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Effect of Shade Levels and IBA During the Rooting of Eight Tree Taxa[1]

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Abstract

Softwood shoot cuttings of *Acer griseum*, *A. rubrum* 'Bowhall', *A. rubrum* 'Franksred' Red Sunset™, *A. saccharum* 'Legacy', *Cornus kousa*, *Quercus alba*, *Q. ellipsoidalis,* and *Q. palustris* were subjected to hormone treatments (IBA and control) and placed in a fog-humidified polyethylene tent rooting chamber under one of three levels of shade (83% or control, 91%, and 97% of ambient sun). Percentage rooting, the number of roots per cutting, and the number of days to root were significantly influenced by shade levels and hormone treatment, but responses were dependent on species or cultivar. For most taxa, percentage rooting was greatest at 91% or 97% shade. Only for *A. griseum* was the control shading treatment best for rooting. Generally, under the greater shade levels, the IBA treated cuttings rooted more often, had more roots, and rooted faster than cuttings without IBA. However, in some cases, the hormone treatment did not provide a clear advantage. Results of this study demonstrate that high shade levels in the rooting environment can increase the rooting performance of cuttings of a number of woody plant taxa.

Index words: propagation, adventitious root formation, cutting, shade.

Species used in this study: paperbark maple (*Acer griseum* {Franch.} Pax); red maple (*A. rubrum* L. 'Bowhall'); (*A. rubrum* L. 'Franksred' Red Sunset™); sugar maple (*A. saccharum* Marsh. 'Legacy'); kousa dogwood (*Cornus kousa* Hance); white oak (*Quercus alba* L.); northern pin oak (*Q. ellipsoidalis* E. J. Hill); and pin oak (*Q. palustris* Muenchh.).

Chemicals used in this study: IBA, indole-3-butyric acid.

Significance to the Nursery Industry

Shading cuttings in the rooting environment to levels at or greater than 91% resulted in the highest percentage rooting of cuttings for 7 of 8 species tested. The control shade treatment (83%) resulted in the highest percentage rooting only for *A. griseum* cuttings. For the most part, IBA treatments were also necessary for the highest rooting percentages, greatest number of roots per cutting, and fewest days to root. However, the best hormone/shade treatment combinations were species and cultivar specific. Subjecting cuttings to relatively high levels of shade (≥ 91%) in the rooting environment was shown to increase rooting performance of some difficult-to-root species, has potential to reduce production costs, is environmentally sound, and should enable growers to increase production and the diversity of selected clonal stocks.

Introduction

Studies have shown that light reduction treatments such as etiolation or opaque banding applied to stock plants prior to cutting collection can increase rooting success of difficult-to-root species (2, 15, 19, 20). However, stock plant light reduction treatments (shading) can be difficult to apply, especially on mature trees (13). Zaczek (29) in a recent study with typically difficult-to-root mature *Quercus rubra* L. demonstrated that rooting was significantly improved by subjecting shoot cuttings to shade levels up to 97% of ambient daylight in the rooting environment compared to lower shade levels. Potentially, high levels of shade applied in the rooting environment could prove to be useful in rooting cuttings from other recalcitrant species or cultivars. This study examined the effects of shade levels in the rooting environment, with and without hormone application, on the rooting of cuttings of 8 tree taxa.

Materials and Methods

Softwood shoot cuttings of *Acer griseum*, *A. rubrum* 'Bowhall', *A. rubrum* 'Franksred' Red Sunset™, *A. saccharum* 'Legacy', *Cornus kousa*, *Quercus alba*, *Q. ellipsoidalis,* and *Q. palustris* were collected from several sources and kept cool and moist until treatment application. The *Q. palustris* and *Q. ellipsoidalis* cuttings were collected from the most recent growth flush in mid to upper crowns of 18-year-old trees on June 14, 1995. Cuttings were trimmed in length to 15 cm (6 in) and had all but the uppermost 3 leaves removed before they were treated and placed in the rooting chamber that same day. *Cornus kousa* cuttings were collected from 4 mature trees located on the campus of The Pennsylvania State University on June 16, 1995, and processed as single node cuttings the same day. Single node *A. griseum*, *A. rubrum*, and *Q. alba* cuttings were collected at The Buddies Nursery, Birdsboro, PA, on June 20, 1995, and processed for rooting over the next 2 days. Potted stock plants of *A. griseum* were approximately 1.5 m (5 ft) tall. Field grown trees of *A. rubrum* cultivars were between 4 to 5 m (13 to 16 ft) tall and approximately 5 cm (2 in) in caliper. Cuttings of *Q. alba* came from 1 to 1.5 m (3 to 5 ft) tall plants estimated at 4 years of age. The *A. saccharum* 'Legacy' cuttings were collected from 2 trees approximately 4 m (13 ft) tall and 5 cm (2 in) in caliper located in an experimental planting (The Pennsylvania State University) on July 7, 1995, and processed that day.

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All cuttings were trimmed to size, soaked in a solution of Olympic Triathlon (Olympic Horticultural Prod., Mainland, PA) at a rate of 1.3 ml per liter of water (1 tsp per gal) for 5 min, rinsed in water, soaked in a solution of Clearys 3336-F (W. A. Cleary Chemical Corp., Somerset, NJ) at a rate of 1.6 ml per liter water (0.2 oz per gal) for 5 min, removed and air dried. For each species, 180 cuttings were processed except for *C. kousa* where 216 cuttings were used. One half of the number of cuttings of each species were treated with indole-3-butyric acid (IBA). For all but *A. griseum*, the bases of freshly trimmed cuttings were dipped for 5 sec 2 cm (0.8 in) deep in either 95% ethanol (control) or in an IBA and ethanol solution. The concentration of the hormone solution was 10,000 ppm for all *Quercus* species, *A. saccharum* 'Legacy', and *C. kousa* and 5000 ppm for *A. rubrum* cultivars. Cuttings of *A. griseum* were dipped 2 cm (0.8 in) deep in either Hormodin #3 powder (0.8% IBA in talc) or in talc alone (control). Cuttings were then inserted in a mix of peat moss, perlite, and sand (1:1:1 by vol) in Ray Leach Single Cell Cone-tainers™ (Stuewe and Sons Inc., Corvallis, OR). For each species, both hormone treated and control cuttings were randomly divided in thirds and placed randomly within one of 2 shade levels or control in the rooting chamber. For each species, 30 (36 for *C. kousa*) cuttings were subjected to each of the 6 shade/hormone treatment combinations.

The rooting chamber was located in a greenhouse and consisted of 1-m- (3.3 ft) tall frames constructed of poly vinyl chloride (PVC) pipe on three 1.7 m × 3.0 m (5.5 ft × 10 ft) roller benches covered entirely by a single sheet of 6-mil polyethylene. This formed a single rooting chamber which minimized potential humidity and temperature differences among treatments. Intermittent cool fog was provided by 4 ultrasonic humidifiers (Sunbeam model 667, Northern Electric Co., Chicago, IL) set outside opposing ends (2 per end) of the tent. Ambient daylength was maintained, but whitewash (Kool-Ray white shading compound, Continental Products Co., Euclid, OH) was applied to the exterior of the greenhouse to reduce light levels and limit solar heating inside the polytent. It is essential to provide relatively heavy shading to minimize solar heating during summer use of polytent systems in climates with high irradiance (17). Our previous experience (29) as well as others (16) have shown that moderate temperatures can be maintained in a polytent rooting environment with ca. 80–85% shade. Therefore, we consider a shade level in this range a 'control' treatment. To provide the shade treatments, the rooting chamber was subdivided into 3 shade level compartments. Two compartments had black polypropylene shade fabrics (80% and 47%) (Yonah Manufacturing Co., Cornelia, GA) suspended 10 cm (4 in) above the roof and along the vertical walls of 2 sections of the rooting chamber. The third compartment (control) received no shade fabric except was bordered by a 47% fabric wall from the adjacent shading treatment. Shade fabric on the inside of the chamber between shade levels was suspended from the top of the chamber down below the top of the cuttings but leaving the lower 25 cm open. This coupled with the porous nature of the shade fabric allowed for humidity and air exchange between the 3 compartments.

Percentage shading for the 3 treatments was determined by measuring photosynthetic photon flux density (PPFD, μmoles m^{-2} s^{-1}) on different days and times during daylight hours at 15 locations in each treatment and outside the greenhouse using the quantum sensor of a portable infrared gas analyzer (model LCA-2, Analytical Development Co., Ltd., Hertz, England). The percentage reduction of ambient sun (percentage shade) for each compartment was determined relative to the outside ambient PPFD reading [(1 – (PPFD tray / PPFD outside)) × 100]. Shade levels were 97%, 91%, and 83% (control). For reference, the average ambient sun (outdoor) PPFD was 1584 μmoles m^{-2} s^{-1} in a previous study during the summer at the same location on different days between 09:00 and 17:00 hours (29).

Hygrothermagraphs (Belfort Instrument Co., Baltimore, MD) were used to monitor humidity levels and air temperature inside each shade level of the rooting chamber. Relative humidities were maintained at 100% except for short time periods when the chamber was opened to check for roots, apply fungicides, or change chart paper. Air temperatures varied less than 1C (1.8F) on average among shade treatments.

Fungicide solutions, either Cleary's 3336-F at a rate of 0.7 ml per liter water (½ tsp per gal) or Chipco Aliette (Rhone-Poulenc Company, Research Triangle Park, NC) at a rate of 1.2 g per liter (0.2 oz per gal) were sprayed on the leaves ca. every 2 weeks during the rooting period. Approximately weekly, the chamber was opened and the leach tubes were checked for emerging roots. Those cuttings with roots were removed from the chamber, the date and the number of roots per cutting measuring at least 5 mm (0.2 in) long were noted, and the cuttings were potted. In late October, all remaining cuttings were checked for roots.

Statistical analyses were performed for each species or cultivar to determine if shade level or hormone treatment influenced rooting results. Logit analysis (7) was performed (at the $p = 0.10$ level) to determine if the categorical variable rooting was related to shade or hormone treatments or both simultaneously. When significant relationships between rooting and treatments were established, pairwise comparisons among treatment means were made at the $p = 0.05$ level using CONTRAST, a computer program (14) based on a chi-square procedure (24). For continuous data, analysis of variance (at the $p = 0.05$ level) (26) was used to test for differences in the number of roots per rooted cutting and days to root among shade and hormone main effects and their interaction. When significant treatment effects on the number of roots per cutting and number of days to root were detected, Duncan's multiple range test was used to compare treatment means. Log transformation was used for the number of roots per cutting because the data were not normally distributed, the treatment standard deviations were proportional to the treatment means, and some of the values were less than 10 (10). In cases where some species or cultivars rooted poorly overall (<10%) resulting in low numbers, incomplete cells, or missing data for specific treatment combinations, the application of the forementioned statistical analyses was not warranted nor performed.

Results and Discussion

Rooting was influenced by shade and hormone treatments either alone or together but the responses varied among species and cultivars. Rooting averaged 28% overall. Rooting by species across all treatments ranged from 1% to 64%. The IBA treated cuttings averaged 37% rooting compared to 21% for control. Mean rooting was 25%, 33%, and 26% for shade levels of 97%, 91% and 83% (control), respectively. Percentage rooting for the various species, shade, and hormone

Table 1. Percentage rooting, the average number of roots per rooted cutting, and the average number of days to root by species, shade, and hormone treatment. Within a species, shade-level means (in a column) with different letters or IBA level means (in a row) with an asterisk are significantly different at the p = 0.05 level. Percentage rooting means tested based on pairwise comparisons using CONTRAST. Numbers of roots and days to rooting means tested using Duncan's Multiple Range Test.

Species	Percentage shade	Percentage rooting			Number of roots per cutting			Number of days to root		
		IBA	no IBA	mean	IBA	no IBA	mean	IBA	no IBA	mean
Acer griseum	83	36.7	10.0	23.3a	5.0	1.3	4.2	109	126	112
	91	26.7	20.0	23.3a	4.1	1.7	3.1	107	125	115
	97	3.3	3.3	3.3b	2.0	1.0	1.5	94	114	104
	mean	22.2*	11.1*		4.5	1.5		107*	124*	
Acer rubrum 'Bowhall'	83	26.7	6.7	16.7a	4.6	2.5	4.2a	85	97	87
	91	66.7	20.0	43.3b	7.1	2.5	6.0a	69	86	73
	97	66.7	23.3	45.0b	13.5	12.7	13.3b	63	91	70
	mean	53.3*	16.7*		9.4	7.3		69*	90*	
Acer rubrum 'Franksred' Red Sunset™	83	80.0	56.7	68.3	16.7	5.7	12.1	69	64	67a
	91	86.7	46.7	66.7	18.0	3.4	12.9	69	71	70a
	97	76.7	40.0	58.3	16.3	3.0	11.7	92	89	91b
	mean	81.1*	47.8*		17.1*	4.2*		76	73	
Acer saccharum 'Legacy'	83	13.3	3.3	8.3	1.5	1.0	1.4	112	112	112
	91	10.0	20.0	15.0	1.7	1.8	1.8	110	104	106
	97	0.0	0.0	0.0	—	—	—	0	—	—
	mean	7.8	7.8		1.6	1.7		111	105	
Cornus kousa	83	77.8	44.4	61.1	10.4	6.8	9.4	112	122	115
	91	83.3	47.2	65.3	11.0	5.7	9.1	113	119	115
	97	83.3	50.0	66.7	11.4	6.0	9.4	107	110	108
	mean	81.5*	47.2*		11.0*	6.2*		110	117	
Quercus alba	83	16.7	23.3	20.0ab	2.8	2.1	3.4	120	117	118
	91	30.0	30.0	30.0a	2.1	1.3	1.7	111	116	114
	97	16.7	10.0	13.3b	4.6	1.3	3.4	111	111	111
	mean	21.1	21.1		2.9*	1.6*		113	116	
Quercus ellipsoidalis	83	0.0	0.0	0.0	—	—	—	0	—	—
	91	3.3	0.0	1.7	1.0	—	1.0	73	—	73
	97	3.3	0.0	1.7	1.0	—	1.0	119	—	119
	mean	2.2	0.0		1.0	—		96	—	
Quercus palustris	83	10.0	3.3	6.7	1.7	1.0	2.0	43	48	44
	91	23.3	3.3	13.3	1.7	2.0	1.8	59	73	61
	97	0.0	3.3	1.7	—	2.0	2.0	0	40	40
	mean	11.1	3.3		1.7	1.7		54	54	

treatment combinations ranged from 0% to 87% (Table 1). Cuttings of *Q. palustris*, *Q. ellipsoidalis*, and *A. saccharum* averaged less than 10% rooting over all treatments and further statistical analyses were limited for these species.

For the other species, logit analyses indicated that rooting was statistically related to hormone treatment alone for *C. kousa* and *A. rubrum* 'Franksred' Red Sunset™ (p = 0.95 and p = 0.60, respectively). The IBA treated cuttings of these two species rooted at rates nearly twice that of untreated cuttings. Rooting response for *A. rubrum* 'Bowhall' and *A. griseum* was dependent on both shade and hormone treatments together (p = 0.91 and p = 0.32, respectively). The highest percentage rooting for both *A. rubrum* 'Bowhall' and *A. griseum* required IBA treatment. However, with IBA treatment, the greatest percentage rooting for *A. griseum* was under the control shade treatment (83%) whereas *A. rubrum* 'Bowhall' rooted most often at increased shade levels (either 91% or 97%).

Shade level as a single factor was significantly related to rooting of *Q. alba* (p = 0.80) with the most cuttings (30%) rooting under the 91% shade level. At this same shade level, rooting was highest or equal to the highest for 7 of 8 of the species or cultivars. Only among cuttings of *A. griseum* did the control treatment result in the highest percentage rooting.

The number of roots per cutting was significantly greater ($p < 0.05$) for hormone treated cuttings compared to control cuttings in 3 of 5 comparisons (not so for *A. griseum* and *A. rubrum* 'Bowhall') by species (Table 1). However, for *A. rubrum* 'Bowhall', shade level significantly ($p < 0.01$) influenced the number of roots with the most occurring at the 97% shade level. Numbers of roots for *Q. alba* cuttings also was somewhat greater at 97% shade compared to other shade treatments but the effect was not quite statistically significant (p = 0.07). Shading had no significant influence on the number of roots per cutting for the other species or cultivar comparisons. There was no significant interaction ($p > 0.05$) between shade and hormone treatments for the number of roots in any species tested. In other studies, it has been shown that the number of roots per cutting was increased (11), decreased (3), or unchanged (1) by lower irradiances during rooting.

The number of days to root was significantly influenced by hormone treatment ($p < 0.05$) for *A. griseum* and *A. rubrum* 'Bowhall' and nearly so ($p = 0.08$) for *C. kousa*. In these cases, hormone treated cuttings rooted faster than controls (Table 1). Shade treatments significantly ($p < 0.01$) influenced the number of days to root for *A. rubrum* 'Franksred' Red Sunset™ cuttings averaging more days to root in the most shade (97%) than either of the other shade levels. There was no significant interaction ($p > 0.05$) between hormone and shade treatments for the number of days to root in any taxa tested.

For the most part, IBA treated cuttings rooted more often, had more roots per cutting, and rooted faster than controls. At least one of these rooting responses has been shown to occur with IBA treatments with various woody taxa (6, 20, 25). In this study, IBA treatments did not always improve rooting responses but were generally not detrimental for any species.

It is commonly assumed by propagators that leafy cuttings should be subjected to a rooting environment with a light level that is conducive to photosynthesis (4, 12). However, little scientific evidence supports this assumption (4) and cuttings do not require high light levels until rooting occurs (5, 18). Photosynthesis during rooting is not an absolute requirement of cuttings for root formation (4), a conclusion that is supported by the rooting of many non-photosynthetic, leafless hardwood cuttings and rooting of *Pisum* cuttings in darkness (3). Zaczek (29) showed that rooting for mature *Q. rubra* benefitted from rooting environment shading levels up to 97% which is near the light compensation point for seedlings of that species. In this study, percentage rooting, for most species, was greatest at shade levels at or more than 91% suggesting that relatively high levels of light in the rooting beds are either unnecessary or detrimental for the species tested at least until rooting occurs.

The beneficial influence of light reduction or exclusion on rooting has been reported by many authors in regards to the pretreatment of stockplants from which cuttings are taken. Rooting success for some recalcitrant woody plant species has been shown to benefit from severely reducing light to the stockplant prior to cutting collection, referred to as etiolation or blanching (2, 15, 19, 20, 21, 28). However, light reduction treatments are difficult to apply to mature trees (13). Results of this study indicate that light reduction treatments during the rooting phase are also effective in increasing rooting of some woody plant taxa and are easily applied after cutting collection.

Optimum levels of shading for stockplants varies from species to species and even among genotypes of a species (22). Our results suggest that the optimum level of shade during rooting also appears to vary by species and genotype and additionally may depend on the presence or absence of hormone application.

Shading during rooting does not appear to be universally beneficial to all species or cultivars especially to those that already have reasonably successful propagation protocols. For example, *A. rubrum* 'Franksred' Red Sunset™, which is considered easy-to-root (9, 23), showed little benefit to rooting from shade. However, *A. rubrum* 'Bowhall', considered difficult to root (9), benefitted greatly from shade levels at or greater than 91%. The *Quercus* species are notoriously poor rooters (5, 8, 27) but *Q. alba* and *Q. palustris* performed best at the 91% shade level. Additionally, results from Zaczek (29) over 2 years demonstrated that cuttings from mature *Q. rubra* generally rooted best at shade levels greater than 92%. These results suggest that the benefit of increased shading during rooting appears to be most pronounced in species or cultivars that have been traditionally difficult to root.

Maintaining high light levels during rooting apparently is not warranted for most of the species tested. Therefore, growers can expect cost savings associated with reduced demands for cooling, humidification through misting or fogging, and supplemental lighting. Additionally, since cuttings do not necessarily require high light levels for rooting, it is possible that rooting chambers could occupy areas other greenhouses, freeing that space for production of other plant materials.

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