BORON FERTILIZATION OF CHILE PEPPER UNDER GREENHOUSE CONDITIONS

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ASTRACT

Many chile (*Capsicum annuum*) growers apply boron (B) without knowing if B is actually needed. The application of B has been suggested to improve specific conditions that limit chile productivity such as alleviating blossom-end rot. Two varieties of chile were grown (159 days) under greenhouse conditions in silica sand and irrigated with seven levels of B (no B, 0.025 mg L^{-1}, 0.05 mg L^{-1}, 0.1 mg L^{-1}, 0.25 mg L^{-1}, 0.5 mg L^{-1}, 1.0 mg L^{-1}) and complete nutrient solution. Leaf B increased linearly with B application, but leaf Ca, pod Ca, and pod B were not affected and therefore had no affect on nutrient induced blossom-end rot. Development of a more definitive response curve of chile plant growth and leaf tissue B will help farmers to determine if B fertilization is necessary.

INTRODUCTION

Chile is used as a coloring agent, spice, ornamental decoration, food, therapeutic agent, and as a valuable source of vitamins A, C and B-complexes (Ochoa-Alejo et. al., 2001). Economically, chile in New Mexico had an estimated 60,140 tons (NMDA. 2008). Chile is the signature cash crop of New Mexico, and its growth and consumption is part of the culture.

The application of B has been suggested to improve specific conditions that limit chile pepper productivity. Boron application is believed necessary to increase the utilization of Ca in plants for the development of fruit and to decrease the incidence of blossom-end rot (Goldberg, 2004). Although New Mexico soils usually have sufficient B, growers are often advised to apply B if the tissue or petiole B concentrations fall below a critical level. Some have questioned the need for B application because no critical level of B has been determined for chile.

Most soils have B concentrations between 2-200 mg kg^{-1} and most frequently from 7-80 mg kg^{-1} (Havlin et al., 2005). Notable arid regions containing high B concentrations in water and soil include San Joaquin Valley, Callifornia (Wimmer et al., 2003), Rio Grande Valley, Texas (Picchioni et al., 2000), Negev region, Israel (Yermiyahu et al., 2006), Jordan River Valley, Israel and Jordan (Yermiyahu et al., 2008), and South Australia (Marcar et al., 1999).

The primarily form of B taken up by plants is boric acid (H_3BO_3) and H_2BO_3. Once inside root cells, boric acid is readily transported in the xylem to leaves. Boron translocation in the phloem from leaves to other plant parts is restricted, resulting in B accumulation in older leaves (Havlin et. al., 2005). The primary function of B in plants is to give the cell wall structural integrity (Savic.et al., 2007). Boron provides cross links between cell wall polysaccharides that give structure to the cell wall – important for cell expansion and control of lignin production, regulation of H^+ transport, and retention of cellular Ca^{+2} (Havlin et. al., 2005). Adequate B levels increase flower production, retention, seed and fruit development.

Typically, B concentration in plant tissues ranges from 5 to 300 mg kg^{-1} on a dry weight basis (Epstien. et al., 2005). In dicots like chile, B ranges between 20 to 60 mg kg^{-1} (Havlin et. al., 2005), but the range of B concentration in tissue varies with species, and cultivars of the same plant species demonstrate a variable response to a specific nutrient supply or deficiency (Gill et al., 1994; Rashid et al., 2002b; Rerkasem and Jamod, 1997). Plant nutrient levels published in the literature focus on tomato but B concentrations vary, and a B critical level has not been established for any chile pepper or related species. In spite of boron's wide use, the literature has only identified the plant B critical levels to range from 20 to 60 mg kg^{-1} (Havlin et. al., 2005).

Boron deficiency symptoms in chile have not been rigorously reported in the research literature. Blossom-end rot is frequently attributed to inadequate B by the chile industry, but no data exists to substantiate the role of B or the critical level of B necessary to avoid B deficiency induced blossom-end rot. Hence, many farmers apply boron without adequate knowledge.

Boron toxicity in plants occurs when B accumulates in older foliage because translocation in the phloem from leaves to other plant parts is restricted. The older foliage may exhibit leaf edge burning or necrosis, off coloring, and stunting of plant growth may occur. While B toxicity is uncommon in most arable soils, B toxicity may occur naturally or develop because of high B concentrations in irrigation water and/or poor drainage.

The rotting or discoloration at or near the end of peppers is called blossom-end rot (Epstein et. al., 2009). Blossom-end rot has long been associated with Ca deficiency. Current blossom-end rot studies mostly focus on tomato and is an often-observed physiological disorder resulting from Ca deficiency in fruit (Marcelis et al., 1999). The same symptom is also found in sweet pepper (Karni et al., 2000). The incidence of blossom-end rot is regarded as a symptom of damaged permeability of cell membrane and cell wall structure due to Ca deficiency. Since Ca is not translocated from the older to the younger tissues, the younger tissues are more susceptible to Ca deficiency. Symptoms occur in the actively growing tissues, such as flowers and developing fruit. Similarities also exist in transport mechanisms of Ca and B within the plant and their role in stabilizing cell-wall structures (Liebisch et al., 2009). Thus, the interaction of B and Ca in regards to blossom-end rot is of interest. Some in the chile industry believe that better irrigation practices can prevent blossom-end rot regardless of plant B levels.

The long term goal of our research is to establish a critical level of B in chile. We report here the affect of B application on chile under greenhouse conditions. Field research and additional greenhouse studies are also underway.

METHODS

A pot culture experiment was conducted under greenhouse conditions from March 11, 2010 to August 17, 2010 at the New Mexico State University Skeen greenhouse. The design structure was a complete randomized design with five blocks. The experimental factors were B levels and chile cultivars. The cultivars were two commonly grown cultivars of NM long green chile pepper, AZ #20 and NuMex Joe E. Parker. Seeds were planted in 33 cm diameter by 25.4 cm deep (~5 gallon) plastic containers. The plastic containers had holes at the bottom for drainage. The growing medium was leached silica sand.

Six seeds were planted per pot on March 11 and eventually thinned on June 14 to one plant per pot. Seeded pots were irrigated with de-ionized water from March 11 to April 15 with half-strength nutrient solution minus B (Table 1). From April 15 to May 14, pots were leached with de-ionized water every other day and irrigated once a week with half-strength nutrient solution minus B. From May 14 to June 7, pots were irrigated with full strength nutrient solution minus

B. From June 7 until harvest pots were irrigated every other day with complete nutrient solution modified with different levels of B and leached once a week with de-ionized water. Malathion was used for insect control.

Table 1. Nutrient Solution

Nutrient	**Nutrient Formula**	**Stock Solution**
		--- g $10L^{-1}$ ---
Calcium Nitrate	$Ca(NO_3)^2$	1079
Potassium Nitrate	KNO_3	503
Magnesium Sulfate	$MgSO_4$*$7H_2O$	503
Potassium Phosphate	KH_2PO_4	288
Iron Chelate	$FeSO_4$*$7H_2O$	48
Manganese Sulfate	$MnSO_4$*H_2O	1.50
Zinc Sulfate	$ZnSO_4$*$7H_2O$	0.20
Copper Sulfate	$CuSO_4$*$5H_2O$	0.05
Molybdic acid	H_2MoO_4 H_2O	0.03

A total of seven B treatments were applied during the vegetative growth stage starting on April 15, 2010. The seven treatments applied were 0.0 mg L^{-1}(control), 0.025 mg L^{-1}, 0.05 mg L^{-1}, 0.1 mg L^{-1}, 0.25 mg L^{-1}, 0.5 mg L^{-1}, 1.0 mg $L^{-1}$of H_3BO_3 dissolved in the nutrient solution.

Plants were subjectively evaluated for bud and/or flower formation, insect occurrence, color and other parameters throughout their growth. Bud and flower formation counts were taken August 6, 2010 and on August 23, 2010. The silica sand was periodically checked for pH (saturated paste) and electrical conductivity (saturated paste extract) to assure no salinity development. At harvest (159 days from planting) above ground vegetative tissue and pod were harvested and fresh weights determined. Pod and leaf tissue were washed with de-ionized water plus a mild detergent and rinsed three times with de-ioniozed water. All samples were weighed, dried at 65^{o}C for 72 hours, reweighed, and then ground.

Total plant B and other nutrients (Ca, S, P, Fe, Mn, Mg, Cu, and K) were determined by microwave digest and nutrient analysis inductively coupled plasma - emission spectroscopy. The results were analyzed by general linear model using SAS (SAS Institute, Cary, N.C. 1997).

RESULTS AND DISCUSSION

Silica sand pH averaged 6.7 and the EC (saturated paste extract) averaged 1.3 dS/m. Aphid infestation occurred but no trend of infestation occurred on any particular treatment.

The control plants (0.0 mg kg^{-1} applied B) were stunted, necrosis occurred at many nodes, and the middle to upper canopy leaves were chlorotic. The highest treatment (1.0 mg kg^{-1} applied B) had marginal scorching and necrosis in the lower canopy leaves. Plants looked healthiest between 0.025 - 0.5 mg kg^{-1} applied B. Bud and flower formation counts taken on August 6, 2010 were not significantly affected by B. Flowering was not significantly affected by B application on August 23, 2010, but bud counts were significantly affected ($p>0.0001$). Bud counts were significantly lowest for control treatment. No blossom-end was found at any B application rate.

Neither variety nor treatment by variety interaction were significant ($P> 0.05$) for most parameters, thus the means presented include both varieties (n=10).

Boron application significantly (P=0.0001) increased leaf B at harvest (Fig. 1). The R^2 of 0.98 indicates a liner relation between B application and uptake. B application had no effect on pod B concentration (data not shown). Boron application did not significantly (P>0.05) increase leaf Ca (Fig. 2) or pod Ca (data not shown). Pods averaged 7.8 mg kg^{-1} Ca while other plant nutrients were generally not affected by B application (data not shown). We conclude that leaf B concentration had no affect on leaf or pod Ca concentration.

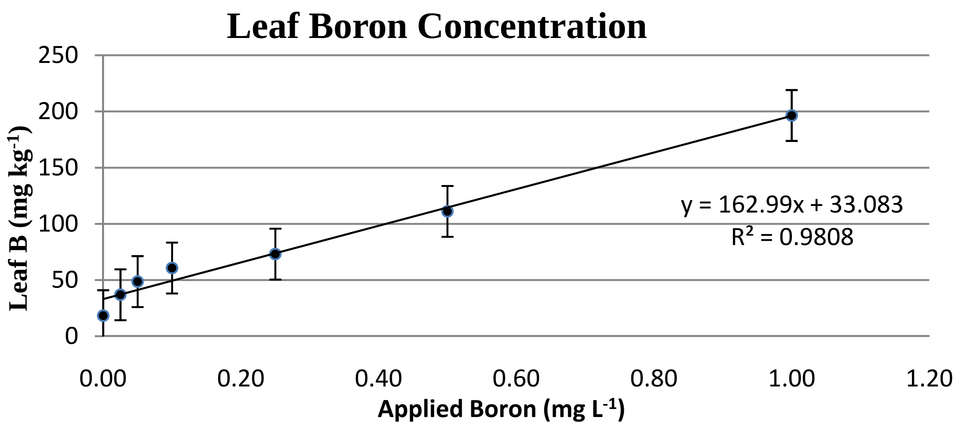

Figure1. Mean (n=10) B concentration of chile leaf tissue under greenhouse conditions in response to B application. Bars are standard error bars.

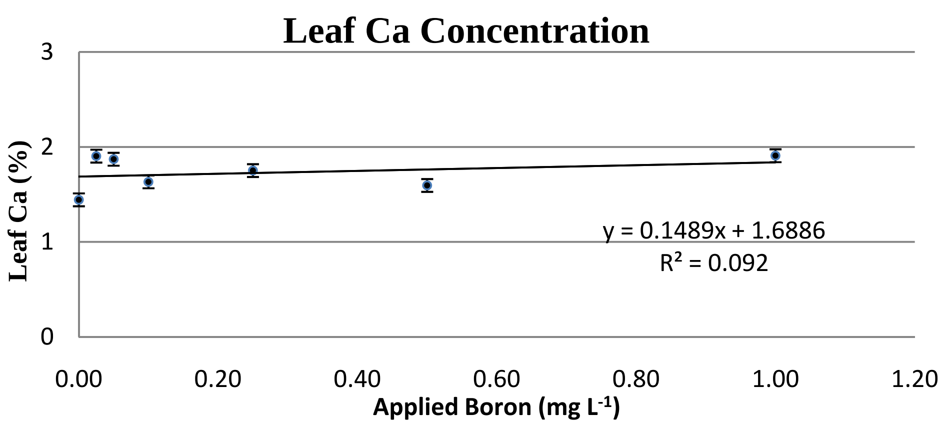

Figure 2. Mean (n=10) Ca concentration of chile leaf tissue under greenhouse conditions in response to B application. Bars are standard error bars.

Vegetative dry weight at harvest significantly increased (P=0.0001) with B application (Fig. 3 and Fig. 4) but most of the weight gain occurred between the control and 0.03 mg L^{-1} B application rate. Boron application had no significant effect on pod dry weight and pod count (data not shown). Pod dry weight averaged 2.4 g and pod counts averaged 1.6 pods $plant^{-1}$.

A second greenhouse experiment will be conducted in spring 2011 and a second field study will be conducted in summer 2011. Results from Fig. 1 show that B treatments may need to be decreased to allow for a detectable critical value under greenhouse conditions in response to B application. A field experiment was also conducted in 2010 and the data is still being analyzed. A second field study will be conducted in summer 2011.

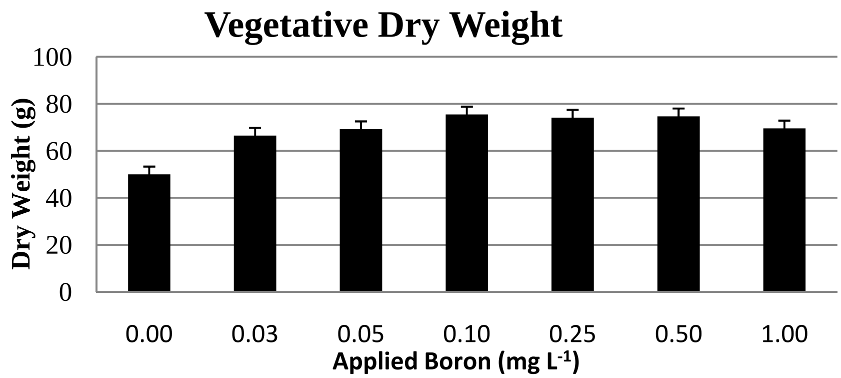

Figure 3. Mean (n=10) vegetative dry weight of chile plants under greenhouse conditions in response to B application. Bars are standard error bars.

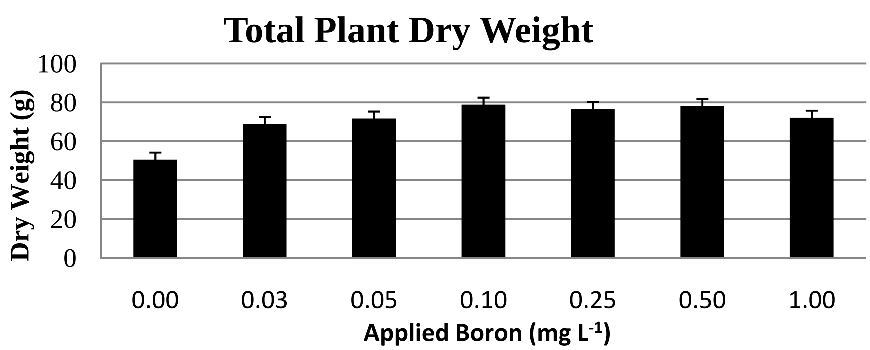

Figure 4. Mean (n=10) total plant dry weight of pod tissue under greenhouse conditions in response to B application. Bars are standard error bars.

SUMMARY

Under greenhouse conditions, leaf B increased linearly with B application, but leaf Ca, pod Ca, and pod B were not affected. These results imply that leaf B has no affect on pod B or Ca and therefore no affect on nutrient induced blossom-end rot. Under field conditions, where more water stress occurs, the interaction of water, B, and Ca might be more important for chile yield and blossom-end rot occurrence. Hopefully, our field experiments will clarify this point. Also, we will develop a more definitive response curve of chile plant growth and leaf tissue B by using lower levels of B in the media so chile farmers will know B fertilization is necessary.

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