Cutting Back Stock Plants Promotes Adventitious Rooting of Stems of *Quercus bicolor* and *Quercus macrocarpa*[1]

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Abstract

Studies were conducted to investigate the severity of cutting back stock plants on adventitious rooting of layered stems and stem cuttings of *Quercus bicolor* Willd. (swamp white oak) and *Quercus macrocarpa* Michx. (bur oak). Rooting averaged 77% in *Q. bicolor* and 70% in *Q. macrocarpa* layered stems from the cutback stock plant group, compared to air layered stems from intact plants which averaged 1% in *Q. bicolor* and 0% in *Q. macrocarpa*. In another experiment cuttings were taken from three stock plant heights [4 cm (1.6 in), or 100 cm (39.4 in) stumps and intact plants ~ 170 cm (66.9 in)] which were either etiolated or grown in natural light and rooted under mist. The best rooting (59%) and average number of roots (9.3) were found in etiolated *Q. bicolor* cuttings taken from 4 cm (1.6 in) stumps. *Q. macrocarpa* cuttings rooted poorly with only 7% of the cuttings rooting. By taking cuttings a week earlier for rooting (2 weeks, at the softwood stage), rooting in *Q. macrocarpa* was possible, with the best rooting (46%) found in etiolated cuttings taken from 4 cm (1.6 in) stumps. Overall, the highest rooting and greatest number of roots occurred in etiolated layers and cuttings from the 4 cm cutback group. Rooting generally increased with increasing extent of stock plant cutback

Index words: etiolation, banding, juvenility, cuttings, layers, propagation, indolebutyric acid.

Species used in this study: swamp white oak (*Quercus bicolor* Willd.) and bur oak (*Quercus macrocarpa* Michx.).

Significance to the Nursery Industry

Poor adventitious rooting continues to limit asexual propagation of many woody plant species thus slowing selection and introduction of superior genotypes. Results from these experiments demonstrate the importance of propagule origin on successful adventitious rooting in layered stems and softwood cuttings. Rooting potential of layered stems and softwood stem cuttings of *Q. bicolor* (swamp white oak) and *Q. macrocarpa* (bur oak) increased with the severity of cutting back the stock plant. Etiolation also improved rooting of stem cuttings and layered stems, with the greatest improvement in rooting stem cuttings. The layering technique, which combined cutting back of the stock plants with etiolation, resulted in the highest rooting percentages.

Introduction

Juvenility is an important consideration in the propagation of difficult-to-root plant species. The juvenile phase in woody plants is characterized by a greater readiness to form adventitious roots and an inability to form flowers (8, 14). The length of this phase varies from no more than 20 to 30 days in seedlings of *Rosa* L. spp. (rose) to an average of 35 years in certain forest and landscape tree species (6). Unfortunately, the length of this phase in difficult-to-root species does not guarantee a wide window of rooting opportunity, as rooting ability has been known to decline long before the onset of the mature phase. Gardener (12) observed this sudden decline in stem cuttings of juvenile *Pinus resinosa* Ait. (red pine) from 1-year-old seedlings (62%), which decreased to less than 10% by the second and third years. Similarly, Morgan et al. (22) and Farmer (10) observed an inverse linear relationship between rooting success, in stem cuttings, and increasing tree (5 to 8 years) and seedling (1 to 4 months) age in *Q. virginiana* Mill. (live oak) and *Q. pagoda* Raf. (cherry bark oak) respectively. The highest rooting was recorded in cuttings from 5-year-old *Q. virginiana* trees (18%) and 1 month *Q. pagoda* seedlings (~ 74%).

From a plant propagator's standpoint, the question then arises as to how selected plant species can be maintained in an easy-to-root state. Rejuvenation practices like hedging, serial grafting of mature scions onto juvenile rootstocks, chemical induction, serial sub-culturing in vitro, and initiation of adventitious buds have been used to maintain good rooting associated with juvenile plant material (5, 7, 15, 23, 24 and 28). Hedging, one of the more common rejuvenation practices has been used successfully to increase rooting in shoots of difficult-to-propagate species like *Malus* spp. (apple) (14), *P. radiata* D. Don (Monterey pine) (22, 4), *Q. robur* L. (english oak) (5) and *Eucalyptus* spp. (eucalyptus) (21). In a study by Black (3), cuttings from mature hedged *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir) rooted at 45% while cuttings from non-hedged controls rooted at 5%. Chalupa (5) also observed increased rooting of cuttings taken from hedged 6-year-old *Q. robur* plants (81%) compared to those from non-hedged controls (56%). Similarly, a correlation between the degree of stock plant cutback and rooting ability of cuttings has been recognized in certain woody plant species. Rosier et al. (25) noted in stock plants of *Abies fraseri* (Pursh) Poir. (Fraser fir) that rooting percentage, primary root production and total root length were inversely proportional to stock plant age and the severity of cutback treatment. Similarly, softwood stem cuttings of 12-year-old *Ulmus americana* L. (American elm) rooted best when taken from 0.3 m (11.8 in) cutback plants (83%), compared to 2.0 to 2.5 m (78.7 to 98.4 in) cutback plants (64%) or the top of non-cutback plants (38%) (27).

Recently, vegetative propagation of oaks has been improved with development of a modified layering technique (1, 16). This technique used in conjunction with etiolation, involves the cutting back of stock plants to within 4 cm (1.6 in) of the soil line and rooting of shoots while still attached to the parent plant. The above studies suggest propagules

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taken from ontogenetically juvenile parts of a plant maintain that state of development and thus have a higher tendency to form adventitious roots. The objective of this research was to determine the effect cutting back of stock plants had on rooting of layered stems and stem cuttings of *Q. bicolor* and *Q. macrocarpa*.

Materials and Methods

Experiment 1: Effect of propagule origin on adventitious rooting of layered Quercus bicolor *and* Quercus macrocarpa *stems.* Trees used in this experiment were of seedling origin. Acorns were collected in 1997 from across New York State and planted out in Arkport sandy loam soil with a pH of 6.2. Prior to the current experiment, no supplementary irrigation was used, trees were repeatedly cutback and weeding was done when necessary.

In May 2004, dormant 7-year-old *Q. bicolor* and *Q. macrocarpa* field-grown trees of ~ 170 cm (66.9 in) tall were either cutback leaving a stump 4 cm (1.6 in) above the soil or left intact (not cutback) for air layering. Treatments were randomly assigned to 121 *Q. bicolor* and 172 *Q. macrocarpa* trees in the cutback treatment and 24 *Q. bicolor* and 54 *Q. macrocarpa* trees in the intact treatment.

Field layering of cutback plants. Upon evidence of epicormic bud swelling (small pink swellings) on the cutback stem, half the stumps were etiolated and the other half left uncovered to grow at natural photoperiod and irradiance levels. Etiolation of cutback stumps was achieved by inverting a #3 (11.3 liter) size pot (covered with aluminum foil to prevent heat buildup) over the stump. The inverted pot was held in place by a concrete block. Irradiance under the container was 0.1 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (LI-189, Li-Cor Corp., Lincoln NE). Shoots arising from both etiolated (Fig. 1A) and light-grown stumps (Fig. 1B) were allowed to reach a length of 8 to 10 cm (3.1 to 3.9 in), which took ~ 12 days (Fig. 2). At that time the basal 4 cm (1.6 in) section of each shoot was painted with 10,000 ppm indolebutyric acid (IBA) dissolved in 98% aqueous ethanol. Only shoots that had reached the desired length of 8 to 10 cm (3.1 to 3.9 in) were treated with IBA (~ 5 shoots per stump), untreated shoots were rubbed off.

Immediately after the IBA solution dried, a bottomless #3 pot was placed over the stock plant, so it rested on the soil surface (Fig. 1C). A moist medium of peat:horticultural grade perlite (1:2, by vol) was filled in to cover the treated shoot bases within the bottomless pot, leaving the growing points exposed. The etiolated plants were subsequently covered with a white plastic bag (Fig. 1D), which was increasingly perforated to allow light into the shoots over a period of 1 week to gradually facilitate greening of the shoots. After a week, the plastic was removed and the shoot tips exposed to natural photoperiod and irradiance levels. The plants were allowed to grow in the field for 3 months after treatment. During this time, the medium around the treated shoots was kept moist and more medium added as the shoots elongated.

Air layering of intact plants. Six softwood shoots in the top one-quarter section of intact plants were allowed to

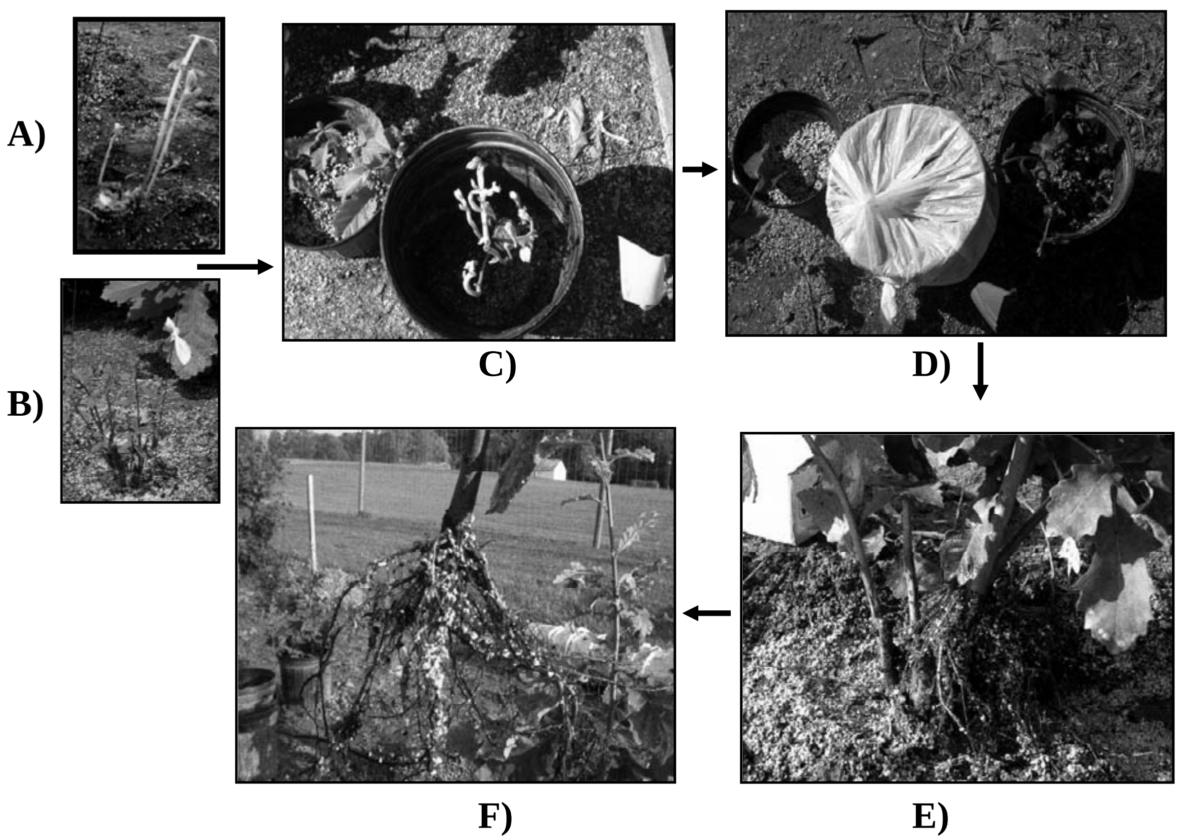

Fig. 1. Field layering of cutback *Quercus* (Expt.1), (A + B) etiolated and light-grown shoots ready for IBA treatment, (C) treated shoots with bottomless pot placed over plant, (D) etiolated plants being acclimated to light, (E) the bottomless pot removed after three months to show rooted shoots still attached to the mother plant, (F) rooted shoot detached from mother plant.

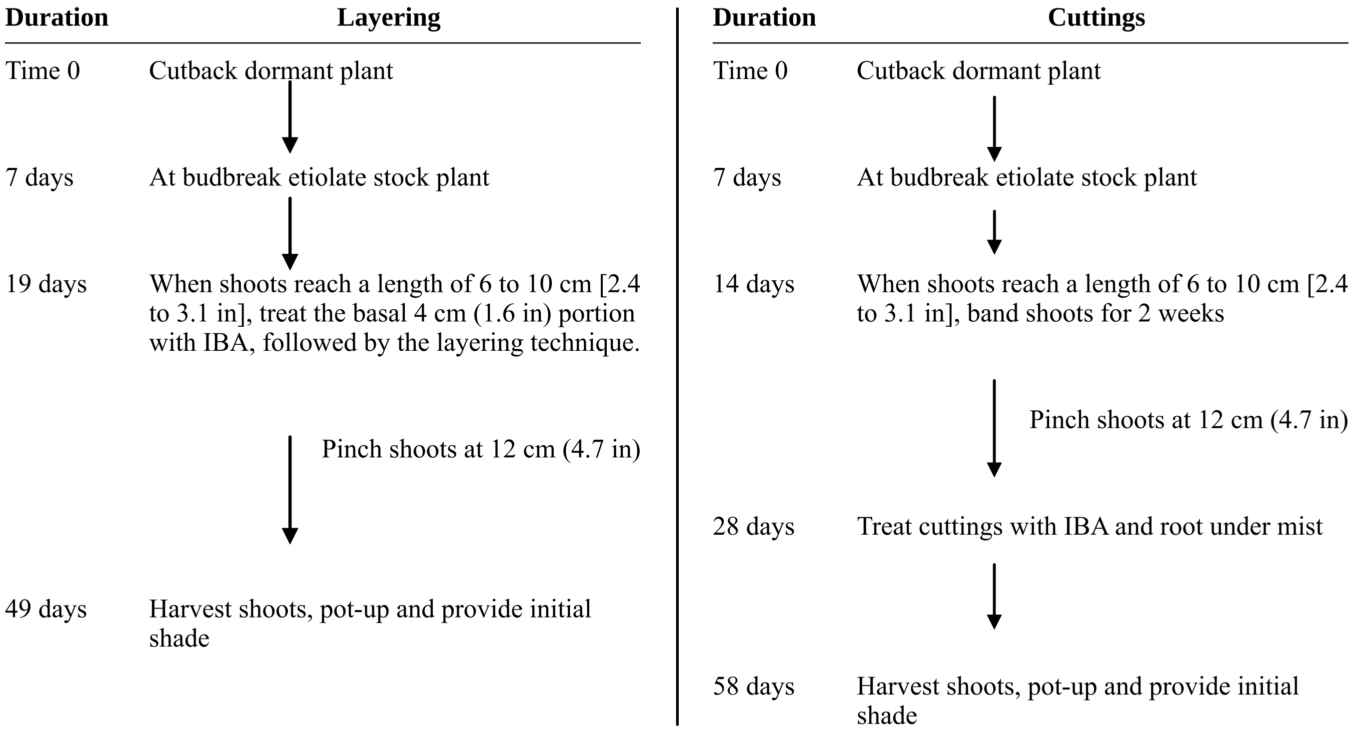

Fig. 2. Suggested Protocol for Rooting *Quercus* spp. Time 0 begins after plants have received their required chilling. Detailed description of the layering technique can be found in the materials and methods section under 'Field Layering of Cutback Plants'.

grow until they reached the desired length of 12 cm (4.7 in), the length attained after 7 to 12 days (Fig. 2). The basal 5 cm (2 in) portion of each shoot internode was painted with a 10,000 ppm IBA solution. In order to ensure proper water penetration rooting medium was prepared by mixing peat with a granular media surfactant (AquaGro 2000, Aquatrols Paulsboro NJ) at a rate of 15 g AquaGro 2000 per cu ft of peat. After the IBA solution dried, a ball [~ 6.0 cm (2.4 in) in diameter] of the moistened rooting medium was placed in a 25 µm (984 µ in) thick white polythene sheet [dimensions 18 × 18 cm (7.1 × 7.1 in)] and secured above and below the treated section using twist ties.

While shoots from cutback plants were either etiolated or grown in natural irradiance, those from intact plants were only grown in natural irradiance due to the difficulty of air layering tender, etiolated shoots. Data were taken three months after shoots were treated. Data were recorded on the number of shoots that rooted per plant as well as number of roots per rooted shoot on both cutback layered and air layered shoots. Shoots were considered rooted if they had at least one root that was ≥ 1 cm (0.4 in) in length.

Experiment 2: Effect of propagule position on rooting in stem cuttings of Quercus bicolor *and* Quercus macrocarpa. Trees used in this experiment were of seedling origin, planted in the same year as those in Expt. 1 but constituted a different set of trees. This second experiment was conducted to test the rooting potential of stem cuttings of *Q. bicolor* and *Q. macrocarpa* taken from three different height positions. In May 2005, 8-year-old, field-grown dormant trees of *Q. bicolor* and *Q. macrocarpa* were cutback leaving a stump 4 cm (1.6 in) or 100 cm (39.4 in) above the soil line, or left intact [150 to 180 cm (59.1 to 70.9 in)]. Upon budbreak, half the plants from each of the abovementioned groups were either etiolated or grown in natural photoperiod and irradiance. Plants were randomly assigned to the three height treatments in the following way; 48, 14 and 42 *Q. bicolor* and 49, 20, and 36 *Q. macrocarpa* respectively.

Stock plant etiolation. Etiolation of 4 cm (1.6 in) cutback stumps was achieved by inverting a #3 (11.3 liter) pot covered with aluminum foil over the stump as previously described (Fig. 3A). Etiolation of plants in the other two groups was achieved by building plastic cages (Fig. 3B) around the plant or around individual branches of intact plants. The cages were covered with two layers of plastic. A black plastic layer on the inside, excluded light and a white plastic layer on the outside, prevented heat build up (Fig. 3C). Light levels inside the etiolation treatment groups were ≤ 0.5 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Stem banding and greening of etiolated shoots. To keep the basal portion of etiolated shoots in the dark while the distal portion of the shoot was acclimated to light, once the expanding shoots reached approximately 6 cm (2.4 in) in length, a 3.0 × 3.0 cm (1.2 × 1.2 in) Velcro™ strip was pressed firmly on either side of the base of each current year's stem. The self-adhesive fabric was pressed firmly to ensure the strip stayed in place. Etiolated shoots from the 100 cm (39.4 in) stump and intact plant setup were acclimated to light by removing the black plastic and slitting the white plastic covering the cage. Etiolated shoots from the 4 cm (1.6 in) stump setup were acclimated to light as in Expt. 1. Greening of etiolated shoots required 1 week.

Harvesting of cuttings and rooting conditions in the greenhouse. During the 3 weeks prior to cutting collection in June, all shoots had their apical buds removed, thereby limiting

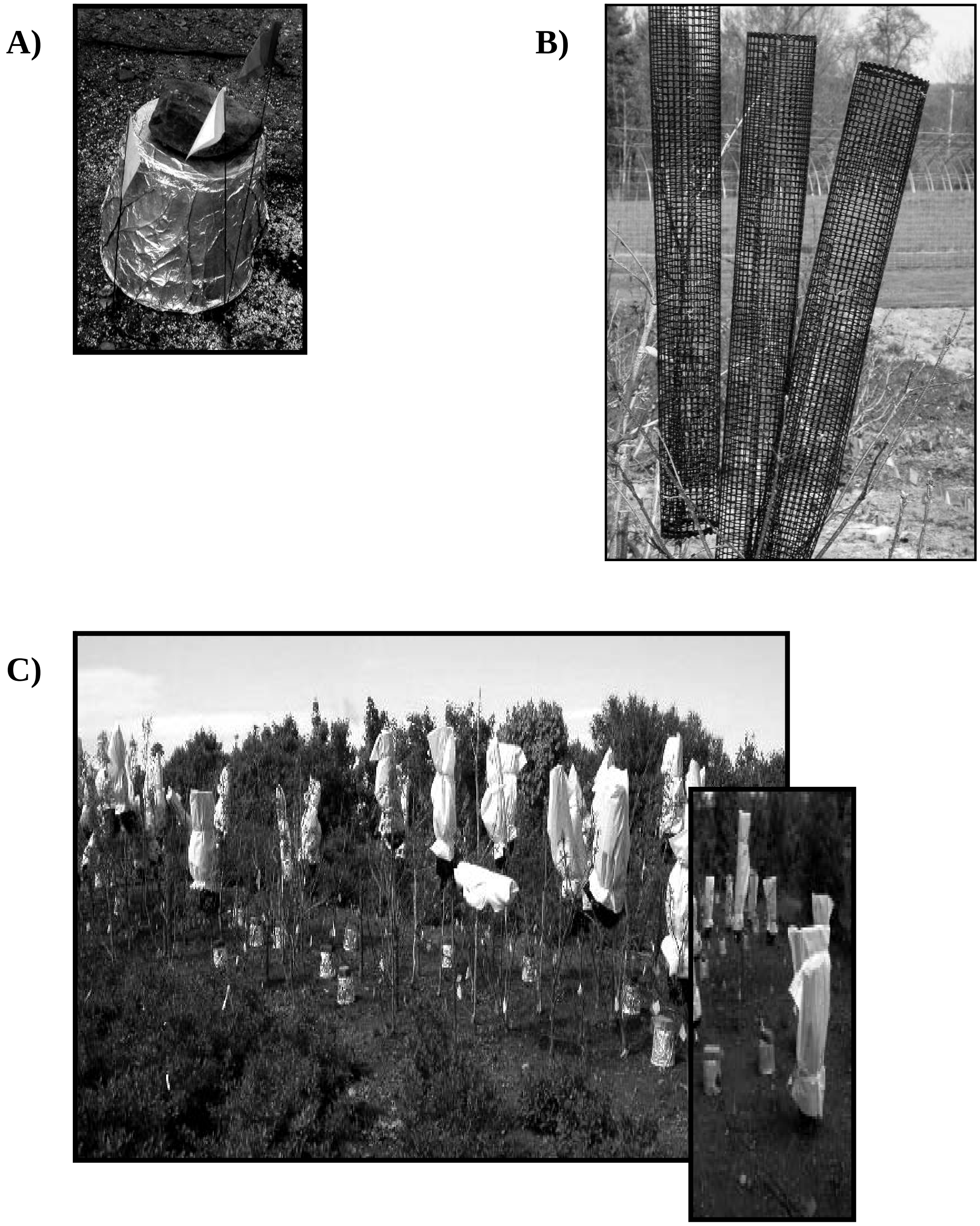

Fig. 3. Etiolation of *Quercus* plants (Expt. 2). (A) etiolation of 4 cm stump, (B) cages were built around shoots in the 170 and 100 cm groups before covering with plastic, (C) etiolation of plants in the field.

shoots to a 12 cm (4.7 in) length. Cuttings were harvested from the uppermost one-quarter section in the intact and 100 cm (39.4 in) height groups. As cuttings were harvested they were sealed in plastic bags, placed in a cooler with ice and transported to the greenhouse for rooting under mist. Each cutting had two leaves; larger leaves were trimmed to half their size and the freshly cut stem bases dipped in 6,000 ppm IBA dissolved in 50% aqueous ethanol to a depth of 5 cm (2 in) for 10 sec and allowed to air dry. Cuttings were inserted into a 100% perlite medium under intermittent mist operating for 6 sec every 8 minutes from 6:00 am – 9:00 pm. Cuttings were sprayed weekly to runoff with Banrot® {15% Etridiozole (5-ethoxy-3-trichloromethyl-1, 2, 4-thiadiazole), 25% Thiophanate-methyl (Dimethyl [(1, 2-phenylene) bis (iminocarbonothioyl)] bis [carbamate]} and the mist bench was covered with 65% shade cloth. Cuttings were rooted under natural photoperiod and irradiance. After five weeks, data were recorded on the number of cuttings that rooted per treatment and the number of roots per rooted cutting. Cuttings were considered rooted if they had at least one root that was ≥ 1 cm (0.4 in) in length.

Experiment 3: Effect of propagule position on rooting in stem cuttings of Quercus bicolor *and* Quercus macrocarpa. Stock plant environment and growing conditions. Trees used in this experiment were the same as those in Expt. 2. In

May 2006, dormant 9-year-old, field-grown *Q. bicolor* and *Q. macrocarpa* trees were cut back to three height levels: [4 cm (1.6 in), 30 to 40 cm (11.8 to 15.7 in) or 70 to 100 cm (27.6 to 39.4 in)]. Upon budbreak, half the plants from each of the abovementioned groups were either etiolated or grown in natural irradiance. Stock plant etiolation, stem banding, greening of etiolated shoots and harvesting of cuttings were the same as in Expt. 2, except cuttings were taken after 2 weeks (instead of 3 weeks as in Expt. 2). Rooting conditions were the same as in Expt. 2, except cuttings were not sprayed with Banrot®. Four weeks after cuttings were treated with IBA, data were taken on the number of cuttings that rooted per treatment group and the number of roots per cutting. Rooting was defined as in Expt. 2.

Experimental design and statistical analysis. Expt. 1 was setup using *Q. bicolor* and *Q. macrocarpa* trees in a randomized block design. Blocking was necessary to account for possible variations in soil drainage due to the gradient of the field. However, there was no significant ($P >$ 0.05) difference in rooting between treatment groups in the two plots; therefore, results from the two plots were pooled. The unit of analysis was a single tree; percent rooting and NRPL were determined for each tree and the average per treatment group presented in the table of results. Expt. 2 was setup using a completely randomized design with 17 to 24 cuttings per treatment per species replicated 4 times. Expt. 3 also used a completely randomized design with 14 to 83 cuttings per treatment. Since the data on rooting and number of roots per shoot in all three experiments did not pass the test for normality, the PROC GENMOD procedure in SAS (26) was employed to analyze the data. Rooting and number of roots per shoot were analyzed using Binomial and negative Binomial regression models respectively (26). Mean separation among treatments was done using least square means.

Results and Discussion

Experiment 1: Effect of propagule origin on adventitious rooting of layered Quercus bicolor *and* Quercus macrocarpa *stems.* Percent rooting and average number of roots in *Q. bicolor* and *Q. macrocarpa* layered shoots were highest in layers from cutback stock plants compared to air layered stock plants (Table 1) confirming results from our previous study (1). Percent rooting in layered shoots from cutback stock plants, either etiolated or light grown, averaged 77 and 69% in *Q. bicolor* and *Q. macrocarpa* respectively, compared to 1 and 0% in intact trees (Table 1). Although, percent rooting in both species from the cutback groups were high, etiolation statistically improved rooting ($P < 0.05$) in *Q. bicolor* but not *Q. macrocarpa* (Table 1). The results for number of roots per layered shoot (NRPL) were similar to that of rooting. NRPL in both species was higher ($P < 0.05$) in cutback treatments than in intact plants (Table 1) and etiolation increased the NRPL in both *Q. bicolor* ($P < 0.05$) and *Q. macrocarpa* ($P < 0.05$) (Table 1).

Experiments 2 and 3: Effect of propagule position on rooting in stem cuttings of Quercus bicolor *and* Quercus macrocarpa. Rooting response in cuttings of *Q. macrocarpa* across treatments in Expt. 1 was exceptionally low (data not presented). However, in *Q. bicolor*, rooting increased ($P <$ 0.05) with the severity of cutting back of stock plants (Table 2). Maximum rooting (59%) and average number of roots per rooted cutting (9.3) were found in cuttings from etiolated 4 cm (1.6 in) stumps, compared with cuttings from taller stock plants (Table 2). The main effect of cutback level on rooting was dramatic. There was a 6 fold increase in rooting (45%) of cuttings from 4 cm (1.6 in) stumps compared to those from 100 cm (39.4 in) stumps (8%) (Table 2). Poorest overall rooting was from the intact plants (4%) (Table 2). Superior rooting in propagules from cutback stumps could be attributed to the juvenile state of propagules arising from the base of the stock plant. Although the entire plant prior to cutback was juvenile as per the classical definition of juvenile plants (those that can not flower even under favorable environmental conditions), these results suggest the presence of a rooting gradient as it relates to position within the juvenile phase. Higher rooting occurred in shoots originating from the most proximal portion of the stock plant stem. Similar trends were observed by Schreiber and Kawase (27) and Rosier et al. (25) in *U. americana* and *A. fraseri*, respectively. Rooting ability of *U. americana* cuttings increased with the severity of stock plant cutback, from 38% in intact plants to 64% in 2.0 to 2.5 m (78.7 to 98.4 in) stumps and 83% in 0.3 m (11.8 in) stumps. Rosier et al. (25) observed an increase in rooting percentage,

Table 1. Effect of cutback and etiolation on rooting and number of roots in *Quercus bicolor* and *Quercus macrocarpa* layered shoots.

	Treatments		
	Cutback-etiolated[z]	Cutback-light[y]	Air layered[x]
Quercus bicolor			
Percent rooting	82.9a (149)[w]	71.0b (133)	1.0c (137)
Number roots/rooted layer[v]	23.7a	18.7b	6.0c
Quercus macrocarpa			
Percent rooting	76.0b (188)	62.4b (172)	0.0c (131)
Number roots/rooted layer[v]	29.9a	17.7b	0c

[z]Cutback-Etiolated etiolated propagules from 4 cm (1.6 in) stumps.

[y]Cutback-Light light grown propagules from 4 cm (1.6 in) stumps.

[x]Air layered light-grown propagules arising from intact plants ~ 170 cm (66.9 in).

[w]Total number of layered shoots per treatment group.

[v]Average number of roots per rooted layer. Different letters represent treatment means significantly different ($P < 0.05$) from each other within species, using least squares means.

Table 2. Effect of stock plant height and etiolation on rooting in *Quercus bicolor* cuttings.

	Stock plant height (cm)					
	4		100		~ 170	
	Treatment					
	Etiolated	Light	Etiolated	Light	Etiolated	Light
Percent rooting	59.3a[z]	32.4b	17.7bc	0	7.7c	0
Avg. percent rooting/cutback level	45.2a		7.5b		3.8b	
Avg. number roots	9.3a	6.9b	2.0c	0	2.5c	0
Number of cuttings per treatment	27 (16)[y]	34 (11)	17 (3)	23 (0)	26 (2)	26 (0)

[z]The different letters represent means significantly different ($P < 0.05$) from each other within species, means were separated using least square means.
[y]Total number of rooted cuttings per treatment group.

primary root production and total root length in stock plants of *A. fraseri* as age of stock plant decreased and the severity of stumping treatment increased. Fishel et al. (11) also noted a gradual and predictable increase (from top to base) in the rooting of shoots forced from the main bole sections of *Q. rubra* L. (red oak). However, they found rooting of *Q. bicolor* cuttings from hedged and *in situ* plants next to impossible, which may have been a result of cuttings not taken from ontogenetically juvenile portions of the plant.

Etiolation played a significant role in the rooting of cuttings and layered shoots with a more pronounced effect on the rooting of cuttings (Tables 1, 2 and 3). An extensive review on etiolation by Maynard and Bassuk (19) attest to etiolation having been used to enhance rooting in over 28 genera including *Quercus* (oak) and *Castanea* (chestnut). In an earlier study by Maynard and Bassuk (18), etiolation and banding pretreatments were observed to have enhanced rooting in 13 woody plant species. Etiolation is thought to enhance a stem's sensitivity to auxin uptake as well as decrease lignification of cells (9, 17, and 20), thus enabling the easy egress of roots or dedifferentiation of root primordia. However, while etiolation significantly increased rooting, across height treatments, (31%) in *Q. bicolor* cuttings compared to those grown in natural light (13%), (Expt. 2, data not presented), the strongest effect on rooting was that of shoot origin (Table 2). As observed in our previous experiments (2), shortening the growth period of shoots by a week, before cuttings were taken (Expt. 3), generally improved rooting in etiolated *Q. bicolor* (85%) and *Q. macrocarpa* (46%) cuttings taken from 4 cm (1.6 in) stumps (Table 3). The number of roots per cutting (NRPC) in both species was also higher in etiolated cuttings from the 4 cm (1.6 in) cutback group (Table 3). The main effect of cutback level on rooting percentage and mean number of roots per rooted cutting, confirmed that the 4 cm (1.6 in) stump height is the ideal cutback height in both species (Table 3).

Our study showed rooting success of *Q. bicolor* and *Q. macrocarpa* cuttings and layered shoots differed considerably with position-of-origin. Trees used in this study were still within the juvenile phase of development, suggesting the presence of a rooting gradient as it related to position within this phase — with better rooting occurring in shoots originating from the most proximal portion of the stockplant stem. Percentage rooting of shoots was higher in *Q. bicolor* and *Q. macrocarpa* layered shoots (~ 77 and 69%, respectively) than in cuttings (~ 61 and 27%, respectively) when taken from severely cutback stumps (Tables 1 and 3).

Etiolation strongly influenced rooting in cuttings, although it did not play as strong a role with layered shoots. *Q. bicolor* cuttings from the severely cutback group rooted better than *Q. macrocarpa*. Similar differences in rooting ability has been previously observed in oak species (13).

Vegetative propagation problems associated with the successful rooting of oaks can be reduced or eliminated if

Table 3. Effect of stock plant cutback level and etiolation on rooting in *Quercus bicolor* and *Quercus macrocarpa* cuttings.

	Cutback level (cm)					
	4		30–40		70–100	
	Treatment					
	Etiolated	Light	Etiolated	Light	Etiolated	Light
Quercus bicolor						
Percent rooting	85.2a[z]	37.9b	11.1c	38.1b	10.5c	26.0c
Avg. number roots	15.0a	6.1b	6.0b	5.7b	6.3b	4.3b
Number of cuttings per treatment	59 (51)[y]	60 (22)	22 (2)	15 (9)	47 (3)	45 (10)
Quercus macrocarpa						
Percent rooting	45.9a	13.3bc	0	30.0ac	12.5bc	0
Avg. number roots	8.8a	4.0b	0	7.3a	3.0b	0

[z]The different letters represent means significantly different ($P < 0.05$) from each other within species means were separated using least square means.
[y]Total number of rooted cuttings per treatment group.

cuttings from ontogenetically juvenile parts of the plant are used. The present study demonstrated the importance of propagule position on the successful rooting of oak species. Rooting percentages in both *Q. bicolor* and *Q. macrocarpa* increased with the extent of stock plant cutback. *Q. bicolor* can successfully be propagated using cuttings and the layering technique, while *Q. macrocarpa* lends itself better to propagation using the layering technique.

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