BORON DEFICIENCY IN BEETS AS CORRELATED WITH YIELDS AND AVAILABLE BORON[1]

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INTRODUCTION

Boron is now known to be one of the 15 essential nutrient elements required by higher plants. Although Wittstein and Apoiger (10) in 1857 found boron in the ash of the seed of *Maesa picta*, it was not until 1915 that Mazé (6) demonstrated that boron is essential for the normal growth of the corn plant. In 1910 Agulhon (1) obtained increased yields of wheat, oats, and turnips by the use of boron in nutrient solutions, but he did not establish the essentiality of boron for the normal growth of the plants. In 1923, Warrington (9) showed that boron is essential to legumes and that its absence causes distinct deficiency symptoms.

Brandenburg (5) in 1931 discovered that the application of boron prevents heart rot of sugar beets, and in 1938 Raleigh and Raymond (7) found that fertilization with boron would control internal breakdown of table beets. Also, in 1938, Walker, Jolivette, and McLean (8) published their findings which showed that boron is essential for the normal growth of table beets, and that a lack of the element causes deficiency symptoms which they called black spot instead of internal breakdown or rot.

The amounts of boron normally present in various plants expressed in parts per million of the dry tissue are as follows: barley, wheat, and corn, three to 10 parts; spinach, celery, and peas 10 to 20 parts; carrot and red clover 20 to 30 parts; and cabbage, alfalfa, turnips, tomato, sugar beet and table beet 30 to 50 parts. Plants containing the higher amounts of boron also require greater amounts of available boron for normal growth.

The boron content of soils varies considerably even though the amounts normally present in soils of the humid temperate

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regions are relatively low. Sands usually contain from two to 10 parts per million of total boron and loams 15 to 40. Ordinarily, about five per cent of the total boron present is available; thus, sands and soils low in organic matter and also calcareous soils usually contain from 0.1 to 0.7 part per million of available boron, while slightly acid soils, high in organic matter, usually contain from 0.7 to 4.5 parts per million.

Methods involving the quinalizarian reaction for the determination of total boron in soils and plants, and available boron in soils have been developed and described by the writers (2), (3), (4). Treatments of soils with boiling water was found to be the most satisfactory procedure for the extraction of available boron, and hence, this means was adopted. The results obtained for available boron with this method were correlated with the boron deficiency symptoms found in table beets and a good correlation was obtained (3).

Visual deficiency symptoms are usually found only when the deficiency becomes rather extreme, and thus slight deficiencies go unnoticed, although yields may be appreciably lowered. In order to obtain additional information regarding boron deficiency symptoms in beets as correlated with yields and the available boron content of soils, further investigations were conducted. A brief discussion of these and the results obtained follow.

Experimental

During a four-year period, field fertilizer experiments were conducted with beets in eastern Wisconsin on three soil types. Each of these experiments involved numerous plots variously treated with the common fertilizers, and in addition some of the plots also received borax. Only data obtained from a set of plots which received a 3–12–12 fertilizer alone, and another set which received borax in addition are presented here (Table I).

The data given in Table I for the available boron content of the soils represent the average of results obtained by analyzing a sample of soil from each plot before treatment. The plots on each soil type were found to be very uniform as regards the available boron content of the soil, the greatest variation being ± 0.15 part per million of boron.

The data given for yields represent an average of four randomized replicated plots; each plot was four rows wide and 70

TABLE I. Yield and boron deficiency symptoms of beets grown on various soil types with and without boron fertilization.

Kind of Beets	Year	Soil Type	Available boron in soil	Acre Yields (1)		Increase due to boron fertilization	Black Spot or Heart Rot		Boron Fertilization (2)	
				without boron fertilization	with boron fertilization		without boron	with boron	pounds per acre	method of application
			p.p.m.	tons	tons	%	%	%		
Table beets	1940	Miami silt loam	0.50	8.33	9.60	15.3	none	none	40	broadcast
Sugar beets	1940	Superior clay loam	0.80	16.85	18.58	10.3	none	none	25	broadcast
Table beets	1941	Miami silt loam	0.80	12.49	15.51	24.2	30.0	3.0	20	side seed
Sugar beets	1941	Superior clay loam	0.70	18.69	20.68	10.6	none	none	25	broadcast
Sugar beets	1941	Carrington silt loam	1.00	18.84	18.60	—1.3 (3)	none	none	25	broadcast
Table beets	1942	Miami silt loam	0.75	5.70	7.70	35.1	none	none	50	broadcast
Sugar beets	1942	Carrington silt loam	1.10	13.10	14.20	8.4 (3)	none	none	25	broadcast
Table beets	1943	Miami silt loam	0.90	5.97	7.80	30.7	none	none	20	side seed
Sugar beets	1943	Miami silt loam	0.95	13.32	13.00	—2.5 (3)	none	none	25	broadcast

(1) Average of 4 randomized replications.
(2) In addition, all plots received 200 pounds of 3-12-12 fertilizer per acre at the side of the seed.
(3) Not a significant change in yield at the 5-per cent level in accordance with the analysis of variance method.

feet long. For obtaining yields, the inner two rows, 60 feet long, were harvested. Boron deficiency symptoms were noted by visual observation of the tops throughout the growing season, and by examination of the roots at harvest.

Discussion

When soil tests for available boron were correlated with boron deficiency symptoms in table beets in a previous investigation (3), it was found that when the soil contained about 0.75 part per million of available boron the boron deficiency symptoms were reduced to a negligible degree. However, in the case of most nutrient elements, even before deficiency symptoms appear, the yield is lowered by a slight deficiency of one of these elements. The results given in Table I show that this holds true for boron in the case of beets. The results also show that sugar beets require at least about one part per million of available boron in soils rather than 0.75 part as previously stated. Table beets probably require slightly more.

The response to applications of borax is greatly influenced by the moisture conditions during the growing season; in 1940, a wet growing season, the increase in yield of table beets was only 15 per cent when borax was applied to a soil having 0.5 part per million of available boron, while in 1943, a dry growing season, the increase in yield was about 31 per cent when borax was applied to a soil having 0.9 part per million of available boron.

The level of available nutrients other than boron is also a factor in determining the amount of available boron needed by the crop. In 1941, on a highly fertile Miami silt loam having 0.8 part per million of available boron, a 24-per cent increase in yield was obtained by the application of borax, and 30 per cent of the beets where borax was not applied had visual boron deficiency symptoms. The yield was greater than in 1940 on this same type of soil, and a greater response to borax was obtained because of larger plant growth due to higher fertility, and consequently a larger demand for boron.

Summary

Since boron deficiency symptoms in beets appear only when the deficiency becomes quite serious and after yields are markedly reduced, such symptoms do not always serve as a satisfactory means of telling when fertilization with boron is needed.

Determination of available boron in soils, involving extraction with hot water, appears to be a much more satisfactory means of doing this. Results from field tests indicate that sugar beets require at least about 1.0 part per million of available boron, and table beets slightly more. Common field crops probably require less than one-half these amounts.

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