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THE PLACE FOR BORON FERTILIZER IN CENTRAL WASHINGTON FIELD CROP PRODUCTION

D. W. James and W. H. Weaver

SYNOPSIS

Boron is recommended only for sugar beets and alfalfa in central Washington field crop fertilizer programs at the present time. Furthermore, boron is recommended for these crops only when the need exists. The need for boron can be diagnosed from deficiency symptoms, leaf analysis and soil tests. Excessive amounts of boron, or application to more sensitive crops, can result in boron toxicity and serious crop losses.

INTRODUCTION

Although boron is needed by all plants for normal growth and development, the actual amount required is very small. For example, a normal alfalfa plant may contain 3% of potassium and 0.3% of phosphorus, but only 0.003% of boron (dry weight basis). Not all plants have the same requirement for boron. While a given soil may have sufficient available boron to meet all the needs of one crop, another kind of crop may fail completely for lack of it. Where soil boron is not present in adequate amounts characteristic deficiency symptoms occur in the plant and its development is noticeably retarded.

Boron fertilization has been a common practice in central Washington for many years. Several kinds of horticultural crops have been treated for boron deficiency, but to date, the list of field crops which are known to have been benefited from boron additions in this area is limited to alfalfa and sugar beets. 1/ This discussion will deal only with problems involving boron usage in field crops. Boron fertilization of horticultural crops has been discussed at length elsewhere (2, 3, 4, 5).

1/ Hops apparently responded to boron in one instance. Greater attention is being directed at this crop to see how widespread boron deficiencies may be. Personal communication, C. E. Nelson, Irrigation Experiment Station, Prosser.

Superficially, boron fertilizer practices in field crop production are very simple. Deficiency situations may be corrected either by broadcast treatments of the material on the soil or applying boron as a spray to the plant foliage. This apparent simplicity is misleading, however, since there is a very narrow range between the amount of boron needed in the soil to permit normal crop growth and the amount of boron which will cause toxicity and growth retardation. Some crops are especially sensitive to excessive amounts of boron.

Boron deficiency in alfalfa and sugar beets has increased dramatically in central Washington in the last three or four years. This increase has been largely limited to the lighter textured soils of the Columbia Basin Irrigation Project although problems exist in the Yakima and Kittitas valleys as well. The change in extent and intensity of boron deficiency has been accompanied by a rapid increase in consumption of boron containing fertilizers. And this has been accompanied by the occurrence of boron toxicity in many different fields.

Boron has not been studied extensively under central Washington conditions. Research is now under way to obtain answers to some important questions related to the use of boron fertilizer. In the meantime, the best available information on the subject of boron soil-plant relationships is brought together in this publication to help alleviate some of the more pressing problems until more definitive research information becomes available. The objectives of this article are:

1. To help in diagnoses of boron deficiency in sugar beets and alfalfa and to prescribe treatments to eliminate the deficiency.

2. To examine the likelihood of boron deficiency in other crops in central Washington based on a study of experiences gained outside this area.

3. To describe boron toxicity in several kinds of crops and to show what problems are encountered by excessive use of boron fertilizer.

DIAGNOSING BORON DEFICIENCY

Deficiency symptoms in alfalfa and sugar beet

Boron deficiency in alfalfa and sugar beets expresses itself in several ways. All of the symptoms discussed here have been described in the scientific literature and excellent examples of each detail have been observed in this area.

The earliest indication of boron deficiency in alfalfa is the yellowing of the leaves near the growing tip. The plant may appear to be normal otherwise in both color and size. As the deficiency becomes worse the top of the plant becomes yellow, or red and yellow. From a distance boron-deficient alfalfa often has a distinct bronze coloration. Another characteristic common to boron-deficient alfalfa is shortening of the internodes near the growing tip. That is, the stem sections between the leaves toward the upper end of the stem do not lengthen normally. The effect is to have several leaves bunched closely together. This characteristic is often described by the term "rosette." In extreme cases of boron deficiency the alfalfa terminal bud dies and the upward extension of the plant ceases. Sometimes the lateral buds start to grow and the plant becomes many-branched taking on the appearance of a bush. When alfalfa is severely affected by lack of boron it is very susceptible to winter killing. Thus, where boron is very deficient in the soil the alfalfa stand is rapidly depleted. Drouthy conditions in the soil aggravate the boron supply problem. When the element approaches limiting levels in the soil the onset of drouth may cause sudden appearance of boron deficiency symptoms in the plant.

In the case of sugar beets, there are at least three distinct manifestations of boron deficiency. Usually all the symptoms can be found in a field of boron deficient beets. The symptoms are: death of the terminal bud along with death and blackening of the leaves in the middle of the crown; checking or scoring of the petiole or leaf stem; blackening and dying of the tissue inside the root immediately below the crown. The latter symptom is often called black heart or heart rot and it is usually the first symptom to appear although it is not very conspicuous. Heart rot is also associated with other causes and should not be interpreted exclusively as a boron deficiency symptom.

A survey of alfalfa and sugar beet fields in 1963 revealed that boron deficiency in both crops was area-wide in central Washington. The deficiency symptoms in many alfalfa fields were uniformly present from one side of a field to the other. Where boron deficiency existed in sugar beets, the symptoms were less obvious and could generally be observed only by detailed examination of a field.

Deficiency symptoms and boron requirements of other crops

Boron deficiency symptoms in the crops discussed above have a common characteristic: that is, the effect on terminal growth and new tissue development. Berger (6) states that boron deficiency invariably affects the terminal growth of any kind of plant in which it occurs. This may therefore be taken as a guide: look for distorted shapes, shortened internodes, "rosetting" of leaves. In the case of corn, the boron deficient plant may appear to be normal in size but ears are greatly distorted or sometimes completely absent (7). Selected comparisons of relative boron requirement of crops common to this and other areas are summarized from the literature in Table 1.

Since the pattern of boron deficiency in central Washington crops is similar to that in other areas, it can be assumed that boron deficiency will not become a major problem in crops like corn, potatoes, and small grains unless soil boron is drastically depleted even in soils that are already rated low for this element in this area.

The foregoing assumption does not mean that boron deficiency in crops other than beets and alfalfa absolutely will not occur. In our continuing efforts to gain a complete understanding of this nutrient element we solicit the help of everyone concerned with fertilizer practices. Any problem where boron deficiency is suspected should be called to our attention for complete diagnoses.

Diagnoses by plant tissue analysis

There may be a considerable difference in the boron content of different parts of a plant. Also, the boron content of a given plant part may vary considerably during the season. For these reasons plant sampling technique must be carefully controlled in order to give validity and reliability to the chemical analysis. The general procedure used at the Irrigation Experiment Station is to sample approximately twenty plants for a single composite sample. The specific part of the plant to be sampled depends on the type of crop. Examples are: the youngest fully mature leaf for corn, grass, and small grains; the youngest fully mature leaf without the petiole for beans, potatoes, and sugar beets; the top three to four inches of the alfalfa plant; and for peas, the stem and leaves down to and including the first node from the terminal bud. The foregoing procedures are intended to minimize the time required to take a good sample without detracting from the quality of the results.

The best time to sample alfalfa is just before the first cutting is taken off in June. If this is missed, then sample subsequent crops in the season just before harvest. The best time to sample sugar beet leaves has not been pinpointed very closely but mid-June to mid-July seems to give good results.

Alfalfa and sugar beets are the only crops in this area that have been calibrated to any extent on the basis of deficiency levels of boron in the tissue. All other crop species mentioned above have been analyzed only to ascertain the levels of boron associated with toxicity situations. It is assumed that if deficiency conditions actually occur in any crop other than alfalfa and sugar beets, sampling during June will also be optimum.

Some results of boron analysis of apparently normal crops are given in Table 2. For purposes of comparison, some values are also included from the literature. There seems to be good agreement between the two sources of information for the respective kinds of plants.

Critically low levels of plant tissue boron are of special interest. Analyses of plant samples taken in 1963 from five alfalfa fields which were unquestionably boron deficient showed the following boron levels in the tissue: 9.4, 10.4, 12.2, 13.5, and 15.8 (table 3 samples 6, 9, 7, 15, 13, respectively) parts per million of boron, respectively. Concomitant with the foregoing values, boron deficiency symptoms in the field ranged from uniform and very severe to spotty and mild. Berger (6) quotes the results of 11 different groups of workers; they reported values in boron deficient alfalfa ranging mostly from 6.9 to 17.0 parts per million. From all indications boron contents of about 20 parts per million in the top four inches of the plant mean that the alfalfa crop is approaching a boron-deficient condition.

In the case of sugar beets, few good samples have been obtained wherein the field was uniformly and/or severely affected by boron deficiency. Three composite plant samples taken from one uniformly affected field averaged 19.6 (Table 3 sample 19) parts per million of boron in the tissue. More information is needed before critical levels of boron in the sugar beet can be established but it is apparent that boron should be in excess of 20 ppm.

<u>Diagnoses by plant growth response</u>.

Measured responses to applications of any fertility element is conclusive proof of deficiency of that element. To date, the only available information along this line in central Washington is qualitative. That is, deficiency symptoms disappear, overall appearance and vigor of crops improve and boron content of plant tissues increase as a result of boron fertilization. Actually, a great deal of quantitative yield information is needed before the picture on soil-plant relationships respecting boron nutrition of crops in this area is complete.

There is some possibility that yield depression, as a result of boron shortage, sets in before the deficiency symptoms occur. This has been demonstrated elsewhere by Berger and Truog (6) who obtained significantly increased yields of red beet and sugar beet where boron deficiency symptoms were not present. This being the case, it would be desirable to assay the boron status of a crop and be able to supplement the supply of boron before it approaches yield limiting levels. This can be accomplished through plant tissue testing but often by the time plant growth has progressed far enough to get a sample and to have it analyzed, it is too late in the season to obtain maximum benefits from boron fertilization.

Predicting boron requirements through soil testing

The most common and practical answer to the problem of assessing the boron nutritional status of a crop is to predict what it will be before the season begins through soil testing.

When soil samples are tested for any nutrient element an index value is obtained. This index number 2/ must be related to the soil's ability to maintain optimum amounts of the element in a form which can be readily utilized by plants. Since the necessary soil-boron-plant correlations are not complete in central Washington, soil testing and boron fertilizer recommendations in this area depend heavily on outside sources of information. Nevertheless, preliminary results indicate that the criteria now being used for boron fertilizer recommendations are quite reliable.

Some of the field and laboratory observations which were made from surveys in 1963 are summarized in Table 3. It should be emphasized that since the data given in Table 3 fall far short of a complete correlation of soil tests, they are only useful as a preliminary guide. Most of the survey work on sugar beet fields was too late in the season to be of much value.

At the present time boron fertilizer is recommended for alfalfa and sugar beets when the soil test is 0.5 and below. The results given in Table 3 indicate that the 0.5 index level provides an ample margin of safety for averting boron shortages for these crops. There were two fields of alfalfa between 0.30 and 0.50 soil test and both were normal in appearance. Out of seven fields having soil tests below 0.30, one appeared normal and six were definitely deficient. For sugar beets, deficiency symptoms were present on soils testing 0.38 and below on eight out of nine fields sampled.

Tissue analysis for boron has already been discussed but it is of interest to correlate tissue tests, soil tests, and deficiency symptoms. This can be done roughly with specific examples given in Table 3 on alfalfa as follows:

Sample number	Deficiency symptom	Plant content ppm	Soil test index
5	Very severe	10.1	0.16
12	Very mild	26.2	0.24
Others	None	Above 32	Above 0.30

The results of tissue analysis on sugar beets cannot be fairly assessed since there was so much variation in sampling time.

2/The soil test index is literally the number of parts of boron per million parts of soil extracted by hot water. All soil test results discussed here are from the Soil Testing Laboratory, Department of Agronomy, Washington State University.

Table 3 includes observations from fields where boron toxicity was present. Reference will be made later to the data on excessive boron.

BORON TOXICITY

Cause and Effect

As stated in the introduction, one of the major objectives of this circular is to help overcome the problem of boron toxicity in central Washington field crops. It may appear to be anomalous that a mineral element which is indispensable to the growth of plants should also be injurious to them. Actually, the poisonous effects of excessive boron have been known for many years, certain amounts being lethal to all plants. Worldwide, the greatest single concern with regard to excessive boron is where soils and irrigation waters contain naturally high levels of the element.

Wilcox (7) has rated various crops according to their ability to tolerate excessive levels of boron in irrigation waters. He found that even sensitive crops would tolerate irrigation waters containing 0.3 ppm B.

The boron content of irrigation water supplies in central Washington (both streams and wells) has been thoroughly characterized by several agencies (1, 8, 9, 10, 11). Examples of some of the analytical results are:

Reference number	Source of water	Time period	No. of samples	Boron content - ppm Mean	Range
8	Columbia River at Grand Coulee Dam	1953-1958	23	0.037	.00-.09
10	Potholes canal headworks	1959-1961	6	0.032	.00-.09
9	Sunnyside canal	1950	(monthly)	.01	-------
9	Roza canal	1950	(monthly)	.00	

All sources of information indicate that the boron content of irrigation waters always averages very low over a period of time. It is obvious that water supplies in this area are completely safe from the point of view of their boron content. It is also known on the basis of analysis of many hundreds of soil samples that boron is naturally low in the soils of this area. The only soils that have yielded high test results for boron are those which have been fertilized with this element. There is no doubt that boron toxicity in central Washington crops arises solely from mismanagement of boron in the fertilizer program.

Examples of boron toxicity which have been observed in commercial fields of alfalfa are given in Table 3, samples 1 through 4 and 8 through 10, inclusively. Crops other than alfalfa that were affected in particular instances in 1963 by high boron were peas, beans, red clover, white clover, and pasture. The boron dosage was lethal for parts of the field in five separate instances. In 1964 severe boron toxicity was noted in five different bean fields. In all of the 1964 incidences the boron was carried over from applications to beets or alfalfa.

Plant symptoms and boron content associated with toxicity

When a plant absorbs moisture from the soil, the boron is carried along and it tends to accumulate in the leaves as the water is lost by transpiration. When too much boron exists in solution its concentration builds up rapidly in the cells near the perimeter of the leaf. The first appearance of boron toxicity is discoloration and then necrosis (death) of cells in the tip and along the margin of older leaves. The dead tissue eventually dries up and takes on a characteristic color for each crop species. In extreme cases necrosis of uneven patches in the leaf occur which give it a mottled appearance. As the problem advances the whole leaf may die and drop off. The result is severely retarded growth or death of the plant.

Field experiment on boron toxicity

In order to obtain a clearer picture of toxicity symptoms and associated boron concentrations in plant tissue, high rates of boron were applied and observations made on an experiment which was conducted at Columbia Basin Research Unit Number 1 (Othello) during 1964. Treatments 2, 4, 8, and 16 pounds per acre of boron in the form of Solubor were sprayed on the soil. The treatments were replicated three times, the effect of the zero rate being estimated by an unreplicated check. After treatment the ground was plowed to a depth of 8 inches after which the seed bed was prepared. The following crops were planted at right angles to the direction of boron treatments: sugar beets, potatoes, peas, spring wheat, beans, sudangrass, and field corn. Except for the boron treatments, the crops were planted and managed normally in all respects. Leaf samples were taken on June 22 and again on July 20. The peas and the spring wheat were disced out about July 1. Therefore, the second sampling does not include wheat or peas. No quantitative measurements of effect on yield were made but toxicity effects were estimated visually on all crops.

Experimental results and discussion

Positive responses to even the low rates of boron fertilizer were not expected and none were observed. Toxicity symptoms appeared at both the 8 and 16 pound per acre rates of boron on all crops. The highest rate for all practical purposes was lethal for beans, peas, and potatoes. Production of beet tops, wheat, sudangrass, and corn was estimated to be 20-50% of normal at the high boron rate.

The results of plant tissue analysis for the check plots are given in Table 1, columns 4 and 5. The difference between crop species and sampling times should be noted. The analytical results for all B rates are given in figures 1 and 2. The comparisons given in figures 1 and 2 indicate that there is considerable variation in the boron absorption characteristics betwen the different crops. Also, there is a sharp increase in boron content on most plots with the later sampling. This probably reflects increased moisture absorption during the warmer weather.

Beans are especially sensitive to excessive boron; boron movement into the bean plant seems to be completely uninhibited. Results from a greenhouse trial showed that B content of bean leaves increased linearly up to 2240 ppm with increasing B rates in the soil. The plants of course did not survive very long under those conditions.

Details on the toxicity symptoms in each kind of crop follow:

Potatoes. The only initial external manifestation of excessive boron was stunted growth. After a few weeks the older potato leaves showed necrosis of a very thin margin in the older leaves and upward cupping of the leaf. Eventually, brown mottled dead areas appeared in the potato leaves.

Sugar beet. A thin necrotic margin developed in the older leaves accompanied by upward cupping of the leaf. The dead tissue took on a grey appearance.

Peas. Toxicity symptoms include necrotic leaf margin and mottling of interveinal areas. Dead tissue is yellowish-brown to grey-brown in color.

Beans. Symptoms of boron toxicity show up as death of leaf margin and mottled interveinal areas. Older leaves drop off soon. Dead tissue is yellow to yellowish-brown.

Spring wheat, corn, and sudangrass. Death of leaf tip and thin marginal strip most of way back to leaf base occurred. Dead tissue was straw colored or brown. Toward the latter part of the season older leaves of corn and sudangrass dried completely and were beaten off by wind.

Alfalfa. Some observations made in 1963 on alfalfa are given in Table 3, samples 4 and 10. Excessive boron manifests itself in alfalfa by yellowing of smooth margins in the older leaves. This tissue soon dies and becomes white. As the condition gets progressively worse the necrotic leaf margin increases in size and eventually the whole leaf dries up and falls off. In extreme cases the whole plant dies but it can be severely stunted and then recover in the following season to make normal growth after the boron in the soil solution has been diluted by leaching or fixation.

On the basis of the foregoing observations the crops may be rated as to their sensitivity to excessive boron. Beans are by far the most sensitive followed by peas, potatoes, wheat, sudangrass, and sugar beets. Although a direct comparison of the foregoing crops with alfalfa was not made it appears that alfalfa would be near sugar beets in its tolerance to boron. These results compare favorably with those reported by Wilcox (7).

The soil type has a considerable effect on soil-plant relationships regarding boron. For example, boron is rapidly transformed into less soluble forms in soils which contain free calcium carbonate (lime). On the other hand, coarse textured soils that have pH values from 6.5 to 7.0 have a very low fixation capacity and fertilizer boron persists in highly soluble forms.

The safest approach to the boron problem is to apply boron only when there is a demonstrated need for it. This means that, for the time being at least, boron should be applied only to alfalfa and sugar beets and then only when soil tests or deficiency symptoms indicate the need. Boron should be applied uniformly and in amounts not to exceed 3 pounds per acre. The rate of application should be lowered if the material is to be banded. The rate of application might also be lowered if a sensitive crop is to follow the alfalfa or sugar beets in the next season.

Fertilizer boron is recommended only when the soil test is below 0.5. The soil test also reflects increasing levels of soil boron as a result of fertilization. The index goes off scale at 4.00 plus. Toxicity levels of boron in plants occurred where the soil test was in the neighborhood of 1.50.

SUMMARY AND CONCLUSIONS

Boron deficiencies in alfalfa and sugar beets in central Washington make boron fertilizer indispensable in many fields for production of these crops. With the possible exception of hops, no other field crop grown in this area has been demonstratably improved with boron fertilizer.

Boron deficiency can be diagnosed from characteristic symptoms. In sugar beets insufficient boron leads to black heart, death of the terminal bud and death and blackening of the leaves in the center of the crown. Petioles often are scored or checked where boron is lacking. In alfalfa the upper leaves become yellow or reddish-yellow. Internodes do not lengthen and the leaf whorl takes on the appearance of a rosette. Severe deficiency leads to death of the terminal bud and branching of the lateral buds to give the plant a bushy appearance. Boron-deficient alfalfa is very susceptible to winter-kill.

Plant foliar analysis indicates that alfalfa is normal with 30-40 ppm of boron in the top four inches of the plant; it is approaching deficiency when the boron content drops to about 20 ppm. Sugar beet is normal with 50-60 ppm of boron in the leaf blade but is approaching deficiency with only 30 ppm.

The soil test for boron is very useful in predicting the need for boron. When the soil test index is below 0.30 in sugar beet and alfalfa land there is a good possibility that boron deficiency will arise. Boron fertilizer is recommended when the soil test is 0.50 and below. This provides a margin of safety for averting boron shortages in alfalfa and sugar beets.

Boron toxicity is a hazard that must be reduced through proper management of boron in the crop rotation and fertilizer program. Serious losses in sensitive crops such as beans and peas may result otherwise. In order to avoid boron toxicity it is recommended that boron be applied only when there is a demonstrated need for it. That is, when deficiency symptoms, foliar analysis or soil tests indicate low levels of the element in crop or soil. Boron should be applied uniformly at rates not to exceed three pounds of the element per acre.

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Table 1. Relative boron requirement for various field and vegetable crops.[1/]

Low	Medium	High
wheat	tomato	alfalfa
oats	carrot	red clover
rye	onion	white clover
barley	lettuce	sweet clover
corn		red beet
soybean		sugar beet
peas		asparagus
beans		rutabaga
potato		cabbage
grass (of various kinds)		

[1/] Adapted from Berger (6).

Table 2. Boron contents of representative plants.

Crop species	Boron content, parts per million dry weight[1/]				
	Literature[2/]	IES[3/]		IES[4/]	
	1	2	3	4	5
barley	2.3				
wheat	3.3			4.2	
corn	5.0			8.8	17.0
pea	21.7	17.5	20.0	23.0	35.8
beet	75.6	55.0	67.2	39.2	69.5
potato	13.9			20.0	21.0
alfalfa	25.0	32.7			
kidney bean	43.0				
bean (Red Mex.)		29.0		20.5	35.8
sudangrass				11.5	16.2

1/ Sampling method in literature only specifies plant tops. For I.E.S., sampling method is described herein.

2/ Data from Bertran et al. reported by Berger (6).

3/ From farmers fields in 1963. Columns 2 and 3 represent different sampling times varying from June in peas and alfalfa to October in beets.

4/ Crops grown at Columbia Basin Research Unit #1 (Othello). Columns 4 and 5 results of sampling dates June 22, 1964 and July 20, 1964.

Table 3. Incomplete correlation between boron deficiency/toxicity symptoms, boron content of plant tissues and soil test index for alfalfa and sugar beets.

Sample No.	Date	County	Description	B in plant ppm	B soil test ppm
			ALFALFA		
1	5/15/63	Franklin	Composite sample from check plots of quadruplicated field experiment; no deficiency symptoms, plants looked good.	31.9	0.30
2	"	"	Same as (1). Composite from plots receiving 3 lbs. B/A (no B response measured--courtesy A. I. Dow).	47.8	0.48
3	"	"	Normal alfalfa surrounding plots in (1) and (2). No symptoms of any kind. Fertilized by farmer.	60.8	0.60
4	"	"	Same as (3) where extra dose of fertilizer applied in strips in order to empty spreader. Toxicity symptoms very pronounced.	453.2	1.29
5	6/3/63	Grant	Field uniformly covered with deficiency symptoms.	10.1	0.16
6	"	"	Alfalfa extremely deficient; field very dry--apparently abandoned.	9.4	0.28
7	"	"	Field uniformly covered with moderately severe deficiency symptoms.	12.2	0.28
8	"	"	Field received uniform application of B by farmer (reportedly 2 lbs. B/A) as dry bulk mix. Crop in excellent condition.	33.5	1.52
9	"	"	Same as (8) but sampled strip on edge of field where fertilizer did not reach evidently. Plants very deficient.	10.4	-

(table continued)

Table 3. (continued)

Sample No.	Date	County	Description	B in plant ppm	B soil test ppm
			BEETS (continued)		
19	8/12/63	Yakima	Uniform and severe B deficiency symptoms. Average of three composite tissue samples.	19.6	0.38
20	10/21/63	Grant	Random sample from field containing few deficiency symptoms.	54.2	0.34
21	"	"	Field with scattered B deficiency symptoms; crop appearance excellent overall.	100.0	0.36
22	"	"	Scattered beets very B deficient; overall crop appearance good.	45.0	0.22
23	10/30/63	Franklin	No B deficiency symptoms. B applied by farmer before planting.	87.5	1.44
24	"	"	Deficiency symptoms very clear on scattered plants.	47.0	0.22
25	"	"	Few B deficiency symptoms.	61.5	0.22
26	"	"	Deficiency symptoms clearly evident on isolated beets.	70.8	0.36
27	"	"	Overall appearance of beets very poor (nitrogen deficiency). B deficiency not evident.	56.0	0.14
28	"	"	Field with very few B deficient plants.	62.0	0.22

Table 3. (continued)

Sample No.	Date	County	Description	B in plant ppm	B soil test ppm
			ALFALFA (continued)		
10	6/3/63	Grant	Same as (8) but fertilizer spreader was emptied in wide loop through field. Plants very sick--stunted.	568.8	4.00 +
11	10/10/63	"	Field reportedly treated with B last fall or spring. Crop in good condition.	42.0	0.22
12	"	"	Deficiency randomly scattered, some plants appeared to be normal.	26.2	0.24
13	"	"	Field with scattered deficiency symptoms. Samples consisted of plants which showed definite symptoms.	15.8	0.22
14	"	"	Same as (13). Sampled only plants without symptoms.	25.8	"
15	"	"	Sampled similar to (13).	13.5	0.22
16	"	"	Same as (15) without symptoms.	22.8	"
			BEETS		
17	7/23/63	Kittitas	Composite samples of leaves from field experiment with five replications, results averaged. Check plots only. (No response to added B.) No symptoms.	62.8	-
18	8/2/63	Grant	Average of four reps. from field experiment B check plots. Beets normal overall. No response to added B. Highly calcareous soil.	55.1	0.35

(table continued)

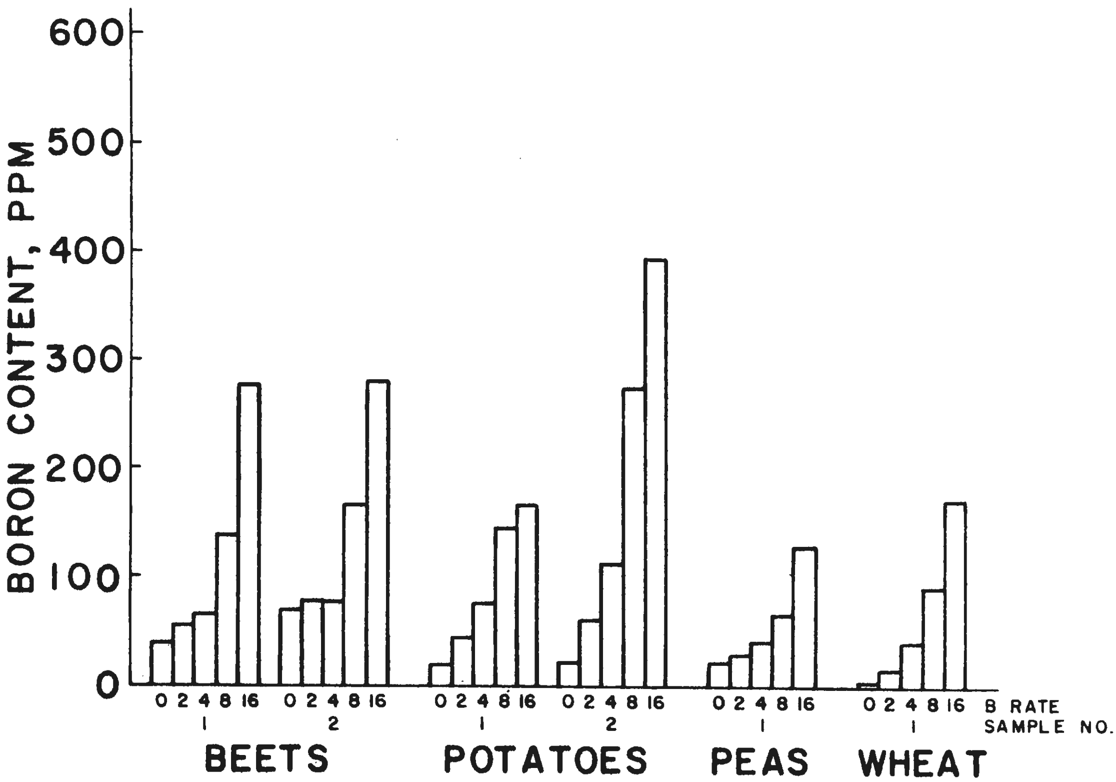

Figure 1. Boron content of sugar beets, potatoes, peas and wheat as affected by boron fertilization (lbs. B/A)

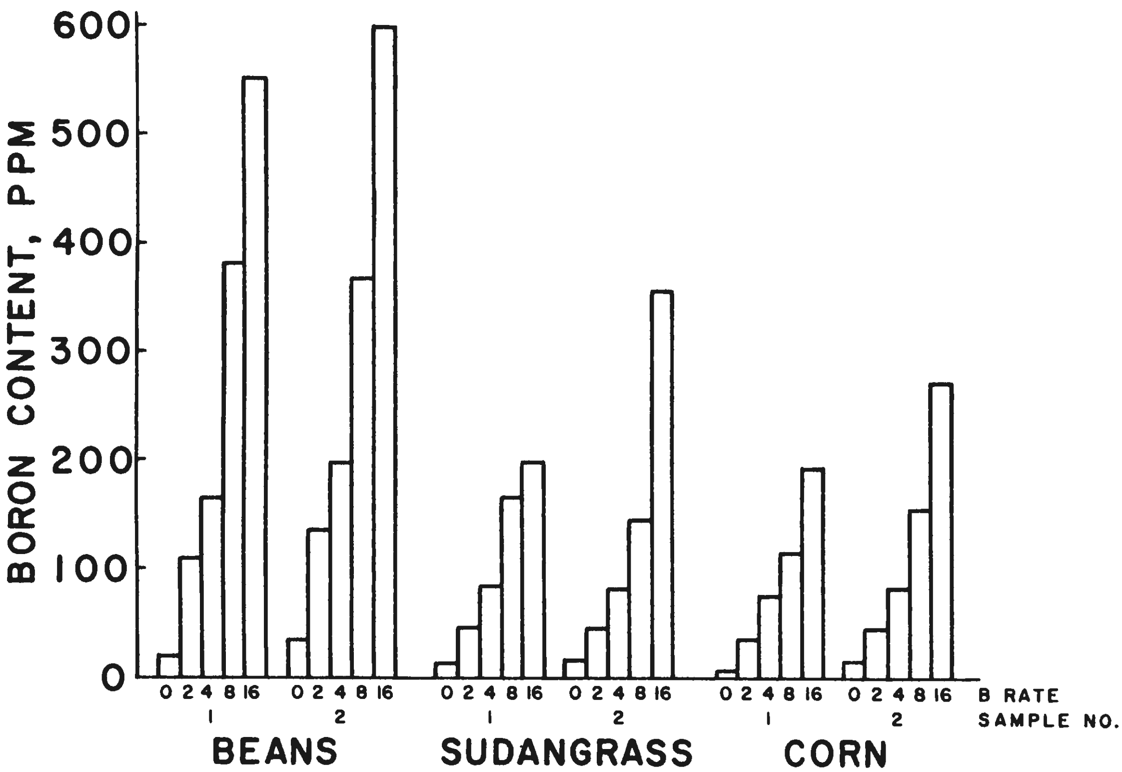

Figure 2. Boron content of beans, sudangrass and corn as affected by boron fertilization (lbs. B/A).