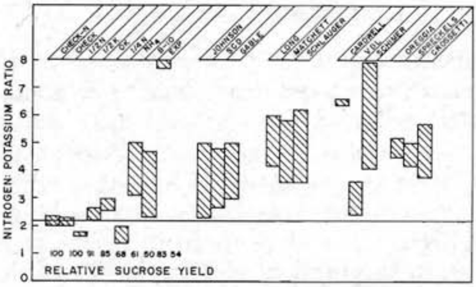


Figure 20.—Seasonal nitrogen-potassium ratio in sugarbeet leaf-blades grown in nutrient solutions and commercial fields. 1961.

is indicated by the length of each diagonally lined column. Check-N and Check exhibit an optimum N:K ratio relative to yield of sucrose. When nitrogen was deficient (½ N and ¼ N) yield of sucrose was depressed to 91 and 61% respectively. When nitrogen was in excess (NH_4) yield of sucrose was likewise depressed (50%). When potassium was in deficient supply (½ K and 0 K) yield of sucrose was relatively low (85 and 68%). Sugarbeets grown on a local field (Exp.) were judged to be deficient in potassium and adequate in nitrogen and phosphorus while beets grown on field B-10 were thought to be adequate in nitrogen up to midseason and deficient in nitrogen the last of the season.

Conclusions Based on Nitrogen-Potassium Ratios

It appears to the authors that while the several farm soils under study were generally well supplied with adequate quantities of nitrogen, phosphorus and potassuim, relative excesses of available nitrogen predominated.

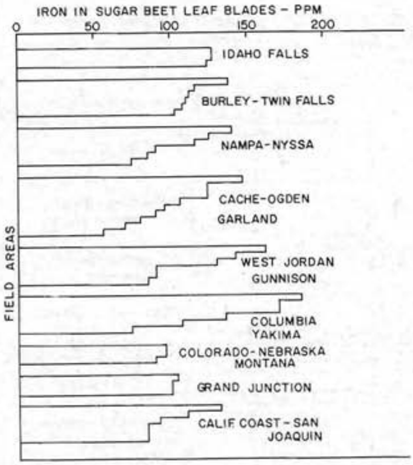
The evidence suggests that either nitrogen fertilization needs to be reduced or that potassium fertilization should be increased on the high producing sugarbeet farms of Western United States.

The practical problem of optimum plant nutrient concentration and balance in commercial sugarbeet fields needs immediate attention.

Minor Nutrient Composition

Iron—Data on iron composition of sugarbeet leaves showed them to range from 50 to 175 ppm (Figure 21).

Zinc—Zinc deficiency in sugarbeets with a critical level of 10 ppm has been reported by Boawn and Viets (2). Data in Figure 22 show all fields studied were well above the deficiency level.



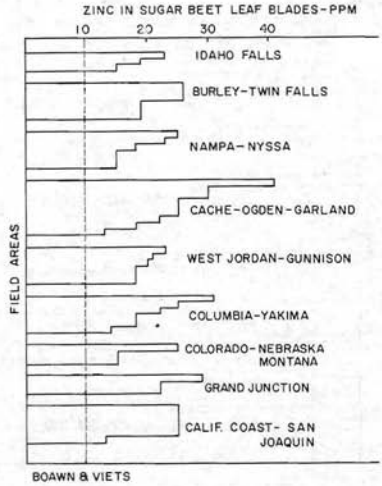


Figure 21.—(left) Iron concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

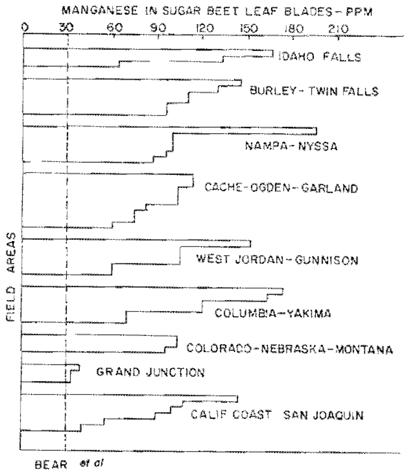
Figure 22.—(right) Zinc concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

Manganese—Bear, *et al.* (1) have proposed a deficiency level of 30 ppm in beet leaves. On this basis beets in the Grand Junction area were very close to the deficiency level. Otherwise, there appeared to be ample manganese in beet leaves on western high-producing farms as shown in Figure 23.

Copper—The authors could not find a report of copper deficiency in sugarbeets. Bear, *et al.* (1) report 3 ppm for clover leaves and 6 ppm for alfalfa tops as deficiency levels. It will be noted in Figure 24 that the lowest average value found in the 48 high producing farms was 7 ppm. It appears unlikely that copper deficiency is an immediate threat to soil productivity among sugarbeet growers.

Sulfur—Sulfur deficiency has been reported with increasing frequency in recent years. As shown in Figure 25 this element does not appear to be an immediate threat to high producing sugarbeet fields. On the other hand, some students of this problem believe the N:S ratio to be a more sensitive indication of sulfur need. The graphical data given in Figure 26 indicate that the Grand Junction area may become deficient in sulfur.

Chlorides—It is well known that western soils contain high amounts of chlorides. While sugarbeets are not thought to be



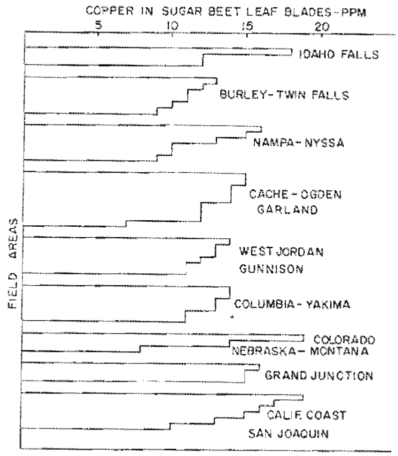
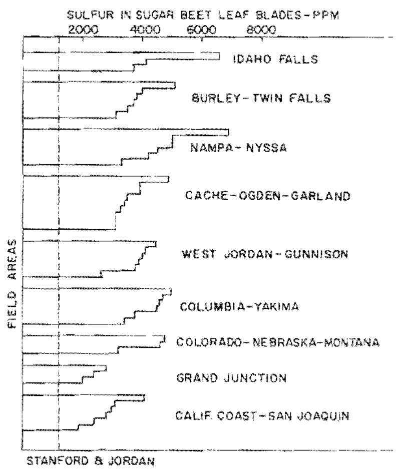


Figure 23.—(left) Manganese concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

Figure 24.—(right) Copper concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)



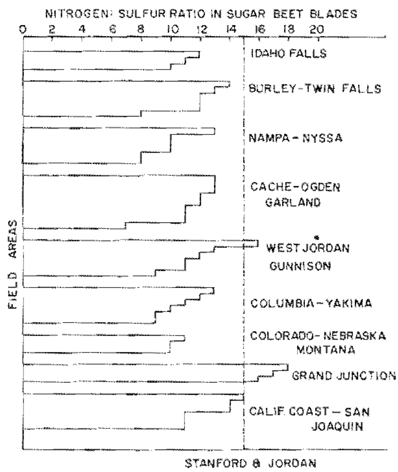
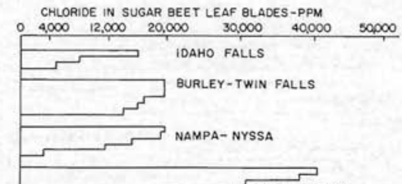


Figure 25.—(left) Sulfur content of sugarbeet leaf-blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

Figure 26.—(right) Nitrogen-sulfur ratio of sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

sensitive to these salts, there is little evidence that more than traces are useful. The wide range of chloride concentration found in sugarbeet plants in this study should throw suspicion on these salts. Particularly in the fact of the following statement by Rorabaugh and Norman (9): "Carbonate and chloride account for three-fourths of the total melassigenic power in beet sirups and should warrant most concentrated efforts." The range of chlorides in sugarbeet leaves shown in Figure 27 is 500 times greater in some plants from Utah and California than from those in the Columbia Basin. It would be surprising indeed if high concentrations of chloride do not adversely influence yield and quality of sugarbeets.

Boron—Data presented in Figure 28 show that sugarbeet plants, on the 48 high producing farms used in this study, were adequately supplied with boron on the basis of reports by Bear, et al. (1). The total range of boron concentration in leaves of beets sampled in this study was only from 32 to 95 ppm. The range between deficiency and toxicity is influenced by many factors other than boron concentration in the soil.



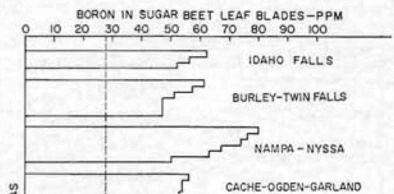


Figure 27.—(left) Chloride concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

Figure 28.—(right) Boron concentration in sugarbeet blades from 48 fields in Western United States. 1961. (mean of 3 sampling dates)

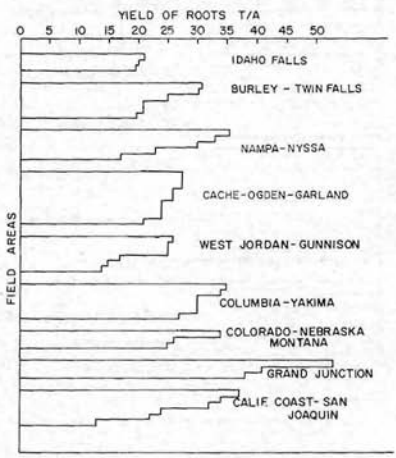
Conclusions on the Need for Minor Elements

Since the sugarbeet fields used in this study were selected because they were in a high state of fertility, one should not expect to find minor nutrient element deficiencies of any kind. At least in the present condition there is little or no evidence that any of the minor elements are bordering on serious deficiencies. However, immediate studies should be undertaken to establish toxic limits for all the minor elements in sugarbeets. An even more desirable goal would be to establish a range of optimum concentrations of all minor elements in sugarbeet tissue.

Yield and Quality of Sugarbeets

Yield—It should be expected that fields selected on the basis of anticipated high yields would produce well over 20 tons per acre. Data in Figure 29 show this assumption to be correct. The range of yield may be considered wide when only the high producing farms are included in this study. However, when one considers a wide range of soil conditions encountered, the range in yield does not appear great. The range in each district is frequently as wide as it is between districts, and is such as to suggest that something besides climate is exerting a powerful influence on yield.

Quality—Data shown in Figure 30 should be quite disturbing



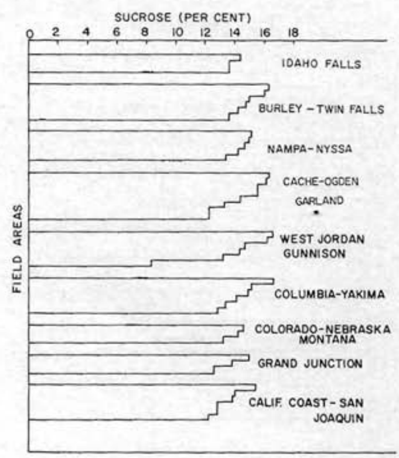


Figure 29.—(left) Yield of roots from 48 sugarbeet fields in Western United States. 1961.

Figure 30.—(right) Sucrose composition of sugarbeet roots grown on 48 farms in Western United States. 1961.

in view of the past 30 years' trend in sugarbeet quality. Nearly half of the best producing farms are delivering sugarbeets to the processor with a sugar percentage of 14 or less. There were only 4 of the 48 farms producing beets with 16% sugar, and none of them reached 17%.

Conclusions

It is evident that the most productive sugarbeet fields in Western United States are far from ideally fertilized. The processor of sugarbeets has been painfully aware of a serious and increasing unbalance in commercial fertilization of sugarbeets since the days of barnyard manure and superphosphate. The immediate problem appears less related to minor element fertilization, than to achieving proper balance of the primary nutrient elements in the soil. A secondary problem appears to be a proper appraisal of the influence of excessive salts, e. g. sodium, chloride, magnesium, calcium and sulfate, and finding ways of managing sugarbeet soils so as to take full advantage of the presence of these salts. Because this study was limited to high yielding fields of sugarbeets, it is not possible to formulate conclusions on nutrient deficiencies in low yielding fields. The wide range of soluble salts found in high yielding fields and in plant tissue grown in these fields suggest the possibility that excesses of various salts may be a greater barrier to proper nutrition of sugarbeets in Western United States than deficiency of nutrient elements.

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