DIAGNOSING B SUFFICIENCY FOR FRESH MARKET TOMATOES: LEAF OR FLOWER ANALYSIS

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ABSTRACT

Soil and/or foliar B applications were applied to fresh market tomatoes grown at two Iowa and one Colorado location. Even though there were significant yield responses at all locations the B treatments did not effect leaf or flower B concentrations. Soil B application on Iowa loam soil significantly (P=0.03) increased extractable soil B, but the change was not detected in leaf or flower tissue. At the Iowa coarse sand site leaf B levels were enhanced 11.6%, from 25 to 29 ppm by harvest. Leaf and flower B concentrations were similar within an Iowa location, but different between locations. At Colorado, where leaf B concentration was 48 to 50 ppm, the flower B concentration ranged from 101 to 132 ppm. But, foliar B application did not affect either leaf or flower B levels. When considering B, which not readily mobile in some crops, the flower, which may contain higher B concentrations than leaf tissue, may be a more suitable sampling tissue to ascertain deficiency/sufficiency levels.

INTRODUCTION

Plant analysis is a useful monitoring tool to avoid crop deficiency or toxicity micronutrient levels. The sampling procedure usually involves leaf tissue, and for tomato that means the most recently matured leaf, usually the fourth or fifth leaf from the growing tip. The tomato leaf sufficiency range for B is typically narrow, from 25 to 75 ppm or 40 to 80 ppm, depending on the region where the research was conducted and the crop physiological stage of growth when the plant was sampled (Mills and Jones, 1996; Marschner, 1995; Wilcox, 1993). Generally, at first flower or early bloom stage of growth the critical value is 25 to 35 ppm (Mills and Jones, 1996). Tomato plants can tolerate higher B concentration levels than most crops and is considered a moderate response crop to B application when grown on deficient soils (Rehm et al., 1993; Francois, 1984). However, the whole-leaf B concentration change to soil applied B can be variable with none, or a marginal increase, and at other times and locations a linear response to applied rate (Peria et al., 2001).

For many years, B has been considered a non-mobile element in plant tissue, but now is considered a mobile or semi-mobile nutrient depending on the crop species. Both Davis et al. (2003) and Oertli (1993) showed B was remobilized from tomato shoot tissue to the root. During the flowering stage of growth the remobilization of most nutrients from leaf to reproductive organ is very high. The exception is Ca and B which are incorporated into structurally bound compounds (Marschner, 1995; Brown, 1993). In addition to its role in cell membrane integrity and cell wall pectins B has a function in pollen germination and pollen tube growth during flowering and retention of developing fruit (Nyomora et al., 2000). But, the extent of remobilization depends on leaf nutrient concentration with high leaf levels transporting considerable and low levels transporting nil (Marschner, 1995). In tree fruits, with high leaf B levels, a high percentage was transported to the reproductive sink, when leaf levels were low (near deficient levels) almost no B was transported to flower tissue (Hanson, 1991).

The purpose of this paper is to illustrate fresh market tomato whole-leaf and flower tissue B concentration change in response to soil or foliar applied B.

MATERIALS AND METHODS

Boron rate studies were conducted as a soil application at Ames, Iowa in 2004 and as foliar applications at Muscatine, Iowa and Rocky Ford, Colorado in 2002. The B source at all locations and treatments was Solubor ($Na_2B_8O_{13}{\cdot}4H_2O$), a commercial product of the US Borax Company containing 20.5% B.

Soil Data

The soil type at Ames is a well drained, central Iowa loam (prairie developed on glacial till, fine-loamy, mixed, mesic Typic Hapadoll) with a pH of 6.82. The soil at Muscatine is a coarse sand along the Mississippi river (Fruitland coarse sand – sandy, mixed mesic Entic Hapludolls) with a pH of 6.32, while the Rocky Ford site consists of alluvial Rocky Ford silty clay loam along the Arkansas river (fine-silty, mixed, calcareous, mesic Ustic Torriorthents) with a pH of 7.14. Soil analysis of the 1-foot depth from the plot area prior to treatment application indicated B levels of 0.51 (± 0.04), 0.20 (± 0.01), and 2.74 (± 0.11) ppm for Ames, Muscatine, and Rocky Ford, respectively. The soil extraction procedure used was modified Mehlich No. 3 with ICP techniques (Keren, 1996; Taber, 2004). A soil B concentration of < 0.7 ppm is defined as the critical value for the Mehlich No. 3 method (Sumner, 2001).

Irrigation Water

Water used for irrigation at all sites was analyzed for mineral content throughout the growing season. Ames water source was a collection pond that averaged < 0.01 ppm B throughout the season. Muscatine water source was a sand-point well (water table about 20 feet below the surface recharged by the Mississippi river) that varied from 0.02 to < 0.01 ppm B. The Rocky Ford site water was from the Arkansas river until August when extremely dry growing conditions resulted in switching to a deep well that was of lesser quality. The B concentration was 0.11 to 0.15 ppm from May to end of July and then averaged 0.29 ppm from August to September. The irrigation water at Ames and Muscatine provided minimal amounts of other nutrients, but Rocky Ford water contained considerable amounts of Ca, Mg, and S.

Cultural System

At all locations tomato transplants, cv. Mountain Spring, were set the second to third week of May, with black polyethylene mulch and a single line source trickle irrigation system. Row width was 5 to 6 ft. and in-row plant spacing was 15 to 17 inches with 18 plants per treatment plot. The center 10 plants were used for harvest while the 3 plants on both ends were used for leaf and flower analysis. A border row separated each plot. The plants were pruned once to the first flower cluster and staked according to the Florida stake and weave training system. Fertilization, weed management, and pest control practices of the area were followed.

Experimental Design and Data Collection

The B results reported in this work were part of a larger study involving K application rates. The design was a split plot, factorial, randomized complete block with four replications. The main factor was preplant K rates. The subplot was B application (soil or foliar). Flower and leaf samples were taken throughout the growing season for elemental analysis. Boron was determined by dry ashing, taking up the ash in 1 N aqua regia, and measuring B by ICP techniques. Ripe fruit was harvested beginning August 2 (Ames), August 5 (Muscatine), or August 7 (Rocky Ford) and harvested once per week for 5 to 7 weeks, depending on location. Fruit were sorted into marketable and unmarketable (cull), and number and weight determined in each category. Cull fruit were those too small, defects greater than 5%, and rots. All results were analyzed via PROC MIXED routine of SAS (version 8e, SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

There was an early tomato yield response to B application at the two Iowa locations, but not at Rocky Ford (Table 1). Early harvest represents the first one or two harvests when the local market price is highest. At Ames (loam soil) in 2004 a preplant 3 lb/acre B soil application significantly ($P < 0.01$) increased early yield 43% (+51 cwt/acre). The effect of foliar B application at Muscatine (coarse sand) was smaller, a 13% early yield increase (+14 cwt/acre). There was no effect on fruit size at either location so the response was one of increased flower number and/or fruit set. Davis et al. (2003) found that fruit set increased 56% to 76% for 'Celebrity' tomato with either foliar or soil applied B. At Rocky Ford the marketable yield for the first two harvests was not affected by foliar B application, averaging 64 cwt/acre which represented 8% of total seasonal fruit produced. For main seasonal yield, B application had no effect at the Iowa locations. In Iowa, unmarketable yield accounted for 1/3 of harvested fruit largely as a result of blotchy ripening because of erratic high temperatures and humidity conditions. Applying foliar B linearly decreased ($P = 0.03$) main seasonal yield at the Rocky Ford location, from 888 to 787 cwt/acre. Cull yield represented only 8% of total fruit at this location.

The soil B application at Ames in 2004 did not elevate whole-leaf or flower cluster B concentration at the early flower or harvest sampling times (Table 2). The values of 40 to 50 ppm B were above the critical sufficiency level of 25 to 35 ppm (Mills and Jones, 1996). However, the soil B application significantly ($P=0.03$) raised the extractable soil B from 0.42 (control) ppm to 0.56 ppm B (the 3 lb/acre rate) when sampled at the last harvest in September.

At Muscatine and Rocky Ford, in 2002, the June foliar B application (early flower stage of growth) did not elevate leaf B concentration as measured by the July sample date (mature green fruit stage of growth), at either site (Table 2). However, after two 0.25 lb/acre B applications the leaf B was significantly elevated 11.6% at Muscatine (harvest sample date). Nevertheless, the leaf B concentration was marginal throughout the growing season; whereas, at Rocky Ford the leaf B concentration almost doubled by the harvest period, 49 to 83 ppm B. Part of this increase could be the result of changing the irrigation source in August from river water to deep well water which contained 0.29 ppm B compared to the river water source of 0.14 ppm. These high leaf B concentrations of > 80 ppm resulted in significant total yield decline (Table 1).

Flower cluster B levels were similar to leaf levels at Ames and Muscatine, while at Rocky Ford the flower B concentration was > 2X that of the leaf at flowering and mature green sampling periods. Other elements that were higher in flower tissue, compared to leaf tissue, were P and Zn (data not presented). Perica et al. (2001) found that the effect of foliar B spray to olive trees was more consistent in flower than leaf tissue. The response of olive flower cluster B concentration was linear to B application concentrations (from 35 to 65 ppm) while leaf tissue B concentration remained constant (19 ppm). Similarly, a three year study with apple found foliar applied B (as solubor) increased leaf B concentration, as compared to water control, only one year; whereas flower B concentration was increased all years, from 28 to 97 ppm B (Peryea 2005). However, in this study flower B levels were unaffected by foliar B treatment at the rapid

Table 1. Total yield response of 'Mountain Spring' fresh market tomato to soil or foliar

B applications at two Iowa locations and one Colorado location. All locations employed the same cultural system: transplants, black polyethylene mulch, trickle irrigation, plants pruned, staked and tied.

Location	B rate	Early Harvest	Main Season Harvest
Ames IA 2004 [Z]	Soil, lb/acre	---------- cwt/acre ----------	
	0	120	632
	3	171	691
P value		0.0004	NS
Muscatine IA 2002 [Y]	Foliar, lb/acre		
	0	109	312
	0.25	124	295
	0.50	122	308
P value		0.06	0.55
s.e.m. [X]		6.3	NS
Rocky Ford CO 2002 [W]	Foliar, lb/acre		
	0	66	888
	0.25	60	848
	0.50	61	787
P value		0.82	0.033, L**
s.e.m.		NS	36.9

[Z] Loam soil. Soil B applied preplant, rotovated in prior to laying black polyethylene mulch. Early harvest = Aug. 2 and Aug. 9; Main season = Aug. 16 through Sept. 20.

[Y] Coarse sand soil. Foliar B applied at 0.25 lb/acre (as Solubor) on June 21 (flowering) and again on July 17 (the 0.50 lb/acre rate). Early harvest = Aug. 5; Main season = Aug. 12 through Sept. 17.

[X] s.e.m**.** **=** standard error of the mean; L = linear, ** = significant at the 0.01 level.

[W] Silty clay loam soil. Foliar B applied at 0.25 lb/acre on June 14 (flowering) and again on July 12 (the 0.50 lb/acre rate). Early harvest = Aug. 7 and Aug. 13; Main season = Aug. 20 through Sept. 23.

flowering stage of growth, except at Rocky Ford where there was < 5% increase (from 101 to 106 ppm). Perhaps earlier foliar B application during rapid vegetative development (within two weeks after transplanting) would have resulted in greater B absorption (Gupta, 1993). Remobilization of B from leaf to reproductive tissue is dependent on plant B concentration levels (Marschner, 1995). When the concentration is close to the deficient or marginal level the leaf and flower contain similar levels and very little movement occurs. However, when concentration is high the reproductive tissue contains a much higher content than the leaf tissue.

Table 2. Whole-leaf and flower B concentration as affected by B treatment at two Iowa locations and one in Colorado. Most recently matured leaves and open flower clusters taken prior to foliar B application.

		Flowering		**Mature Green**		**Harvest**
Location	**B rate**	Leaf	Flower	Leaf	Flower	Leaf
Ames IA 2004 [Z]	Soil, lb/acre	-------------------- ppm B, dry weight basis ------------				
	0	38	38	-	-	52
	3	40	39	-	-	49
P value		0.09	0.77			0.06
Muscatine IA 2002 [Y]	Foliar					
	0.00	22	24	21	23	25
	0.25	22	24	21	24	25
	0.50	23	25	22	25	29
P value		0.35	0.91	0.54	0.80	0.008
Rocky Ford CO 2002 [X]	Foliar					
	0.00	47	132	48	101	77
	0.25	50	125	48	110	82
	0.50	48	128	49	101	85
P value		0.41	0.12	0.86	0.03	0.24

[Z] Loam soil with pH of 6.8 and initial soil B of 0.51 (±0.04) ppm. The 3 lb/acre B (as Solubor) applied broadcast and rotovated in just prior to laying black polyethylene much. Irrigation water from a collection pond with B concentration < 0.01 throughout the season.

[Y] Coarse sand soil with pH of 6.3 and initial soil B of 0.21 (±0.01) ppm. Irrigation water B concentration was < 0.01 ppm throughout the season. Foliar B applied at 0.25 lb/acre (as Solubor) on June 21 (flowering) and again on July 17 (the 0.50 lb/acre rate) the mature green fruit stage of growth.

[X] Silty clay loam soil with pH of 7.1 and soil B of 2.74 (±0.11) ppm. Irrigation water had a B concentration of 0.11 to 0.15 ppm B from May to July, then 0.29 ppm during Aug-Sept when source changed from Arkansas river to deep well. Foliar B applied at 0.25 lb/acre foliar on June 14 (flowering) and again on July 12 (the 0.50 lb/acre rate), the mature green fruit stage.

This is observed consistently with tree fruits (Perica et al., 2001; Peryea, 2005) and was observed at the Rocky Ford location in this study. Thus, perhaps the flower cluster should be considered as the sampling tissue for tomato to determine B critical values. The higher values may differentiate more clearly between sufficient and deficient levels (Gupta, 1993).

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