Journal of Applied Horticulture, 14(1): 29-32, 2012

Growth and foliar nutrient concentration response of *Clerodendrum thomsoniae* to increasing fertilization

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Abstract

The growth response, root substrate environment, and foliar nutrient concentrations of clerodendrum were evaluated in a range of fertilizer concentrations. A green-leaf selection of clerodendrum was grown for 129 days using a complete fertilizer containing micronutrients at concentrations of 50, 100, 200, 300 and 400 mg L^{-1} N. Shoot length and dry weight; root substrate electrical conductivity (EC); and foliar N, P, K, Cu, and Mn levels increased with increasing fertilizer concentration, while root substrate pH and foliar Mg and S decreased. The response of foliar Ca, Fe, Zn, and B concentrations to fertilizer concentration was not significant. Although clerodendrum grown with 100 to 400 mg L^{-1} N had similar foliar N, P, and K concentrations by mean separation, foliage was lighter green at ≤100 mg L^{-1} N; thus 200 mg L^{-1} N is recommended because it provided adequate fertility without excessive shoot growth.

Key words: Bleeding glory-bower, glory tree, fertilizer, nitrogen, phosphorous, potassium, *Clerodendrum thomsoniae* Balf.

Introduction

Clerodendrum thomsoniae is a vine grown commercially in hanging baskets (Dole and Wilkins, 2005). The trade and scientific literature contains a range of suggestions for fertilizing *C. thomsoniae*, however, recommendations based on replicated trials are unavailable. Sanderson *et al.* (1990) fertilized weekly with 20.0N-8.8P-16.6K (20N-20P_2O_5-20K_2O) at 400 mg L^{-1} N. Alvensleben and Steffens (1989) used two applications of $Ca(NO_3)_2$ alternated with one application of 10.0N-5.2P-12.4K (10N-12P_2O_5-15K_2O) at 100 mg L^{-1} N. Wendzonka (1978) recommended applying an acidic fertilizer, such as 28.0N-7.9P-6.6K (28N-18P_2O_5-8K_2O) at 431 mg L^{-1} N weekly. Beck (1975) proposed applying a complete fertilizer at 200 mg L^{-1} N at each irrigation for the first three weeks after potting then reducing the concentration to 100 mg L^{-1} N. Fertilization with 200 mg L^{-1} N beyond three weeks would delay flowering. Koranski (1976) reported iron chlorosis when the root substrate pH exceeded 6.3. von Hentig (1987) reported injury of clerodendrum roots by high soluble salts and recommended maintaining root substrate between pH 5.5 and 6.5 to avoid Fe deficiency. In a recent study, Davis *et al.* (2011) described additional disorder visual symptoms and established foliar nutrient concentrations in a variegated-leaf selection of clerodendrum grown to induce N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B deficiencies and B toxicity.

To increase growth efficiency and plant quality, growers monitor and manage root substrate pH and electrical conductivity (EC) and foliar nutrient concentrations to provide adequate, but not excessive, levels of essential elements. Therefore, this study was conducted to evaluate the growth response, root substrate environment, and foliar nutrient concentrations of clerodendrum in a range of fertilizer concentrations.

Materials and methods

This fertilizer concentration experiment was conducted in the double layer polycarbonate Reid Greenhouse at North Carolina A&T State University in Greensboro, NC (36° north latitude) from 7 March to 13 July 2007. Rooted stem cuttings of a green-leaf selection of clerodendrum were transplanted with two plants per 19.05 cm diameter azalea (2.6 L) pot on 7 March 2007. The root substrate was 4 peat : 1 perlite (v/v) amended with dolomitic limestone at 5.9 kg·m^{-3} and Aquagro 200-G (Aquatrols, Paulsboro, NJ) at 111 g·m^{-3}. Plants were fertilized at each irrigation with one of five liquid fertilizer levels (50, 100, 200, 300, and 400 mg L^{-1} N) using Excel® 13-2-13 (The Scotts Co., Marysville, OH), which contained the following percentage analysis of nutrients: 13N-0.86P-10.8K-6Ca-3Mg-0.006B-0.028Cu-0.05Fe-0.028Mn-0.0075Mo-0.028Zn. Plants were irrigated as needed using a drip system utilizing sump-pumps (Model 1A, Little Giant Pump Co., Oklahoma City, OK), and plants were harvested at 37, 69, 97, and 129 d after planting. Greenhouse day/night set-points were 24/20 °C.

At each harvest date, plant height (measured from the substrate level to the uppermost part of each plant) and shoot dry weight were recorded. The most recently matured leaves were also sampled from the third harvest (97 d). Sampled leaves were rinsed in tap water for 30 s, then rinsed in deionized water for 30 s, and finally dried at 70 °C for 48 h.

On each harvest date, the root substrate in each pot was dried at 70°C for 96 h. The substrate was then broken up and a representive sample of 100 cm^3 was mixed with 200 mL of deionized water and allowed to rehydrate for 1 h. The pH and electrical conductivity (EC) were then recorded using a Hanna Meter HI 9811 (Hanna Instruments, Woonsocket, RI).

Tissue analysis: Oven dried tissue was ground in a stainless steel Wiley Laboratory Mill Model 4 (Thomas Scientific, Philadelphia) to pass a 1 mm screen (20-mesh). A 1.25 g sample was combusted at 490 °C for 6 h. The resulting ash was dissolved in 10 mL 6 N HCl and diluted to 50 mL with deionized water. Phosphorus, K, Ca, Mg, S, Fe, Mn, Cu, Zn, and B concentrations were determined by inductively coupled plasma emission spectroscopy (ICP-OES; Perkin-Elmer Optima 3300DV, Norwalk, CT). Nitrogen was determined with a Perkin Elmer 2400 CHN elemental analyzer (Norwalk, CT) on 10 mg samples. All tissue analyses were conducted at the Analytical Services Laboratory, School of Agriculture and Environmental Sciences, NC A&T State University.

Experimental design and statistical analysis: The experiment was a randomized complete block design with five fertilizer treatments × four sample dates × six replications. Data were subjected to analysis of variance using PROC ANOVA (SAS Inst., Cary, NC). Data values for dependent variables with significant analysis of variances were regressed using the PROC GLM procedure to determine the best-fit linear and quadratic models. Terms of the model were based on a comparison of F values at $\alpha = 0.05$.

Results and discussion

Although data were collected on growth and substrate parameters at four destructive harvests, similar trends were observed at all four harvests. Therefore, only data from 69 and 129 d are presented to avoid redundancy.

Growth: The responses to fertilizer concentration for stem length and shoot dry weight were best-fit to linear models at both 69 and 129 d after planting (Table 1). Stem length increased with increasing fertilizer concentration. The differences among treatments were greater at 129 d than 69 d as reflected in the steeper slope on the linear equation. Shoot dry weight also increased with fertilizer concentration. Although these relationships were linear, the stem lengths and shoot dry weights at 69 and 129 d at the two highest fertilizer concentrations tested (300 and 400 mg L^{-1} N) were similar to each other with respect to least significant differences.

Root substrate: The responses of root substrate pH to fertilizer concentration were best-fit to linear models at both 69 and 129 d after planting (Table 1). Root substrate pH decreased with increasing fertilizer concentration. Root substrate pH was generally maintained between 5.5 and 6.5 as recommended by von Hentig (1987), except at the highest fertilizer concentration (400 mg L^{-1} N) where it dipped below pH 5.4. Iron deficiency symptoms were not visible in any of the treatments. However, foliage on plants grown at the two lowest fertilizer concentrations (50 and 100 mg L^{-1} N) were an overall lighter green in color. The response of root substrate EC to fertilizer concentration was best-fit to a linear model at both 69 and 129 d after planting (Table 1). Root substrate EC increased with increasing fertilizer concentration; however, soluble salts did not become excessive enough to inhibit growth.

Foliar nutrient concentrations: The mean concentrations of all the measured nutrients in the most recently matured leaves at 97 d after planting were greater than the levels identified by Davis *et al.* (2011) as deficient. However, fertilization did effect the foliar nutrient concentrations.

The response of foliar N, P and K concentrations were best-fit to linear models (Table 2). However, by mean separation, the foliar N, P and K concentrations at 50 mg L^{-1} N from 13N-0.86P-10.8K were lower than the foliar concentrations of these nutrients at the four higher fertilizer concentrations (100, 200, 300, and 400 mg L^{-1} N). Although deficiency symptoms were not observed with 50 or 100 mg L^{-1} N , the plants at the two lowest concentrations were overall lighter green in color. This suggests that ≤100 mg L^{-1} N fertilizer rate provided inadequate nutrition.

The response of foliar Ca concentration to fertilizer concentration was not significant as determined by analysis of varience (Table 2). The mean Ca concentration for all fertilization treatments was 2.07%.

Table 1. Effect of fertilizer application of 13N-0.86P-10.8K at five concentrations (50, 100, 200, 300, and 400 mg L^{-1} N) on the stem length, shoot dry weight, substrate pH, and substrate electrical conductivity of green-leaf clerodendrum at 69 and 129 days after planting

Fertilizer concentration mg L^{-1} N	Stem length (cm)		Shoot dry weight (g)		pH		Electrical conductivity mS cm^{-1}	
	69 days	129 days	69 days	129 days	69 days	129 days	69 days	129 days
50	59.3	119.8	8.9	26.8	6.12	6.35	0.39	0.42
100	64.0	106.2	10.7	31.2	5.93	6.10	0.60	0.77
200	71.2	141.8	14.7	45.3	5.68	5.68	1.14	1.46
300	88.0	178.2	17.6	79.9	5.48	5.53	1.88	1.75
400	96.2	193.8	16.4	88.6	5.35	5.38	2.43	2.24
LSD (0.05)[z]	19.1	37.8	4.9	14.0	0.07	0.12	0.31	0.28
Linear[y]	<0.0001	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Quadratic	0.8396	0.7429	0.1292	0.7622	0.0040	<0.0001	0.5811	0.1159
a	52.8	95.2	8.64	13.8	6.17	6.38	0.0326	0.261
b_0x	0.109	0.251	0.0239	0.193	-0.00217	-0.00272	0.00598	0.00509
b_1x^2	-	-	-	-	-	-	-	-
r^2	0.45	0.49	0.33	0.83	0.92	0.87	0.90	0.87
CV	21	23	33	21	2.5	2.4	21	19

[z] LSD values are for comparing between fertilizer concentrations.

[y] The equation coefficients for either the linear ($y = a + b_0x$) or quadratic ($y = a + b_0x + b_1x^2$) regression models are provided for whichever model had the lowest significant Pr>F. The coefficient of determination (r^2) and coefficient of variation (CV) were calculated for the best fit model (n = 6). When the linear and quadratic models had the same level of significance; the equation, r^2, and CV are given for the simplest model (linear).

Table 2. Effect of fertilizer application of 13N-0.86P-10.8K at five concentrations (50, 100, 200, 300, and 400 mg·L^{-1} N) on foliar N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and B concentrations of green-leaf clerodendrum at 97 days after planting

Fertilizer (mg L^{-1} N)	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn	B
	(%)						(mg kg^{-1})				
50	3.00	0.53	2.47	2.14	0.86	0.30	2.9	88	46	12	39
100	4.24	1.09	3.30	2.29	0.92	0.32	3.0	93	57	18	48
200	4.20	1.17	3.22	2.15	0.78	0.24	3.0	104	68	15	43
300	4.33	1.34	3.30	1.82	0.64	0.24	3.0	108	109	18	41
400	4.45	1.41	3.58	1.94	0.60	0.22	4.2	111	123	18	49
LSD (0.05)[z]	0.36	0.32	0.49	NS	0.12	0.04	0.7	NS	28	NS	NS
Linear[y]	0.0001	0.0003	0.0028	-	<0.0001	<0.0001	0.0029	-	<0.0001	-	-
Quadratic	0.0063	0.0961	0.3154	-	0.9479	0.3834	0.0265	-	0.6972	-	-
a	3.41	0.670	2.70	-	0.953	3.22	2.60	-	32.5	-	-
b_0x	0.00302	0.00209	0.00226	-	-0.000922	-0.000283	0.00295	-	0.230	-	-
b_1x^2	-	-	-	-	-	-	-	-	-	-	-
r^2	0.42	0.37	0.28	-	0.51	0.47	0.28	-	0.66	-	-
CV	12	32	0.0028	-	16	15	20	-	27	-	-

[z] LSD values are for comparing between fertilizer concentrations.

[y] The equation coefficients for either the linear ($y = a + b_0x$) or quadratic ($y = a + b_0x + b_1x^2$) regression models are provided for whichever model had the lowest significant Pr>F. The coefficient of determination (r^2) and coefficient of variation (CV) were calculated for the best fit model (n = 6).

The response of foliar Mg concentration was best-fit to a linear model with foliar Mg concentration decreasing with higher fertilizer concentration (Table 2). The decrease in foliar Mg concentration with increasing fertilizer concentration ≥100 mg L^{-1} N was presumably due to an anatagonism by the monovalent cation macronutrients (Robson and Pitman, 1983). Foliar Mg concentrations at the three lower fertilizer concentrations (50, 100, and 200 mg L^{-1} N) were significantly higher than the foliar Mg concentrations at 300 and 400 mg L^{-1} N. Although Mg deficiency symptoms were not observed in this study, Mg deficiency symptoms have been observed during commercial clerodendrum production in NC (B. Whipker, personal observation).

The response of foliar S concentration was best-fit to a linear model with foliar S concentration decreasing with higher fertilizer concentration (Table 2). The decrease in foliar S concentration was presumably due to an anatagonism by the monovalent anion macronutrients. Foliar S concentrations at the two lowest fertilizer concentrations (50 and 100 mg L^{-1} N) were significantly higher than the foliar S concentrations at 200, 300 and 400 mg L^{-1} N.

The response of foliar Cu concentration was best-fit to a linear model with foliar Cu concentration increasing with fertilizer concentration (Table 2). The foliar Cu concentrations at 50, 100, 200, and 300 mg L^{-1} N were significantly lower than the foliar Cu concentration at 400 mg L^{-1} N.

The response of foliar Mn concentration was best-fit to a linear model with foliar Mn concentration increasing with fertilizer concentration (Table 2). The foliar Mn concentrations at 50, 100, and 200 mg L^{-1} N, respectively were lower than the foliar Mn concentrations at 300 and 400 mg L^{-1} N.

The response of foliar Fe, Zn, and B concentrations to fertilizer concentration were not significant as determined by analysis of variance (Table 2). The mean Fe, Zn, and B concentration for all treatments were 101, 16, and 44 mg kg^{-1}, respectively. The results from this study contribute to understanding the fertilization of clerodendrum. Stem length and shoot dry weight of the green-leaf selection increased linearly with fertilizer concentration. At 97 d after planting, the lowest mean nutrient concentrations for the most recently matured leaves in the green-leaf selection for all nutrients were above the levels previously reported. Nutrients that increased with increasing fertilizer concentration (N, P, K, Cu and Mn) were above the critical minimum value in plants grown using 50 mg L^{-1} N. Although, clerodendrum grown at the four highest fertilizer rates had similar foliar N, P and K concentrations at 97 d, foliage on plants grown at 100 mg L^{-1} N were an overall lighter green in color. In plants grown at 400 mg L^{-1} N, nutrients that decreased with increasing fertilizer concentration (Mg and S) were above the level previously reported in plants showing foliar deficiency symptoms, but lower than the other treatments at the two highest fertilizer rates (300 and 400 mg L^{-1} N). These results would indicate that among the concentrations tested, 200 mg L^{-1} N provided adequate mineral nutrition without excessive growth.

Acknowledgements

The authors gratefully acknowledge financial assistance from the Opt-Ed Program at North Carolina Agricultural and Technical State University (NCA&TSU) and Agricultural Research Programs at NCA&TSU (Evans-Allen Funds) and North Carolina State University (Hatch Funds).

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Received: May, 2011; Revised: August, 2011; Accepted: December, 2011