Effect of Foliar Boron Sprays on Yield and Fruit Quality of Citrus[1]

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Abstract

Deficiency of boron (B) in citrus has serious consequences for tree health and crop production. There is evidence that B deficiency may be a problem in Arizona citrus. Certainly, many symptoms of B deficiency are apparent, especially on the Yuma Mesa. A field trial was conducted at Yuma, Arizona to examine the effect of foliar boron application on fruit yield and quality of Citrus sinensis and C. limon. Boron was applied to 5 year old Citrus sinensis cv. Hamlin and C. limon cv. Rosenberger Lisbon trees at 5 different concentrations (0 ppm, 500 ppm, 1000 ppm, 2000 ppm, 3000 ppm) either before flowering or after flowering. At harvest, fruit yield and quality, and boron concentrations were determined. Foliar application appeared to increase leaf boron concentration (r= 0.50, p=0.004). Fruit set was increased in Hamlin trees receiving bloom and post bloom applications of boron at the 1000 ppm level. Boron applications had no significant effect on lemon yield in these studies. This fruit set increase in Hamlin accounted for a 35% increase in overall yield relative to control trees. However, there was no significant difference in fruit weight, fruit pH, titratable acidity, peel thickness, juice volume, or soluble solid content of the fruits among treatments. Previous studies indicate that boron influenced in vivo and in vitro pollen germination in many crops. A plausible explanation for increased fruit yield may be that the applied boron was transported to the flowers where it exerted its influence of increased fruit set through an effect on pollen viability and/or pollen tube growth. However, clearly boron supplementation must be performed judiciously to avoid fruit drop from over-application of the element.

Introduction

Boron (B) is a micronutrient that is often thought to be toxic to many crops, even at low concentrations in leaves. However, deficiency of B is equally serious, and may be a problem in Arizona citrus. Certainly, many symptoms of B deficiency are apparent in Arizona citrus and especially on the Yuma Mesa. Prior research indicates that B application increases crop yield and quality. Boron application was correlated with increased yield of soybean (Schoen and Blevins, 1990), alfalfa (Gizzard and Matthews, 1942), sour cherry (Hanson, 1991), and canola (Porter, 1993). Boron deficiency reduced the yield of maize (Mozafar, 1989), wheat (Rerkasem and Loneragan, 1994), and reduced the yield and fruit quality of tomato (Lopez *et al.*, 1988).

The effects of B deficiency on vegetative growth of citrus are well known, and occur when leaf B concentrations are less than 15 ppm. Some of these symptoms include translucent or water-soaked flecks on leaves and

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deformation of those leaves, yellowing and enlargement of the midrib of older leaves, death and abortion of new shoots, dieback of twigs, and gum formation in the internodes of stems, branches and trunk tissue (Reuther *et al.*, 1968). Many of these symptoms are seen in Arizona.

Furthermore, the supply of B needed for reproductive growth in many crops is greater than that needed for vegetative growth (Mengel and Kirkby, 1982, Marschner, 1986; Hanson, 1991), and the same may be true in citrus. Boron appears to accumulate in citrus peel to a much greater extent than in the leaves, ranging in lemon peel from 1600 to 3500 $ug \cdot g^{-1}$ (Sinclair, 1984). Concentrations of B may be higher in flower parts as well. It is entirely possible that Arizona citrus appearing to have adequate B for vegetative growth may exhibit deficiency symptoms during flowering, fruit set, and fruit maturation. In citrus, B deficiency leads to low sugar content, granulation and excessive fruit abortion (Reuther *et al.*, 1968) as well as rind thickening; symptoms that are seen regularly in fruit grown here in Arizona, particularly on the Yuma Mesa. Therefore, we examined whether supplemental foliar B sprays improved citrus growth, fruit set and fruit quality.

Materials and Methods

Plant Material and Treatments. The experiment was conducted in a 5 year old block of *Citrus sinensis*. The split plot design contained 3 blocks and 2 spray times. Foliar applications of boron were made at rates of 500, 1000, 2000, and 3000 ppm during the spring of 1995, prior to flowering and one month after flowering. In each block, each treatment was applied to a row of 14 trees. Fruit number was recorded from three trees per treatment. Mature fruits were harvested weighed, and the peel thickness was determined. Fruit juice was extracted for determination of titratable acidity, juice pH, and soluble solid content using a pH meter and a refractometer, respectively. Four leaves were collected from each tree in each treatment at fruit maturity. These leaves were pooled for each treatment, washed in 5% HCl, dried in a 70°C forced air oven and leaf boron was determined using a microwave digestion method (Pennington *et al.*, 1991) and ICP analysis. Using this procedure the mean elemental compositions of 3 samples of National Bureau of Standard (tomato leaves) were measured to ensure that the nutrient concentrations were within the referenced standard error. A nitric acid digestion was used for P and K analyses. Leaf samples were completely digested in 250 mg aliquots in 3 ml concentrated HNO_3 at 125°C. P and K were determined spectrophotometrically. Zn, Cu, Mg, Mn, and Ca were measured using atomic absorption spectrometry.

Determination of Soluble Sugars and Starch. Flowers were collected throughout development to determine the levels of several soluble sugars and starch in the whole flower and in the pollen. HPLC was performed using a Carbopac PA-1 column and pulsed amperometric detection, to determine the sugars. Starch was determined as in Haussig and Dickson (1979), with the glucose oxidase method described in the Sigma Technical Bulletin # 510. Starch content was calculated by multiplying glucose content by a coefficient of 0.9.

Statistical Analysis. Analysis of variance (ANOVA) was done using SAS. Pearson and Spearman Correlation studies were done for normally distributed and non-normally distributed raw data respectively.

Results and Discussion

Boron applications had no significant effect on lemon yield or any other parameters measured in these studies. An analysis of variance demonstrated that there was a significant difference in yield (Table 1) and fruit number per Hamlin tree (Table 2) among treatments and with timing of application of boron. Although the 500 ppm treatment gave the highest number of fruit set per tree, it was not significantly different from the control treatment (Fig. 1). The 1000 ppm treatment gave significantly higher fruit set relative to the control treatment. The highest significant fruit yield was obtained with post bloom application of 500 ppm boron (Fig. 2).

There was a positive correlation between applied boron and leaf boron concentration (Fig. 3), suggesting that once applied boron was mobilized from the leaves. To examine whether other nutrients influenced boron's effect we analyzed other leaf micronutrients. There were no significant correlations between boron concentration and other micronutrient concentrations. Fruit granulation was a problem in the Hamlin block. To examine whether applied boron had any effect on granulation we measured the amount of juice produced by fruits in different treatments. There was no significant difference in juice volume. We also found no significant differences among treatments for fruit weight, fruit pH, titratable acidity, peel thickness, or soluble solid content among treatments. However, there was an apparent trend of increasing fruit weight with increasing boron application for the pre-bloom application time (Fig. 4). This must be viewed as simply an effect of the decreased fruit set (Fig. 1) on the relative demand for photosynthates to each developing fruit.
Studies of other crops indicate that boron influences *in vivo* and *in vitro* pollen germination (Pierson et al., 1994; Dabas and Jindal, 1981; Misra, 1972). A plausible explanation for increased fruit yield may be that the applied boron was transported to developing flowers where it increased fruit set improving pollen viability and/or pollen tube growth. Boron requirement for reproductive growth in many crops is more than that needed for vegetative growth (Mengel and Kirkby, 1982; Marschner, 1986; Hanson, 1991). Application of boron in the pollen growth media increased pollen germination percentage, pollen tube length in wheat (Cheng and Rerkasem, 1993), lily (Polster, 1992), avocado (Robbestse *et al.*, 1990) and olive (Viti *et al.*, 1990). Boron deficiency caused poorly developed pollen and anthers in wheat (Li *et al.*, 1978; Rerkasem *et al.*, 1989; cited from Cheng and Rerkasem, 1993). Boron content of stigma and stile was found to be important for pollen germination in maize (Vaughn, 1977). The significant increase in fruit set suggests that it is likely that fruit set is increased with boron application. It is likely that flower abortion with pre-bloom B applications at the higher B concentrations lowered yield, while post bloom application resulted in relatively higher yields (Fig. 1).

To investigate the effect of boron on fruit yield and it's mechanism, pollen viability and pollen tube growth analysis techniques were developed specifically for citrus (Fig. 5). The highest pollen germination rate was obtained at a level of 44%. This level will become the target we will seek to achieve in our field studies as we assess the levels of sucrose and boron that are present in the pollen or the growth medium for pollen in an intact flower (the transmitting tissue of the floral pistil). In addition, our sampling of flowers at the Phoenix site (Cactus Lane Ranch) shows significant differences in soluble sugar and starch contents of flowers during development. The highest levels of both pools were at ten days post floral bud emergence. This is the point at which we noted the greatest pollen viability and pollen tube growth. It is this window that we hope to impact by boron applications in subsequent experiments.

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Table 1. Anova for fruit number

Source	Df	F value	P value
Block	2	1.40	0.27
Treatment time	1	6.10	0.02
Treatment	4	3.69	0.02
Trt time*Trt	4	2.10	0.13

Table 2. Anova for fruit yield

Source	Df	F value	P value
Block	2	0.83	0.45
Treatment time	1	3.83	0.06
Treatment	4	4.39	0.01
Trt time*Trt	4	2.10	0.11

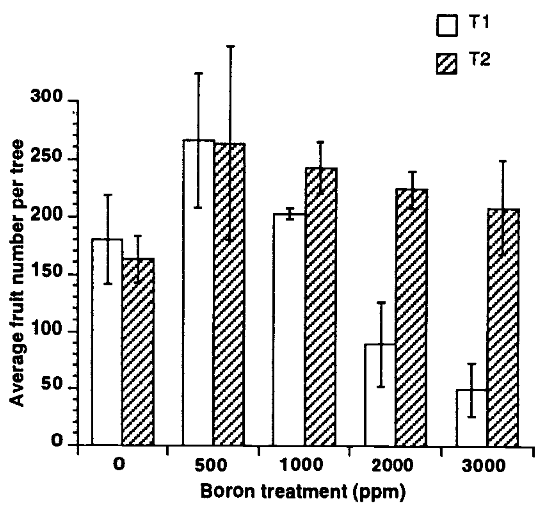

Figure 1: Average fruit number per tree at 0, 500, 1000, 2000, and 3000 ppm boron appliedd either at bloom (T1) or 4 weeks post bloom.

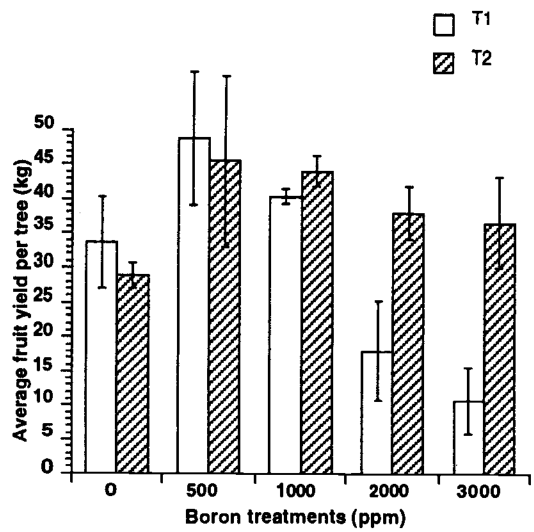

Figure 2: Average fruit yield per tree at 0, 500, 1000, 2000, and 3000 ppm boron applied either at bloom (T1) or 4 weeks post bloom (T2).

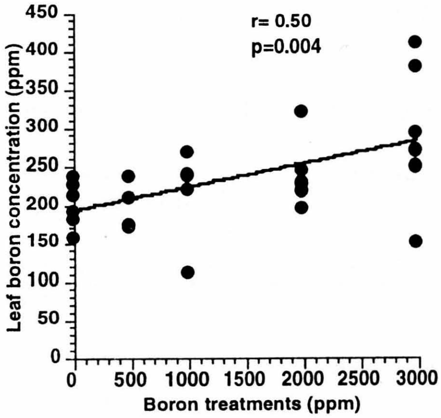

Figure 3: Correlation between the applied boron treatments and leaf boron concentration.

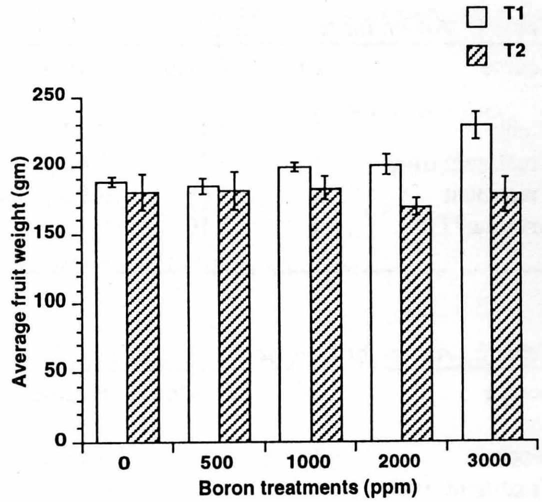

Figure 4: Average fruit weight (gm) at 0, 500, 1000, 2000, and 3000 ppm boron applied either at bloom (T1) or 4 weeks post bloom (T2).

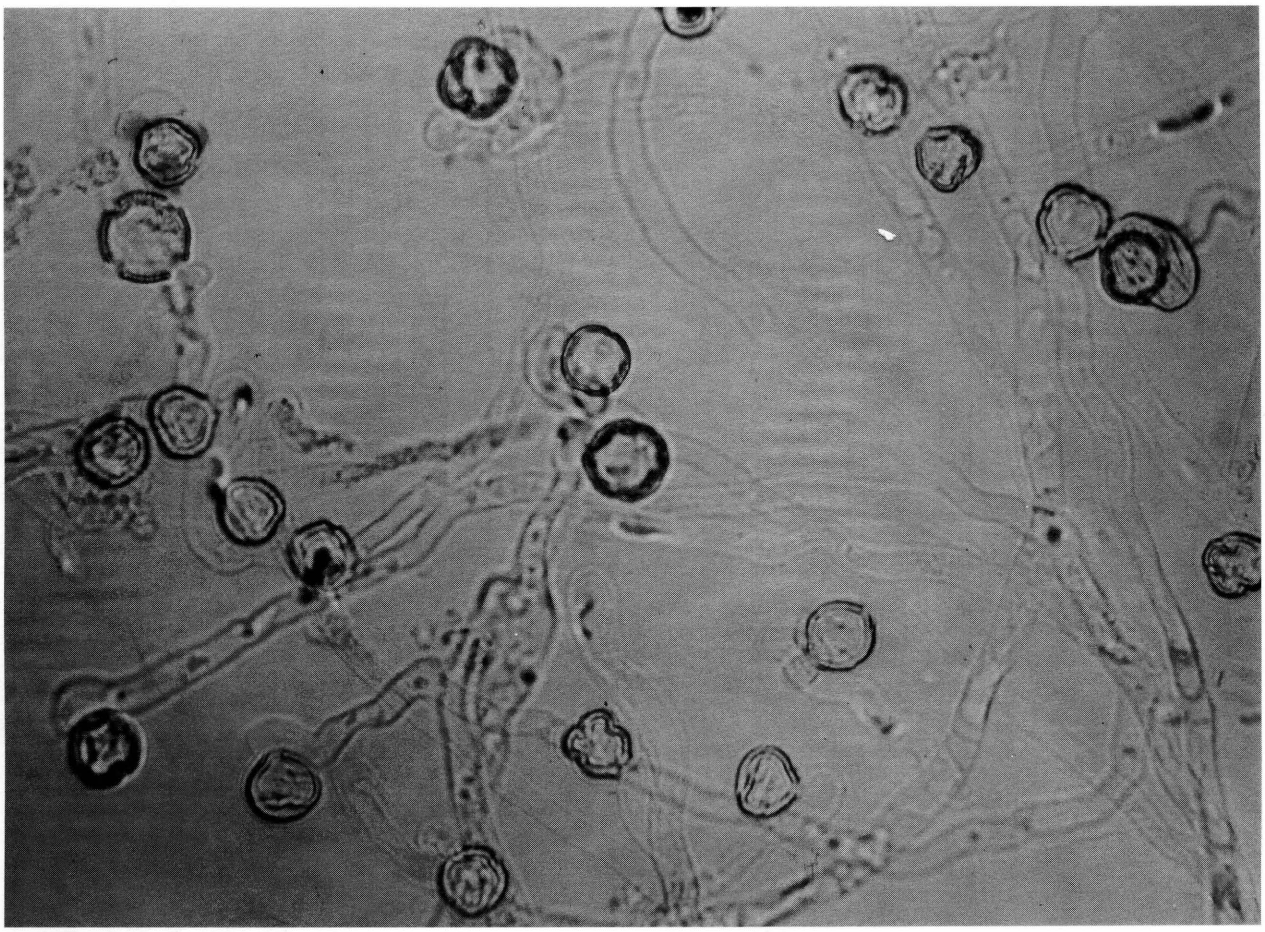

Fig.5. *In vitro* pollen germination.