Light Levels and Hormone Effects During the Rooting of Selected Tree Taxa

James J. Zaczek
Southern Illinois University, Department of Forestry, Carbondale, Illinois 62901-4411

Charles W. Heuser, Jr.
The Pennsylvania State University, Department of Horticulture, University Park, Pennsylvania 16802

Kim C. Steiner
The Pennsylvania State University, School of Forest Resources, University Park, Pennsylvania 16802

INTRODUCTION

Light reduction treatments such as etiolation or opaque banding applied to stock plants prior to cutting collection have been shown to increase rooting success of difficult-to-root species (Bollmark and Eliasson, 1990; Leakey and Storeton-West, 1992; Maynard and Bassuk, 1986). However, stock plant light reduction treatments (shading) can be difficult to apply, especially on mature trees (Hecht-Poinar et al., 1989). Zaczek (1994) in a recent study with typically difficult-to-root mature *Quercus rubra* demonstrated that rooting was significantly improved by subjecting shoot cuttings to shade levels up to 97% of ambient daylight in the rooting environment. 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 eight 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 14 June 1995. Cuttings were trimmed in length to 15 cm (6 inches) 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 four mature trees located on the campus of The Pennsylvania State University on 16 June 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 20 June 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 inches) 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 two trees approximately 4 m (13 ft) tall and 5 cm (2 inches) in caliper located in an experimental planting (The Pennsylvania State University) on 7 July 1995 and processed that day.

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 liter^{-1} of water (1 tsp gal^{-1}) 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 liter^{-1} water (0.2 oz gal^{-1}) 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 inches) 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 inches) 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 volume) in Ray Leach Single Cell Cone-tainers^{Tm} (Stuewe and Sons Inc., Corvallis, Oregon). 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-tall (3.3-ft) 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. Our previous experience (Zaczek, 1994) has shown that moderate temperatures can be maintained in a polytent rooting environment with ca. 80% to 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, Georgia) suspended 10 cm (4 inches) 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 three 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}.

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 $liter^{-1}$ water ($^1/_2$ tsp gal^{-1}) or Chipco Aliette (Rhone-Poulenc Company, Research Triangle Park, North Carolina) at a rate of 1.2 g $liter^{-1}$ (0.2 oz gal^{-1}) 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.

Statistical analyses were performed for each species or cultivar. Logit analysis (Fienberg, 1980) 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 (Hines and Sauer, 1989) based on a chi-square procedure (Sauer and Williams, 1989). For continuous data, analysis of variance (at the p=0.05 level) (Steel and Torrie, 1980) 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 (Fowler and Cohen, 1990). 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 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.

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.

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 (Davis, 1988; Hartmann and Kester, 1983). However, little scientific evidence supports this assumption (Davis, 1988) and cuttings do not require high light levels until rooting occurs (Dirr and Heuser, Jr., 1987; Loach and Gay, 1979). Photosynthesis during rooting is not an absolute requirement of cuttings for root formation (Davis, 1988), a conclusion that is supported by the rooting of many non-photosynthetic, leafless hardwood cuttings and rooting of *Pisum* cuttings in darkness (Davis and Potter, 1981). Zaczek (1994) 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.

Optimum levels of shading for stockplants varies from species to species and even among genotypes of a species (Moe and Andersen, 1988). 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

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	Shade (%)	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	

easy-to-root (Flemer, 1982), showed little benefit to rooting from shade. However, *A. rubrum* 'Bowhall', considered difficult to root (Flemer, 1982), benefitted greatly from shade levels at or greater than 91%. The *Quercus* species are notoriously poor rooters (Dirr and Heuser, Jr., 1987; Flemer, 1962; Teclaw and Isebrands, 1987) but *Q. alba* and *Q. palustris* performed best at the 91% shade level. 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.

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The Recycling of Propagation Materials

Michael Kolaczewski

Flora and Fauna, Horticultural & Biological Consultants, 324 Silver Street, Elgin, Illinois 60123

INTRODUCTION

The reuse of certain products or byproducts in manufacturing is not new. The nature of various horticultural production methods culminates with materials passing through the manufacturing scheme once. This type of operational setup can, and will continue to add costs to production, and can impact upon the desired net income of an operation. This qualitative look at what our firm does to stream line production costs may be applicable to your company.

No one wants to spend more on getting a product into a customer's hands than necessary. Added costs impact upon prequoted prices, affect bids, and upset bankers. How then do you keep costs down yet produce a marketable plant product? For myself, I have settled upon a propagation method which allows me to reuse various components over and over again.

The 1-gal plastic pot inventory, Lerio Mfg., is at about 5500 units. There are about 2500 to 3000 pots in production at any one time. An almost equal number of various bandpots, Anderson Mfg., are also in the mix as well. Bandpot prices, for a 6-inch bandpot, are at about 13¢ per unit, priced per thousand. If you would use more, say 25 to 50 thousand, the price would drop several pennies. You of course must factor in a shipping cost, but this is a one time charge, which is reasonable when sending a truck load, versus a few boxes via UPS. In fact, the majority of our 4- and 6-inch bandpots and 1-gal containers have been in continuous use for over 5 years.

Plants are shifted from plug trays into bandpots, and in some cases, later finished in 1-gal containers. In most cases, plants go from plugs into bandpots, and are later sold, or installed as a "bandpot" 1 gal. The consideration here is that over 85% of what is grown is used in house. We are "barerooting" the majority of the plants grown. These for the most part are installed into landscapes, when the resale plants go out, some are knocked out of their pots. Those that are not, go to people who know to return the pots for which they get a credit. The pots come back, are cleaned and reused.