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Effect of N and NPK fertilizers on early field performance of narrow-leaved ash, *Fraxinus angustifolia*

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Abstract: *The effect of fertilization in the first growing season on early survival and growth of narrow-leaved ash (NLA) (Fraxinus angustifolia ssp. oxycarpa) was evaluated throughout the first 3 years of growth in Adapazari, Turkey. A randomized complete block design with four replications was established to investigate fertilization effects. Granular N urea [46%, $(NH_2)_2CO$, NH_2-N] and NPK (15/15/15%; NH_3-N, P_2O5, K_2O) fertilizers were applied in mid-May of the first growing season. Fertilization treatments per tree were control, 67 g NPK (equal to 10/10/10 g N/P_2O_5 /K_2O tree^{-1}), 133 g NPK (20/20/20 g N/P_2O_5 /K_2O tree^{-1}), 33 g urea N (15 g N tree^{-1}) and 54 g urea N (25 g N tree^{-1}). After three growing seasons under these fertilizer treatments, 98% of trees were still viable. Compared to the control treatment, fertilization had a large and positive effect on diameter and height growth during the first 3 years of growth. However, since there were no significant differences among the fertilized plots in terms of tree diameter and height growth, addition of P and K to the fertilizer regime was not beneficial. The results show that N fertilization in the first growing season has the potential to improve early field growth of narrow-leaved ash.*

Key words: *Fertilization, Fraxinus angustifolia, Growth, Plantation, Survival*
PDF of full length paper is available online
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Introduction

Ash species (*Fraxinus excelsior, F. angustifolia*) are becoming important in European forestry due to their fast growth and valuable wood, and extensive research has been undertaken into their silviculture, breeding, genetics, and gene conservation (Fraxigen, 2005). Narrow-leaved ash (NLA, *F. angustifolia* ssp. *oxycarpa*) is the most common ash species in northern coastal regions of Turkey and dominates the bottomland forests. It also grows in riparian areas and is found as scattered trees or small groups in mixed stands on mountains (Mayer and Aksoy, 1986). This species is also found throughout southern and eastern Europe, Syria, Caucasus, Iran and southern Russia (Fraxigen, 2005). NLA is a fast-growing species with a rotation of 40 years in Turkey. Although NLA stands are mainly confined to marginal bottomlands (heavy clay soil, extreme seasonal variations in soil moisture, poor drainage, high water table; Pliura, 1999; Fraxigen, 2005), the mean annual increment can reach 25 $m^3 ha^{-1}$ and 15 $m^3 ha^{-1}$ in plantations and natural stands, respectively (Kapucu *et al.*, 1999). It is possible that this species is the fastest-growing ash species in the northern hemisphere. The tree yield can be increased even more by planting on soils with a better texture, breeding or genetic improvement programs, and intensive silvicultural treatments such as fertilization and irrigation.

Over the last two decades, forest plantation areas have rapidly increased worldwide. In such plantations, fertilization is commonly practiced as a silvicultural tool, and site-specific research has been undertaken to increase the yields. Smethurst (2000), states that site-specific soil analyses are common in agriculture and horticulture, and are becoming increasingly common in plantation forestry. However, fertilization has not been practiced in the Turkish forestry service. Fertilization has only been used in privately owned poplar plantations, specifically for hybrid poplars. The most effect time for fertilization in plantations is before canopy closure, when the trees require all forms of nutrients but receive few nutrients from leaf litterfall (Miller, 1981). Soil nutrient losses (especially of N) after clear cutting can be very high, particularly in areas where there is a high rate of decomposition (Heal *et al.*, 1982). Hence, fertilization of newly planted trees before full canopy closure can be particularly significant in increasing future tree yields.

Many studies throughout the world have demonstrated that fertilization of young trees increases the performance of fast-growing hardwood species. Chang (2003) found that fertilization of sweetgum (*Liquidambar styraciflua*) increased diameter growth and that simultaneous use of N and P is more effective in promoting growth. A study in a cutover pine site showed that N fertilization twice per year increased tree diameter and height growth in the early years (Scott *et al.*, 2004). Fertilization (N, P, Ca and Mg) at planting was found to be very effective in promoting height and volume growth of aspen (*Populus tremuloides*), depending on fertilizer type, dose, and study site (Van den Driessche *et al.*, 2005). N and P fertilization applied separately or together, significantly increased stem growth of hybrid poplars throughout four growing seasons when applied shortly after planting (Brown and Van den Driessche, 2005). P application at the time of planting significantly increased height and basal stem diameter of koa (*Acacia koa*) trees obtained from a local seed source (Scowcroft and Silva, 2005). In black walnut (*Juglans nigra*), white ash (*Fraxinus americana*), and tulip tree (*Liriodendron tulipifera*), NPK fertilization at planting promoted diameter and height growth at the end of the first 2 years, but did not affect survival (Jacobs *et al.*, 2005). Graciano *et al.* (2006) found that N and P fertilization promoted growth of young *Eucalyptus grandis*. Fertilization (N and NPK) at planting significantly increased birch (*Betula pubescens*) growth over 6 years, and growth was dependent on the amount of fertilizer provided (Oskarsson *et al.*, 2006). However, there is no study on the effect of fertilization on NLA.

In Turkey, to regenerate NLA stands in bottomland areas, the preferred method is clear-cutting and replanting. Survival and early growth are often poor in NLA plantations because of the small tree size and low-grade seedlings used (planting stock), the low-planting density (delayed onset of crown closure), lack of post-planting treatments (maintenance), and high competition from herbaceous plants (Cicek *et al.*, 2007a). In these sites, high competition from weeds is observed during the early years after planting because of the site conditions. The weedy vegetation can grow up to 1.5-2.0 m height in a few months once it starts growing (Cicek *et al.*, 2007b). Fertilization of tree seedlings at or shortly after planting can increase tree growth and reduce the cost of cultural treatments in sites containing excess and vigorous weedy vegetation.

Information on the response of NLA to fertilization is required to establish post-planting silvicultural techniques in plantations. The objective of this study was to assess the effects of fertilization with N or NPK on the early field performance of NLA plantations.

Materials and Methods

Study site, climate and site preparation: The study was conducted in a bottomland hardwood area in Akyazi-Adapazari, Turkey (40°48' N, 30°33' E, 25 m asl). The area has alluvial soils with a smooth and homogeneous soil structure. The mature natural stand on the site was dominated by NLA, with scattered trees of *Ulmus laevis*, *U. minor*, *Quercus robur*, *Q. hartwissiana*, *Acer campestre* and *Populus alba*. Adapazari Meteorological Station (40° 47' N, 30° 25' E, 30 m asl) 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 during April to October. The mean annual temperature is 14.3°C, and the mean temperature during the growing season (April–October) is 18.8°C. Compared to the last 32-year mean rainfall during the growing season (420 mm), rainfall during the 2005 growing season was higher (474 mm), but was lower in 2006 (268 mm) and 2007 (295 mm). Annual rainfall in 2006 (651 mm) and 2007 (679 mm) was also lower than the last 32-year mean (846 mm). Compared to the mean air temperature over 32 years, the mean annual and mean growing season values during 2005, 2006, and 2007 were higher. Furthermore, mean relative humidity during the growing season of the study years, especially in summer, was lower compared to the 32-year mean value.

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 NLA and other fast-growing tree species plantations in Turkey.

Soil analysis: Although some general soil features (e.g., texture, pH, organic matter) of NLA forests in bottomland are known (Tufekcioglu *et al.*, 2005; Cicek *et al.*, 2006a, 2007c), information regarding macro- and micronutrients of these soils is very limited. To determine the various physical and chemical soil properties of the study site, three representative soil pits were dug, and soil samples were taken from 0–30, 31–60, and 61–100 cm depths before clear cutting. These samples were air-dried, sieved through a 2-mm screen, and analyzed. Sand, silt and clay ratios of the samples were determined by the Bouyoucos hydrometer method. The organic carbon content was analysed using the Walkey and Black wet digestion method. Soil pH was measured with a glass electrode (1.0:2.5 soil/water), electrical conductivity (soluble salts) was measured in a 1.0:2.5 soil/water mixture, and exchangeable K, Na, Ca, Mg, Mn, and Zn were determined by atomic absorption spectrophotometry on 1 mol l^{-1} ammonium acetate extracts. Soil phosphorus (P_2O_5) was extracted by the Olsen method (sodium bicarbonate), which is recommended for calcareous soils and $CaCO_3$ was determined with the Scheibler Kalsimeter method. Total N was determined using a Leco FP-328 elemental N analyzer (Leco Corporation, St. Joseph, Michigan, USA). All soil analyses were done by the Eastern Black Sea Soil Testing Laboratory of the Turkish Forest Service.

Seedling material: The 1-year-old bare-root seedlings used in this study were not purchased from a local nursery because their seedlings were only 20–40 cm tall and were of low quality (Cicek *et al.*, 2007a). Instead, seeds for this study were collected from the NLA-dominated stands at Hendek (40°52' N, 30°36' E, 25 m) in the fall of 2003 and were sown in spring 2004. In order to break seed 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. One-year-old bare-root seedlings were grown in a seedbed at about of 80 seedlings m^{-2} at the Hendek Forest Nursery (40°48' N, 30°43' E, 60 m) in the growing season of 2004. Undercutting was done in the nursery before lifting by forcing a tractor-driven blade through the seedbed 25 cm below the soil surface. When lifted, the seedlings were then graded for uniformity of height (70 ± 5 cm) and to ensure that shoot and root systems were well developed and structurally sound. Mean root collar diameter of the seedlings was 10–11 mm. Hand-lifted seedlings were root pruned prior to planting in mid-December 2004. Based on the Turkish Standards Institute (TSI) standards, all seedlings fell into the category of first class seedling grade (TSI, 1988).

The seedlings were hand planted at a spacing of 2.5 x 1.6 m (equal to 2500 trees ha^{-1}) in mid-December 2004. In total, 3,000 seedlings were planted in a 1.2 ha area. To control weedy vegetation, the study plots were treated by both hand hoeing a 70 cm radius circle of soil around the seedlings and disking between rows (double passing) in early June 2005 and 2006 and only hand hoeing in June 2007.

Experimental design and treatments: A randomized complete block design with four replications was established to examine fertilization effects. Each experimental unit (plot) contained four rows with 30 trees in each row. The row in the middle of the plot was used for measurements and the other rows acted as a buffer. Fast-release granular N-urea (46%, $(NH_2)_2CO$, NH_2-N] and NPK (15/15/15%; NH_3-N, P_2O_5, K_2O) fertilizers were applied at the following rates: 0 g, 67 g NPK, 133 g NPK, 33 g urea, and 54 g urea tree^{-1}, which provided 0 g, 10 g N/P/K, 20 g N/P/K, 15 g N-urea, 25 g N-urea tree^{-1}, respectively (Table 1). These fertilizers are commonly used in agricultural lands around the study site. Fertilizer rates were converted on a volume basis from laboratory trials to facilitate application. Thus, for each seedling, the appropriate fertilizer rate was measured by volume and manually applied to the soil surface around the seedlings (~1 m^2) in mid-May 2005.

Measurements and statistical analysis: Basal diameters (± 0.1 mm) and heights (± 1.0 cm) of the seedlings were determined after planting in December 2004. Basal diameter (2.5 cm above ground) was measured instead of root collar diameter because of the muddy (mesic) site conditions. Survival, diameter, and height were recorded in December in the years following planting.

No statistical analysis was used to examine the treatment effects on seedling survival since survival percentages were more than 98% in all treatments after three growing seasons. Analyses of variance (ANOVA) were used to evaluate the effects of fertilization on diameter and height growth. The variables analyzed were the mean plot values of the trees. Growth increments at the end of each year were the difference between the initial and the following year (first, second, and third) tree sizes. We also evaluated the growth increments in the second and third growing seasons. The normal distribution of variables was controlled before ANOVA. If analyses of variance indicated significant differences ($p<0.05$), the treatment means were separated by Duncan's New Multiple Range test ($p<0.05$).

Results and Discussion

Soil analysis: The soils on the site were deep and not well drained, and the Ah horizon was very thin to absent due to rapid decomposition. Soil analyses showed that the study site had heavy textured (clay content >70%) and slightly to moderately alkaline soils. The soils had excess P and Mn; high K, Ca, and Mg; low soluble salts; and very low total N and Zn availability/supply. The percentage of organic matter decreased with depth, while pH increased with depth (Table 2).

Considering the amount of nutrients in most forest soils (Cepel, 1995), it would appear that, apart from N and Zn, the soil in the study site is adequate to rich (Table 2). Soils from hillsides near the bottomland in the study region have a medium Zn content (Cicek *et al.*, 2006a). The low N content of the soil in the study site may be the result of rapid decomposition of leaf litter and favorable climatic conditions for decomposition in most of year. Corona *et al.* (2006) found that litter of NLA degraded very rapidly. On the other hand, soil N is generally determined at the beginning of the growing season (Smethurst, 2000). In this study, soil samples were taken in early fall, which might account for the very low level of N reported here. Mislevy *et al.* (1989) reported that clay soils are rich in plant nutrients, particularly P and K, but are deficient in N. Ash species, like most hardwood species, grows well in deep, well drained, and fertile soils with a high moisture content and pH 6–7 (Evans 1984, Kerr and Evans, 1993; Kerr, 1995; Kerr and Cahalan, 2004; Fraxigen, 2005). The soil in the study site was heavy, with a pH of 7.52–7.88. This demonstrates that NLA can tolerate clay soils and higher soil pH, although it grows better in more open soils with a lower pH.

Survival and growth: Tree survival was near perfect for all treatments, with 98% survival after three growing seasons. It is likely that, in addition to weed control, the larger size and higher quality of the seedlings also influenced the results. In conventional NLA planting 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). Increased survival in other studies on NLA that have similar growth conditions to the study site is related directly to the use of high quality and larger-size planting stock (Cicek *et al.*, 2006a,b, 2007a,c). Hence, the use of high quality and larger seedling material (even without fertilization) may reduce the need for replanting and thus reduce the cost of plantation establishment.

ANOVAs showed that the initial diameter and height of the seedlings did not differ among the treatments ($p > 0.05$), and that fertilization in the first growing season significantly affected the diameter and height growth of NLA during the first 3 years ($p < 0.001$; Table 3). However, differences among the treatments according to the fertilizer used were not significant.

At planting, the mean basal diameter and height were 8.4 mm and 70 cm, respectively. Fertilization in the first growing season had a large and positive effect on diameter and height increments throughout the first 3 years of growth. Compared to the control (no fertilizer), fertilization accelerated the diameter and height increments, respectively, by 54 and 52% in the first year, 37 and 39% in the second year and 32 and 34% in the third year. At the same time, total diameter and height of the fertilized plots at the end of each year was approximately 24-26% higher than those of the control treatment (Table 4). Height increments in the control were 33 cm in the first, 47 cm in the second and 49 cm in the third growing season, while in the fertilized plots the values for the three seasons were 69, 62 and 64 cm, respectively. Accordingly, compared to the control, fertilization led to a 52% increase in height in the first growing season, but the height increases in the second and third growing seasons were lower (24-23%). Diameter increments also followed a similar trend

Table - 1: Treatments in terms of fertilizer type and dose

Fertilizer	Treatments as total fertilizer dose		Treatments as pure fertilizer dose	
	(g tree^{-1})	(kg ha^{-1})	(g tree^{-1})	(kg ha^{-1})
Control	-	-	-	-
NPK (15/15/15%)	67	167.5	10/10/10*	25/25/25
NPK (15/15/15%)	133	332.5	20/20/20**	50/50/50
N Urea (46%)	33	82.5	15	37.5
N Urea (46%)	54	135	25	62.5

*: 10 g N + 10 g P_2O_5 (4.4 g P) + 10 g K_2O (8.3 g K), **: 20 g N + 20 g P_2O_5 (8.8 g P) + 20 g K_2O (16.6 g K)

Table - 2: Physical and chemical soil properties of the study site (average for three soil samples at each depth); OM: organic matter

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OM (%)	pH	Total $CaCO_3$ (%)	Soluble salts (mmhos cm^{-1})	Total N (%)	P_2O_5 (ppm)	K (meq 100 g^{-1})	Ca (meq 100 g^{-1})	Mg (meq 100 g^{-1})	Mn (ppm)	Zn (ppm)
0–30	10.34	17.92	71.74	2.61	7.52	15.4	0.152	0.052	74.7	0.95	16.6	2.53	29.1	0.000
31–60	8.45	19.34	72.20	2.51	7.62	16.3	0.139	0.035	60.4	0.76	16.3	2.52	48.0	0.000
>61	6.57	22.87	70.55	1.13	7.88	14.4	0.128	0.001	41.1	0.64	16.3	2.61	49.7	0.000

Table - 3: Summary of ANOVAs (*F* and *P* values) for the effect of fertilization on growth variables

Year	Diameter increment		Total diameter		Height increment		Total height	
	F	P	F	P	F	P	F	P
0	-	-	0.728	0.590	-	-	17.624	2.921
1	17.081	<0.001	17.519	<0.001	42.205	<0.001	39.702	<0.001
2	48.229	<0.001	47.960	<0.001	64.678	<0.001	135.074	<0.001
3	26.052	<0.001	25.437	<0.001	40.353	<0.001	62.662	<0.001

Table - 4: Mean growth values of NLA in response to fertilization during the first 3 years of growth

Year	Treatment	Diameter increment (mm)	Total diameter(mm)	Height increment (cm)	Total height (cm)
1	Control	3.6 b[1]	**12.0 b**	33 b	**103 b**
	67 g NPK	8.0 a	**16.3 a**	64 a	**137 a**
	133 g NPK	6.9 a	**15.5 a**	68 a	**136 a**
	33 g N urea	8.5 a	**17.0 a**	72 a	**143 a**
	54 g N urea	8.2 a	**16.3 a**	73 a	**142 a**
2	Control	10.3 a	**18.7 b**	80 b	**150 b**
	67 g NPK	16.2 a	**24.5 a**	127 a	**200 a**
	133 g NPK	15.7 a	**24.3 a**	133 a	**201 a**
	33 g N urea	16.9 a	**25.3 a**	134 a	**204 a**
	54 g N urea	16.8 a	**24.9 a**	130 a	**199 a**
3	Control	17.0 b	**25.4 b**	129 b	**199 b**
	67 g NPK	25.4 a	**33.7 a**	190 a	**263 a**
	133 g NPK	24.7 a	**33.0 a**	197 a	**265 a**
	33 g N urea	25.1 a	**34.1 a**	199 a	**270 a**
	54 g N urea	25.4 a	**33.3 a**	193 a	**262 a**

[1] means within each year and column followed the same letter are not significantly different ($p<0.05$)

(Table 4); thus, the effect of fertilization was similar for diameter and height increments. The control took 3 years to reach the diameter and height values attained in 2 years after fertilization. The last 2 years in which this study was conducted were drier and hotter than average thus, under normal (average) circumstances, the growth of seedlings would be even higher.

Nitrogen was the primary limiting macronutrient in the study site (Table 2), and N fertilization in the first growing season was very effective in promoting growth of NLA (Table 4). Smethurst (2000) stated that fertilizing soils that have concentrations of nutrients lower than the critical concentration is likely to result in a significant increase in yield. Studies on green ash (*F. pennsylvanica*) and common ash (*F. excelsior*) also showed that N fertilization promoted growth in the early years (Remphrey and Davidson, 1996; Zoralioglu and Uludag, 1998). These results confirm that N-rich soils are especially desirable for growth of ash species (Kerr, 1995; Kerr and Cahalan, 2004). Since, in our study, no differences were found between N and NPK fertilization treatments in terms of growth at the end of each year, it appears that P and K fertilization had no effect on NLA tree growth (Table 4). Soil analyses showed that the soil had sufficient P and K (Table 2). In terms of growth, no differences among N doses were found, and the main effect of fertilization on growth was seen in the first growing season. This suggests that much of the added N may have been lost through leaching. A study on early growth of American sycamore (*Platanus occidentalis*) found similar biomass accumulation with 150 and 450 kg ha^{-1} N-urea fertilization; however, N loss was high after 450 kg ha^{-1} N fertilization but was negligible after 150 kg ha^{-1} N fertilization (Tschaplinski *et al.*, 1991). In another study on the same species, 450 kg ha^{-1} N-urea fertilizer was applied at different combinations during the first 3 years of growth. At the end of 3 years, a single 450 kg ha^{-1} dose shortly after planting had a short-term effect on growth, and excess NO_3 leached out in the first year. The authors suggested that instead of giving fertilizers only in the first year, it would be better to give smaller amounts of fertilizer in each of the 3 years (Van Miegroet *et al.*, 1994). Thus, for the first growing season, low-dose N fertilization (10 g N $tree^{-1}$) can be recommended, followed by further low N application in the following years. Further studies should be conducted on N fertilization of tree species. According to soil analysis of the study site, there is a deficiency of Zn, and it may be appropriate to add Zn in addition to N fertilization in this area.

In our study site, provided that high-quality, large seedlings are used and fertilizer is added, a 3-year weed control or post-planting treatment is sufficient. Although the last 2 years were drier and hotter than the average in the study area, seedlings were tall enough to compete with the weedy vegetation at the end of 3 years (Table 4). In conventional planting, low-quality and small seedlings are commonly used, leading to the need to replant (at least 20-30%), and such seedlings take at least 5 to 6 years to reach a height that allows them to compete with weedy vegetation (Cicek *et al.*, 2007a). This practice greatly increases the cost of stand establishment. Furthermore, in Turkish forestry, weed control is basically performed by hand and herbicides are not used, further increasing the cost of weed control or post-planting treatment. Thus, using larger and higher quality seedlings, together with N fertilization in the first growing season, can decrease the cost of plantation establishment of NLA on bottomland sites.

The soil in the bottomland NLA site lacked or was deficient in N and Zn. Compared to the control (no added fertilizer), N fertilization in the first growing season significantly promoted tree growth over 3 years, but addition of P and K had no further effect on growth. There was no significant difference in growth with different doses of N (10, 15, 20, and 25 g per seedling). Hence, for the first growing season, 10 g N per seedling is sufficient.

In conclusion, as for the effects of fertilization in the first growing season with N or NPK, it can be stated that N itself has positive effects, with insignificant respect with dose, on growth in later years. Although P and K did not appear to affect further growth, adding Zn in fertilizer with N could be considered in the following growing seasons. Nevertheless, further studies are needed to achieve optimum fertilization of this species.

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References

Brown, K.R. and R. Van den Driessche: Effects of nitrogen and phosphorus fertilization on the growth and nutrition of hybrid poplars on Vancouver Island. *New For.*, **29**, 89-104 (2005).

Chang, C.X.: Seedling sweetgum (*Liquidambar styraciflua* L.) half-sib family response to N and P fertilization: Growth, leaf area, net photosynthesis and nutrient uptake. *For. Ecol. Manage.*, **173**, 281-291 (2003).

Cepel, N.: Forest ecology. Istanbul University Press, Istanbul (1995).

Cicek, E., F. Yilmaz, F. Tilki, M. Yilmaz and B. Cetin: The effects of site, provenance and seedling size on the early growth of narrow-leaved ash (*Fraxinus angustifolia* Vahl.) plantings. *J. Balkan Ecol.*, **9**, 297-304 (2006a).

Cicek, E., F. Tilki and N. Cicek: Field performance of narrow-leaved ash (*Fraxinus angustifolia* Vahl.) rooted cuttings and seedlings. *J. Biol. Sci.*, **6**, 750-753 (2006b).

Cicek, E., N. Cicek and N. Bilir: Effects of seedbed density on one-year-old *Fraxinus angustifolia* seedling characteristics and outplanting performance. *New For.*, **33**, 81-91 (2007a).

Cicek, E., F. Yilmaz, M. Yilmaz and S. Yilmaz: Determining the weedy vegetation in terms of post-planting treatment in narrow-leaved ash (*Fraxinus angustifolia* Vahl.) clear-cutting area. *Orman Muh. Derg.*, **44**, 25-28 (2007b).

Cicek, E., F. Tilki, S. Kulac, M. Yilmaz and F. Yilmaz: Survival and growth of three hardwood species (*Fraxinus angustifolia, Ulmus laevis* and *U. minor*) on a bottomland site with heavy clay soil. *J. Plant Sci.*, **2**, 233-237 (2007c).

Corona, M.E.P., M.C.P. Hernandez and F.B. De Castro: Decomposition of alder, ash, and poplar litter in a Mediterranean riverine area. *Comm. Soil Sci. Plant Anal.*, **37**, 1111-1125 (2006).

Evans, J.: Silviculture of Broadleaved Woodland. For. Com. Bull. 62, HMSO, London (1984).

Fraxigen: Ash species in Europe: Biological characteristics and practical guidelines for sustainable use. A summary of findings from the FRAXIGEN project, EU project EVK-CT-00108. Oxford Forestry Institute, University of Oxford, UK (2005).

Graciano, C., J.F. Goya, J.L. Frangi and J.J. Guiamet: Fertilization with phosphorus increases soil nitrogen absorption in young plants of *Eucalyptus grandis*. *For. Ecol. Manage.*, **236**, 202-210 (2006).

Heal, O.W., M.J. Swift and J.M. Anderson: Nitrogen cycling in United Kingdom forests: the relevance and basic ecological research. *Phil. Trans. Roy. Soc. Ser. B*, **296**, 427-444 (1982).

Jacobs, D.F., K.F. Salifu and J.R. Seifert: Growth and nutritional response of hardwood seedlings to controlled-release fertilization at outplanting. *For. Ecol. Manage.*, **214**, 28-39 (2005).

Kapucu, F., H. Yavuz and A.U. Gul: Stem Volume, Site Index and Yield Table in *Fraxinus* Stands. Black Sea Technical University Research Project No: 96.113.001.4, Trabzon (1999).

Kerr, G. and J. Evans: Growing Broadleaves for Timber. Forestry Commission Handbook 9, HMSO, London (1993).

Kerr, G.: Silviculture of ash in southern England. *Forestry*, **68**, 63-71 (1995).

Kerr, G. and C. Cahalan: A review of site factors affecting the early growth of ash (*Fraxinus excelsior* L.). *For. Ecol. Manage.*, **188**, 225-234 (2004).

Krinard, R.M. and H.E. Kennedy: Five-year-old cottonwood plantation on a clay site: growth, yield, and soil properties. *Southern J. App. For.*, **4**, 80-83 (1980).

Mayer, H. and H. Aksoy: Turkish forests. Gustav Fischer Verlag, Stuttgart (1986).

Miller, H.G.: Forest fertilization: some guiding concepts. *Forestry*, **54**, 157-167 (1981).

Mislevy, P., W.G. Blue and C.E. Roessler: Productivity of clay tailings from phosphate mining. I. Biomass crops. *J. Environ. Qual.*, **18**, 95-100 (1989).

Oskarsson, H., A. Sigurgeirsson and K.R. Rasmussen: Survival, growth, and nutrition of tree seedlings fertilized at planting on Andisol soils in Iceland: Six-year results. *For. Ecol. Manage.*, **229**, 88-97 (2006).

Pliura, A.: *Fraxinus* spp. conservation strategy. *In*: Noble hardwood network (*Eds.*: J. Turok, J. Jensen, C. Palmberg-Lerche, M. Rusanen, K. Rusell, S. deVries and E. Lipman). Report of the 3rd meeting, 13-16 June 1999, Sagadi, Estonia. IPGRI, Rome. pp. 8-20 (1999).

Remphrey, W.R. and C.G. Davidson: The effect of nitrogen on growth and architecture of *Fraxinus pennsylvanica* 'Patmore' (green ash) in field-grown containers at two sites in Manitoba, Canada. *Can. J. Plant Sci.*, **76**, 825-833 (1996).

Scott, A.D., J.A. Burger, D.J. Kaczmarek and M.B. Kane: Growth and nutrition response of young sweetgum plantations to repeated nitrogen fertilization on two site types. *Biomass Bioenergy*, **27**, 313-325 (2004).

Scowcroft, P.G. and J.A. Silva: Effects of phosphorus fertilization, seed source and soil type on growth of *Acacia koa*. *J. Plant Nut.*, **28**, 1581-1603 (2005).

Smethurst, P.J.: Soil solution and other soil analyses as indicators of nutrient supply: A review. *For. Ecol. Manage.*, **138**, 397-411 (2000).

Tschaplinski, T.J., D.W. Johnson, R.J. Norby and D.E. Todd: Biomass and soil nitrogen relationships of a one-year-old sycamore plantation. *Soil Sci. Soc. Am. J.*, **55**, 841-847 (1991).

TSI: Seedling Quality Classes of the Turkish Standard Institute for Broadleaf Forest tree Seedlings. TS 5624 (1988).

Tufekcioglu, A., L. Altun, Z. Kalay and M. Yilmaz: Effects of soil properties on the growth of hybrid poplar in the Terme-Golardi region of Turkey. *Turk. J. Agric. For.*, **29**, 221-226 (2005).

Van den Driessche, R., F. Niemi and L. Charleson: Fourth year response of aspen seedlings to lime, nitrogen and phosphorus applied at planting and 1 year after planting. *For. Ecol. Manage.*, **219**, 216-228 (2005).

Van Miegroet, H., R.J. Norby and T.J. Tschaplinski: Nitrogen fertilization strategies in a short-rotation sycamore plantation. *For. Ecol. Manage.*, **64**, 13-24 (1994).

Zoralioglu, T. and T. Uludag: Techniques for increasing the productivity by using irrigation and fertilization in ash (*Fraxinus excelsior* L.) plantations. Poplar and Fast Growing Forest Trees Res. Ins., Tech. Bull. No. 188, Izmit (1998).