Effect of Fall Fertilization on Freeze Resistance of Deciduous Versus Evergreen Azaleas[1]

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Abstract

Plants that maintain their leaves throughout winter may respond differently to fall fertilization than deciduous plants. The effects of fall fertilization on cold hardiness, nutrient uptake, growth and flower production of evergreen versus deciduous azaleas were studied. *Rhododendron canescens* (Michx.) Sweet and *R.* ×*satsuki* 'Wakaebisu' were grown in containers, outdoors in Athens, GA, under three fall fertigation regimes applied daily as 0.5 liter (0.13 gal) solutions containing: 1) 75 mg·liter^{-1} N from August 1 through September 29, 2) 75 mg·liter^{-1} N from August 1 through November 28, and 3) 125 mg·liter^{-1} N from August 1 through November 28. Stem freeze resistance was analyzed monthly November through March. Growth of azaleas that received 120 days of extended fertigation (August 1 through November 28) was not increased compared to azaleas that received 60 days of extended fertigation (August 1 through September 29). Growth of the two taxa did not differ in their response to fertilization treatments. The high rate of extended fertilization 125 mg·liter^{-1} N (from August 1 through November 28) reduced stem freeze resistance November through February, while the moderate rate of extended fertilization (75 mg·liter^{-1} N from August 1 through November 28) reduced azalea freeze resistance in December. Fall fertilization regimes did not produce differences in the timing of cold acclimation, or deacclimation of *R. canescens* and *R.* ×*satsuki.* The high rate of extended fertilization promoted early budbreak of *R.* ×*satsuki* and postponed flower budbreak of *R. canescens.* Flower production of *R. canescens* was not affected by fall fertilization, but the high rate of extended fertilization increased flower production of *R.* ×*satsuki* compared to plants that received the moderate rate of fertilization 75 mg·liter^{-1} N from August 1 through September 29.

Index words: *Rhododendron*, *R. canescens*, *R.* ×*satsuki,* 'Wakaebisu', fertigation, nitrogen, frost, cold, hardiness.

Significance to the Nursery Industry

The design of this study included fall fertilization and taxa treatments to determine if extending the application of fertilizer in fall affects the cold hardiness of evergreen and deciduous azaleas differently. Results indicated that nursery growers and landscape managers do not need different fall fertilization schedules for managing the freeze resistance of evergreen versus deciduous azaleas.

Extending fall fertilization through November 28, especially at the high rate (125 mg·liter^{-1} N), may reduce freeze hardiness of azaleas. The moderate rate of extended fertilization (75 mg·liter^{-1} N from August 1 through November 28) decreased freeze hardiness of azaleas in December only, while the high rate of extended fertilization (125 mg·liter^{-1} N) reduced freeze hardiness November through February compared to azaleas that received 75 mg·liter^{-1} N from August 1 through September 29. Nursery growers interested in building the nutrient reserves of their azaleas should avoid application of high rates of extended fertilization, but may benefit from extended fertilization when it is applied at a moderate rate (75 mg·liter^{-1} N).

Introduction

Plants that maintain their leaves throughout winter may respond differently to fall fertilization than deciduous plants. Leaf retention affects the carbohydrate supply that is required for active nutrient uptake, and the transpiration pull that is responsible for the movement of inorganic ions within the xylem. For fertilizer ions in the substrate to reach the cytoplasm of a leaf or stem cell, they must be actively transported across plasma membranes at least three times (5, 21), and carried upward in the xylem by the transpirational stream.

In studies that investigated N uptake of deciduous species, defoliation of *Prunus domestica* L. subsp. *domestica* (25) and shade applied to *Malus domestica* Borkh. (6) and *Prunus domestica* L. subsp. *domestica* (23) reduced carbon assimilation and inhibited N uptake. Compared to ungirdled *Prunus persica* L. Batsch, trees that were girdled after apical meristem growth ceased had a 5-fold decrease in N uptake compared to ungirdled trees (12). These studies emphasize the importance of photosynthate production and the translocation of metabolites from photosynthesizing leaves through phloem to promote uptake of N.

Low temperature may reduce transpiration and photosynthetic activity but low temperatures above freezing did not prevent N uptake of *Ilex crenata* Thunb. (27), or *Ligustrum* ×*ibolium* Coe ex Rehder (9), species with persistent leaves. Nitrogen application rate had more influence on total plant N than temperature when *Ilex crenata* plants were exposed to low temperatures above freezing (27).

Fall fertilization may increase spring growth (3, 9, 11, 17, 19) and flower production (14). However, fall fertilization may also reduce the freeze resistance of woody ornamental plants (11, 13, 20, 28).

In this research, a deciduous and an evergreen species of the genus *Rhododendron* were compared to determine if extended fertilizer applications in fall affect growth and freeze resistance of evergreen and deciduous plants differently. The objective of this research was to determine if different fall fertilization schedules should be used for evergreen versus deciduous plants.

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Materials and Methods

Uniform liners of *Rhododendron canescens* (a deciduous azalea) and *Rhododendron ×satsuki* 'Wakaebisu' (an evergreen azalea) were planted in 2.2 liter (#1) containers in a nursery production area at the University of Georgia's Riverbend Horticulture Research Facility in Athens, GA, on May 1, 2003. The growing substrate was aged pine bark amended with 2.37 kg·m^{-3} (4 lb·yd^{-3}) dolomitic limestone and 0.59 kg·m^{-3} (1 lb·yd^{-3}) Micromax micronutrient (The Scotts Company, Marysville, OH).

Prior to the initiation of fertility treatments on August 1, 2003, all plants were fertigated daily with a 0.5 liter (0.13 gal) solution containing 75, 33 and 62.5 mg·liter^{-1} of N, P and K. Beginning August 1, 2003, each *Rhododendron* taxa was grown under three different fall fertility regimes: 1) 60 days of extended fertilizer application from August 1 through September 29 at a moderate rate (75 mg·liter^{-1} N), 2) 120 days of extended fertilizer application from August 1 through November 28 at a moderate rate (75 mg·liter^{-1} N) and 3) 120 days of extended fertilizer application from August 1 through November 28 at a high rate (125 mg·liter^{-1} N). Azaleas from treatments that received 60 days of extended fertigation (August 1 through September 29) received 0.5 liter (0.13 gal) of irrigation, applied daily, from September 29 through November 28. The three fertility treatments were chosen based on a previous study (11), in which a high rate (125 mg·liter^{-1} N) of fertilization extended from August 1 through November 28 increased growth and decreased freeze resistance of *R. ×kurume* 'Hinodegiri' compared to plants that received a moderate rate (75 mg·liter^{-1} N) of fertilization that was extended through either September 29 or November 28.

Fertilizer treatments were applied using a constant liquid feed fertilizer application of Harrell's (Sylacauga, AL) 16-3.5-6.6 (N-P-K) liquid fertilizer solution. To prevent osmotic stress induced damage, electrical conductivity of leachate was monitored daily using the Virginia Tech Extraction Method (29), 0.5 liter (0.13 gal). Irrigation was applied as a leachate prior to fertigation when conductivity of any treatment reached 1.0 dS·m^{-1}. Floating row cover (Specialty Converting and Supply Inc., Nashville, GA) was applied for freeze protection when minimum temperatures fell below –6.7 C (20 F).

This experiment was arranged as a 2 × 3 factorial experiment with two taxa (*R. canescens* and *R. ×satsuki)* and three fall fertilization regimes in a randomized complete block design with three replications. Uniform 4 cm stem sections from three azaleas per treatment-replication combination were harvested and pooled on November 15 and December 17, 2003, and January 16, February 18 and March 19, 2004. Forty uniform stem sections were selected from each Taxa × Fall fertilization replicate, and four of these sections were randomly selected and exposed to each of ten progressively lower temperature intervals between –3 and –30C (26.6 and –27.4F) (under laboratory conditions in order to estimate azalea freeze resistance (16). The Spearman-Karber Method (4) was used to estimate a lethal temperature (LT_{50}) value (temperature at which 50% of stems were killed).

In order to analyze stem N concentration, on February 17, 2004, stem sections were collected and pooled from five randomly selected azaleas from each taxa × fall fertilization replicate. Stem sections were dried at 55 C (131 F) for 72 hours, and analyzed for total N with a CNS-2000 elemental analyzer (LECO Corp., St. Joseph, MI) according to the methods described by Kirsten (15).

Flower counts began April 15, 2004, prior to initial bud break and continued until all buds had flowered (F_{max}). Flowering was defined as bud break showing petal color; and flowers were counted on five plants per treatment-replication combination three times per week. Linear regression analysis was used to characterize the relationship between day of year and flower count. Regression equations were then used to calculate F_{50} (date which 50% of flowers were in bloom, or F_{max} / 2) for each treatment-replicate combination.

The same five azaleas from each treatment-replication combination used in F_{50} and F_{max} were used to calculate plant growth index (PGI) on May 21, 2004. Maximum height (H), maximum width (W1) and width perpendicular to W1 (W2) were used in the calculation GI = (H + (W1 + W2) / 2) / 2.

Stem N concentration, PGI, flower production and flower budbreak were analyzed using analysis of variance, and stem freeze resistance was analyzed using repeated measures analysis of variance (SAS Institute Inc., Cary, NC). Tukey's Studentized range test was used to test for differences between treatment means variance.

Results and Discussion

Fall fertilization treatments did not affect the growth of *R. canescens* or *R. ×satsuki*. Because there was not a detectable interaction between fall fertilization and taxa treatments, growth data from this study do not support the use of different fertilization regimes for evergreen versus deciduous azaleas.

Due to the absence of interaction between fall fertilization and taxa, growth data for the two azalea taxa were pooled within each fertilization treatment (Table 1). Extended fertigation through November 28 with either 75 or 125 mg·liter^{-1} N did not increase azalea growth compared to azaleas that received 75 mg·liter^{-1} N from August 1 through September 29 (Table 1). In contrast, previous research demonstrated that fall fertilization can increase growth of other evergreen [*Rhododendron ×kurume* 'Hinodegiri' (11), *Ligustrum ibolium* Coe ex Rehder and *Euonymus alatus* (Thunb.) Siebold (9), *Juniperus chinensus* L. (3), *Forsythia ×intermedia* Zabel (17)], and deciduous plants [*Syringa vulgaris* L. (18)].

Fall fertilization and taxa treatments did not interact in their effect on freeze resistance; therefore, stem freeze resistance data for the two taxa were pooled within each fertilization treatment (Table 2). Compared to azaleas that

Table 1. Effect of fertilization treatments on plant growth index (PGI[z]) measured May 21, 2004, and pooled for *R. canescens* and *R. ×satsuki* 'Wakaebisu'.

N fertilization (mg·liter^{-1})		
August 1 to September 29	September 30 to November 28	PGI
75	0	46.5a[y]
75	75	47.8a
125	125	43.3a

[z]Maximum height (H), maximum width (W1) and width perpendicular to W1 (W2) were used in the calculation PGI = (H + (W1 + W2) / 2) / 2.

[y]Mean separation within columns by Tukey's Studentized range test at $P \leq 0.05$.

Table 2. Effect of fertilization treatments on pooled freeze resistance (LT_{50}[z]) of *R. canescens* and *R. ×satsuki* 'Wakaebisu' stem tissue.

N fertilization (mg·liter^{-1})		LT_{50} (C)				
		Stem harvest dates				
August 1 to September 29	September 30 to November 28	November 12	December 11	January 14	February 18	March 19
75	0[y]	–6.3b[x]	–20.4c	–23.8b	–24.8b	–15.4a
75	75	–5.6b	–16.8b	–22.3ab	–22.6ab	–18.6a
125	125	–3.4a	–13.6a	–19.9a	–19.8a	–19.6a

[z]Temperature at which 50% of stems were killed

[y]Data for the two azalea taxa were pooled within each fall fertilization treatment because fall fertilization and taxa treatments did not interact in their effect on freeze resistance.

[x]Mean separation within columns by Tukey's Studentized range test at $P \leq 0.05$.

were fertilized with 75 mg·liter^{-1} N for 60 days (August 1 through November 28), stem tissue from azaleas that received the high rate of extended fertilization for 120 days (125 mg N·liter^{-1}, from August 1 through November 28), had reduced freeze resistance in November, December, January, and February (Table 2). However, compared to azaleas fertilized at a moderate rate (75 mg·liter^{-1} N) from August 1 through September 29, the moderate rate of extended fertilization (August 1 through November 28) only reduced the freeze resistance of azalea stem tissue in December (Table 2). In other studies, fall fertilization reduced the freeze resistance of certain container-grown evergreen [*Rhododendron ×kurume* (11), *R. obtusum* (Lindl.) Planch. (28), *Pyracantha coccinea* M. Roem. and *Ilex crenata* Thunb. (13)], and deciduous [*Forsythia intermedia* Zabel (20)] plants.

Table 3. Repeated Measures Analysis of Variance for freeze resistance of azalea stems measured monthly November through March.

Source of variation	D.F.	P > F
Rep	2	0.57
Taxa	1	< 0.01
Fertilization	2	< 0.01
Taxa × Fertilization	2	0.17
Error	10	
Time	4	< 0.01
Time × Rep	8	0.85
Time × Taxa	4	0.21
Time × Fertilization	8	0.70
Time × Taxa × Fertilization	8	0.90
Error	40	

Freeze injury often depends on the timing of cold acclimation in fall or deacclimation in spring (26). Previous studies attributed the negative effects that high rates of fall fertilization had on freeze resistance to differences in growth cessation (8, 10), delayed bud development (8) and early bud break (1). In this study, when freeze resistance was analyzed over time using repeated measures, fertilization and taxa treatments affected stem freeze resistance, but fertilization and taxa treatments did not interact in their influence on the timing of cold acclimation in fall nor deacclimation in spring (Table 3). Cold acclimation data do not support the use of different fall fertilizer regimes for evergreen versus deciduous azaleas.

Fertilization with 125 mg·liter^{-1} N from August 1 to November 28 promoted early anthesis of *R. ×satsuki*, but postponed flower budbreak of *R. canescens* compared to plants that received 75 mg·liter^{-1} N from August 1 to September 29 (Table 4). Similar to *R. canescens*, N applied in late fall to *Prunus persica* delayed bloom up to 6 days on twig samples that were taken from the trees and placed in a heated greenhouse (22). Delay was attributed to reduced carbohydrate reserves. However, in other research, *R. ×satsuki*, *Ilex crenata* 'Helleri' and *Ilex cornuta* 'Burfordi' (7), *Juniperus chinensis* 'Pfizerana'(3), and conifer seedlings (1, 2, 24) with high tissue nutrient content in fall began growth earlier the next spring.

Flower production of *R. canescens* was not affected by fertilization treatments, but the high rate of extended fertilization (125 mg·liter^{-1} N from August 1 through November 28) more than doubled the flower production of *R. ×satsuki* compared to plants that received 75 mg·liter^{-1} from August 1 to September 29 (Table 4). Kiplinger and Bresser (14)

Table 4. Effect of fertilization on the day of the year in which 50% of flowers were in bloom (F_{50}) and flower production (Fmax).

	N fertilization (mg·liter^{-1})			
Taxa	August 1 to September 29	September 30 to November 28	Flower budbreak (F_{50}) day of the year	Flower production
R. canescens	75	0	106.2b	6.9a[z]
	75	75	112.1ab	4.5a
	125	125	115.2a	5.7a
R. ×satsuki	75	0	127.6a	26.3b
	75	75	127.6a	40.0ab
	125	125	126.7b	54.8a

[z]Mean separation within columns by Tukey's Studentized range test at $P \leq 0.05$.

Table 5. Effect of fertilization treatments on N[z] concentration of azalea stem tissue harvested February 17, 2004.

	N fertilization (mg·liter^{-1})		
Taxa	August 1 to September 29	October 1 to November 28	N concentration (g·kg^{-1})
R. canescens	75	0	7.7b[y]
	75	75	13.5a
	125	125	14.6a
R. ×satsuki	75	0	7.9c
	75	75	10.7b
	125	125	13.5a

[z]Stem tissue analyzed for total N with a CNS-2000 elemental analyzer (LECO Corp., St. Joseph, MI) according to the methods described by Kirsten (15).

[y]Mean separation within columns by Tukey's Studentized range test at P ≤ 0.05.

found that the number of *Rhododendron ×kurume* 'Coral Bells' flower buds increased from 126.5 to 170.9 as N applied through September 20 was increased from 10 to 50 mg·liter^{-1} N.

Taxa and fertilization treatments interacted in their effect on azalea stem N concentration, which indicates that *R. canescens* and *R. ×satsuki* responded differently to fall fertilization treatments. Stem N concentration of the deciduous *R. canescens* increased when fall fertilization was extended through November 28 at either the moderate (75 mg·liter^{-1} N) or the high rate (125 mg·liter^{-1}) compared to plants that received 75 mg·liter^{-1} N from August 1 through November 28, but the increase in stem N concentration was not greater in plants that received the high versus the moderate rate of extended fertilization (Table 5). One reason why extended fall fertilization through November 28 increased the stem N concentration of *R. canescens* compared to plants that were only fertilized through September 29 is leaf retention. Leaves of *R. canescens* that received extended fertilization remained green and persisted longer than those did not receive extended fertilization. Leaves of the deciduous *R. canescens* that received extended fall fertilization remained green and persisted for more than a month after extended fertilization treatments were terminated November 28, 2004. Active green leaves may have provided photosynthates and transpirational flow needed for deciduous azaleas to maintain nutrient uptake throughout the period of fall fertilizer application.

Stem N concentration of *R. ×satsuki* increased when fall fertilization was extended through November 28 and the increase was greater when N was applied at 125 versus 75 mg·liter^{-1} N. Within three days after fertigation was terminated, electrical conductivity of media leachate decreased to undetectable levels, indicating low nutrient levels in the substrate. Leaves of *R. canescens* persisted long after fertilization was terminated and nutrient levels in the substrate solution declined. While stem N concentration of the evergreen taxa (*R. ×satsuki*) increased in response to the high rate of extended fertilization, the time of leaf abscission indicates that this response should not be attributed to the difference in leaf retention between the two taxa.

The results of this study indicate that nursery growers interested in building the nutrient reserves of their plants should avoid the application of high rates of extended fertilization, but may benefit from extended fertilization when it is applied at a moderate rate. Notwithstanding effects on flowering and nutrient reserves, the absence of interaction between fall fertilization and taxa treatments indicate that nursery growers and landscape managers do not need different fall fertilization schedules to manage growth and freeze resistance of evergreen versus deciduous azaleas.

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