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Effects of spacing and post-planting treatments on survival and growth of *Fraxinus angustifolia* seedlings

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Abstract: *This study was conducted at a bottomland hardwood site with heavy textured soil in Akyazi, Turkey to determine the effect of initial spacing (3.0 x 3.0, 3.0 x 2.0, 2.5 x 1.6 and 2.5 x 1.2 m) and post-planting treatments (untreated check, moving, hoeing, disking, and hoeing plus disking) on early survival and growth of Fraxinus angustifolia Vahl. One-year old bare-root seedlings (70±5 cm in height) were hand-planted in December 2004. Through three years survival was perfect with a rate of 98% in all treatments. Spacing and the interaction between spacing and post-planting treatment did not significantly affect seedling growth through three years. However, height and diameter growth increased over time and differed significantly among post-planting treatments. The hoeing and hoeing plus disking treatments gave the highest growth, and resulted in about 31% increase in diameter and height increment, and in total diameter and height about 20%. These results suggest that post-planting treatments on bottomland sites with heavy textured soil give promising results.*

Key words: *Ash, Field performance, Spacing, Vegetation control*
PDF of full length paper is available online

Introduction

Ash species is getting more important in European forestry due to their fast growth ability and valuable wood. *Fraxinus angustifolia* Vahl. (Narrow-leaved ash) occurs naturally in southern Europe, Balkans, Caucasus and Iran (Fraxigen, 2005). It is the most common and useful native ash species and dominates the bottomlands forest of northern coastal region of Turkey. It also grows in riparian areas and is found as a scattered tree or small groups in mixed hardwood stands on mountain areas (Davis, 1987; Mayer and Aksoy, 1986). Although natural habitats of this species are mostly confined to bottomlands which is regarded marginal for the plant growth (heavy textured soils, extreme seasonal variations in soil moisture, weak drainage, high ground water level *etc.*) (Pliura, 1999), its stands have a high productivity, and mean annual increment can reach to about 15 and 25 $m^3 ha^{-1}$ in natural stands and plantations, respectively (Kapucu *et al*., 1999). Its wood characteristics show similarities to common ash (*F. excelsior*) and it yields white, high quality wood and is especially preferred in the veneer and furniture industry. Despite its relative importance, little is known about plantation establishment of *F. angustifolia,* and studies concentrate on their silviculture, breeding, genetics and gene conservation (Fraxigen, 2005).

Spacing affects growth and wood quality, stand establishment, and management costs (Savill *et al*., 1997; Ozcelik and Eler, 2009; Uner *et al.,* 2009). *Fraxinus angustifolia* has been grown at spacings of 3 x 2 and 3 x 2.5 m until 1980s and later spacings of 3.7 x 3.7 m and 4 x 4 m in Turkey. Now-a-days, spacing of 4.0 x 2.0 m (1250 trees ha^{-1}) has been practiced in Turkey. But ash trees planted at 3 x 2 m or wider provided poor tree form and low timber quality (Cicek, 2004). Silviculturists have always been clear that where high timber production is an important objective of management most hardwood species including ash should be established at least 2500 stems ha^{-1} to produce high quality timber (Evans, 1984). In Europe, some hardwood species tend to be planted at a spacing of 3.0 x 3.0 m but for high quality timber production at least 2.0 x 2.0 m initial spacing were advised for ash, oak and birch species (Kerr and Evans, 1993; Kerr, 1995; Evans, 1997). Close spacing encourages stem straightness and minimize branch development (Wardle, 1967). Thus, more research is needed in order to optimize the initial spacing or density of *F. angustifolia*.

Control of competing vegetation is essential for the successful plantation establishment and this usually requires potentially expensive post-planting treatments (Willoughby *et al*., 2007). Vegetation control in forest plantations often increases growth of crop trees but can also affect biomass and nutrient partitioning to tree components (Petersen *et al*., 2008). Post-planting treatments is very important for successful establishment of plantations, especially on sites with excessive and vigorous weedy vegetation (Evans, 1984; Kerr and Evans, 1993). Competition from weeds for light, water and nutrients, and physical damage on establishment site leads to reduced seedling survival and growth. Weed control is critical for plantation establishment in most species and it can be achieved mechanically or chemically.

In Turkey, to regenerate *F. angustifolia* stands found on bottomlands, the preferred method is clear felling and planting (Cicek *et al*., 2007a). The potential *F. angustifolia* sites on bottomlands are also afforested by plantings. In these sites, during the early years of

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planting, because of the site conditions, an excessive weed competition problem is observed. The weedy vegetation can grow up to 1.5 m or more height in a few months once it comes out. *Lythrum salicaria*, *Pulicaria dysenterica* and *Alisma plantago-aquatica* are the main weed competitors; other significant weeds include *Epilobium* sp., *Mentha pulegium, Agrostis* sp., *Ranunculus repens* and *Plantago major* (Cicek *et al*., 2007b). It is important to control competing vegetation because ash species don't tolerate heavy competition from weeds (Evans, 1997; Fraxigen, 2005). Weedy vegetation was controlled by mechanically rather than by any chemical weed control treatments in Turkey. Survival and early growth are often poor for traditional plantings because of small sizes and low grade seedlings (20-40 cm in height) grown at high seedbed densities, excessive herbaceous plant competition, neglected post-planting treatments and low planting densities in Turkey (Cicek *et al*., 2007a). Information about *F. angustifolia* response to weed control was needed for developing post-planting silvicultural techniques for successful *F. angustifolia* stand establishment in Turkey. Thus, the objective of this study was to evaluate the effects of spacing and post-planting treatments on survival and growth of *F. angustifolia* plantation at a bottomland site in Akyazi, Turkey.

Materials and Methods

Study site and site preparation: The study was established at a bottomland hardwood site in Akyazi-Adapazari, Turkey (lat. 40°48' N, longt. 30°33' E, alt. 25 m a.s.l.). The mature natural stand on the site was dominated by *F. angustifolia,* with scattered trees of *Ulmus laevis*, *U. minor*, *Quercus robur*, *Q. hartwissiana*, and *Acer campestre*. The site has heavy textured soil with soil pH of 7.50-7.95. The alluvial soil is deep and weak drained, and the Ah horizon is too thin to due to rapid decomposition (Cicek *et al*., 2006a). According to Adapazari Meteorological Station record, the area has a warm climate and receives approximately 846 mm of rainfall each year. The mean annual temperature is 14.3 ºC. Furthermore, mean relative humidity during the growing season of the study years, especially in summer, was lower compared to the 32-year mean value (Anonymous, 2008). 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.

Seedling material: Seeds were collected from the *F. angustifolia* dominated stands in Hendek, Adapazari and were sown in nursery in spring of 2004. In order to overcome dormancy, the seeds were subjected to 30 days of warm stratification (20±1°C) followed by 30 days of cold stratification (4±1°C) before sowing. The seeds were sown by hand in March 2004 and one-year old bare-root seedlings for this study were grown at about a density of 80 seedlings m^{-2} at Hendek Forest Nursery. Undercutting was done in the nursery before lifting by forcing a tractor-driven blade through the seedbed 25 cm below soil surface. After seedlings were lifted by hand in December 2004, the seedlings were graded for uniformity of height (70±5 cm) to ensure that shoots and root systems (collar diameter 11 mm) were well developed and structurally sound. Based on the Turkish Standard Institute (TSI), all the seedlings fall into the category of first seedling grade class (TSI, 1988).

Experimental design and treatments: The study consisted of a two factorial split-plot design with three blocks. Whole plot treatment was spacing (four levels) and subplot treatment was post-planting treatment (five levels). The whole and the subplot were 3750 m^2 (50 x 75 m) and 750 m^2 (50x15 m), respectively. Each row was 50 m length and comprised 17-42 seedlings depending on the spacing within row. About 9,500 seedlings were hand planted in December 2004. In each subplot two interior rows were measured and surrounding rows were buffers.

We used one square spacing (3x3 m) and three rectangular spacings (3x2 m, 2.5x1.6 m and 2.5x1.2 m) at planting. These spacings were equivalent to 1111, 1666, 2500 and 3666 trees per hectare, respectively. Spacing between 3x3 m and 2.5x1.2 m were selected to provide a range of stand density conditions.

Five post-planting treatments were tried as the untreated check, moving, hand hoeing, disking, and the combination of hoeing and disking treatments. Except mowing, the post-planting treatments were repeated twice in each growing season in June and September.

Data collection and analyses: Basal diameters (±0.1 mm) and heights (±1.0 cm) of the seedlings were determined. 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 in December in the years following planting.

Analyses of variance (ANOVA) were used to evaluate the effects of spacing and post-planting treatment. If analyses of variance indicated significant effects, the treatment means were separated by Duncan's New Multiple Range Test ($p<0.05$). Statistical analyses (ANOVA) were performed with the help of the computer software package SPSS.

Results and Discussion

First-year seedling survival was 100% and survival averaged 98% at 2 and 3 years of age. It is likely that, the larger size and higher quality of the seedlings used in this study produced high seedling survival. 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 (Cicek *et al*. 2007a). Moreover, in 2007, mortality reached 47% in such plantations (A. Simsek, personal communication). Increased survival in other studies on *F. angustifolia* that have similar growth conditions with the study site (Cicek *et al*., 2006a and 2007c) is related directly to the use of high quality and larger-size planting stock. Although producing and planting large size seedlings can cost more, larger size seedlings can compete and protect themselves from excessive weedy vegetation in clear-felling areas on bottomland

Table - 1: Analyses of variance (p values) for the effect of spacing and post-planting treatment on growth variables during the first 3 years of growth

Year	Factor	Degrees of freedom	Diameter increment (mm)	Total diameter (mm)	Height increment (cm)	Total height (cm)
1st	Spacing (A)	3	0.236	0.204	0.430	0.242
	Post-planting treatment (B)	4	0.029	0.078	0.046	0.001
	AxB	12	0.827	0.493	0.751	0.870
2nd	Spacing (A)	3	0.330	0.318	0.396	0.306
	Post-planting treatment (B)	4	0.000	0.000	0.000	0.000
	AxB	12	0.993	0.990	0.827	0.944
3rd	Spacing (A)	3	0.475	0.503	0.304	0.226
	Post-planting treatment (B)	4	0.000	0.000	0.000	0.000
	AxB	12	0.943	0.914	0.888	0.835

Table - 2: Mean growth values of *F. angustifolia* in response to spacing during the first 3 years of growth (average for five post-planting treatments)

Year	Spacing treatment (m)	Diameter increment (mm)	Total diameter (mm)	Height increment (cm)	Total height (cm)
1st	3x3	3.4	11.8	27	98
	3x2	2.8	11.2	25	95
	2.5x1.6	3.0	11.3	26	96
	2.5x1.2	3.3	11.8	29	100
2nd	3x3	10.3	18.7	70	140
	3x2	9.8	18.2	65	135
	2.5x1.6	9.3	17.7	65	135
	2.5x1.2	9.6	18.1	68	138
3rd	3x3	14.6	22.9	108	179
	3x2	13.9	22.3	102	172
	2.5x1.6	14.5	22.9	110	180
	2.5x1.2	13.0	21.5	99	169

Table - 3: Mean growth values of *F. angustifolia* in response to post-planting treatment during the first 3 years of growth (average for four spacings)

Year	Spacing treatment (m)	Diameter increment (mm)	Total diameter (mm)	Height increment (cm)	Total height (cm)
1st	check	2.8^{b}	11.2^{a}	24^{b}	94^{b}
	mowing	2.9^{b}	11.3^{a}	25^{b}	96^{b}
	hoeing	3.3^{ab}	11.6^{a}	29^{ab}	99^{ab}
	disking	2.8^{b}	11.4^{a}	25^{b}	94^{b}
	hoeing+disking	3.8^{a}	12.1^{a}	32^{a}	104^{a}
2nd	check	7.8^{c}	16.2^{c}	52^{c}	122^{c}
	mowing	10.0^{b}	18.4^{b}	69^{b}	139^{b}
	hoeing	10.8^{b}	19.2^{b}	79^{a}	149^{a}
	disking	7.9^{c}	16.5^{c}	54^{c}	123^{c}
	hoeing+disking	12.2^{a}	20.5^{a}	81^{a}	152^{a}
3rd	check	11.2^{c}	19.6^{c}	83^{c}	153^{c}
	mowing	13.5^{b}	21.9^{b}	107^{b}	177^{b}
	hoeing	16.7^{a}	25.1^{a}	124^{a}	195^{a}
	disking	11.3^{c}	19.9^{c}	85^{c}	154^{c}
	hoeing+disking	17.3^{a}	25.6^{a}	125^{a}	196^{a}

Means within each year and column followed by the same letter are not significantly different ($p<0.05$)

sites, and thus planting large size seedlings may reduce the need for replanting and reduce the cost of reforestation.

Analyses of variances showed that spacing had no significant effect on height and diameter growth when analyzed for each measurement year ($p>0.05$) (Tables 1, 2). Since all trees were free to grow during the first three years, spacing didn't affect height and diameter growth after three growing seasons in the present research. The effect of spacing on growth and survival may appear later when competition among trees begins, and this is expected to be earlier at close spacings. Early studies have reported different results in the effects of spacing on early growth of various hardwood species.

Height, diameter, and stem volume of common ash (*Fraxinus excelsior*) at age five decreased with decreasing planting density although there was no competition among trees (Kerr, 2003). Spacing significantly affected early diameter and height growth in *Alnus rubra* and *Populus* clones at age five and three, respectively (Giordano and Hibbs, 1993; DeBell and Harrington, 1997), and had a significant effect on growth of *Eucalyptus* clones after 30 months because of competition among trees (Bouvet, 1997). Spacing also affected early growth of *Eucalyptus urophlla* at age six (BaoLing *et al*., 2000). However, Burgan (1971) found a similar result with our study that spacing did not affect height and diameter growth of *Fraxinus uhdei* at age eight.

However, except for the total diameter at the end of the first year, the effect of post-planting treatment on seedling growth was found to be significant during the first three years (Tables 1 and 3). The interaction between spacing and post-planting treatment had no significant effect on growth variables ($p>0.05$) (Table 1).

During the three years hoeing and hoeing plus disking treatment resulted in the highest total height and height increment which were the lowest in control and disking. The mowing treatment provided a growth performance among those two treatment group. Total height and height increment was approximately 22 and 34%, respectively greater in both hoeing and hoeing plus disking treatments compared to the untreated control and disking after three years of growth. Diameter growth followed a similar trend too. The moving treatment had more diameter (16%) and height (20%) increments than the control and disking treatments after three years (Table 3).

After one year of growth, total diameter did not differ among the weed treatments. Hoeing plus disking treatment resulted in the highest total diameter and diameter increment at the age of two. As in the first growing season, diameter and height increment in the second and third vegetation period were higher in hoeing and hoeing plus disking treatments than that of the other treatments (Table 3).

Hoeing and hoeing plus disking were the most effective post-planting treatment methods after three years and resulted in about 34% increase in growth increments compared to control and disking. Since disking plus hoeing did not increase seedling growth compared with hoeing alone, it might be stated that disking between rows provided no benefit to *F. angustifolia* establishment. Hand cultivation-hoeing and mowing eliminate the weeds around the seedlings, and thus made more water and nutrient available to the seedlings. Evans (1997) stated that ash was certainly sensitive to weed competition, especially from grasses. However, with a good post-planting treatment and adequate protection, ash is an easy tree to grow. On the other hand, the last 2 years in which this study was conducted were drier and hotter than average, and thus under normal (average) circumstances, the growth of seedlings would be even higher.

Groninger *et al*. (2004) found that disking between rows in green ash (*Fraxinus pennsylvanica*) plantations on a bottomland site did not affect growth. However, some results showed that disking significantly increased survival and growth of hardwoods including green ash planted on bottomlands with clay soils compared to control or mowed plots (Kennedy, 1981; Krinard and Kennedy, 1987; Zutter *et al*., 1987). Devine *et al*. (2000) found that both disking and mowing significantly increased the growth of green ash on a bottomland site. Similarly, after three growing seasons, growth was best in the rototilling treatments in white ash on a bottomland site (Cogliastro *et al*., 1990). George and Brennan (2002) found a contrasting result with our study that hand hoeing did not effectively control weeds and not improve survival or increase seedling growth at age two compared to the control in *Eucalyptus* plantations. Although disking did not increase the growth during the first three years in our study, the effect of disking should be followed in the following years.

Except for moving, the post-planting treatments were applied two times in a growing season in this study (in both June and September). Hand hoeing applied once in a growing season (in June) in some studies having different aims on *F. angustifolia* bottomlands showed similar survival and growth values as found in this study (Cicek *et al*., 2006a,b; Cicek *et al*., 2007c). One of the reasons why seedling survival and growth are low in traditional plantations might be that soil cultivation has been done when soil is not appropriate for cultivation due to adverse soil conditions during July. Therefore, it might be said that post-planting treatment once a year (in June) might be prefer to compete with weedy vegetation. On the other hand, although hoeing was more effective to increase growth of seedlings after 3 years compared to mowing, it is more expensive and difficult to perform than mowing due to climatic conditions (high temperature and moisture) during summer months in the present study. Thus, sometimes mowing may be used for performing post-planting treatment instead of hoeing.

The results of this study demonstrated that spacing did not significantly affect seedling growth but post-planting treatment is effective in increasing growth of *F. angustifolia*, and it might be concluded that managers who wish to increase growth of planted narrow-leaved ash on bottomland sites with clay soils through the early years may consider either hoeing or mowing treatment in June.

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