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# Low Irradiance During Rooting Improves Propagation of Oak and Maple Taxa[1]

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## Abstract

Rooting trials were conducted to determine if the duration of exposure to low levels of solar irradiance during root initiation influenced rooting and survival of semihardwood cuttings of six tree species. Cuttings of oak (*Quercus imbricaria*, *Q. nigra*, *Q. palustris*, *Q. rubra*) and maple (*Acer rubrum* 'Bowhall', and *A. truncatum*) were treated with IBA and placed in a fog-humidified polyethylene tent rooting chamber for 119 or 117 days (*A. rubrum* and *Q. nigra*) under either 82% (control) or 93% (low irradiance) shading of ambient outdoor solar radiation. Cuttings were exposed to either 0, 10, 20, 40, or 119 days of 7% irradiance followed by placement under control conditions (18% irradiance) for the remainder of the treatment. Percentage rooting, the number of roots per cutting, and the number of days to root were significantly influenced by exposure to 7% irradiance during rooting, but responses were dependent on taxa. For most taxa, the highest rooting percentages required at least 10 days of exposure to 7% irradiance. Overwinter survival of rooted cuttings averaged 58.8% and was not affected by treatment. Results of this study demonstrate that low irradiance in the rooting environment can increase the rooting of cuttings of oak and maple taxa.

**Index words:** Vegetative propagation, adventitious root formation, cutting, irradiance, shade.

**Species used in this study:** Red maple (*Acer rubrum* L. 'Bowhall'); purpleblow maple (*A. truncatum* Bunge); shingle oak (*Quercus imbricaria* Michx.); water oak (*Q. nigra* L.); pin oak (*Q. palustris* Muenchh.); northern red oak (*Q. rubra* L.).

**Chemicals used in this study:** Indole-3-butyric acid, (IBA).

### Significance to the Nursery Industry

Subjecting cuttings to low irradiances (93% shading relative to outdoor ambient solar radiation) for 10 days or more while in a fog humidified polytent rooting chamber resulted in the highest percentage rooting of cuttings for four of six species tested. The optimal duration of shading was species specific. Shading treatments during rooting did not affect subsequent overwinter survival of rooted ramets. Treating cuttings with a duration of low irradiance while rooting is an uncomplicated, environmentally responsible, and low-cost technique that should enable growers to increase production and diversity of selected woody plants.

### Introduction

Reduction (shading) or exclusion of irradiance to stock plants before cutting collection increases rooting of some difficult-to-root taxa (3, 14, 16). Irradiance reduction techniques can be difficult and costly to apply when stock plants are large trees (13).

In recent years, increases in rooting for several tree species have been obtained by severely limiting irradiance (shading) after cutting collection for the duration of the rooting phase (29, 31). In these studies, percentage rooting was greatest at or above 91% shading of ambient irradiance for most taxa. However, it is unknown whether continued exposure to low irradiance after root induction may affect the subsequent survival of rooted propagules. This study evaluated the effect of varying durations of low irradiance during the rooting phase on rooting and survival of cuttings of six tree taxa.

### Materials and Methods

Semihardwood shoots of *Quercus imbricaria*, *Q. nigra*, *Q. palustris*, *Q. rubra*, *Acer rubrum* 'Bowhall', and *A. truncatum* were collected from several sources and kept cool and moist until treatment application. Shoots from *Q. palustris* were collected from the most recent growth flush in mid to upper unshaded crowns of three 20-year-old trees on June 18, 1997. The *Q. imbricaria* shoots were collected from the lower third crowns of three open-grown mature trees greater than 51 cm (20 in) in diameter at breast height on June 18, 1997. Shoots of *Q. rubra* were collected from approximately 200 two-year-old field-planted grafts whose scions originated from seedlings. Shoots from *A. truncatum* were collected from two trees approximately 4 m (13 ft) tall and 5 cm (2 in) in caliper on June 19, 1997. *Quercus nigra* and *A. rubrum* cuttings were collected at The Buddies Nursery, Birdsboro, PA, on June 20, 1997. Field-grown trees of *A. rubrum* and *Q. nigra* trees were approximately 4 to 6 m (13 to 19 ft) tall and 5 to 10 cm (2 to 4 in) in caliper.

All shoots were prepared for treatment the day after collection. Oak shoots were trimmed to 15 cm (6 in) long and had all but the uppermost three leaves removed. Maple shoots were pruned to provide single-node cuttings. Immediately after trimming to size, cuttings were immersed for 5 min in a solution of Olympic Triathlon (Olympic Horticultural Prod., Mainland, PA) at a concentration of 1.3 ml per liter of water (1 tsp per gal). Cuttings were then rinsed in water, soaked

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for 5 min in a fungicide solution (Cleary 3336-F, 1.6 ml per liter water (0.2 oz per gal), W. A. Cleary Chemical Corp., Somerset, NJ), removed, and allowed to air dry. The basal ends of cuttings were freshly trimmed and dipped for 5 sec 2 cm (0.8 in) deep in an IBA and ethanol solution. The concentration of the hormone solution was 10,000 ppm for all oaks and 5000 ppm for the maples. After allowing the hormone solution to air dry, cuttings were then inserted in a premoistened 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 150 cuttings were processed, except for *Q. rubra*, where 450 cuttings were used. By species, the cuttings were randomly: divided in fifths, assigned to the five shade duration treatments, and then placed in the rooting chamber.

The rooting experiment was conducted in a greenhouse within a single chamber polytent that minimized humidity and temperature differences among treatments. Intermittent cool fog was provided by four ultrasonic humidifiers (Sunbeam model 667, Northern Electric Co., Chicago, IL) located outside opposing ends (two per end) of the polytent. Ambient daylength was maintained. However, whitewash (Kool-Ray white shading compound, Continental Products Co., Euclid, OH) was applied to the greenhouse exterior to reduce irradiance and limit solar heating inside the polytent. When using polytent systems, it is essential to provide relatively heavy shading to minimize solar heating during summer in climates with high irradiance (18). Our experiences (29, 31), as well as others' (17), have shown that moderate temperatures are maintained in a polytent rooting environment with 80–85% shade of ambient outdoor solar irradiance. Therefore, we consider a shade level in this range a 'control' treatment when using a polytent system.

The 3 m by 5 m (10.0 ft by 16.5 ft) rooting chamber built on 3 roller benches was subdivided into two shade level compartments. One compartment had black polypropylene shade fabric (80%) (Yonah Manufacturing Co., Cornelia, GA) suspended outside the chamber 10 cm (4 in) above the roof and along the vertical walls of two sections of the rooting chamber. The control compartment received no shade fabric except for a fabric wall from the adjacent shading treatment. Shade fabric on the inside of the chamber separating shade level compartments was suspended from the top of the chamber down below the top of the cuttings but leaving the lower 25 cm (10 in) open. This, coupled with the porous nature of the shade fabric, allowed air exchange between compartments.

Percentage shading for each compartment was determined by measuring photosynthetic photon flux density (PPFD, µmoles $m^{-2}$ $s^{-1}$) on different days and times during daylight hours at 10 locations in each treatment and outside the greenhouse by using the quantum sensor of a portable infrared gas analyzer (model LCA-2, Analytical Development Co., Ltd., Hertz, England). Percentage reduction of ambient sun (percentage shade) for each compartment was determined relative to the outside ambient PPFD reading [(1 – (PPFD compartment / PPFD outside)) × 100]. Shade levels were 93% (7% irradiance) and 82% (control, 18% irradiance). For reference, the average ambient sun (outdoor) PPFD was 1584 µmoles $m^{-2}$ $s^{-1}$ in a previous study during a prior summer at the same location between 0900 and 1700 hr (29).

Cuttings were placed in the rooting chamber for 119 days (117 for *A. rubrum* and *Q. nigra*) under five low-irradiance duration regimes. Cuttings received either 0, 10, 20, 40, or 119 days of 93% shade (0, 10, 20, 40, or 117 for *A. rubrum* and *Q. nigra*) and then were transferred to 82% shade for the remainder of the treatment in the rooting chamber. For each species there were 30 cuttings per treatment, except for *Q. rubra*, where 90 cuttings per treatment were used.

The cool fog maintained a thin film of water on the cuttings except for short time periods when the chamber was opened to check for roots, apply fungicides, or replenish chart paper. Based on previous studies in the same rooting chamber, air temperatures varied less than 1C (1.8F) on average among shade treatments (29, 31).

Fungicide solutions, either Cleary 3336-F at 0.7 ml per liter water (½ tsp per gal) or Chipco Aliette (Rhone-Poulenc Company, Research Triangle Park, NC) at 1.2 g per liter (0.2 oz per gal) were sprayed on the cuttings about every 2 weeks. Approximately weekly, the Leach cells were checked for roots emerging from the bottoms of containers. Cuttings with roots were removed from the chamber. The number of roots at least 5 mm (0.2 in) long and originating from the cutting stem or callus were noted. In mid October, all cuttings remaining in the polytent were checked for roots. Rooted cuttings were potted in Pro-Mix BX ( Dorval, Quebec, Canada) and placed under cool fog and 82% shade for a week, then transferred to ambient greenhouse conditions.

Rooted cuttings were maintained in a heated greenhouse until mid November when they were transferred to a minimally heated greenhouse for overwintering. The following spring, cuttings were moved to a heated greenhouse to break dormancy. Overwinter survival was recorded for those cuttings that broke bud and formed shoots by mid June.

Statistical analyses were performed for each taxon to determine if shade duration influenced rooting results. To test for treatment differences in percentage rooting and overwinter survival, pairwise comparisons among treatment means were made at the $p = 0.05$ level using CONTRAST, a computer program (15) based on a chi-square procedure (25). Because of relatively low numbers of rooted cuttings for most taxa and treatment combinations, a statistical comparison of overwinter survival was made among treatments by pooling across all taxa. For each taxon, 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 the number of days to root between shade duration treatments. When 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 (9, 26).

## Results and Discussion

Rooting by taxa across all treatments ranged from 24.7 to 63.3% (Table 1). The duration of exposure to low irradiance influenced rooting but responses varied among taxa (Table 1). For most taxa (except *Q. rubra and Q. imbricaria*), the highest rooting percentages involved at least 10 days of exposure to 93% shade.

The number of roots per cutting was influenced by low irradiance duration treatments only for *A. rubrum* 'Bowhall' cuttings (Table 1). In other studies, with varied species, it has been shown that the number of roots per cutting was

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**Table 1. Percentage rooting, the average number of roots per cutting, and the average number of days to root by species and low irradiance (93% shade) duration treatment.**

| Species[z] | Low irradiance treatment (days) | Percentage rooting | Number of roots per cutting[y] | Number of days to root |
|---|---|---|---|---|
| *Acer truncatum* | 0 | 13.3b[x] | 3.3 | 117a |
| | 10 | 36.7a | 2.5 | 82bc |
| | 20 | 33.3a | 2.3 | 66c |
| | 40 | 30.0a | 2.0 | 68c |
| | 119 | 33.3a | 2.0 | 101ab |
| | mean | 29.3 | 2.3 | 83 |
| *Acer rubrum* 'Bowhall' | 0 | 53.3b | 9.8b | 46ab |
| | 10 | 56.7b | 14.6ab | 38bc |
| | 20 | 56.7b | 18.5a | 32c |
| | 40 | 70.0ab | 8.8b | 45abc |
| | 117 | 80.0a | 7.3b | 54a |
| | mean | 63.3 | 11.4 | 44 |
| *Quercus imbricaria* | 0 | 26.7abc | 3.6 | 82 |
| | 10 | 30.0ab | 2.7 | 79 |
| | 20 | 50.0a | 3.0 | 86 |
| | 40 | 13.3bc | 2.5 | 93 |
| | 119 | 10.0c | 2.0 | 64 |
| | mean | 26.0 | 2.9 | 83 |
| *Quercus nigra* | 0 | 50.0b | 2.6 | 100 |
| | 10 | 20.0c | 2.3 | 93 |
| | 20 | 43.3b | 2.8 | 99 |
| | 40 | 76.7a | 4.2 | 101 |
| | 117 | 50.0b | 2.1 | 96 |
| | mean | 48.0 | 3.0 | 99 |
| *Quercus palustris* | 0 | 13.3b | 1.3 | 59 |
| | 10 | 10.0b | 2.0 | 70 |
| | 20 | 40.0a | 3.7 | 45 |
| | 40 | 23.3ab | 2.3 | 52 |
| | 119 | 36.7a | 3.5 | 40 |
| | mean | 24.7 | 2.9 | 48 |
| *Quercus rubra* | 0 | 40.0ab | 2.9 | 88 |
| | 10 | 33.3b | 2.9 | 100 |
| | 20 | 46.7ab | 3.3 | 90 |
| | 40 | 47.8a | 3.7 | 92 |
| | 119 | 44.4ab | 3.2 | 89 |
| | mean | 42.4 | 3.3 | 91 |

[z]For each species, 30 cuttings per treatment were used (except 90 cuttings per treatment for *Q. rubra*).

[y]Numbers of roots per cutting and days to rooting means tested using Duncan's Multiple Range Test.

[x]Within a species, means in a column with the same letter are not different at the p = 0.05 level. Percentage rooting means tested with pairwise comparisons using CONTRAST.

increased (20, 29, 31), decreased (4), or unchanged (1, 2, 31) by lower irradiances during rooting.

It is generally assumed that leafy cuttings should be subjected to a rooting environment with an irradiance conducive to photosynthesis (5, 12). However, there is little scientific evidence that supports this assumption (5) as many other factors are known to affect rooting success. For example, in one experiment, though cuttings of *Cordia alliodora* (Ruiz & Pavon) actively photosynthesized at widely varying rates, the authors concluded that there was no clear relationship between photosynthesis and rooting (22). However, in a different experiment they concluded that *C. alliodora* rooting was related to photosynthetic activity, which itself, was influenced by microclimate and cutting leaf area (23). The relationship between irradiance, photosynthesis, and root formation is partly obscured by the many interacting factors that influence the physiological state of cuttings during rooting.

Although shoot cuttings photosynthesize before root formation, photosynthesis during root formation is not required for root initiation (5). This is supported by the rooting of leafless hardwood cuttings and rooting of *Pisum* shoot cuttings in darkness (4). Supplementary irradiance during rooting may have no effect on rooting (10). In fact, high irradiance during rooting can be detrimental to unrooted shoots. Leafy shoot cuttings subjected to high irradiances during propagation with mist rooted poorly and were associated with internal water deficits compared to reduced irradiance (1). Cuttings do not require high irradiances until rooting occurs (6, 19). In the present study, the highest percentage rooting for four of six taxa required at least 10 days of low irradiance (93% shade). However, exposure to low irradiance throughout the entire duration of the experiment resulted in optimal percentage rooting only for *A. rubrum* 'Bowhall'. Apparently, relatively higher irradiances during rooting are either unnecessary or detrimental for the taxa tested at least until rooting occurs.

For most of the taxa tested, percentage rooting was greatest with at least 10 days exposure to low irradiance followed by transfer into higher irradiance for some period of time. This suggests that exposure of cuttings to low irradiance aids in the induction of rooting but subsequent transfer into higher irradiance levels benefits further development of roots.

The number of days to root was influenced by low irradiance duration for both *A. truncatum* and *A. rubrum* 'Bowhall' (Table 1). For these species, rooting tended to occur most rapidly in the 10, 20, and 40 day low irradiance treatments. Additionally, for these species, rooting tended to take longer with either no exposure or continual exposure to low irradiance. This further suggests that rooting may be induced more rapidly by a period of low light and that subsequent exposure to higher irradiance augments additional root development.

Overwinter survival pooled across species averaged 58.8%. Paired contrasts showed that there were no significant differences in percentage overwinter survival among the shade duration treatments.

For some recalcitrant woody plant species, rooting success has been influenced by stock plant irradiance. Supplemental irradiance provided to stock plants has decreased rooting capacity (24). Rooting may improve after severely reducing irradiance to the stock plant prior to cutting collection, a process referred to as etiolation or blanching (3, 16, 21, 28). However, stock plant irradiance reduction treatments are difficult to apply to mature trees (13). Results of this study show that low irradiances applied to cuttings for at least 10 days at the start of the rooting phase are also effective in increasing rooting of some woody taxa.

Shading during rooting does not appear to be beneficial to all species or cultivars, especially to those that already have reasonably successful propagation protocols (31). However, species that are recalcitrant have shown rooting improve-

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ment with low irradiance treatment during rooting. For example, *A. rubrum* 'Bowhall', considered difficult-to-root (8), was shown to benefit greatly from shade levels at or greater than 91% (31). In this study, this cultivar exhibited high percentage rooting when maintained under low irradiance for the entire duration in the rooting environment.

Oak species are notoriously poor rooters (6, 7, 27), but several researchers have reported positive results depending on treatment and maturity of the stock plant (29, 30, 31). *Quercus nigra* and *Q. palustris* in this study rooted best with at least 20 days in 93% shade. In another study, *Q. alba* and *Q. palustris* rooted best in the lowest irradiance (91% shade) level (31). Results from Zaczek (29) over 2 years showed that rooting of cuttings from mature trees benefitted from shading up to 97% during rooting, which is near the light compensation point for seedlings of that species. However, cuttings from the first growth flush of juvenile (<1-yr-old) *Q. rubra* did not benefit from low irradiance in the same study. Cuttings from juvenile (90-day-old) plants of other tree species had reduced rooting with reduced irradiance (11). These results suggest that low irradiance during rooting appears to be most beneficial for species or cultivars that have been traditionally difficult-to-root and, especially, for mature individuals.

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