Success Varies when Using Subirrigation Instead of Mist to Root Softwood Cuttings of Woody Taxa[1]

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Abstract

A subirrigation method for rooting softwood cuttings of seven woody taxa was compared to use of intermittent mist. Both methods resulted in >90% rooting of 'Goldflame' spirea (*Spiraea* x *bumalda* Burv. 'Goldflame'). Averaged over two dates, >50% of 'Pioneer' elm (*Ulmus* L. 'Pioneer') cuttings rooted, and >70% of cuttings retained leaves and formed callus regardless of method. Subirrigation without mist was unsuccessful for rooting Lamarck serviceberry (*Amelanchier lamarckii* F.G. Schroed.), Amur maackia (*Maackia amurensis* Rupr. & Maxim.), or 'Kwanzan' cherry (*Prunus serrulata* Lindl. 'Kwanzan'). Subirrigating cuttings without mist resulted in reductions in rooting percentage, leaf retention, and callus formation of >90% for Lamarck serviceberry and >50% for 'Kwanzan' cherry compared to misted cuttings. For misted cuttings of Amur maackia, percentage rooting, leaf retention, and callus formation were 23, 48, and 35%, respectively; in contrast, no subirrigated cuttings of Amur maackia survived. 'Charles Joly' and 'Michael Buchner' lilacs (*Syringa vulgaris* L. 'Charles Joly' and 'Michael Buchner') varied in response to the propagation methods. Sixty-one, 15, and 42% of 'Charles Joly' lilac cuttings rooted when misted, when subirrigated with tap water, and when subirrigated with a solution of complete fertilizer that contained N at 5.4 mM (75 ppm), respectively. For 'Michael Buchner' lilac, 48, 7, and 19% cuttings rooted under mist, when subirrigated with water, and when subirrigated with fertilizer, respectively. We recommend use of subirrigation without mist for rooting softwood cuttings of 'Goldflame' spirea, 'Pioneer' elm, and 'Charles Joly' lilac.

Index words: propagation, callus.

Species used in this study: Lamarck serviceberry (*Amelanchier lamarckii* F.G. Schroed.); Amur maackia (*Maackia amurensis* Rupr. & Maxim.); 'Kwanzan' cherry (*Prunus serrulata* Lindl. 'Kwanzan'); 'Goldflame' spirea (*Spiraea* x *bumalda* Burv. 'Goldflame'); 'Charles Joly' and 'Michael Buchner' lilacs (*Syringa vulgaris* L. 'Charles Joly' and 'Michael Buchner'); and 'Pioneer' elm [*Ulmus* L. 'Pioneer' (*Ulmus glabra* Huds. x *U. carpinifolia* Ruppius ex Suckow)].

Significance to the Nursery Industry

Many woody taxa are propagated from softwood cuttings. Unless relative humidity is unusually high, it is considered essential to use intermittent mist, fogging systems, or enclosures to prevent leaf desiccation before roots form. Supplemental humidification adds to production costs and complicates management of propagation by leaching nutrients from foliage and rendering cutting leaves prone to desiccation after removal from the propagation bench. A simple, inexpensive method of propagating plants by using subirrigation without mist, fog, or enclosures has been effective previously in experiments that involved softwood cuttings of only red maple (*Acer rubrum* L.) and Japanese tree lilac [*Syringa reticulata* (Blume) Hara]. We have tested the method for seven additional woody taxa important to the nursery industry and conclude that the method is viable for only 'Goldflame' spirea (*Spiraea* x *bumalda* 'Goldflame'), 'Charles Joly lilac (*Syringa vulgaris* L. 'Charles Joly') and 'Pioneer' elm (*Ulmus* 'Pioneer'). Our results indicated that subirrigation without mist is not a useful technique for Lamarck serviceberry (*Amelanchier lamarckii*), Amur maackia (*Maackia amurensis*), 'Kwanzan' cherry (*Prunus serrulata* 'Kwanzan'), and 'Michael Buchner' lilac (*Syringa vulgaris* 'Michael Buchner'). Propagators seeking the benefits of the subirrigation method should use it selectively and on a small scale initially because of variation in responses among taxa.

Introduction

Plant propagators curtail water loss from leafy, softwood cuttings by using propagation systems that involve intermittent mist, fog, or polyethylene tents (4, 7). Although such propagation systems are widely used in the nursery industry, problems may result. Cuttings held under mist can develop nutritional deficiencies due to leaching of foliage by misted water (1, 6, 17). Desiccation of foliage on rooted cuttings during de-acclimatization to environments with low relative humidity (RH) after mist propagation also can occur (20). In addition, high installation and maintenance costs are associated with mist systems (11).

Propagation of woody plants by using subirrigation without mist has been reported (15, 21). Rooting percentage and root dry mass for 'Franksred' (Red Sunset®) red maple and Japanese tree lilac were higher for cuttings subirrigated than for cuttings provided intermittent mist, with over 90% rooting of 'Franksred' red maple achieved in greenhouses with 50 to 68% RH (21). In an earlier report, rooting percentages >90% were reported for an unspecified lilac (*Syringa* L.) taxon by using a different subirrigation procedure (15). Initial trials we conducted indicated subirrigation has applicability for additional woody taxa but also suggested variability among taxa. Our objective was to compare the effect of intermittent mist and subirrigation without mist on leaf retention and callus and root formation of softwood cuttings of seven economically important shrub and tree taxa.

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Materials and Methods

Sources of plant material. Stock plants of 'Kwanzan' cherry (*Prunus serrulata* 'Kwanzan') and 'Pioneer' elm (*Ulmus* 'Pioneer') from J. Frank Schmidt & Son Co., Boring, OR, were held at ambient conditions on greenhouse benches in Ames, IA. Plants were irrigated with tap water as needed and fertilized once weekly with N at 10.8 mM (150 ppm) from Peters Excel All-purpose 21N–2.2P–16.6K (21–5–20) fertilizer (Scotts, Marietta, GA). Cuttings were taken from actively growing shoots.

Softwood cuttings of Lamarck serviceberry (*Amelanchier lamarckii*), 'Goldflame' spirea (*Spiraea* x *bumalda* 'Goldflame'), and 'Charles Joly' and 'Michael Buchner' lilacs (*Syringa vulgaris* 'Charles Joly' and 'Michael Buchner') were obtained from field-grown plants at Sherman Nursery Co. in Charles City, IA. Cuttings of *Maackia amurensis* were obtained from one tree (MLA #670974, #1) at the Minnesota Landscape Arboretum, Chanhassen, MN. Terminal shoot sections ≈15 cm (6 in) long were taken from all taxa in the field, placed in black plastic bags, wetted with tap water, and placed into coolers filled with ice. The shoot sections were returned to Ames within 3 to 4 hr and placed in a refrigerator at 5C (40F) overnight. Propagation treatments in the greenhouse began on the following day.

Propagation of 'Goldflame' spirea in 1995. Terminal shoot cuttings were taken on May 31 and June 27, 1995. Experiments were conducted on a greenhouse bench that was 5.5 by 1.5 m (18 ft by 5 ft). The bench was divided into six sections of equal area separated with vertical partitions of polyethylene. Individual sections were considered blocks and were randomly assigned to either mist or subirrigation; thus, there were three sections each with mist and subirrigation. Mist was provided from ≈0.5 hr before dawn until ≈1.5 hr after dusk in cycles of 15 seconds every 10 minutes. Single cuttings were placed in individual 250 ml plastic cups filled with perlite as described previously (9). Before cuttings were placed into perlite, the shoot sections were trimmed so the cuttings were ≈10 cm (4 in) long. The lower ≈2.5 cm (1 in) of the stems of cuttings were scraped with a razor blade to remove epidermis, dipped in tap water, and then dipped in talc that contained indole-3-butyric acid (IBA) at 1 g/kg (1000 ppm; Hormodin #1, MSD-AGVET, Rahway, NJ). Electrical conductivity (EC) of the mist and tap water used in this and all subsequent experiments was 0.43 mS/cm.

Five treatments were applied. Misted cuttings were placed into perlite pre-soaked with either tap water or with a solution with N at 10.8 mM (150 ppm) from the fertilizer used for stock plants. Subirrigated cuttings received either tap water or a solution of the fertilizer that contained N at either 5.4 mM (75 ppm) or 10.8 mM (150 ppm). Additional tap water and solution were provided to subirrigated cuttings twice weekly for 25 days (9). Within sections, there were four single-cutting samples of each of the five mist or subirrigation treatments. Percentage rooting was determined for each section, resulting in three experimental units for each treatment at the two cutting dates.

Propagation of six taxa in 1996. Cuttings of 'Pioneer' elm and 'Kwanzan' cherry were taken on April 17 and June 21, 1996. Cuttings of Lamarck serviceberry and 'Michael Buchner' and 'Charles Joly' lilac were taken on June 18 and July 25, 1996. Cuttings of Amur maackia were taken on June 14 and August 5, 1996. The same greenhouse bench and partitions were used with two blocks comprised of three sections each. For each cutting date, each section contained two flats without drainage holes that were 10 by 36 by 51 cm (4 by 14 by 20 in) (Dyna-flats, Hummert International, St. Louis, MO) and filled with coarse perlite (12 flats total for each cutting date). We modified the subirrigation method of Zhang and Graves (21) by drilling one hole in each side of the flats, 2.5 cm (1 in) from the bottom. Loss of excessive liquid through these holes kept the subirrigation solution in the lower 2.5 cm (1 in) of flats and below the cut ends of stems. We drilled eight drainage holes through the bottoms of flats used under mist. Each block was randomly assigned one section with mist and two sections for subirrigation. Mist was provided for 15 seconds every 10 minutes from ≈0.5 hr before dawn until ≈1.5 hr after dusk. Subirrigated flats in one section in both blocks received tap water. In the other subirrigation section of both blocks, flats received fertilizer solution with N at 5.4 mM (75 ppm). Solutions were applied to subirrigation flats twice weekly, and the volume was sufficient when applied to cause excess to flow from the holes in the sides of the flats.

At each cutting date, the 12 flats each received six cuttings of each taxon (five of Amur maackia on the second date). The cuttings were placed in rows within each flat, with one taxon per row, and with the position of the rows randomly assigned. Individual cuttings in each flat were treated as samples; hence an experimental unit was a flat, with four experimental units for each treatment at each cutting date. Single-node cuttings of 'Pioneer' elm and 'Kwanzan' cherry were used. Terminal shoot cuttings with one or two leaves were used for the other five taxa. The shoot sections were trimmed so that the final length of cuttings was 8 to 12 cm (≈3 to 5 in). Two 2.5-cm-long incisions were made through the epidermis on opposite sides of the stem by using a razor blade at the base of all cuttings. Cuttings were dipped in a solution containing 0.25% IBA and 0.125% 1-napthaleneacetic acid (NAA) (Dip'n Grow, Astoria-Pacific, Clackamas, OR) for 5 to 10 seconds before placement in flats. Subirrigation solutions were applied twice weekly for 56 days (98 days for Amur maackia).

Environmental conditions. The greenhouse was glazed with glass coated with a shading compound. Photosynthetic photon flux (*PPF*), air temperature, and RH adjacent to cuttings were measured by using a LI-COR 1600 steady-state porometer (LI-COR, Lincoln, NB) at midday on 10 and 16 days during experiments in 1995 and 1996, respectively. Measurements were obtained at six positions on the bench on each date. In 1995, *PPF* ranged from 31 to 217 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (155-1085 klx), air was 20 to 33C (68 to 91F), and RH was 34 to 86%, with means being 130 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (850 klx), 25C (77F), and 55%, respectively. In 1996, *PPF* ranged from 8 to 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (40–1250 klx), air was 7 to 30C (45 to 86F), and RH was 9 to 94%, respectively. Means were 88 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (440 klx), 24C (75F), and 59%, respectively.

Data collection and analysis. Cuttings were carefully removed from the flats, and perlite was rinsed from the roots. For 'Goldflame' spirea, percentage rooting was determined for each block. For other taxa, the presence or absence of leaves, callus, and roots on each cutting was noted. Individual cuttings in each flat were treated as samples, and percentage leaf retention, callus formation, and rooting were determined for each flat. Roots were excised from all cuttings and dried at 67C (153F) for 48 hr. We report mean root dry mass only for cuttings that formed roots.

Data were analyzed by using the Statistical Analysis System (SAS; SAS Institute, Cary, NC). A separate analysis of variance was performed for each taxon for rooting percentage, root dry mass, percentage of plants with leaves, and the percentage with callus by using the General Linear Model (GLM). GLM models included main effects of the five (1995) and three (1996) treatments, the date of treatment, and the interaction of these effects.

Results and Discussion

Propagation of 'Goldflame' spirea in 1995. The treatment effect on rooting percentage varied with date. All misted cuttings rooted on both dates, and all subirrigated cuttings taken on the second date (June 27) rooted. There was 83, 75, and 42% (LSD = 26%) rooting when cuttings collected on May 31 were subirrigated with water, N at 5.4 mM (75 ppm), and N at 10.8 mM (150 ppm), respectively. Treatment and date affected root dry mass. Averaged across both dates, root dry mass was 31 and 24 mg for misted cuttings propagated in perlite pre-soaked with tap water and with N at 10.8 mM (150 ppm), respectively. Root dry mass was 26, 32, and 17 mg (LSD = 7 mg) among unmisted cuttings subirrigated with water, with N at 5.4 mM (75 ppm), and with N at 10.8 mM (150 ppm), respectively. Mean root dry mass across treatments was 12 and 38 mg (LSD = 5 mg) at the first and second cuttings dates, respectively.

'Goldflame' spirea is considered easy to propagate from stem cuttings (4). This is consistent with our results, which show a high overall rooting percentage and a reduction in rooting percentage only for cuttings taken on May 31 and subirrigated with a solution containing N at 10.8 mM. Poorer rooting among the subirrigated cuttings at the first date may have been due to a relatively low resistance to water loss from leaves or to an osmotic effect of the subirrigation solution. Subirrigated cuttings that did not root showed leaf desiccation, suggesting incomplete cuticle formation or some other factor related to water loss from the young leaves contributed to the death of the cuttings. We conclude that with proper timing, subirrigation without mist is a feasible method of propagating 'Goldflame' spirea. Our results also provide justification for spirea propagators to conduct trials to evaluate the subirrigation method with other cultivars.

Propagation of six taxa in 1996. For several taxa, the influence of treatment on rooting percentage or percentage of plants with leaves or callus varied with date (Table 1). In such instances, results corresponding to the two dates are provided separately (Table 2). Where there was a main effect of either cutting treatment or date, but no interaction, the mean values for the main effects are presented (Table 3).

For Lamarck serviceberry, rooting percentage and percentage of cuttings with leaves and with callus were greater under mist than with either subirrigation treatment (Table 3). Rooting percentages >50% have been reported for *Amelanchier alnifolia* Nutt. (2), *Amelanchier arborea* (Michx.f.) Fern. (3), and *Amelanchier laevis* Weig. (18) held under mist. However, there is very little information on rooting of *A. lamarckii* (4). Rooting percentages <30% regardless of treatment (Table 3) illustrate our difficulty rooting Lamarck serviceberry and indicate that subirrigation does not enhance rooting compared to mist. Timing of cutting collection is essential to the success of rooting of serviceberries (4), and we achieved more rooting on June 18 than on July 25 (Table 3). Plants had set terminal buds by July 25, which may be related to the low rooting percentage achieved for cuttings taken then. Further research could focus on timing and varying rates of IAA or NAA to enhance rooting of Lamarck serviceberry and other *Amelanchier* species by using both mist and subirrigation methods.

Treatment effects on rooting percentage, and percentage of cuttings with roots and callus varied with date for Amur maackia (Table 1). Callus formation and rooting percentage for misted cuttings increased, while the percentage of cuttings with leaves decreased, between June 14 and August 5 (Table 2). No subirrigated cuttings had leaves, callus, or roots (Table 2). Neither treatment nor date affected root dry mass (Table 1). The rooting percentage achieved in this study is lower than most of the rooting percentages for Amur maackia reported by McNamara et al. (14). In contrast to that report, our data indicate the date of taking cuttings strongly affects maintenance of leaves and formation of callus and roots among misted cuttings. We conclude that subirrigation without mist is not a viable technique for rooting cuttings of Amur maackia.

Rooting percentage, and percentages of cuttings with leaves and callus were greater for 'Kwanzan' cherry pro-

Table 1. Significance of irrigation treatment and date of taking cuttings main effects and their interaction for six taxa propagated during 1996.

	Treatment	Date	Interaction
Amelanchier lamarckii			
Rooting percentage	**[z]	*	NS
Root dry mass	NS	NS	na[y]
Percent with leaves	***	NS	NS
Percent with callus	***	NS	NS
Maackia amurensis			
Rooting percentage	***	**	***
Root dry mass	na	NS	na
Percent with leaves	***	*	**
Percent with callus	***	**	***
Prunus serrulata 'Kwanzan'			
Rooting percentage	**	***	NS
Root dry mass	NS	NS	NS
Percent with leaves	**	na	na
Percent with callus	***	***	NS
Syringa 'Charles Joly'			
Rooting percentage	***	***	*
Root dry mass	NS	NS	NS
Percent with leaves	***	***	**
Percent with callus	***	***	NS
Syringa 'Michael Buchner'			
Rooting percentage	***	***	**
Root dry mass	NS	NS	na
Percent with leaves	***	NS	NS
Percent with callus	***	NS	NS
Ulmus 'Pioneer'			
Rooting percentage	NS	**	*
Root dry mass	NS	**	NS
Percent with leaves	NS	na	na
Percent with callus	NS	NS	NS

[z]NS, *, **, *** Nonsignificant, or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

[y]Not available. Data were not recorded for this variable during the first run of the experiment. For dry mass, there were too few plants with developed roots to test for main effects or interaction.

Table 2. **Means of dependent variables for which there was an interaction of treatment and date of cuttings. Cuttings of 'Pioneer' elm and 'Kwanzan' cherry were taken on April 17 and June 21, 1996. Cuttings of Lamarck serviceberry and 'Michael Buchner' and 'Charles Joly' lilac were taken on June 18 and July 25, 1996. Cuttings of Amur maackia were taken on June 14 and August 5, 1996. Cuttings were subirrigated with tap water or fertilizer solution with N at 5.4 mM (75 ppm). Values are means of four replications. The LSD value represents the least significant difference between the six treatments within dependent variables at P = 0.05.**

	Date of cutting collection						
	First			Second			
		Subirrigation with			Subirrigation with		
	Mist	Fertilizer	Water	Mist	Fertilizer	Water	LSD
Maackia amurensis							
Rooting percentage	4	0	0	42	0	0	11
Percentage with leaves	71	0	0	25	0	0	22
Percentage with callus	4	0	0	65	0	0	16
Syringa 'Charles Joly'							
Rooting percentage	96	29	75	25	0	8	24
Percentage with leaves	100	42	100	92	0	88	15
Syringa 'Michael Buchner'							
Rooting percentage	88	13	38	8	0	0	21
Ulmus 'Pioneer'							
Rooting percentage	25	69	29	79	58	67	30

vided with mist compared to subirrigation, and callus formation and rooting were greater at the first (April 17) compared to the second (June 21) date (Table 3). Root dry mass did not vary with treatment or date (Table 3). Previous research has shown 'Kwanzan' cherry is easily rooted by using hormones and mist (13). Our results suggest that cuttings of this taxon require mist to maintain rooting above 50%, and we do not recommend subirrigation without mist be used commercially.

For 'Charles Joly' lilac, treatment effects on rooting percentage and percentage of plants with leaves and callus varied with date (Table 1). Mean rooting across treatments was 67% at the first date (June 18) and 11% at the second date

Table 3. **Means of dependent variables by treatment and dates of cuttings for variables not showing an interaction between these main effects. Cuttings of 'Pioneer' elm and 'Kwanzan' cherry were taken on April 17 and June 21, 1996. Cuttings of Lamarck serviceberry and 'Michael Buchner' and 'Charles Joly' lilac were taken on June 18 and July 25, 1996. Cuttings of Amur maackia were taken on June 14 and August 5, 1996. Cuttings were subirrigated with tap water or fertilizer solution with N at 5.4 mM (75 ppm). Values are means of eight replications (treatment) or 12 replications (date) per main effect.**

	Treatment				Date of cutting collection		
		Subirrigation with					
	Mist	Fertilizer	Water	LSD[z]	First	Second	LSD
Amelanchier lamarckii							
Rooting percentage	29	0	4	13	17	6	11
Root dry mass (mg)	42	0	16	NS	34	49	NS
Percentage with leaves	52	0	10	18	19	22	NS
Percentage with callus	35	0	4	15	17	10	NS
Maackia amurensis							
Root dry mass (mg)	69	0	0	na	95	62	NS
Prunus serrulata 'Kwanzan'							
Rooting percentage	67	31	35	15	67	22	12
Root dry mass (mg)	56	85	60	NS	69	62	NS
Percentage with leaves	42	8	13	10	na[y]	na	na
Percentage with callus	67	31	35	15	67	22	12
Syringa 'Charles Joly'							
Root dry mass (mg)	93	30	65	NS	72	70	NS
Percentage with callus	81	15	71	13	71	40	11
Syringa 'Michael Buchner'							
Root dry mass (mg)	55	59	36	NS	57	25	NS
Percentage with leaves	100	17	77	30	67	63	NS
Percentage with callus	94	8	60	24	58	50	NS
Ulmus 'Pioneer'							
Root dry mass (mg)	124	144	112	NS	71	178	52
Percentage with leaves	88	63	71	NS	na	74	na
Percentage with callus	81	69	69	NS	69	76	NS

[z]LSD represents the least significant difference between the treatment means within dependent variables at P ≤ 0.05, NS = nonsignificant.

[y]Not available. Data were not recorded for this variable during the first run of the experiment. For dry mass of Amur maackia, the number of cuttings with roots was too small to test for main effects or interaction.

(July 25) (Table 2). Misted cuttings and cuttings subirrigated with water had >88% leaf retention at both dates, but leaf retention of cuttings subirrigated with fertilizer was lower for cuttings collected on July 25 than for those collected on June 18 (Table 2). The percentage of cuttings that formed callus was greater with either mist or subirrigation with water compared to cuttings subirrigated with fertilizer, and callus formation was greater for cuttings taken in June than for those taken in July (Table 3). Rooting percentage of cuttings of 'Michael Buchner' lilac declined from the first to the second date for all three treatments (Table 2). The average rooting percentage across the three treatments decreased from 46% for cuttings taken on June 18 to 2.7% for cuttings taken on July 25. Leaf retention and callus formation were reduced among cuttings subirrigated with fertilizer compared to cuttings either misted or subirrigated with water (Table 3).

Optimum timing is essential for successful propagation of common lilac cultivars (4, 10, 16). Miske and Bassuk (16) increased rooting percentages of several cultivars by using stock plant etiolation and reported ≈50 to 90% rooting of 'Michael Buchner' grown in a greenhouse and 0 to 60% rooting for 'Charles Joly' grown outdoors. The reason for the discrepancy between this previous report and our data is unclear and may relate to dates cuttings were taken, condition of stock plants, or environmental conditions under which cuttings were propagated. Based on our results, we recommend mist or subirrigation with water to propagate 'Charles Joly' lilac, but cannot recommend subirrigation for 'Michael Buchner' lilac.

The influence of treatment on rooting of 'Pioneer' elm varied with date (Table 1). At the first date (April 17), the greatest percentage rooting was for cuttings subirrigated with fertilizer, but at the second date, there was no difference between treatments (Table 2). Root dry mass of 'Pioneer' elm varied with the date but was not affected by irrigation treatment (Table 3). Townsend and Masters (19) reported that 'Pioneer' elm can be easily propagated by using IBA and mist on cuttings taken from May through August. We found that percentage rooting across the three treatments increased from 41% in April to 68% in June. The immaturity of cuttings or the influence of greenhouse conditions may have contributed to the lower rooting percentage of cuttings collected in April. Likewise, root dry mass was greater for plants propagated in June. These data indicate that timing of cutting collection has a greater influence over the success of propagation than mist and subirrigation treatments. With proper timing, use of subirrigation can be as effective as mist for cutting propagation of 'Pioneer' elm.

This research demonstrates that taxa vary in how successfully subirrigation without mist can be used to propagate softwood cuttings. Taxa showing a high percentage of rooting in subirrigation tended to root more quickly than those performing poorly with this method. For instance, 90% of misted and subirrigated cuttings of 'Goldflame' spirea rooted after 3 weeks. After 8 weeks, 55% of 'Pioneer' elm cuttings and 11% of Lamarck serviceberry had rooted. Amur maackia, the slowest taxon to root, had 23% rooting under mist and no rooting when cuttings were subirrigated for 14 weeks. The relationship between rate of rooting and success of the subirrigation method may be related to the capacity for cuttings to sustain a favorable water balance before roots form, which is essential for survival of leafy cuttings (8, 12). In our subirrigation treatments, fast-rooting taxa such as 'Goldflame' spirea had to sustain a favorable water balance without mist or roots for a shorter period than the slow-rooting taxa. Leaf water loss and turgidity of cuttings are influenced more by the vapor pressure gradient between leaves and the atmosphere than by water uptake through cut stems (5, 8). Thus, low rooting of subirrigated Amur maackia and Lamarck serviceberry may have resulted primarily from excessive leaf water loss before root initiation. Rate of root formation, however, was not the only factor influencing the survival of subirrigated cuttings. Among subirrigated cuttings of all taxa, foliage of only Amur maackia became completely desiccated within a few days after cuttings were placed into perlite. This suggests the capacity for cut stems to transport water from subirrigated perlite and the diffusive resistance of leaves to water loss also varied among the taxa we used.

In conclusion, we have found that cuttings of woody taxa vary in their response to subirrigation. Previous research has demonstrated success of using the subirrigation method with cuttings of red maple and Japanese tree lilac (21), and our results show the success of the subirrigation method can equal or exceed the success of using mist for 'Goldflame' spirea, 'Pioneer' elm, 'Charles Joly' lilac. Yet the importance of the date of taking cuttings for some taxa, and the failure of the method regardless of date for other taxa underscore the importance of using the subirrigation method with caution. We encourage propagators to test the method on samples of cuttings of individual taxa before subirrigation without mist is adopted commercially.

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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