Boron Distribution and the Effect of Lime on Boron Uptake by Pansy, Petunia and Gerbera Plants

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Abstract

Reports of boron (B) deficiency have become more prevalent in pansy (*Viola* ×*wittrockiana)*, petunia (*Petunia* ×*hybrida*), and gerbera (*Gerbera jamesonii*) plug production. When symptoms are observed in production the presence and severity of symptoms have no obvious pattern; symptomatic plants can be located adjacent to asymptomatic plants in the same plug flat. The availability of B in the soil decreases as soil pH increases. 'Yellow Dynamite' pansy, 'White Storm' petunia, and 'Festival Apricot' gerbera seedlings were grown in a peat:perlite substrate that was amended with pulverized dolomitic limestone at a rate of 3,560, 4,746, 5,933, or 11,866 g/m^3. As the rate of lime incorporated into the substrate increased so did soil pH and shoot tissue concentrations of Ca while shoot tissue concentrations of B decreased. Many commercially available germination substrates are amended with macro- and micro-nutrient fertilizers as fertilizer granules. Relatively small amounts of each element are incorporated into the substrate and uneven mixing could result in varying amounts of nutrients in individual cells of a plug flat. This variability could lead to nutrient deficiencies early in the crop cycle. Six commercially available germination substrates were used to fill plug flats and individual cells were sampled and analyzed for B concentrations. Of the substrates tested, there was no variation in B concentration from cell to cell.

INTRODUCTION

Boron (B) is available to plants as boric acid [$B(OH)_3$] (Marschner, 1995). As with most other elements, boron availability is pH dependent and is more readily available with pH values <6.0 (Gupta, 1993). The pKa of B is at pH 9.25, therefore B is found as boric acid at lower pH values and as unavailable borate at higher pH values. The application of lime has been observed to cause temporary B deficiency in plants (Goldberg, 1993).

The pH of a substrate may increase over time due to the basic effects of alkalinity in irrigation water or the practice of liming substrate. Irrigation water alkalinity would only account for the occurrence of boron deficiency late in the production cycle due to the lag time required for the alkalinity to increase the substrate pH. In addition, if one would expect this to be the primary cause of boron deficiency, its prevalence should be much greater in the Midwest US and US Plains states where high alkalinity is a problem - and practically nonexistent in the Southeast US where the water is of low alkalinity. Observations of pansy, petunia and gerbera crops over the past several years do not support this; severe incidents have been seen at a large North Carolina greenhouse with excellent water quality (pers. commun., Sim McMurray, Metrolina Greenhouses, Huntersville, N.C.). Liming of the substrate, if done well in advance of sowing, could cause boron to become unavailable earlier in the production cycle. The use of sphagnum

peat for a root substrate makes liming a common practice in greenhouse operations, and the use of finer grades of lime can reduce the time needed to raise the substrate pH. Plug producers have developed production guidelines that control excessive alkalinity in the irrigation water (target level of 0.8 to 1.3 meq for most crops) and monitor the substrate pH to ensure it is within the acceptable pH range of 5.4 to 6.0 (Dole and Wilkins, 2005).

In addition to being amended with lime, substrates are also amended with macro- and micro-nutrients. Typically the amount of B added to a substrate before use is 11.78 g per cubic meter (m^3). This requires that 11.78 g of B be evenly distributed so that when 288-plug flats are filled there is a consistent amount of B and all other nutrients in each cell. Even though growers are applying B to plugs as a liquid feed, which does not usually occur until several days after germination, B deficiency symptoms are still observed. In previous studies we were able to determine that when the plant is temporarily deprived of B the plant can exhibit B deficiency symptoms which persist after B was reintroduced (Krug, 2007). If the B distribution is not consistent when plug flats are filled this could be a cause of a temporary B deficiency in plug crops beginning at germination and explain the erratic pattern of symptoms within a plug flat.

High calcium (Ca) levels in the substrate can also negatively affect the levels and availability of B. Soils high in Ca generally will have a high pH, making B less available to the plant (Gupta, 1993). In tomato plants it has been reported that as Ca concentrations increased, so did the severity of B deficiency (Reeve and Shive, 1944). Like B, Ca is also commonly added to the substrate before use and distribution could be inconsistent.

The first objective of these studies was to determine how different liming rates, and in turn the substrate pH, can affect the plant availably of B. The second objective was to determine if Ca and B distribution was consistent throughout a plug flat in several different commercially available germination substrates.

MATERIALS AND METHODS

Experiment 1

Berger peat moss (Berger Peat Moss, St. Modeste, Quebec, Canada) was combined with perlite to create a 80:20 peat:perlite mix (by volume). The substrate was amended with pulverized dolomitic limestone at a rate of 3,560, 4,746, 5,933 or 11,866 g/m^3. On 9 May 2007 'Dynamite Yellow' pansy, 'White Storm' petunia and 'Festival Apricot' gerbera seeds were sown in 288-plug trays cut into 6×6 cell flats (each cell: 2×2×3 cm deep), one seed per cell. The experiment was a completely randomized design with 8 flats (36-cell) of each treatment. Once sown, the seeds were placed in a growth chamber with temperature set point of 20°C. Light was provided by fluorescent bulbs with a PPFD of 24 to 75 μmol m^{-2} s^{-1} at plant canopy for 12 h per day. On 17 May (8 days after seeding, DAS) the pansy, petunia and gerbera seedlings were moved to a greenhouse with the day/night temperature set points of 23.9/17.8°C. Plants were fertilized at each watering after germination with 50 mg L^{-1} N from Champion 13-2-13 Plug Special (Scotts, Marysville, Ohio) (13N-0.86P-10.79K). A fifth treatment with 8 replications was included where the substrate was amended with 11,866 g/m^3 lime and weekly foliar sprays of B at 0.25 mg L^{-1} were applied.

Electrical conductivity (EC) in mS/cm and pH were determined weekly using a Cardy Twin EC (Spectrum Technologies, Inc. Plainfield, Ill.) and a Cardy Twin pH Meter (Spectrum Technologies, Inc. Plainfield, Ill.), respectively, according to the Press Extraction Method (PEM) as described by Scoggins et al. (2000).

Pansy, petunia and gerbera plants were harvested on 19 June 2007. Plants were severed at the base of the stem and plants from two individual flats, excluding the outside edges (32 plants), were combined into one replication. The experiment was a completely randomized design with 4 replications per treatment.

Experiment 2

Five 288-plug flats were filled from each of 6 different commercially available

germination substrates. The substrates were Berger BM2, Fafard Superfine GM (Fafard Anderson S.C.), Sun-GroRedi-earth, LG-3 and LP-5 (Sun-Gro Horticulture, Bellevue, Wash.), Premier Pro-Mix PGX (Premier Horticulture, Dorval, Quebec, Canada). Substrate was collected from 9 cells from each flat. Using the procedure described in Experiment 1, 9 cells of each flat were tested for EC and pH. For statistical comparison of nutrient concentration, pH, and EC a total of 3 blocks were taken from each soil mix, with a block being a combination of 3 subsamples from each of 5 separate flats.

Tissue Analysis

To determine tissue B concentration, tissue samples were rinsed in deionized water, then washed in 0.2 N HCl, and again rinsed in deionized water. The samples were then oven dried at 70°C for 72 h. Dried tissue was ground in a stainless steel Wiley mill through a 1 mm screen (20-mesh) and 0.15 g was digested in a microwave digester (MARS; CEM Corp, Matthews, N.C.) using a modified EPA method (EPA method 3051 with additional peroxide step). Nutrient content, except N, was determined with inductively coupled plasma optical emission spectroscopy (ICP-OES; Model IRIS Intrepid II, Thermo Corp., Waltham, Mass.). A quality control was run every ten samples and if any element was determined to be more than 10% higher or lower than the standard value, the instrument was recalibrated. Tomato standards (NIST reference material 1573) were compared every 20 samples and tomato and spinach standards (NIST reference material 1570a) were compared every 40 samples.

Growing Media Analysis

To determine the plant available B concentrations of the substrates a saturated media extract (SME) as described by Warncke (1986) was used. Using the collected solution from the SME nutrient concentration, except N, was determined with ICP-OES as described above.

Data Analysis

Data were tested by analysis of variance (ANOVA) using general linear model (SAS Institute, Cary, N.C.) and means were separated by least significant differences (LSD) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Experiment 1

Plant species had no significant effect on the substrate pH; therefore, the means of the species, over time, were pooled. The substrate pH increased as lime rate increased (Fig. 1). The lowest lime rate (63,560 g/m^3) resulted in a pH of 5.82 while the highest treatment rate (11,866 g/m^3) resulted in a pH of 7.19. There was no effect on EC either by species or lime rate (data not shown).

Symptoms of B deficiency were not observed for any species or at any lime rate. The 11,866 g/m^3 treatments had a B concentration lower than any other treatment in the study for all three species (Fig. 2). Shoot tissue B concentrations for the 11,866 g/m^3 treatments in pansies and petunias were only slightly higher than those reported to cause B deficiency symptoms in fully expanded mature leaves from transplanted pansy or petunia plants, 72 or 102 DAS, respectively (Pitchay, 2002). Shoot tissue B concentrations for the 5,933 and 11,866 g/m^3 treatments in gerberas were lower than optimal levels for gerberas 2 weeks after transplant when fertilized with 50-75 mg L^{-1} N (Whipker et al., 2007). The negative effect on B concentration by the 11,866 g/m^3 lime rate was overcome by the weekly foliar applications of B in all three species [22.65, 16.13 and 24.09 mg L^{-1}, respectively for pansy, petunia and gerbera ($P \leq 0.05$)]. The increase in substrate pH due to increased lime rates could be one cause of lower concentration of B, as B is less available at higher pH values (Peterson, 1982). Dolomitic limestone is a source of Ca; consequently as the rate of lime incorporated into the substrate increased so

did the Ca concentrations in all three species (Fig. 2). Increased Ca uptake can have an antagonistic effect on B causing a decrease in the uptake of B by the plant (Reeve and Shive, 1944).

Experiment 2

There were no significant ($P \leq 0.05$) differences in plant available B concentrations, substrate pH or substrate EC for any of the six substrates in this experiment (Table 1). Fafard Superfine GM was the only substrate with values lower than the range for B (0.05-0.5 mg L^{-1}) as recommended by the Scotts Co. (Keith Santner, pers. commun.) (Table 1).

CONCLUSION

Increasing the amount of lime incorporated into the germination substrate increased substrate pH and tissue Ca concentration, and therefore decreased the tissue concentration of B. Plug growers should only incorporate sufficient lime to raise the substrate pH to 5.5 to 6.0. In addition, growers should monitor substrate pH and take any corrective measures to maintain a proper substrate pH. Plug growers can apply foliar sprays to increase B concentration in shoot tissue and may consider applying a supplemental drench of B at the time of sowing to ensure an adequate amount of B is available to the plant at germination. Non-uniform distribution of B is not the cause of sporadic symptoms of B deficiency in gerbera, pansy and petunia plug crops as all substrates sampled had even B distribution throughout a 288-plug tray.

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Tables

Table 1. Substrate plant available B concentrations (saturated media extract), pH and electrical conductivity (EC) for Berger BM2, Sun-Gro LG3, and Sun-Gro LP5 Premier Pro-Mix PGX, Sun-Gro Redi-earth, and Fafard Superfine GM soilless germination substrates.

Block[z]	B (mg L^{-1})	pH	EC (mS/cm)
		Berger BM2	
1	0.13	6.05	0.91
2	0.12	6.01	0.91
3	0.13	5.99	0.91
P-value[y]	NS	NS	NS
		Sun-Gro LG3	
1	0.08	5.32	1.06
2	0.07	5.10	1.06
3	0.08	5.18	1.05
P-value[y]	NS	NS	NS
		Sun-Gro LP5	
1	0.07	5.55	0.98
2	0.07	5.47	0.93
3	0.07	5.43	0.96
P-value[y]	NS	NS	NS
		Premier Pro-Mix PGX	
1	0.13	6.56	1.65
2	0.12	6.52	1.86
3	0.12	6.47	1.74
P-value[y]	NS	NS	NS
		Sun-GroRedi-earth	
1	0.08	5.58	1.85
2	0.09	5.46	1.88
3	0.08	5.46	1.93
P-value[y]	NS	NS	NS
		Fafard Superfine GM	
1	0.04	5.70	1.11
2	0.04	5.56	1.13
3	0.05	5.57	1.13
P-value[y]	NS	NS	NS

[z] Blocks were taken from each soil mix, with a block being a combination of 3 subsamples from each of 5 separate flats.

[y] NS - Not significant. Means are compared by substrate in columns under each element.

Figures

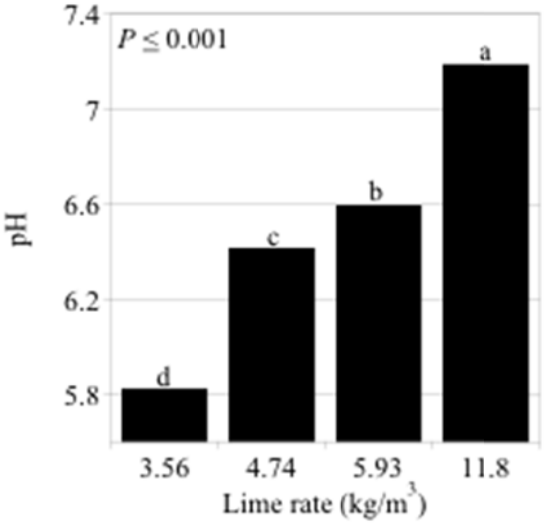

Fig. 1. Substrate pH when 'Dynamite Yellow' pansy, 'White Storm' petunia and 'Festival Apricot' gerbera were grown in substrate amended with pulverized dolomitic limestone at a rate of 3,560, 4,746, 5,933 or 11,866 g/m^3. Values are pooled means across species (pansy, petunia and gerbera), n=96.

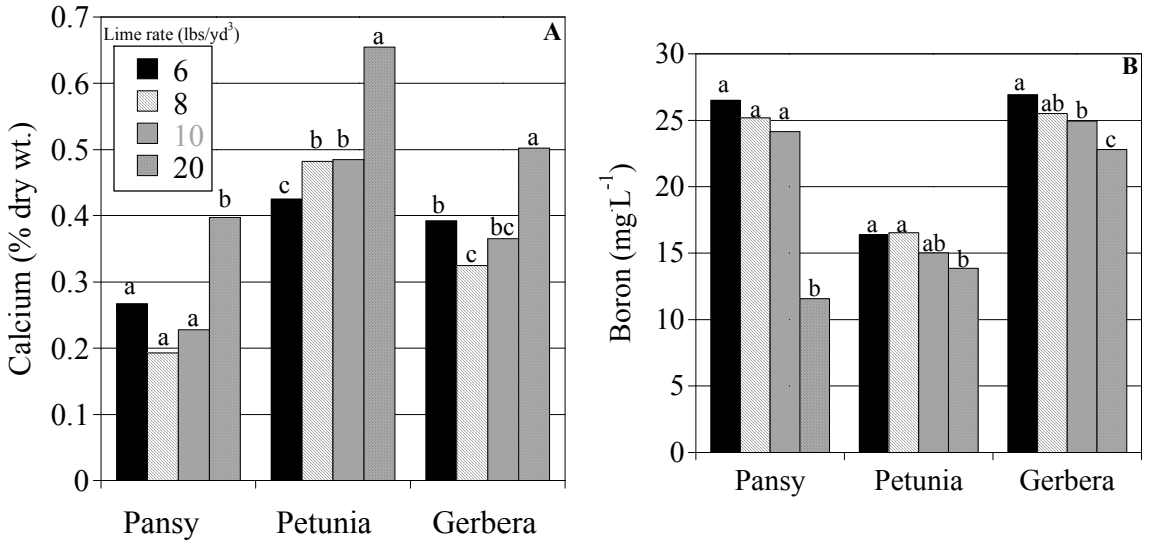

Fig. 2. Calcium (A) and boron (B) tissue concentrations for 'Dynamite Yellow' pansy, 'White Storm' petunia and 'Festival Apricot' gerbera plants at 38 d after sowing grown in a peat-based substrate amended with pulverized dolomitic limestone at a rate of 3,560, 4,746, 5,933 or 11,866 g/m^3. Means separation conducted by LSD (P≤0.05) within plant species.