

## NUTRIENT DISORDER SYMPTOMOLOGY AND FOLIAR CONCENTRATIONS OF *CLERODENDRUM THOMSONIAE*

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□ *Clerodendrum thomsoniae* plants were grown in silica sand culture to induce and photograph nutritional disorder symptoms. Plants were grown with a complete modified Hoagland's all nitrate solution. The nutrient deficiency treatments were induced with a complete nutrient formula minus one of the nutrients. Boron toxicity was also induced by increasing the element ten times higher than the complete nutrient formula. Reagent grade chemicals and deionized water of 18-mega ohms purity were used to formulate treatment solutions. The plants were automatically irrigated and the solution drained from the bottom of the pot and captured for reuse. The nutrient solutions were completely replaced weekly. Plants were monitored daily to document and photograph sequential series of symptoms as they developed. Typical symptomology of nutrient disorders and critical tissue concentrations are presented. Plants were harvested for nutrient analysis when initial symptoms were expressed. Nutrient deficiency symptoms were described and foliar nutrient concentrations provided.

Keywords: bleeding glory-bower, tropical bleeding-heart vine, glory tree, bag flower, deficiency, fertilizer, macronutrient, micronutrient, symptoms

### INTRODUCTION

*Clerodendrum* species are members of the family Verbenaceae (Bailey and Bailey, 1976) and native to tropical Africa and Asia (Huxley et al., 1992). *Clerodendrum thomsoniae* Balf., *C. x speciosum*, and *C. ugandense* are vines commercially grown as flowering potted plants. Of these species, *C. thomsoniae*

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is the most commonly grown (Dole and Wilkins, 2005). Common names include bleeding glory-bower, tropical bleeding-heart, bleeding-heart vine, glory tree, and bag flower (Bailey and Bailey, 1976).

Clerodendrum has been grown primarily in hanging baskets. Although grown commercially for years, limited information on mineral nutrition of *C. thomsoniae* appears in the literature. Sanderson et al. (1990) used weekly applications of 20.0 nitrogen (N)-8.8 phosphorus (P)-16.6 potassium (K) (20N-20P<sub>2</sub>O<sub>5</sub>-20K<sub>2</sub>O) at 400 mg·L<sup>-1</sup> N on plants grown in a growth regulator study. Alvensleben and Steffens (1989) made two applications of calcium nitrate [Ca(NO<sub>3</sub>)<sub>2</sub>] alternated with one application of 10.0N-5.2P-12.4K (10N-12P<sub>2</sub>O<sub>5</sub>-15K<sub>2</sub>O) at 100 mg·L<sup>-1</sup> N for research plants. In a trade publication, Wendzonka (1978) recommended weekly applications of an acidic fertilizer, such as 28.0N-7.9P-6.6K (28N-18P<sub>2</sub>O<sub>5</sub>-8K<sub>2</sub>O) at 431 mg·L<sup>-1</sup> N. Beck (1975) proposed applying a constant-feed at 200 mg·L<sup>-1</sup> N for the first three weeks after potting then reduced the concentration to 100 mg·L<sup>-1</sup> N. Continuation with 200 mg·L<sup>-1</sup> N beyond the first three weeks delayed flowering. Von Hentig (1987) reported clerodendrum roots can be injured by high soluble salts and Fe deficiency can occur if the pH is not maintained between 5.5 and 6.5. Koranski (1976) found iron chlorosis was a problem when pH exceeded 6.3. Limited nutrient deficiency and toxicity descriptions are unavailable for clerodendrum, yet growers must often make quick diagnoses when nutritional problems occur.

Therefore, the following research was conducted to: 1) describe visual symptoms of nutrient disorders from incipient to advanced stages of development and 2) establish foliar analysis standards by correlating nutrient levels with initial stages of deficiencies for N, P, K, calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), and boron (B) and toxicity for B in clerodendrum.

## MATERIALS AND METHODS

This experiment was conducted in the glass greenhouse at the N.C. State University Horticulture Field Laboratory in Raleigh, NC (35° north latitude) from 4 May to 12 July 2007. Rooted stem cuttings of a variegated-leaf selection of clerodendrum were transplanted on 4 May 2007 into 13.74-cm diameter (1.29-L) plastic pots containing silica sand [Millersville #2 (0.8 to 1.2 mm diameter), Southern Products and Silca Co., Hoffman, NC, USA]. Greenhouse day/night set points were 24/18 °C.

An automated, recirculating, irrigation system was constructed from PVC pipe (Charlotte Plastics, Charlotte, NC, USA). The system consisted of 48 separate irrigation lines with each line containing six openings to hold the plants. Twelve replications, each consisting of one pot with one plant, were assigned to each elemental treatment.

Plants were grown with a complete modified Hoagland's all nitrate solution: (macronutrients in mM) 15 nitrate (NO<sub>3</sub>)-N, 1.0 phosphate (PO<sub>4</sub>)-P,

6.0 K, 5.0 Ca, 2.0 Mg, and 2.0 sulfate ( $\text{SO}_4$ )-S (Hoagland and Arnon, 1950) plus  $\mu\text{M}$  concentrations of micronutrients (72 Fe, 18 Mn, 3 Cu, 3 Zn, 45.0 B, and 0.1 Mo). Thirteen nutrient disorder treatments consisted of a complete nutrient formula, 11 nutrient deficiency formulas (each devoid of one nutrient), and a B toxicity formula containing 450  $\mu\text{M}$  B. Reagent grade chemicals and deionized water of 18-mega ohms purity were used to formulate treatment solutions (Pitchay, 2002). The plants were automatically irrigated every 2 hrs with a drip system utilizing sump-pumps (Model IA, Little Giant Pump Co., Oklahoma City, OK, USA). The solution drained from the bottom of the pot and was recaptured for reuse. Nutrient solutions were replaced weekly.

Plants were monitored daily to document and photograph the sequential series of symptoms on youngest, young, recently mature, and mature leaves as they developed. When the first visible symptoms occurred, the recently mature leaves were sampled from three replications of the deficiency treatment and the control treatment to establish incipient deficiency tissue levels. Tissue samples were first rinsed in deionized water, washed in 0.2 N hydrochloric acid (HCl) for 30 s, re-rinsed in deionized water, and then dried at 70°C for 48 h.

### **Tissue Analysis**

Oven dried tissue samples were ground in a stainless steel Wiley Laboratory Mill Model 4 (Thomas Scientific, Philadelphia, PA, USA) to pass 1 mm screen (20-mesh) and 0.15 g was digested in a microwave digester (MARS; CEM Corp, Matthews, NC, USA) using a modified EPA method (EPA method 3051 with additional peroxide step). Nutrient concentrations of P, K, Ca, S, Mg, B, Cu, Fe, Mn, and Zn were determined with inductively coupled plasma optical emission spectroscopy (ICP-OES; Model IRIS Intrepid II, Thermo Corp., Waltham, MA, USA). 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. Tissue analysis for N was performed with a C-H-N analyzer (model 2400 Series II, Perkin-Elmer, Norwalk, CT, USA) by weighing 3.5 mg of dried tissue into tin cups for testing in the analyzer. Every ten samples, acetanilide was run as a control and every twenty samples, spinach and tomato standards were analyzed as additional quality controls.

### **Experimental Design and Statistical Analysis**

The data set for each deficiency disorder included three treated plants and three control plants harvested on the same day. These data sets were

**TABLE 1** Tissue nutrient concentrations and dry weight as percentage of control at the initial stages of nutrient disorders in recently matured leaves from variegated-leaf clerodendrum plants grown hydroponically

Treatment											
-N	-P	-K	-Ca	-Mg	-S	-Cu	-Fe	-Mn	-Zn	-B	+B
Elemental tissue concentration											
N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B	B
%						mg·kg <sup>-1</sup>					
Control plants—Initial											
3.53	0.93	3.68	2.32	0.52	0.44	7.9	114.2	219.5	9.1	21.6	23.6
Disorder plants—Initial											
1.54	0.08	1.29	0.39	0.13	0.14	1.5	49.0	21.2	5.4	4.9	73.0
Significance <sup>z</sup> —Initial											
***	***	***	**	***	***	**	***	***	*	***	**
Disorder plants—Dry weight % of Control											
54	32	66	57	74	70	37	47	40	57	56	89
Significance <sup>z</sup> —Dry weight											
*	*	NS	NS	NS	NS	**	*	**	NS	NS	*

<sup>z</sup> \*, \*\*, \*\*\* Significant at  $P \leq 0.05$ , 0.01, or 0.001, respectively, for each control and deficiency pair during the initial stage of deficiency development.

analyzed separately as completely randomized designs (equivalent to two sample t-tests for two unpaired samples) using SAS's PROC ANOVA (SAS Institute, Cary, NC, USA).

## RESULTS AND DISCUSSION

Following are the descriptions of visual disorder symptoms of each nutrient for the variegated-leaf clerodendrum. Corresponding tissue concentrations and dry weight as a percentage of the control at the initial observation of the nutrient disorder are listed in Table 1.

### Nitrogen

In the initial symptoms, the young and youngest leaves were lighter and paler green than the control, with the mature leaves equal in color to young leaves. The leaf variegation was faded or less pronounced. The foliar N concentration was 1.54%, as compared to 3.53% for the control (Table 1). The N deficient plants weighed 54% of the control. As intermediate symptoms, leaf variegation was even less pronounced. Growth was stunted. Older leaves were chlorotic and the new growth was lime-green with no variegation.

In the advanced stage, the new growth faded to yellow with no variegation. Flowering was delayed in the N deficient plants.

### **Phosphorus**

In the initial symptoms of P deficiency, the older leaves were slightly chlorotic and had rolled-up leaf margins. The foliar P concentration was 0.08%, as compared to 0.93% for the control (Table 1). The P deficient plants weighed 32% of the control. In the intermediate stage, leaves were dull green in color with less distinct variegations. Lower leaves turned yellow and abscised. Leaves had a downward orientation. In the advanced stage, yellowing with necrotic centers, defoliation and curling symptoms became more extreme. Plants were more compact than the control.

### **Potassium**

Initially, K deficiency began with chlorotic older leaves with necrotic edges and a slight interveinal necrosis. The foliar K concentration was 1.29%, as compared to 3.68% for the control (Table 1). The mean dry weight of the K deficient plants did not differ significantly from the control. In later stages of K deficiency, plants were more compact than the control with a dull-green color overall. Flowers also began to abort.

### **Calcium**

Calcium deficiency began with flower abortion and curled younger leaves. The flowers become star-shaped as the deficiency progressed. The foliar Ca concentration was 0.39%, as compared to 2.32% for the control (Table 1). The mean dry weight of the Ca deficient plants did not differ significantly from the control.

### **Magnesium**

In the initial stage of Mg deficiency, leaf edges were rolled upward. The new growth was smaller. The oldest leaves were slightly chlorotic. The foliar Mg concentration was 0.13%, as compared to 0.52% for the control (Table 1). The mean dry weight of the Mg deficient plants did not differ significantly from the control. Interveinal chlorosis on the oldest leaves became visible as symptoms advanced.

### **Sulfur**

The earliest visual symptom of S deficiency was a lighter green color in the top half of the plant than the bottom half. Flowers developed with narrow petals that were slightly curled under, giving them a star-shaped appearance

as compared to the more round flowers on the control plants. The foliar S concentration was 0.14%, as compared to 0.44% for the control (Table 1). The mean dry weight of the S deficient plants did not differ significantly from the control.

### **Copper**

Copper deficiency began with strap-like youngest leaves on a compact plant. Flowering was later than in the control. The foliar Cu concentration was  $1.5 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $7.9 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). The Cu deficient plants weighed 37% of the control.

### **Iron**

Plants were an overall yellowish-lime green color and some tip burn developed. Plants had a dull hue cast. The foliar Fe concentration was  $49.0 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $114.2 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). The Fe deficient plants weighed 47% of the control. As symptoms advanced, the variegation faded and the veins were green with interveinal chlorosis on youngest leaves.

### **Manganese**

Plants were more compact with a more pronounced variegation than the control. The most recently matured leaves were narrower and a strap-like appearance developed on the youngest leaves. The foliar Mn concentration was  $21.2 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $219.5 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). The Mn deficient plants weighed 40% of the control.

### **Zinc**

Zinc deficiency began with curled new growth and chlorotic lower leaves. The foliar Zn concentration was  $5.4 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $9.1 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). The mean dry weight of the Zn deficient plants did not differ significantly from the control. As the symptoms advanced, flowers were star shaped. Flowers developed with narrow petals that were slightly curled under to appear star-shaped as compared to the more round flowers on the control plants. However, plants grown with insufficient Zn flowered earlier than the controls.

### **Boron**

The first symptoms of B deficiency were aborted flowers and leaves thickened and curled. The foliar B concentration was  $4.9 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $21.6 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). The mean dry weight of the B

deficient plants did not differ significantly from the control. As the deficiency progressed, flowers opened to a star shape. Deficient plants were shorter than the control.

Plants receiving toxic levels of B initially developed a marginal chlorosis on mature leaves, which over time became necrotic. Flowers developed with narrow petals that were slightly curled under to appear star-shaped as compared to the more round flowers on the control plants. The foliar B concentration was  $73.0 \text{ mg}\cdot\text{kg}^{-1}$ , as compared to  $23.6 \text{ mg}\cdot\text{kg}^{-1}$  for the control (Table 1). Plants receiving excess B weighed 89% of the control and were more compact.

## CONCLUSION

Nutrient deficiency symptoms for N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and B and toxicity symptoms for B in a variegated-leaf selection were described. Also, tissue samples of most recently matured leaves were taken when initial symptoms were visible. This data will aid growers in diagnosing nutritional problems of *Clerodendrum thomsoniae* and establish lower tissue concentration limits for tissue testing laboratories.

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