Propagation of *Quercus phillyreoides* by Stem Cuttings[1]

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Abstract

Stem cuttings of two clones (clones 1 and 2) of seedling origin of *Quercus phillyreoides* A. Gray (ubame oak) in the adult growth phase were taken on four dates that represented four growth stages (semi-hardwood, hardwood, softwood, and transitional growth between softwood and semi-hardwood). All cuttings were treated with selected concentrations and formulations of indolebutyric acid (IBA) and placed under intermittent mist for rooting. Greatest rooting for both clones was achieved with softwood cuttings with 97% and 56% rooting for clones 1 and 2, respectively, treated with 8000 ppm (0.8%) IBA in talc. Six weeks later when cuttings were in a softwood/semi-hardwood condition, rooting of clone 1 was still comparable to softwood cuttings whereas clone 2 rooted poorly. For both clones, rooting of semi-hardwood cuttings was poor, which was the same for hardwood cuttings of clone 2. Moderate rooting of 58% was noted for nontreated hardwood cuttings of clone 1. Auxin treatments generally increased root number. As mean root number increased mean root length decreased. Greater overwinter survival was observed for rooted softwood cuttings, which produced a flush of new growth following rooting in comparison to softwood/semi-hardwood cuttings that did not flush following rooting.

Index words: ubame oak, auxin, indolebutyric acid, adventitious rooting.

Significance to the Nursery Industry

Quercus phillyreoides is a small to medium size, evergreen oak native to Japan and China. Although it is relatively unknown in the United States, it has several desirable landscape characteristics with potential for use in southern landscapes and other areas of the United States (10).

Results herein demonstrate that selected clones of the species, when in the adult growth phase, can be propagated by stem cuttings, which should allow selection and propagation of trees with desirable physiological and morphological characteristics. Despite apparent clonal differences (tree to tree variation) in rooting, the optimum growth stage for rooting was softwood. At this growth stage maximum rooting (percent and root number) was achieved by treating cuttings with 3000 (0.3%) or 8000 ppm (0.8%) IBA in talc. Rooted softwood cuttings also produced a flush of growth following rooting which may aid in overwinter survival.

Introduction

Quercus phillyreoides (ubame oak) is an attractive, evergreen species indigenous to warm, temperate, broad-leaved evergreen forests of Japan and China (17). It grows as a shrub or small tree reaching a height of 6 to 9 m (20 to 30 ft). The foliage is glossy dark green and leathery in appearance with obovate-oblong leaves 3 to 6 cm (1.2 to 2.4 in) long and 1.5 to 3.0 cm (0.6 to 1.2 in) wide (1). Several cultivated varieties exist in Japan where it is extensively utilized for hedges and is commonly planted in parks (18).

In its native habitat *Q. phillyreoides* forms thickets in dry coastal regions having low annual rainfall, high evapotranspiration, and drying winds. Excessive moisture loss by transpiration is reduced by thick leathery leaves (17). Based on the environmental conditions under which the species thrives in its native habitat, it appears *Q. phillyreoides* has great potential for use in landscapes in the southern United States in addition to being well suited for urban situations. Its adaptability to southern landscapes has been further supported by the excellent performance of two clones of *Q. phillyreoides* growing in the North Carolina State University Arboretum, Raleigh.

The traditional method of propagating most species of oak (*Quercus* L. spp.) is by seed. However, sexual propagation of oaks results in great phenotypic and genotypic variability (8). Propagation by asexual (vegetative) means would reduce this variability and might eventually lead to selection and introduction of superior genotypes. For a number of reasons vegetative propagation of oaks has been difficult to accomplish.

Studies have indicated that stem cuttings of oaks root poorly (5, 6, 7). Attempts to propagate various species of oak by micropropagation (tissue culture) have also met with little success (22). Grafting remains the most successful method of commercial vegetative propagation. Unfortunately, grafting results in plants that are badly stunted for several years (7). In addition, graft incompatibility can be a problem. Development of more efficient techniques for asexual propagation of oaks would be beneficial to the nursery industry as this would lead to greater utilization of particular species (e.g. *Q. phillyreoides*) with desirable landscape characteristics. Since a preliminary investigation indicated that stem cuttings of *Q. phillyreoides* can be rooted, the following research was conducted to develop a protocol for propagation of the species by stem cuttings. Specifically, the influence of timing (growth stage) and indolebutyric acid treatment on rooting were investigated.

Materials and Methods

Terminal cuttings with fully expanded leaves were taken from each of two trees growing in the North Carolina State University Arboretum on four dates that represented specific growth stages: November 3, 1993 (semi-hardwood), February 8, 1994 (hardwood), April 28, 1994 (softwood), and June 10, 1994 (transition between softwood and semi-hardwood). Cuttings were taken throughout the crown of each tree by using hand pruning shears and those from each stock plant were kept separate to maintain clonal identity.

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Stem tissue of semi-hardwood and hardwood cuttings was firm and a distinct snapping sound was noted when broken. Application of pressure to the cuttings resulted in breakage and separation of the pieces at the point at which pressure was applied. Stem tissue of the softwood and transitional softwood/semi-hardwood cuttings was soft yet sufficiently firm so as not to appear flaccid. Application of pressure to the transitional softwood/semi-hardwood cuttings resulted in breakage but the stem pieces held together, not separating at the break point. On the other hand, the softwood cuttings were quite pliable. They did not break or snap when pressure was applied.

Both trees were of seedling origin and had produced flowers and fruit, indicating they were in the adult growth phase. One tree, hereafter referred to as clone 1, was an attractive 40-year-old, multi-stemmed specimen with a height of 6 m (20 ft) and a spread of 11 m (36 ft). The second clone, clone 2, was also multi-stemmed and had a faster growth rate. It was 8 years old, had a pronounced fastigiate growth form, and had reached a height of 6 m (20 ft). Both trees appeared to be relatively free of insect and disease problems and had survived conditions of extreme drought. Clones 1 and 2 had withstood winter temperatures of –22C (–9F) and –18C (0F), respectively, with no apparent injury.

As cuttings were collected, they were placed in plastic bags and kept on ice during transport to the Horticultural Science Greenhouses, Raleigh, NC. After collection, all cuttings were trimmed from the bases resulting in lengths of 5 and 6 cm (2.0 and 2.4 in) for cuttings of clones 1 and 2, respectively. Leaves from the basal 2 cm (0.8 in) of clone 1 and the basal 3 cm (1.2 in) of clone 2 were removed, which were the same distances to which the cuttings were later inserted into the rooting medium. The basal 0.5 and 1.0 cm (0.2 and 0.4 in) of each cutting of clones 1 and 2, respectively, were then treated with 0, 3000 (0.3%), 6000 (0.6%), or 9000 ppm (0.9%) indolebutyric acid (reagent grade IBA in 50% isopropanol) for 1 to 2 sec. The cuttings were air-dried for 15 min before insertion into a raised greenhouse bench containing a steam pasteurized medium of peat:perlite (1:1 by vol).

The design within the propagation bench for the semi-hardwood and hardwood cuttings was a randomized complete block with a factorial arrangement of treatments: two clones × four auxin concentrations, six blocks, and six cuttings per treatment per block. An identical design was used for the softwood and transitional softwood/semi-hardwood cuttings, except that three additional treatments were included: a 50% isopropanol control, Hormodin 2 [3000 ppm (0.3%) IBA in talc] and Hormodin 3 [8000 ppm (0.8%) IBA in talc] (MSD AGVET, Division of MERCK & Co., Inc., Rahway, NJ). The additional treatments were utilized in response to observations made during harvest of the hardwood cuttings. Greater rooting of the nontreated hardwood cuttings of clone 1 compared to the other treatments, suggested that the free acid of IBA when applied as an alcohol dip was inhibitory to rooting (Table 1). This was supported further by pronounced basal stem necrosis on cuttings treated with IBA solutions and also greater mortality of the auxin-treated cuttings.

When treating cuttings with Hormodin, the bases of the cuttings were first dipped into water followed by treatment of the basal 0.5 and 1.0 cm (0.2 and 0.4 in) of each cutting of clones 1 and 2, respectively, with Hormodin. Following treatment, the base of each cutting was gently tapped to remove excess powder and the cuttings were inserted into the rooting medium by means of a dibble.

Cuttings were maintained at approximate day/night temperatures of 24 ± 4/16 ± 4C (75 ± 7/61 ± 7F). Intermittent mist operated daily 6 sec every 3.3 min during daylight hours. A natural photoperiod was provided and light intensity was reduced by approximately 40% with a greenhouse shading compound. To control fungi, cuttings were sprayed initially and weekly thereafter alternating captan (3a,4,7,7a-tetrahydro2[(trichloromethyl)thiol]- 1 H-isoindole-1 ,3(2H)-dione) and daconil (tetrachloroisophthalonitrile) at 2.4 g/liter (0.32 oz/gal) and 2.5 ml/liter, (0.32 oz/gal), respectively.

Cuttings were harvested after 12 weeks for each growth stage, and data were recorded on percent rooting, number of primary roots ≥ 1 mm (0.04 in), and root length. Data for

Table 1. Effects of rooting treatments on percent rooting of stem cuttings of *Q. phillyreoides* taken at four growth stages.[z]

	Growth stage							
	Semi-hardwood		Hardwood		Softwood		Softwood/semi-hardwood[y]	
Treatment	Clone 1	Clone 2	Clone 1	Clone 2	Clone 1	Clone 2	Clone 1	Clone 2
Nontreated	16.6a[x]	0	58.3a	2.7a	61.1b	25.0ab	58.3b	5.5a
3000 ppm IBA	16.6a	5.5a	19.4b	8.3a	86.1a	38.0a	94.4a	0
6000 ppm IBA	11.1a	5.5a	25.0b	0	75.0ab	16.7ab	88.9a	0
9000 ppm IBA	2.7a	2.7a	19.4b	5.5a	75.0ab	25.0ab	80.5a	0
50% isopropanol	—	—	—	—	75.0ab	16.7ab	75.0ab	2.7a
Hormodin 2	—	—	—	—	88.8a	47.2a	80.5a	8.3a
Hormodin 3	—	—	—	—	97.2a	55.5a	52.8b	0
Analysis of variance								
Clone	*		**		**		**	
Treatment	NS		**		**		**	
Clone × treatment	NS		**		NS		**	

[z]Each value is based on 36 cuttings.

[y]Transitional growth stage between softwood and semi-hardwood.

[x]Mean separation within columns by the LSD test, 5% level.

NS, *, **, Nonsignificant or significant at the 5% or 1% levels, respectively.

Table 2. Effects of rooting treatments on mean root number of stem cuttings of *Q. phillyreoides* taken at three growth stages.[z]

	Growth stage					
	Hardwood		Softwood		Softwood/semi-hardwood[y]	
Treatment	Clone 1	Clone 2	Clone 1	Clone 2	Clone 1	Clone 2
Nontreated	1.7b[x]	4.1a	1.5d	1.4b	2.1b	1.1a
3000 ppm IBA	7.0a	1.5a	4.4bc	2.1b	3.6b	0
6000 ppm IBA	8.8a	0	5.4b	2.0b	6.1a	0
9000 ppm IBA	6.4a	0.8a	6.0b	2.3b	5.7a	0
50% isopropanol	—	—	2.0d	2.1b	1.6b	0.5a
Hormodin 2	—	—	10.0a	3.6a	7.2a	1.9a
Hormodin 3	—	—	9.0a	3.4a	6.5a	0
Analysis of Variance						
Clone	NS		**		**	
Treatment	NS		**		*	
Clone x Treatment	NS		**		NS	

[z]Each value is based on the number of cuttings which rooted for a particular treatment.

[y]Transitional growth stage between softwood and semi-hardwood.

[x]Separation of least square means within columns by General Linear Model Procedures, 5% level.

NS, *, **, Nonsignificant or significant at the 5% or 1% levels, respectively.

root number and length were based on the actual number of cuttings which rooted. Ordinary means of balanced data were subjected to analysis of variance (ANOVA) procedures and means were separated by the LSD test. General Linear Models procedures (Proc GLM) were used to separate least-square means of unbalanced data (19).

Following recording of rooting data for softwood and softwood/semi-hardwood cuttings of both clones, cuttings which rooted were potted in 7.6 cm (3 in) square plastic pots containing a medium of bark:sand (3:1 by vol). Each pot was top dressed with 1 g (0.03 oz) of an 18N–2.6P–9.9K slow-release fertilizer (Osmocote 18–6–12, Grace/Sierra, Milpitas, CA) and the pots were placed under natural photoperiod in a greenhouse maintained at day/night temperatures of 24 ± 4/16 ± 4C (75 ± 7/61 ± 7F). Rooted cuttings remained under these conditions until October 14, 1994, during which time the majority of the softwood cuttings produced a new flush of growth whereas the softwood/semi-hardwood cuttings did not. On October 14, 1994, the cuttings were placed in a lath house where they were acclimated to outdoor conditions and exposed to several frosts. On December 15, 1994, they were placed in a polyethylene covered greenhouse and overwintered at temperatures >0C (32F).

Results and Discussion

Results demonstrated that selected clones of *Q. phillyreoides* can be propagated by stem cuttings. However, a critical factor influencing rooting is timing (growth stage) (Tables 1 to 3).

Rooting of 97% and 56% for clones 1 and 2, respectively, was achieved with cuttings taken at the softwood stage and treated with Hormodin 3 [8000 ppm (0.8%) IBA in talc] (Table 1). Six weeks later as the new growth became firmer

Table 3. Effects of rooting treatments on mean root length (mm) of stem cuttings of *Q. phillyreoides* taken at three growth stages.[z]

	Growth stage					
	Hardwood		Softwood		Softwood/semi-hardwood[y]	
Treatment	Clone 1	Clone 2	Clone 1	Clone 2	Clone 1	Clone 2
Nontreated	129.2a[x]	55.2a	31.2a	42.3a	78.2b	28.7a
3000 ppm IBA	127.2a	21.7a	7.2b	10.0b	22.1c	0
6000 ppm IBA	83.4a	0	6.7b	7.7b	11.0c	0
9000 ppm IBA	90.2a	41.7a	6.1b	7.5b	10.4c	0
50% isopropanol	—	—	18.1b	11.3b	48.8b	19.8a
Hormodin 2	—	—	5.9b	6.8b	17.9c	3.1a
Hormodin 3	—	—	5.0b	6.7b	8.4c	0
Analysis of variance						
Clone	**		NS		**	
Treatment	NS		**		**	
Clone x treatment	NS		NS		NS	

[z]Each value is based on the number of cuttings which rooted for a particular treatment.

[y]Transitional growth stage between softwood and semi-hardwood.

[x]Separation of least square means within columns by General Linear Model Procedures, 5% level.

NS, **, Nonsignificant or significant at the 1% level, respectively.

and cuttings were in a transitional growth stage between softwood and semi-hardwood, high rooting percentages were still noted for clone 1 whereas a precipitous decrease in rooting occurred for clone 2. As tissue maturity progressed to the point that cuttings were in a semi-hardwood condition, rooting of both clones was negligible.

Some improvement in rooting occurred for hardwood cuttings in comparison to semi-hardwood cuttings of clone 1 with 58% rooting of nontreated cuttings (Table 1). On the other hand, rooting of clone 2 was still extremely poor (9%).

Although basal stem necrosis was extensive for cuttings treated with IBA solutions and cutting mortality was high, we do not feel these were contributing factors to poor rooting of semi-hardwood and hardwood cuttings. Cuttings at each growth stage were damaged to some extent by all IBA treatments. However, roots formed above the damaged basal portion of the stem. In addition, the appearance of root primordia was evident during evaluation of softwood and softwood/semi-hardwood cuttings, indicating that nonrooted cuttings may have produced roots if they had remained under mist for an extended period.

With the exception of the nontreated hardwood cuttings of clone 1, which rooted in significantly greater percentages than cuttings treated with IBA solutions (Table l), IBA treatments were generally beneficial in stimulating increased root numbers (Table 2). This was particularly true for softwood cuttings of clones 1 and 2 and softwood/semi-hardwood cuttings of clone 1 which typically produced higher root numbers in response to increasing IBA concentrations.

In contrast, auxin treatments generally resulted in decreased root length in comparison to the nontreated cuttings (Table 3). Thus, as mean root number increased, mean root length decreased. This may have resulted from a competition between the developing roots for a finite quantity of mineral nutrients and/or carbohydrates in each cutting (2, 20). Values for root lengths and number of roots per rooted cutting at the semi-hardwood stage were not included in Tables 2 and 3 because least square means at this stage were nonestimable.

With few exceptions, for each growth stage, cuttings of clone 1 rooted in higher percentages (Table 1) and had higher root numbers (Table 2) than clone 2. These data suggest that clone 1 has a greater capacity for adventitious rooting than clone 2. Such a finding is not surprising considering that clonal differences (tree to tree variation) in rooting have been reported for many woody species including *Pseudotsuga menziesii* L. (Douglas-fir) (3), *Juniperus virginiana* L. (eastern red cedar) (9), *Pinus strobus* L. (eastern white pine) (11), *Abies fraseri* (Pursh) Poir. (Fraser fir) (12), *Quercus ilex* L. (holly oak) (4), and *Quercus virginiana* Mill. (live oak) (14, 15).

The greater rooting capacity of clone 1 is also borne out by examination of the rooting data for the softwood and softwood/semi-hardwood cuttings (Table 1). The best rooting for clone 2 (56%) was achieved for softwood cuttings treated with Hormodin 3 [8000 ppm (0.8%) IBA in talc]. Six weeks later when cuttings in a transitional softwood/semi-hardwood growth stage were taken and treated in the same manner, rooting was negligible. On the other hand, high rooting percentages were noted for softwood cuttings of clone 1, particularly those treated with auxin. After 6 weeks these percentages were generally similar. Thus, the time period for taking stem cuttings of clone 1 in which high rooting was achieved was much greater than that of clone 2 when only moderate rooting occurred.

In the spring following overwintering it was observed that 93% of the rooted softwood cuttings which flushed after rooting survived the winter whereas survival of 37% was noted for the softwood/semi-hardwood cuttings which did not flush prior to overwintering. These findings agree with previous reports that overwinter survival of particular rooted species such as *Quercus* L. spp. (6, 7), *Stewartia pseudocamellia* Maxim. (Japanese stewartia), *Acer saccharum* Marsh. (sugar maple), and *Cornus florida* L. (flowering dogwood) (20, 21) is highly dependent on the cuttings producing a flush of growth following rooting.

Greater overwinter survivability of softwood cuttings as opposed to softwood/semi-hardwood cuttings strongly suggests that softwood cuttings should be taken for rooting. Why the rooted softwood cuttings flushed following rooting is unknown. It is not suspected that it was a result of fertilization since both the rooted softwood and softwood/semi-hardwood cuttings were fertilized with the same rate of Osmocote. The cuttings did not receive an extended photoperiod which may have stimulated growth. However, following recording of rooting data, the rooted softwood cuttings were placed in the greenhouse on July 22, 1994, when natural daylengths were still relatively long. On the other hand, following data collection, the rooted softwood/semi-hardwood cuttings were placed in the greenhouse on September 2, 1994, when natural photoperiod was shorter. The decrease in photoperiod from the time the rooted softwood cuttings were placed in the greenhouse to the time the rooted softwood/semi-hardwood cuttings were treated in the same manner may have accounted for the latter not flushing.

The phenomenon of juvenility/maturation is an important consideration when propagating many woody species by stem cuttings including oaks. For example, Morgan (13, 16) reported that when rooting stem cuttings of *Q. virginiana* (live oak) rootability decreased with stock plant age. In the present study, however, it appears that the maturation phenomenon will not limit rooting of stem cuttings of particular clones of *Q. phillyreoides* because both clones were in the adult growth phase yet stem cuttings from these trees were capable of adventitious rooting. The fact that stem cuttings can be rooted from trees in the adult growth phase should also prove beneficial for selection of trees with particular physiological and morphological characteristics. This should be particularly advantageous when selecting for desirable morphological characteristics which often are not expressed until the adult growth phase is reached.

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Production Method Affects Tree Establishment in the Landscape[1]

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Abstract

Trunk growth rates one year after transplanting 5 cm (2 in) caliper laurel oak (*Quercus laurifolia* Michx.) from above-ground plastic containers, from in-ground fabric containers or from the field (B&B) matched or exceeded growth rates before transplanting. Growth rates for all three treatments were similar seven months after transplanting. Shoots on field-grown trees grew more in the first year after transplanting than those from fabric or plastic containers. Roots removed at the time of digging were completely replaced on field and fabric container trees six months after transplanting. One year after transplanting, roots occupied the same soil volume as just prior to transplanting. Trees from plastic containers regenerated roots slower than B&B trees or those from fabric containers. When irrigation frequency was reduced 14 weeks after transplanting (WAT), trees from plastic containers were water stressed more (had more negative xylem potential) than B&B or fabric container trees. Growth rates of East Palatka holly (*Ilex* x *attenuata* Ashe. 'East Palatka') responded similarly to laurel oak; however hollies took longer to establish roots into landscape soil and took longer for the trunk growth rate to match that on trees prior to transplanting.

Index words: establishment rate, B&B, fabric container, field-grown, irrigation, planting, plastic container, root growth, transplanting.

Species used in this study: East Palatka holly (*Ilex* x *attenuata* Ashe. 'East Palatka'); laurel oak (*Quercus laurifolia* Michx.).

Significance to the Nursery Industry

Provided trees are regularly irrigated after they are installed in a landscape, method of nursery tree production caused only a small difference in growth after transplanting. That is, trees from above-ground plastic containers were slightly shorter with smaller trunks than those from the field (B&B) or from fabric containers two years after transplanting. Trunk growth rates for all methods of production were nearly identical by 18 months after transplanting to the landscape. If irrigation is cut back too soon, trees from plastic containers appear to undergo more stress than field grown trees and would die first in an extended drought. This is probably due to the increased shoot:regenerated root ratio in the landscape on trees planted from plastic containers compared to B&B trees or those from fabric containers. On the other hand, if freshly dug trees from a field nursery are not irrigated regularly after transplanting, plastic container trees perform better in the months following transplanting (11).

Introduction

Contractors, arborists, landscape architects and horticulturists often have the choice of purchasing trees from a vari-

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