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Early-Season Fertilization Reduces Fertilizer Use Without Reducing Plant Growth[1]

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Abstract

Three experiments were conducted to determine the effect of season-long continuous fertigation (constant application of water soluble fertilizer during irrigation events) or various periods of fertigation on growth of seedlings of 17 woody plant species. For 13 of the 17 species, growth was vigorous; typically seedlings doubled in size during the 13-week experiment [from 1 m (3 ft) initial height to 1.5 or 2 m (4.5 to 6 ft) final height]. In the second and third experiments, seedlings grown under three to four weeks of fertigation (580 and 380 mg N per day, 1995 and 1996, respectively, from water soluble fertilizer) and then switched to weekly fertigation (580 and 380 mg N per week, 1995 and 1996, respectively) had similar height as seedlings receiving fertigation for 13 weeks. The three- to four-week fertigation treatment reduced nutrient application rates by 63 to 55% without reducing plant growth.

Index words: water soluble fertilizer, composts, constant feed, fertigation, nursery production, container production, seedling production.

Species used in this study: Eastern redbud (*Cercis canadensis* L.); splindletree (*Euonymus europaeus* L.); white ash (*Fraxinus americana* L.); blue ash (*F. quadrangulata* Michx.); Japanese Raisintree (*Hovenia dulcis* Thumb.); butternut (*Juglans cinera* L.); cucumbertree magnolia (*Magnolia acuminata* L.); umbrella magnolia (*M. tripetala* L.); blackgum (*Nyssa sylvatica* Marsh.); Amur Corktree (*Phellodendron amurense* Rupr.); waffer-ash (*Ptelea trifoliata* L.); Tatar wingedceltis (*Pteroceltis tatarinowii* Maxim.); sawtooth oak (*Quercus acutissima* Carruth.); shingle oak (*Q. imbricaria* Michx.); northern red oak (*Q.. rubra* L.); sassafrass (*Sassafrass albidum* Nees.); and, yellowhorn (*Xanthocerus sorbifolium* Bge.).

Significance to the Nursery Industry

Early season fertigation, three to four weeks of 200 mg/liter N from water soluble fertilizer applied after spring potting, and then switching to once per week fertigation produced seedlings of similar height to seedlings fertigated all season long. This fertilization practice reduced fertilizer application by 63 to 55% without reducing seedling growth. Early season continuous fertigation and then shifting to late season weekly fertigation can significantly reduce mineral nutrient application rates in containerized seedling production.

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Introduction

Nursery managers sensitive to maintaining environmental quality search for methods of reducing nutrient loss from container production areas. Ideally, increased crop nutrient use efficiency could be achieved without reducing plant growth. However, with blackgum and red oak, the greatest growth was achieved with the least efficient fertilizer application method (15); N recovery (whole plant N content relative to the total amount N applied) was low, 4 to 19%. With 'Sunglow' azalea, N efficiency (defined as the amount of N in the plant relative to the sum of N in effluent and plant) was higher, 56% (18). In that study, the most efficient fertilizer application method resulted in the largest plants.

Controlled release fertilizers and cyclic irrigation are two common methods used for increasing fertilizer efficiency. The appeal of controlled release fertilizers is that nutrient release is matched with crop demand resulting in increased fertilizer efficiency. Achieving increased fertilizer efficiency is a challenge for several reasons: ignorance of the seasonal patterns of whole plant nutrient content (which establishes crop nutrient demand), differing release characteristics of controlled release fertilizer types, yearly variation in climatic conditions, especially temperature, which affect nutrient release from controlled release fertilizer products (5), rainfall and irrigation scheduling. Increases in fertilizer efficiency will occur when fertilizer application methods that match plant nutrient demand or nutrient uptake potential are developed.

This study was conducted to determine the effects of season-long fertigation (water soluble fertilizer applied during an irrigation event) or different periods of fertigation on the growth of 17 woody plant species in an effort to reduce mineral nutrient use without reducing plant growth in containerized woody plant production. Water soluble fertilizer was used so that nutrient application rates could be better controlled.

Materials and Methods

Seeds of redbud, white and blue ashes, cucumbertree and umbrella magnolias, blackgum, Amur Corktree, sawtooth, northern red and shingle oaks and sassafrass were collected locally (either on The Ohio State University campus or the Dawes Arboretum, Newark, OH) in fall. Seeds of spindle tree, Japanese Raisin Tree, butternut, waffer-ash, wingedceltis and yellowhorn were obtained from Sheffield Seed, Inc. (Locke, NY). Seeds were packed in moist peatmoss in plastic bags and stratified at 2C (36F) until February of each year. In mid-February, seeds were sown in flats and germinated in a greenhouse. Seedlings were transplanted to Spinout-treated (Griffin Corp., Valdosta, GA) 13 × 13 × 16 cm containers (5.3 × 5.3 × 6.25 in, Classic 250 XL, Nursery Supplies, Fairless Hills, PA) and grown in the greenhouse. The seeds were germinated and seedlings grown in Metro Mix 510 (O.M. Scotts and Son, Marysville, OH). During the greenhouse phase, all seedlings were irrigated as needed and fertilized once per week with 200 ppm N from Peter's 20N–4.6P–16.6K (1995) or 20N–9.2P–16.6K (1996) water soluble fertilizer (20–10–20 or 20–20–20, respectively, O. M. Scotts, Marysville, OH).

In mid-May seedlings were transferred out-of-doors to 70% shade for one week and then potted into Spinout-treated No. 3 round plastic containers (Classic 1200 C Nursery Supplies, Fairless Hills, PA). A 3:1 (by vol) rice hulls (Docksite, Warsaw, IL):compost (Comtil, a composted municipal sewage sludge, City of Columbus, (see 16 for Comtil's physical properties; it contained 1% N, and less than 1% P and K)) medium was used.

In the first 1995 experiment, blue ash, butternut, cucumbertree magnolia, umbrella magnolia, blackgum, waffer-ash, sawtooth, shingle and red oaks, sassafrass and yellowhorn were grown under two fertilizer regimes. Twenty plants of each species received continuous (13 weeks) fertigation with 200 mg/liter N from 20–10–20 water soluble fertilizer. The fertilizer was applied in two 45-minute irrigation events using 0.5 gal (1.9 liters) per hour trickle emitters; thus 0.75 gal (2.9 liters) of water and 580 mg N were applied per plant per day. Twenty additional plants of each species received weekly fertigation (fertilized one day per week with two fertigation events, which delivered a total of 580 mg N per plant per week). When not fertigated, these plants received 0.75 gal (2.9 liters) of water daily split between two 45-minute irrigation events. For all experiments, fertigation treatments were applied between June 12 and September 15 of each year. Plants were grown in a randomized complete block design with two, 10-plant replications.

Table 1. Nitrogen, phosphorus, and potassium amounts applied during the 1995 and 1996 growing seasons.

Year	Fertilizer treatment (weeks of fertigation[z])	g mineral element^{-1} plant season^{-1}		
		N	P	K
1995	weekly[y]	7.5	1.7	6.3
	1	11.0	2.5	9.1
	2	14.5	3.3	12.0
	3	18.0	4.1	14.9
	4	21.5	4.9	17.8
	13	52.8	12.1	43.7
1996	weekly	4.9	2.3	4.1
	1	7.2	3.3	6.0
	2	9.5	4.4	7.9
	3	11.8	5.4	9.8
	4	14.1	6.5	11.7
	13	34.6	15.9	28.7

[z]When fertigated in 1995, each plant received daily 0.75 gallons (2.9 liters) of 200 mg^{-1} N from 20–10–20 water soluble fertilizer (two 45-minute irrigation events daily using 0.5 gal. [1.9 liters] hour^{-1} trickle emitters for 13 weeks between June 12 and September 15), delivering 580 mg N/plant/day. In 1996, fertigated plants received daily 0.5 gal. (1.9 liters) fertilizer solution from 20–20–20 water soluble fertilizer (two 30-minute irrigation events daily using 0.5 gal [1.9 liters] trickle emitters) delivering 380 mg N/plant/day. When not fertigated, plants received a similar volume of water as fertigated plants.

[y]Weekly fertigation treatment plants received two fertigation events one day per week.

In the second 1995 experiment, redbud, Japanese Raisintree, Amur Corktree and wingedceltis were fertigated as described above for the first one, two, three or four weeks after potting and then switched to weekly fertigation for the remainder of the growing season. Two additional treatments were included, continuous (13 weeks) fertigation and weekly (once per week from time of potting) fertigation. There were 20 plants in each fertilizer treatment and species, a total of 120 plants per species. Within a species, plants were grown in a randomized complete block design with two, 10 plant replications.

In 1996, the second 1995 experiment was repeated using spindletree, white ash, Japanese Raisintree and Amur Corktree. In 1996, the irrigation time was reduced to two 30-minute irrigation events per day. Thus, when fertigated, plants received 0.5 gal (1.9 liters) of water and 380 mg N per day. In 1996, Peter's 20N–9.2P–16.6K (20–20–20) water soluble was used. Within a species, plants were grown in two, 10-plant replications.

Initial plant height measurements were taken in early June before fertilizer treatments began. Final height measurements were taken in October, by which time shoot elongation had stopped. Data from individual species were subjected ANOVA using the Oneway procedure contained in SPSS/PC+ V 7.5 for Windows (SPSS, Chicago, IL). Means were separated using the Student-Newman-Keuls procedure at the $\alpha = 0.05$ significance level.

Results and Discussion

In 1995 and 1996, the 13-week continuous fertigation treatment applied about seven times the N, P and K as did the

Table 2. **First season height growth for 11 species. Plants received either season-long continuous fertigation or were fertigated weekly (one day per week).**

Species (common name)	Average initial height (cm)[z]	Fertilizer treatment (weeks of fertigation)[y]	Height on October 15 (cm)
Fraxinus quadrangulata (blue ash)	16	weekly	15a[x]
		13	19a
Juglans cinerea (butternut)	40	weekly	40a
		13	41a
Magnolia acuminata (cucumbertree magnolia)	52	weekly	133a
		13	155b
M. tripetala (umbrella magnolia)	49	weekly	146b
		13	129a
Nyssa sylvatica (Blackgum)	52	weekly	145a
		13	173b
Ptelea trifoliata (waffer-ash)	22	weekly	28a
		13	27a
Quercus acutissima (sawtooth oak)	50	weekly	99a
		13	126b
Q. imbricaria (shingle oak)	15	weekly	17a
		13	42b
Q. rubra (northern red oak)	45	weekly	70a
		13	143b
Sassafrass albidum (sassafrass)	33	weekly	69a
		13	77a
Xanthocerus sorbifolium (yellowhorn)	13	weekly	21a
		13	36a

[z]Initial height was taken on June 12. Each value is the mean of 20 plants.

[y]When fertigated in 1995, each plant received daily 0.75 gallons (2.9 liters) of 200 mg/N from 20–10–20 water soluble fertilizer (two 45-minute irrigation events daily using 0.5 gal [1.9 liters]/hour trickle emitters for 13 weeks between June 12 and September 15). Plants given weekly fertigation received two fertigation events one day per week. When not fertigated, plants received a similar volume of water as fertigated plants.

[x]Each value is the mean of 20 plants per treatment. Means within a species followed by different letters are statistically different from each other at $\alpha = 0.05$ level using the Student-Newman-Keuls test.

weekly fertigation treatment (Table 1). Thirty-three percent less N, P and K were applied by the respective fertigation treatments in 1996 than in 1995 because of the reduced irrigation time, 30 minutes vs 45 per irrigation event.

Height growth under the two fertigation treatments varied by species. Seedlings of blue ash, butternut, waffer-ash and yellowhorn, grew little during the experiment so there were no significant differences in height growth between seedlings under the weekly and continuous fertigation treatments (Table 2). Seedlings of cucumbertree magnolia, blackgum, sawtooth, shingle and red oaks, were taller when grown under the continuous rather than the weekly fertigation treatment (Table 2). For umbrella magnolia, seedlings under the weekly fertigation treatment were taller than those under the continuous fertigation treatment, while there was no difference in sassafrass seedling height between the fertigation treatments (Table 2). For those species where height growth was significantly greater under the continuous fertigation treatment, the height increase was not proportional to the additional N, P or K applied. The maximum height difference between treatments occurred in red oak, 73 cm (29 in). Here a doubling of height was achieved with a seven-fold increase in nutrient application. These results suggest that a more efficient fertilizer application method exists. For instance, shorter periods of continuous fertigation (one to four weeks) before shifting to weekly fertigation may result in similar sized plants and significant fertilizer savings as season-long continuous fertigation.

In the second and third experiments, six species were grown under 1, 2, 3 or 4 weeks of continuous fertigation before switching to weekly fertigation for the remainder of the growing season. Vigorous growth occurred under all fertigation treatments in both years; typically plant sized doubled during the experiment from 1 m (3 ft) to 2 m (4.5 to 6 ft) (Table 3).

For all species, three to four weeks of continuous fertigation applied at the beginning of the growing season followed by weekly fertigation resulted in similar sized plants as continuous season-long fertigation (Table 3). For Japanese Raisintree and Amur Corktree, the two species grown in both 1995 and 1996, the results were similar for both years. Thus a nursery manager can reduce N, P and K application rates by 63 to 55% (three or four weeks of continuous fertigation and then weekly fertigation, compared to 13 weeks of continuous fertigation) without reducing plant growth. The risk of environmental damage due to excessive fertilizer application would also be greatly reduced.

The relatively high water soluble fertilizer application rates used in this study are in contrast with optimum rates identified for *Cryptomeria japonica* 'Elegans Aurea' (11), *Cupressus arizonica* var. *glabra* 'Carolina Sapphire' (17) and *Maackia amurensis* (8), 20, 25 and 100 mg N liter^{-1}, respectively, but were similar to *Acer rubrum* 'Red Sunset' (6) and *Pyrus calleryana* 'Bradford' (7), 150 mg N liter^{-1}. Wright and Niemiera (19) recommend 100 mg N liter^{-1} in the soil solution for optimum woody plant nutrition.

The results also demonstrate the value of matching the length of an irrigation event with container/medium moisture holding capacity as a method of increasing fertilizer efficiency. In 1995, daily irrigation delivered 0.75 gallons (2.9 liters) of water and 580 mg N per container; in 1996 each irrigation event lasted 30 minutes, delivered 0.5 gallons (1.9 liters) of water and 380 mg N per container. Reducing irrigation time by 33% (from 45 to 30 minutes) saved a propor-

Table 3. **First season height growth for seven species, from Experiments 2 and 3. Plants received either season-long continuous fertigation or were fertigated for one, two, three or four weeks before switching to weekly fertigation for the remainder of the growing season. *Hovenia dulcis* and *Phellodendron amurense* were grown in both the 1995 and 1996 seasons.**

Species	Year	Average initial height (cm)[z]	Fertilizer treatment (weeks of fertigation)[y]	Height on Oct. 15 (cm)
Cercis canadensis (redbud)	1995	107	weekly	184a[x]
			1	189a
			2	234a
			3	199a
			4	189a
			13	203a
Euonymus europaeus (spindletree)	1996	15	weekly	24a
			1	39a
			2	39a
			3	38a
			4	36a
			13	33a
Fraxinus americana (white ash)	1996	30	weekly	62a
			1	57a
			2	66a
			3	52a
			4	60a
			13	60a
Hovenia dulcis (Japanese Raisin Tree)	1995	98	weekly	193a
			1	231b
			2	242b
			3	238b
			4	225ab
			13	208a
	1996	73	weekly	205a
			1	203a
			2	217a
			3	201a
			4	232a
			13	206a
Phellodendron amurense (Amur Cork Tree)	1995	22	weekly	44a
			1	46a
			2	102ab
			3	83ab
			4	156b
			13	144b
	1996	67	weekly	92a
			1	139b
			2	145b
			3	149b
			4	168b
			13	150b
Pteroceltis tatarinowii (Tatar Wingedceltis)	1995	126	weekly	199a
			1	196a
			2	239a
			3	228a
			4	222a
			13	225a

[z]Initial heights were taken on June 12 in 1995 and June 24 in 1996. Each value is the mean of 20 plants.

[y]When fertigated in 1995, each plant received daily 0.75 gallons (2.9 liters) of 200 mg/N from 20–10–20 water soluble fertilizer (two 45-minute irrigation events daily using 0.5 gal [1.9 liters]/hour trickle emitters between June 12 and September 15). In 1996, fertigated plants received daily 0.5 gal. (1.9 liters) fertilizer solution from 20–20–20 water soluble fertilizer (two 30-minute irrigation events daily using 0.5 gal [1.9 liters] trickle emitters) delivering 380 mg N/plant/day. When not fertigated, plants received a similar volume of water as fertigated plants. Plants grown under the weekly fertigation treatment received two fertigation events one day per week.

[x]Each value is the mean of 20 plants per treatment. Means within a species and year followed by different letters are statistically different from each other at $\alpha = 0.05$ level using the Student-Newman-Keuls test.

tional amount of fertilizer without reducing plant growth. This was possible because the plants were being over watered in 1995. The rice hull:Comtil medium had approximately 40% (by volume) plant available water; the container at field capacity would contain approximately 5.7 liters (1.5 gal) of water. Others have shown an increase in irrigation efficiency by using cyclic microirrigation (1, 12) and by managing the leaching fractions (3, 9, 10, 12, 14).

Unknown is the mineral nutrient benefit of the compost used in the container medium. Comtil, composted municipal sewage sludge, is considered to be a slow release nitrogen source. The vigorous growth obtained in this study may have been maintained by the mineralization of nitrogen in the compost. However, little is known about the N release rates of Comtil. Although the nutrient content of Comtil is low (1 to 3% N), a large volume was added to each container resulting in the application of 3.4 g N per container (15). For comparison, 4.9 g of N per container were applied in the weekly fertigation treatment used in 1996. Other studies have shown composts to be a significant source of mineral nutrients (2, 4, 18). In a growing medium without compost, and without the slow-release nitrogen source, different results may be found. The nutritional benefit of compost in growing media, especially as a slow release nitrogen source, needs further study.

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