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Essential Micronutrients:

BORON

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BORON (B) is indispensable for plants but not animals. It is classed as a micronutrient because such small amounts are needed. Different plant species vary greatly in B requirements as well as in tolerating high levels in the soil. Toxic levels are easily reached, which explains why borax was one of the first used chemical herbicides. Care must be exercised when using fertilizer B.

Boron in Plants

All plant parts contain B. Deficiencies cause a degeneration of meristematic tissue associated with a restriction in terminal growth; thickened, wilted or curled leaves; a thickened, cracked or water-soaked condition of petioles and stems, and a discoloration, cracking or rotting of fruit, tubers or roots.

Table 1. Relative Responses of Selected Crops to Boron[1]

High response		Medium response		Low response	
Alfalfa	Sugarbeet	Broccoli	Lettuce	Asparagus	Pea
Cauliflower	Table beet	Cabbage	Parsnip	Barley	Peppermint
Celery	Turnip	Carrot	Radish	Bean	Potato
		Clover	Spinach	Blueberry	Rye
		Tomato		Cucumber	Sorghum
				Corn	Spearmint
				Grass	Soybean
				Oat	Sudan grass
				Onion	Sweet corn
				Wheat	

[1] *From MSU Extension Bulletin E-486.*

Boron functions as a regulator in the plant metabolism of carbohydrates. Crops vary in response to fertilizer B, as suggested in Table 1. Response occurs infrequently in the "medium" group. The B utilized by crops is extremely low. Total uptake seldom exceeds 0.1 pound per acre, although an 8-ton crop of alfalfa may contain as much as 0.2 pound.

Plant analysis is one way of diagnosing both deficiencies and toxicities. The data in Table 2 illustrate the "sufficiency range" for selected crops. Boron levels outside the range suggest opportunities for either deficiencies or toxicities. Analyses of other plant parts or samples taken at other than the suggested time are difficult to interpret.

Natural excesses of B in Michigan are unknown. However, the misuse of B-containing fertilizers can cause leaf tip yellowing and in some instances a purpling of the entire leaf on small grains. When excesses are great, plants die.

Boron in Soil

Most of the B in soil is in tourmaline, a very insoluble mineral. The total B in the plow layer varies greatly and is not closely related to crop availability. Most soils range between 20 and 200 pounds per acre B with less than 5% generally available to plants.

Plant-available B occurs in two broad groups, mineral and organic. Mineral forms are primarily borates of calcium (Ca), magnesium (Mg) and sodium (Na). Soil micro-organisms and plants utilize such forms to produce B-containing organic compounds. Upon death

Table 2. Boron Sufficiency Range[1].

Crop	Sample	ppm[2]
Corn	Ear leaf at first silk	4-25
Soybeans	Top fully developed leaf prior to bloom	21-55
Alfalfa	Top 6 inches prior to initial bloom	31-80
Wheat	Upper leaves prior to initial bloom	6-40
Sugarbeets	Center fully developed leaf — midseason	26-80
Vegetables	Top fully developed leaf — midseason	30-60
Potatoes	Petioles, recently developed leaf — midseason	15-40
Navy beans	Top fully developed leaf — midseason	15-50

[1] *From several sources, primarily MSU Extension Bulletin E-486.*
[2] *ppm - parts per million.*

Table 3. Average Extractable Boron in Profiles of Michigan Soil Groups[1].

Dominant profile texture	Soil group symbol	Soil[2] profile symbol	Natural drainage class: Well drained (a)	Somewhat poorly drained (b)	Poorly drained (c)
			Pounds per acre[3]		
Clay and Clay . Loam	1 & 1.5	A	2.0	2.0	2.3
		B	1.8	1.8	2.0
		C	1.9	1.9	1.4
Silt Loam and Sandy Loam	2.5 & 3	A	1.8	1.9	2.2
		B	1.5	1.5	1.6
		C	1.3	1.4	1.4
Loamy Sand and Sand	4 & 5	A	1.5	1.8	2.1
		B	1.3	1.3	1.5
		C	1.2	1.1	1.2

[1] *For more details, refer to MSU Agr. Exp. Sta. Research Report 287.*
[2] *A - Plow layer, B - Subsoil, C - Parent material.*
[3] *Equivalent to 2 million pounds of soil material.*

of the plants and micro-organisms, decomposition is initiated, and the organic B reverts back into a mineral form.

Boiling water-soluble B represents the best evaluation of soil B availability. Typical analyses of boiling water soluble B in the profile of Michigan soils are reported in Table 3. Test levels of less than 2 pounds per acre are in the low range. From these data, it is evident that, on the average, Michigan soils contain relatively low amounts of available B and that coarse-textured soils and those low in organic matter contain the lowest levels; also, that available B is concentrated in the plow layer.

The MSU laboratory does not test for B because demand for the test is low and correlations with yield responses from fertilizer B also have been low. Recommendations are now made only for crops with "high" responses that are grown on soils with relatively high pH levels.

Low soil-moisture levels reduce the degree of soil B availability. For this reason deficiencies of B occur most frequently under drought conditions.

The soluble or plant available form of soil B is an anion (negative charge) $B03^{---}$. Because most soil colloids[1] are negatively charged, soluble B leaches easily, which partially explains the naturally low levels of availability in sandy soils.

Boron fixation into insoluble or unavailable forms is well known. Clays fix the most, silts an intermediate amount and sands very little. Soil organic matter is also known to fix B.

[1] *Matter having very small (submicroscopic) particle size and a correspondingly high surface area per unit of mass.*

An interesting unexplained situation is developing in Michigan because a recent study showed that cropped soils contained only two-thirds as much available B as uncropped soils. In some localities where historically symptoms of B deficiency were common, deficiency symptoms no longer appear, and some farmers no longer use fertilizer B. This is the situation with both alfalfa and sugarbeets. An explanation is not apparent, but it is believed that those who have discontinued the use of B are again likely to encounter a deficiency.

Boron in Manure

The average B content of livestock manure is low, as is shown in Table 4, and is approximately the same as the feed utilized. Boron levels in livestock feed range between 0.01 and 0.03 pounds per ton, while levels in manure range between 0.02 and 0.12.

Because B levels are low, crop requirements are not satisfied where less than 10 tons per acre are used. Where very high rates are used, farmers report that

Table 4. Boron Levels in Three Rates of Manure[1].

Kind of manure	Tons per acre of manure: 1	5	20
	Pounds Boron		
Chicken — no litter	0.12	0.60	2.40
Chicken — old floor litter	0.03	0.15	0.60
Dairy cows	0.03	0.15	0.60
Fattening cattle	0.04	0.20	0.80
Hog	0.08	0.40	1.60
Horse	0.03	0.15	0.60
Sheep	0.02	0.10	0.40

[1] *Calculated from several sources.*

Table 5. Common Sources of Boron[1].

Carrier	Formula	%B
Boron frits	--	10-17
Borax	$Na_2B_4O_7 \cdot 10H_2O$	11
Boric Acid	H_3BO_3	17
Sodium pentaborate	$Na_2B_{10}O_{16} \cdot 10H_2O$	18
Sodium tetraborate		
Fertilizer borate - 46	$Na_2B_4O_7 \cdot 5H_2O$	14
Fertilizer borate - 65	$Na_2B_4O_7$	20
Solubor	$Na_2B_{10}O_{16} \cdot 10H_2O$	20

[1] *Fertilizer Handbook — The Fertilizer Institute.*

deficiency symptoms on alfalfa and sugar beets are reduced or eliminated.

Boron in Water

Very little is known about the B levels in Michigan waters. At this writing, water is not considered to be a satisfactory source of B for crop production, regardless of source.

On the other hand, B levels in Michigan waters are low enough that B toxicities have never been diagnosed on irrigated crops. This is in contrast with the arid West where the water sometimes contains in excess of 2 ppm.

Boron in Municipal Sludges and Waste Waters

Boron levels in municipal sludges are low but variable, ranging between 4 and 1000 ppm, depending upon the source. Even the highest level represents only 0.1%. Thus, sludges are not considered good sources of B. Also they are not likely to cause toxicities.

Waste waters also contain variable quantities of B. Toxicities from waste water have been observed. Therefore, before being used for irrigation, such water should be analyzed and then used at rates where B toxicity is not possible.

Hopefully in the future, B levels in waste water will be reduced at the point of origin so that it can easily be used for irrigation of field crops.

Boron Carriers

Sodium borates are the major forms of B in fertilizer. The most common sources are shown in Table 5. With suitable equipment such materials can be applied directly to the soil. The material "Solubor" can be used as a foliar spray. The average farmer needing to use fertilizer B finds it easiest to have it mixed with fertilizer containing the major nutrients.

Recommendations for Fertilizer Boron

In Michigan, fertilizer B is recommended only for those crops which have demonstrated a response to the element. Fertilizer B should not be used on crops in the low responsive group because of opportunities for injury.

Fertilizer B recommendations are made on the elemental basis and not on the basis of the carrier. Where soil pH levels are relatively high, rates of 1.5 to 3.0 pounds per acre are recommended for the highly responsive crops, while 0.5 to 1.0 pound is recommended for those crops with medium requirements. Application may be broadcast or banded. Fertilizer at planting time containing B should not be in contact with the seed. For such crops as alfalfa, B should be used as a topdressing and not as a part of a planting-time fertilizer.

When B carriers are blended with other fertilizer materials, segregation may cause problems of variable rates. The significance of this is now recognized by fertilizer manufacturers who attempt to have granules of all carriers the same size and completely mixed.

Foliar sprays have been successful, but rates should be greatly reduced to prevent toxicities. Between 0.1 and 0.3 pound per acre of B is recommended when used as a spray. "Solubor" is the best material to use as a foliar treatment because other carriers are less soluble.

Summary

Boron is an essential element for all plants but not for animals. Some soils in Michigan contain inadequate levels for economic crop production; therefore, supplemental B is required.

Fertilizer B may be broadcast, sprayed on plants or used as part of a banded planting time fertilizer. Care should be exercised to be certain that the use of B does not create toxic conditions.

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