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4 authors:

Emrah Cicek
Düzce University

Fahrettin TİLKİ
Artvin Coruh University

Ali Kemal Özbayram
Düzce University

Bilal Çetin
Düzce University

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Three-year Growth Comparison Between Rooted Cuttings and Seedlings of *Fraxinus angustifolia* and *Ulmus laevis*

[1]Emrah Çiçek, [2]Fahrettin Tilki, [1]Ali Kemal Özbayram, [3]Bilal Çetin

[1]Düzce University, Faculty of Forestry, Düzce-81620, Turkey
[2]Artvin Çoruh University, Faculty of Forestry, Artvin-08000, Turkey
[3]Istanbul University, Faculty of Forestry, Istanbul-34473, Turkey

Abstract: Early field growth of *Fraxinus angustifolia* and *Ulmus laevis* rooted cuttings was compared with that of seedlings using annual measurements collected during three years at a bottomland site in Adapazarı, Turkey. Two stock types (seedlings & rooted cuttings) were sorted by stock height (small, 45-55 cm; medium, 75-85 cm; large, 105-115 cm) and then planted. A two factorial (stock type & stock size) randomized block design with three blocks was used for each species. After three seasons of field growth, more than 99% of the plants had survived, irrespective of stock type in each species. Height and diameter increments of the rooted cutting of narrow-leaved ash at the end of third year were higher than that of seedlings. The heights of rooted cuttings and seedlings averaged 232 and 208 cm, respectively. However, height and diameter increments of white elm seedlings were higher than that of rooted cuttings. After three seasons of field growth, the heights of rooted cuttings and seedlings of white elm averaged 221 and 269 cm, respectively. Stock size and the interaction between stock type and stock size had no effect on three years growth variables in both species.

Key words: Field performance, narrow-leaved ash, rooted cutting, seedling, white elm

INTRODUCTION

Fraxinus angustifolia Vahl. (Narrow-leaved ash) and *Ulmus laevis* Pall. (White elm) are among the valuable hardwoods and getting more important in European forestry due to their ornamental values, fast growth ability and valuable woods[1,2,3,4]. *Fraxinus angustifolia* is the most common ash species in Turkey, and dominates the bottomland forests of northern coastal regions of Turkey. It also grows in riparian areas and is found as scattered trees in mountain forests[3,5]. *Fraxinus angustifolia* is a fast-growing species with a rotation of 40 years in Turkey. Although its stands are mainly confined to marginal bottomlands (heavy clay soil, extreme seasonal variations in soil moisture, poor drainage, high water table[3,4], the mean annual increment can reach 25 m^3 ha^{-1} and 15 m^3 ha^{-1} in plantations and natural stands, respectively[5].

Ulmus laevis has a limited distribution in Turkey. This species is usually found on bottomland forests dominated by *F. angustifolia*[6,7]. It has been known that elm species are being threatened by Dutch elm disease (*Ophiostoma nova-ulmi*). Infect, *U. laevis* is certainly more seriously threatened by the habitat destruction of the white elm populations[1,2]. The bottomland forests encountered extensive destruction throughout the centuries, drained and reclaimed for agriculture or poplar cultivation; therefore, the forest area of these species was diminished greatly[3].

The field performances of rooted cuttings and seedlings have been studied in a few hardwood species and many conifer species. Rockwood and Warrag[8] found that vegetative propagated planting stock had higher field growth performance than seedlings in *Ecucalyptus* spp. A similar result was also reported for *Paulownia* spp.[9]. However, Gaspar *et al.*[10] found that there were no significant differences between the two types of plant material (cuttings versus seedlings) for growth in *Eucalyptus globulus*. Through age 10 years, height, diameter and volume showed no difference between rooted cuttings and seedlings of loblolly pine[11,12,13]. There were also no morphological differences between the rooted cuttings and the seedlings of *Chamaecyparis nootkatensis*[14]. Ritchie *et al.*[15] observed no height differences between seedlings and tissue culture plantlets after 5 years of field growth. However, height growth of *Picea glauca* seedlings was higher than that of the rooted cuttings after five years[16]. On the other hand, reverse results were found in *Pinus taeda* and rooted cuttings outgrew seedlings[17]. Gemmel *et al.*[18] reported that both survival and height of *Picea abies* were superior in cuttings compared with seedlings eight years after planting. These field performance discrepancies between rooted cuttings and seedlings can be explained by the factors such as age of the donor plants, morphological and physiological status of stock at

Corresponding Author: Fahrettin Tilki, Artvin Coruh University Faculty of Forestry Artvin, 08000-Turkey
E-mail: fahrettintilki@yahoo.com Tel: +90 466 2121100

planting, inherent characteristics of species or provenances, field characteristics the trials applied, and the interactions among these factors.

Although *F. angustifolia* and *U. laevis* are wide spread in Europe, there is limited research on the plantation establishment of these species. More research is needed on conservation (*ex situ* and *in situ*), breeding, habitat restoration, plantation establishment, promoting and sustainable use of these species. One-year field performance of rooted cuttings and seedlings of *F. angustifolia* was assessed by Çiçek *et al.*[19]. The objective of this study was to compare three-year field survival and growth of rooted cuttings and seedlings of *F. angustifolia* and *U. laevis* within each species.

MATERIALS AND METHODS

Study site: The study was established on a bottomland hardwood area in Akyazı-Adapazarı, Turkey (40°48' N, 30°33' E, 25 m asl). The mature natural stand on the site was dominated by *F. angustifolia,* with scattered trees of *Ulmus laevis*, *U. minor*, *Quercus robur*, *Q. hartwissiana*, *Acer campestre* and *Populus alba*. The area has alluvial clay soils (slightly to moderately alkaline) with a smooth and homogeneous soil structure. The soil on the site is deep and not well drained, and the Ah horizon was very thin to absent due to rapid decomposition. Adapazarı Meteorological Station (lat. 40° 47' N, longt. 30° 25' E, alt. 30 m a.s.l.) is about 15 km south-west from the study site. According to the station records, the area has a warm climate and receives approximately 846 mm of rainfall each year, with about 50% (420 mm) falling from April to October. The mean annual temperature is 14.3 ºC, and the mean temperature during the growing season (April–October) is 18.8ºC.

Older natural stands at the study site were clear cut and their stumps were uprooted in the fall of 2004. After the stumps and slash were disposed of, the soil was first ripped (60–80 cm soil depth) and then disked (20–30 cm soil depth) to aerate the soil. The operation was similar to the procedures for site preparation for *F. angustifolia* and other fast-growing tree species plantations in Turkey.

Planting Stock: Seedlings and rooted cuttings of both species were 1+0 and bare-root, and represents Hendek provenance. The seedlings and rooted cuttings were grown at a density of 80 plant m^{-2} and 33 plant m^{-2}, respectively. More detail about the planting stock (the seedlings & the rooted cuttings) used in this study can be obtained from Çiçek[20] and Çiçek *et al.* [21]. The seedlings and the rooted cuttings were grouped into three height categories: small (45-55 cm), medium (75-85 cm) and large (105-115 cm).

Experimental Design and Planting: A two factorial randomized block design with four replications were conducted for each species (2 stock types x 3 stock sizes x 4 replications). Each row contained 20 planting stock was an experimental unit (plot). Each block contained six rows and, each row consisted of planting stock from a stock type with three stock size categories (small, 45-55; medium, 75-85 and large, 105-115 cm). Stock type and stock size combinations were randomly assigned in each block. A total 480 plants (240 seedlings and 240 rooted cuttings) were used for each species. The seedlings hand planted at 3x2 m spacing in early March, 2004. To control weedy vegetation, the study plots were treated by hand hoeing $1 m^2$ of soil around the plants and disking between rows in early June during 2005-2007.

Measurements and Analyses: Basal diameters (2.5 cm above the root collar, ± 0.1 mm) and heights (± 1.0 cm) of the seedlings were determined in both species after planting in March 2004 (Table 2). Basal diameter (2.5 cm above ground) was measured instead of root collar diameter because of the muddy site conditions. Survival, diameter, and height were recorded at the end of the each growing season.

No statistical analysis was used to examine the factor (stock type & stock size) effects on seedling survival since survival percentages were ≥ 99% in all treatments in both species after three growing seasons. Analyses of variance (ANOVA) were used to evaluate the effects of stock type and stock size on field growth variables for each experiment. The variables analyzed were the mean plot values of the trees/plants. Yearly growth increments were the difference between the previous year and the subsequent year tree sizes of the plots. Three years increments were the difference the initial and the third year tree sizes. The normal distribution of variables was controlled before ANOVA. If analyses of variance indicated significant effects ($P < 0.05$), the treatment means were separated by Duncan's New Multiple Range Test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Survival of the rooted cuttings and seedlings of the both species were 100% at the end of the first year, and more than 99% at the end of the following years. High survival may be related directly to the use of high quality and larger-size planting stock, and adequate weed control through summer season. In conventional *F. angustifolia* plantings in Turkey, low-grade and small-size (20–40 cm high) seedlings obtained from high-seedbed densities are generally used, leading to high seedling mortality (at least 25–30%) in the early years of growth[22]. Moreover, in

2007, mortality reached 47% in such plantations (A. Simsek, personal communication). Karlsson ve Russel[14] found that rooted cutting and seedling did not significantly affect survival percentage as found in the present study. However, Bergmann[9] found that vegetative propagated planting stock of *Paulownia* spp. had higher survival than seedlings which were grown directly from seed.

Analyses of variance for *Fraxinus angustifolia* showed that stock type significantly effected diameter and height increments in the first growing season (P<0.001), but not in the second and third growing seasons (P>0.05). Stock type also affected three years increments, and the total diameter and total height after three years of growth (P<0.001). However, stock size only affected total diameter and total height at the end of the each growing season and the three years height increment (P<0.01). The interaction between stock type and stock size had no significant effects on variables (P>0.05) (Table 1).

Rooted cuttings of *F. angustifolia* performed more diameter (61% & 1.7 mm) and height increments (96% & 25 cm) in the first growing season. But, both the rooted cuttings and the seedlings had similar increments within the each of the second and third growing seasons (Tables 2 and 3). Therefore, it was said that the differences during the three years increments and the total values were derived from the growth differences in the first growing season. Because, the rooted cuttings of *F. angustifolia* had almost 1.7 mm (9%) more total diameter and 24 cm (19%) more total height compared to seedlings over three years. From a silvicultural point of view, differences in three years diameter increment and total diameter were small despite their statistical significance. After three years of growth, the heights of rooted cuttings and seedlings averaged 232 and 208 cm, respectively (Table 3). Stocks at different sizes had similar diameter and height increments, and the significant differences among stock sizes at planting were also significant after three years of growth (Tables 2 and 3).

Stock type did not significantly affect the increments in the first and the second growing seasons in *Ulmus laevis* (P>0.05). However, stock type had significant effect on diameter and height increments in the third growing season (P<0.001). Besides, stock type had significant effect on three years diameter and height increments and total height (P<0.001). On the other hand, stock size significantly affected the diameter increment in the first growing season and the height increments in the first and second growing seasons, and the total diameter and height after three years of growth. However, stock size did not significantly affect the three years increments. The interaction between stock type and stock size had no significant affect on all the growth variables (P > 0.05) (Table 4).

Rooted cuttings and seedlings of *U. laevis* had similar diameter and height increments within the each of the first and second growing seasons. However, seedlings performed much more diameter (%37 & 2.6 mm) and height increments (%37 & 2.6 mm) in the third growing season (Tables 5 and 6). After three years of growth, the seedlings of *U. laevis* used in this study had similar total diameter as rooted cuttings but had higher diameter increment (11% & 2.6 mm), height increment (34% & 47 cm) and total height (21% & 46 cm) than rooted cuttings due to high growth rate in the 3rd year. Small sized stocks showed high diameter and height growth rate after 1st growing season but the differences were not statistically significant between stock sizes after 3 years.

Trees of rooted cuttings of *F. angustifolia* seemed more bulky stem form than the seedlings. Thus, the biomass production of rooted cuttings may be much more than that of the *F. angustifolia* seedlings. However, except for differences in diameter and height growth, no visible morphological differences observed in *U. laevis* as observed in some conifer species[23,24].

Field trials that compared the field performance of rooted cuttings and seedlings have been studied in a few hardwood species. Rockwood and Warrag[8] found that vegetative propagated planting stock had higher field growth performance than seedlings in *Ecucalyptus* spp. A similar result was also reported for *Paulownia* spp.[9]. However, Gaspar *et al.* [10] found that there were no significant differences between the two types of plant material (cuttings versus seedlings) for growth in *Eucalyptus globulus*.

Stock type significantly affected first year diameter and height growth rate of *F. angustifolia*, and both diameter and height growth was higher in rooted cuttings than seedlings[19]. The results for *F. angustifolia* in the present study are in accordance with what has been reported for most species. But it was shown that the differences after three years were derived from the growth differences during the first growing season. Thus, it might be said that results in the following years will show no difference in height and diameter between the *F. angustifolia* rooted cuttings and seedlings. However, the differences in *U. laevis* growth after three years were derived from the growth differences during the third growing season. Therefore, the rate of increase of the yearly growth rate can be larger for seedlings than for rooted cuttings in the following years.

Table 1: Analyses of variance (*P* values) for the effect of stock type and stock size on growth variables during 3 years of *F. angustifolia* growth

Year	Factor	df	Diameter increment	Total diameter	Height increment	Total height
1st year	Stock type (A)	1	0.000	0.000	0.000	0.000
	Stock size (B)	2	0.541	0.000	0.643	0.000
	AxB	2	0.823	0.406	0.875	0.705
2nd year	Stock type (A)	1	0.65	0.000	0.167	0.000
	Stock size (B)	2	0.393	0.004	0.145	0.000
	AxB	2	0.583	0.399	0.077	0.145
3rd year	Stock type (A)	1	0.86	0.000	0.719	0.000
	Stock size (B)	2	0.745	0.001	0.008	0.000
	AxB	2	0.268	0.055	0.062	0.092
Three years	Stock type (A)	1	0.000	-	0.000	-
	Stock size (B)	2	0.917	-	0.057	-
	AxB	2	0.080	-	0.690	-

Table 2: Mean diameter growth of *F. angustifolia* stock type (average for three stock sizes) and stock size (average for two stock types). DI: diameter increment, TD: total diameter.

Factor	Treatment	Initial diameter (mm)	DI 1st year (mm)	TD 1st year (mm)	DI 2nd year (mm)	TD 2nd year (mm)	DI 3rd year (mm)	TD 3rd year (mm)	Three years DI (mm)
Stock type	rooted cutting	9.3 a	4.5 a	13.8 a	10.5 a	24.3 a	6.3 a	30.6 a	21.3 a
	seedling	9.3 a	2.8 b	12.1 b	9.9 a	22.0 b	6.9 a	28.9 b	19.6 b
Stock size	large	11.6 a	3.7 a	15.3 a	9.8 a	25.1 a	6.8 a	31.9 a	20.3 a
	medium	9.4 b	3.5 a	12.9 b	10.8 a	23.7 b	6.4 a	30.1 b	20.7 a
	small	6.9 c	3.8 a	10.7 c	9.9 a	20.6 c	6.6 a	27.2 c	20.3 a

Means within each column and factor are not significantly different (α = 0.05).

Table 3: Mean height growth values of *F. angustifolia* stock type (average for three stock sizes) and stock size (average for two stock types). HI: Height increment, TH: total height.

Factor	Treatment	Initial diameter (mm)	DI 1st year (mm)	TD 1st year (mm)	DI 2nd year (mm)	TD 2nd year (mm)	DI 3rd year (mm)	TD 3rd year (mm)	Three years DI (mm)
Stock type	rooted cutting	81 a	51 a	132 a	51a	183 a	49 a	232 a	151 a
	seedling	81 a	26 b	107 b	54 a	161 b	47 a	208 b	127 b
Stock size	large	112 a	37 a	149 a	51 a	200 a	46 a	246 a	134 a
	medium	79 b	39 a	118 b	54 a	172 b	48 a	220 b	141 a
	small	51 c	40 a	91 c	53 a	144 c	49 a	193 c	142 a

Means within each column and factor are not significantly different (α = 0.05).

Table 4: Analyses of variance (*P* values) for the effect of stock type and stock size on growth variables during 3 years of *U. laevis* growth

Year	Factor	df	Diameter increment	Total diameter	Height increment	Total height
1st year	Stock type (A)	1	0.060	0.275	0.875	0.700
	Stock size (B)	2	0.018	0.000	0.009	0.000
	AxB	2	0.825	0.618	0.602	0.961
2nd year	Stock type (A)	1	0.072	0.004	0.670	0.519
	Stock size (B)	2	0.805	0.001	0.032	0.000
	AxB	2	0.655	0.731	0.424	0.618
3rd year	Stock type (A)	1	0.001	0.188	0.000	0.000
	Stock size (B)	2	0.438	0.000	0.133	0.001
	AxB	2	0.857	0.993	0.126	0.766

Table 4: Continue

Three years	Stock type (A)	1	0.417	-	0.000	-
	Stock size (B)	2	0.609	-	0.135	-
	AxB	2	0.859	-	0.590	-

Table 5: Mean diameter growth of *U. laevis* stock type (average for three stock sizes) and stock size (average for two stock types). DI: diameter increment, TD: total diameter.

Factor	Treatment	Initial diameter (mm)	DI 1st year (mm)	TD 1st year (mm)	DI 2nd year (mm)	TD 2nd year (mm)	DI 3rd year (mm)	TD 3rd year (mm)	Three years DI (mm)
Stock	rooted cutting	8.9 a	4.4 a	13,3 a	9.8 a	23.1 a	9.1 b	32.2 a	23.3 b
type	seedling	7.4 b	4.2 a	11,6 a	9.2 a	20.8 b	12.5 a	33.3 a	25.9 a
	large	11.3 a	3.7 b	15,0 a	9.4 a	24.4 a	11.4 a	35.8 a	24.5 a
Stock	medium	8.3 b	4.0 b	12,3 b	8.9 a	21.2 b	10.9 a	32.1 b	23.8 a
size	small	5.8 c	5.0 a	10,8 c	9.4 a	20.2 b	10.1 a	30.3 b	24.6 a

Means within each column and factor are not significantly different (α = 0.05).

Table 6: Mean height growth values of *U. laevis* stock type (average for three stock sizes) and stock size (average for two stock types). HI: height increment, TH: total height.

Factor	Treatment	Initial diameter (mm)	DI 1st year (mm)	TD 1st year (mm)	DI 2nd year (mm)	TD 2nd year (mm)	DI 3rd year (mm)	TD 3rd year (mm)	Three years DI (mm)
Stock	rooted cutting	82 a	46 a	128 a	50 a	178 a	43 b	221 b	139 b
type	seedling	81 a	47 a	128 a	49 a	177 a	92 a	269 a	188 a
	large	112 a	43 b	155 a	41 b	196 a	74 a	270 a	158 a
Stock	medium	80 b	42 b	122 b	51 ab	173 b	65 a	238 b	158 a
size	small	53 c	54 a	107 c	56 a	163 b	63 a	226 b	173 a

Means within each column and factor are not significantly different (α = 0.05).

Conclusion: The rooted cuttings of both species had perfect survival and grew well in the field after three growing seasons. The growth of rooted cuttings of *F. angustifolia* were greater than for seedlings due to high growth rate during the first growing season but seedlings of *U. laevis* had higher total height than rooted cuttings due to during the third growing season. Differences between the height and diameter growth of seedlings and rooted cuttings did not vary among stock sizes in each species. However, the performance of seedlings and rooted cuttings should be followed in the following years and further studies should be conducted to compare the performance of rooted cuttings and seedlings of these species.

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