Turk J Agric For
29 (2005) 483-491

Fifth Year Performance of Morphologically Graded *Cedrus libani* Seedlings in the Central Anatolia Region of Turkey*

Akkın SEMERCİ
Central Anatolia Forestry Research Institute, P.K. 24, 06501 Bahçelievler, Ankara - TURKEY

Received: 09.02.2004

Abstract: The effects of morphological characteristics on seedling performance were studied in *Cedrus libani* seedlings at 3 locations in the Central Anatolia region of Turkey. Some 2+0 seedlings were morphologically graded according to height and root collar diameter sizes. The seedlings were divided into 5 height categories and each height category was divided into small and large root collar diameter subcategories. The morphologically graded seedlings were planted at 3 locations. After 5 growing seasons, the mean survival of the seedlings planted in Ankara, Eskişehir and Konya locations was 84.4%, 77.9% and 54.7%, respectively. The mean height of seedlings planted in Ankara, Eskişehir and Konya was 78.5, 51.8 and 48.7 cm, respectively. Survival and height growth of graded seedlings showed significant differences among the locations, which might be a reflection of differences in climatic and physiographic conditions among the locations. The initial height and root collar diameter of seedlings had no effect on survival. Only root collar diameter had a significant effect on height growth. Initial height differences among different sized stocks were still significant after 5 years, but had not expanded. Our results suggest that initial seedling morphology is not a good predictor of field survival but root collar diameter is a good indicator of the growth potential of *C. libani* seedlings after planting. This study indicated that the physiological characteristics of seedlings have a strong influence on seedling survival potential.

Key Words: *Cedrus libani*, Seedling quality, Morphological characteristic, Seedling performance

Morfolojik Olarak Sınıflanmış Toros Sediri (*Cedrus libani*) Fidanlarının İç Anadolu Bölgesindeki Beşinci Yıl Performansı

Özet: Bu çalışmada İç Anadolu Bölgesinde 3 yerde yapılan denemelerle, *Cedrus libani* fidanlarına ait morfolojik özelliklerin dikim sonrası performansa olan etkisi araştırılmıştır. 2+0 yaşlı fidanlar boy ve kök boğazı değerleri kullanılarak sınıflanmıştır. Fidanlar 5 boy sınıfına ve her boy sınıfı da kalın ve ince kök boğazı çapında olanlar şeklinde 2 alt sınıfa ayrılmıştır. Morfolojik olarak sınıflanan fidanlar 3 deneme alanına dikilmiştir. Ankara, Eskişehir ve Konya alanlarına dikilen fidanların 5 vejetasyon mevsimi sonra yaşama yüzdeleri sırasıyla % 84.4, 77.9 ve 54.7 olmuştur. Ankara, Eskişehir ve Konya alanlarına dikilen fidanların ortalama boyları sırasıyla 78.5, 51.8 ve 48.7 cm olmuştur. Yaşama yüzdesi ve boy bakımından deneme alanları arasında beşinci yıl sonunda görülen farkların nedeni deneme alanları arasındaki klimatik ve fizyografik farklar olabileceği sanılmaktadır. Fidanların dikim anındaki boy ve kök boğazı çapı büyüklüklerinin fidanların yaşama yüzdeleri üzerinde etkisi yoktur. Fidanların boy büyümeleri üzerinde yalnızca fidan kök boğazı çapının etkisinin olduğu belirlenmiştir. Dikilecek fidanlar arasında başlangıçta var olan boy farkı dikimden 5 yıl sonra da korunmuştur, fakat artmamıştır. Bu çalışma, *C. libani* türünde dikimde kullanılan fidanların morfolojisinin, arazideki tutma başarısının önceden tahmini için iyi bir gösterge olmadığı, ancak dikim sonrası büyüme potansiyelinin belirlenmesinde kök boğazı çapının iyi bir gösterge olduğunu göstermiştir. Bu çalışma ayrıca, fidanların yaşama potansiyelleri üzerinde fizyolojik karakteristiklerin önemli bir etkisinin olduğunu ortaya koymuştur..

Anahtar Sözcükler: Toros sediri, Fidan kalitesi, Morfolojik karakteristik, Fidan performansı

Introduction

The Taurus cedar, *Cedrus libani* A.Rich., occurs in the Jebel Alaonite Mountains in Syria, and Lebanon and Anti-Lebanon, where it is now very rare (about 2000-3000 ha of forests of this species), but it is plentiful in the Taurus Mountains in Turkey (Vidakovic, 1991). In general, humid (oro-Mediterranean), semi-humid-semi-boreal (leeward region of Mediterranean (Taurus) Mountains-Zonoecotone), or boreal semi-dry (inner or Central Asia Minor) climatic conditions prevail where it grows (Atalay, 1987; Boydak, 1996). Boydak (2003) after Quézel (1979, 2000) stated that it occurs in supra-

*Data were derived from the experimental parts of a PhD thesis prepared at Karadeniz Teknik University Faculty of Forestry in 2001.
Correspondence to: aksemerci@yahoo.com

Mediterranean, mountain-Mediterranean and oro-Mediterranean zones on the Taurus Mountains facing seawards, where per humid, humid, sub-humid and semi-arid climatic conditions prevail. Prolonged summer drought is its habitat, but it can withstand frost damage at about –20 °C in an arboretum in Massachusetts (Goor and Barney, 1976), outside of its natural distribution (Akgül and Yılmaz, 1987) and at about –35 °C in its natural distribution in Turkey (Atalay, 1987, 1990). The total natural forest area of *C. libani* is 99,325 ha in Turkey (OGM, 1980). It also has very good adaptability and can have a high survival rate when planted on suitable sites outside of its natural ranges or distribution (Boydak et al., 1990; Boydak, 1996). According to Yahyaoğlu and Genç (1990), this species is used widely in the Mediterranean region because of its resistance to high temperature, drought and frost. Şimşek et al. (1996) reported that in experimental areas of Tokat, Kütahya, Eskişehir and Ankara, *C. libani* showed great success and in fact it competed well against broad-leaved tree species used in their study. They suggested that this species must be taken into consideration when planting in the semi-arid Central Anatolia region. For those reasons, the Turkish Forest Service has planted a total of 110,487 ha of *C. libani* (Konukçu, 2001).

Seedlings are exposed to a wide range of environmental stress conditions in planting sites. These conditions could reduce the performance (survival and growth) of newly planted seedlings. Planting success depends largely upon the physiological and morphological preparedness of seedlings to survive and grow after planting (Duryea and McClain, 1984). This preparedness has been collectively termed "seedling quality".

Successful tree establishment by reforestation or afforestation requires good quality seedlings. Good quality seedlings are better able to withstand transplanting shock and difficult conditions in planting sites. Good quality seedlings provide an increased survival rate, grow fast and reduce costs of planting and maintenance. Using poor quality seedlings may reduce survival and early growth rates (Şimşek, 1987; Edwards, 1998).

Numerous morphological and physiological characteristics regarding seedling quality evaluation have been reported in the literature (Chavasse, 1980; Jaramillo, 1980; Sutton, 1980; Ritchie, 1984; Munson, 1985; Yahyaoğlu, 1986; Puttonen, 1989; Boydak and Dirik, 1990; Dirik, 1991; Genç 1992; Mattsson, 1997; Edwards, 1998; Sarvas, 2001). These physiological attributes include carbohydrate reserves of seedlings, chlorophyll contents of needles, cold hardiness, cold or frost injury, detection of dead plant tissues, dormancy, gas exchange, mineral nutrients, mitotic index, plant growth substances, plant water status, root growth potential and stress resistance (Puttonen, 1989). Morphological characteristics are physically or visually determinable attributes of seedlings. Morphological characteristics have been used widely and traditionally to assess seedling quality. The major morphological attributes are height, root collar diameter, bud length, shoot:root ratio, shoot weight and root weight. Morphological characteristics, specifically height and root collar diameter, currently provide the best estimate of seedling performance after outplanting (Mexal and Landis, 1990). Seedling height and root collar diameter generally have large and positive correlations with the other parts of seedlings. These correlations also have been indicated in *C. libani* species (Bilir, 1997; Demirci and Bilir, 2000; Semerci, 2001; Bilir, 2002). These 2 parameters are universally accepted measures of performance potential (Mexal and Landis, 1990).

In general, the correlation between initial height and survival is often contradictory and tree planters prefer shorter seedlings for arid sites, and taller seedlings for places where vegetative competition or animal damage is severe. Seedling root collar diameter is generally regarded as a better measure of survival and growth than seedling height (Munson, 1985; Mexal and Landis, 1990). In general, height is not highly correlated with survival, but is a good predictor of growth following outplanting (Munson, 1985; Mexal and Landis, 1990; Savil et al., 1997).

There are many large successful plantations of *C. libani* in Eastern and Central Anatolia (Akgül and Yılmaz, 1987; Boydak et al., 1990; Boydak, 1996). This species is still being planted in Central Anatolia, where semi-arid and arid environmental conditions are dominant. In arid and semi-arid areas where humidity is low and transpiration is high, seedlings are subject to great water loss, which causes physiological weakness and mortality after planting. Tree planters must use proper planting tools and techniques and high quality seedlings to increase the rate of survival and reduce the cost of planting in these areas. Grading for height and root collar diameter

is a practice for separating poor quality seedlings. Seedling heights are typically listed as ranges between some minimum and maximum, whereas root collar diameter is usually a minimum standard (Mexal and Landis, 1990).

The data evaluated in this paper were derived from the experimental parts of a PhD thesis prepared at Karadeniz Teknik University Faculty of Forestry in 2001. However only first-year survival rates and third-year heights of seedlings were evaluated in this thesis. This paper contains fifth-year results and shows considerable differences from the PhD thesis.

The objectives of this study were to determine the effects of initial root collar diameter, seedling height (morphological quality characteristics of seedlings) and planting location on survival and height growth of 2+0 *C. libani* bare-root seedlings at the end of 5 years in the Central Anatolia region.

Materials and Methods

Seedling Materials

2+0 Taurus cedar seedlings were used in this study. The seedlings were produced in Eskişehir forest nursery from seeds collected from Belceğiz, Isparta.

Grading Method

Five hundred seedlings were systematically sampled from the nursery bed in December 1996. Their heights and root collar diameters were measured with a 0.1 cm and 0.1 mm accuracy, respectively. The frequency distribution of the seedlings according to seedling height and root collar diameter was obtained to divide them into categories. For this purpose, the 95% confidence interval of height measurements was calculated using the formula $\overline{X} \pm 2S$, in which $\overline{X}$ and S refer to the mean and standard deviation of height values, respectively (Düzgüneş 1963; Bryant 1966; Kalıpsız, 1988). The range between the upper and lower confidence limits was divided into 5 height categories with 5 cm intervals. In addition, each height category was divided into small and large subcategories according to root collar diameter (Table 1) using the median value of each height category in the regression line showing the relationship between height and root collar diameter.

Experimental Design and Statistical Analysis

The experimental design was a randomized block design with 10 seedling categories and 3 planting sites arranged in 3 replications (blocks) per site. Seedlings were planted with spacing of 3.0 m between the rows and 1.5 m in the rows. Twenty-five seedlings per replication were used for recording survival (%) and seedling height (cm). In total, 2250 seedlings were measured.

Seedlings in each category were planted on March 12th 1997 at 3 locations (Ankara, Eskişehir and Konya) in Central Anatolia. Some physiographic and soil properties and meteorological data of the locations are given in Table 2.

Analysis of variance was performed to determine significant differences in height growth and survival of seedlings among the 3 planting sites at the end of 5 growing seasons. The Student Newman Keuls test was used in the mean separation of groups ($P < 0.05$). Survival percentages per site were transformed to arcsine square roots before analysis.

Table 1. Heights and root collar diameters of seedling categories.

Seedling Height Categories	Heights (cm)	Root Collar Diameter Categories (mm)	
		Large	Small
1	32.4-27.5	7.1-6.1	6.0-5.1
2	27.4-22.5	6.3-5.3	5.2-4.3
3	22.4-17.5	5.5-4.5	4.4-3.5
4	17.4-12.5	4.8-3.8	3.7-2.8
5	12.4-7.5	3.9-3.0	2.9-2.0

Table 2. Some physiographic attributes and meteorological data of seed source and planting locations.

Physiographic attributes and meteorological data	Seed source and planting locations			
	Isparta	Ankara	Eskişehir	Konya
Elevation (m)	1610	1450	1100	1450
Aspect	North	North	South	Southeast
Slope (%)	-	20	10	3
Soil Texture				
0-30 cm depth	-	Clay loam	Silt loam	Clay
30-60 cm depth	-	Clay loam	Silt loam	Clay
60-90 cm depth	-	Sandy clay loam	Silt loam	Clay
pH				
0-30 cm depth	-	7.4	7.8	7.8
30-60 cm depth	-	7.4	8.0	8.0
60-90 cm depth	-	7.5	8.0	8.0
Total $CaCO_3$ (%)				
0-30 cm depth	-	0.0	5.3	19.0
30-60 cm depth	-	0.0	9.0	39.3
60-90 cm depth	-	0.0	9.0	66.5
Annual Precipitation (mm)*	598.2 (Semi-arid)	441.9 (Semi-arid)	383.3 (Semi-arid)	292.3 (Arid)
Precipitation for Vegetation Period (mm)	222.9	190.1	178.7	153.1
Mean Annual Temp. (°C)	12.1	11.7	10.8	11.5
Water Deficits of Locations (mm) (Calculated using the Thornthwaite method)	297.0 (For long period)	360.8 (For experiment period)	335.8 (For experiment period)	421.3 (For experiment period)
Precipitation Effectiveness Index** (Calculated using the Erinç method for Vegetation Periods)	20	17	15	11

* In general, regions that receive less than 300 mm of precipitation a year considered arid. Semi-arid regions receive an annual precipitation of over 300 and up to 600 mm (Goor and Barney, 1976).

** Erinç classified that index value <8 means very drought; 8-15 means drought; 15-23 means semi-drought; 23-40 means semi-humid; 40-55 means humid; 55< index value means very humid (Türkeş, 1990).

Results

The F-values of survival and height at the end of 5 growing seasons obtained from field experiments are shown in Table 3.

Analysis of variance revealed that only location (planting site) had a significant effect on survival at $P < 0.001$ level (Table 3). The mean survival of the *C. libani* seedlings planted in Ankara, Eskişehir and Konya was 84.4%, 77.9% and 54.7%, respectively, and the survival of seedlings in Konya was significantly different from the others. The reason why survival rate was the lowest in Konya might be the high water deficit and heavy soil texture at that location (Table 2).

Analysis of variance indicated that planting areas, initial height and root collar diameter categories had significant effects on heights of seedling categories (Table 3). The mean height of seedlings planted in Ankara, Eskişehir and Konya was 78.5, 51.8 and 48.7 cm, respectively. Ankara was significantly different from the other 2 locations. About 28 cm height differences between Ankara and the other locations may be a reflection of better climatic conditions for living seedlings,

Table 3. F-values from ANOVA on main effects and interactions for seedling height and root collar diameter categories on survival and height at the end of 5 years.

Source of variation	Degrees of freedom	F-values for survival of seedling categories[1]	F-values for height of seedling categories
Locations (A)	2	30.69 ***	95.09 ***
Height categories (B)	4	1.05 ns	13.48 ***
Diameter categories (C)	1	0.07 ns	3.95 *
Replicate (D)	2	1.62 ns	5.08 **
Interaction A x B	8	0.68 ns	0.71 ns
Interaction A x C	2	2.75 ns	1.58 ns
Interaction B x C	4	0.87 ns	0.47 ns
Interaction A x B x C	8	0.29 ns	0.56 ns

* Significant at $P < 0.05$ level, ** significant at $P < 0.01$ level, *** significant at $P < 0.001$ level, ns: none-significant.

[1]Survival percentages were transformed to arcsine square roots before analysis.

especially the lower water deficit and north aspect with better soil conditions in Ankara (Table 2).

After 5 growing seasons, mean heights of surviving seedlings ranged from 48.1 to 69.0 cm. According to the Student Newman Keuls multiple comparison of means test, initial height differences between seedling heights categories were still present at the end of 5 years, but had not expanded. Furthermore, on average of 5-seedling height categories seedlings with large root collar diameters were 3.9 cm taller than those with smaller root collar diameters (Table 4).

Discussion

As the seedlings planted at all 3 locations were in the same height and root collar diameter categories at the beginning of the study, the survival differences among locations at the end of 5 years were a reflection of climatic and physiographic differences among the planting areas. The first priority in the planting of *C. libani* should be given to Ankara and Eskişehir instead of Konya, which has arid climatic conditions. Similarly, Bilir (2002) showed the effects of climate and topography on survival in the Black Sea region during his provenance trials study.

Seedling survival was more than 75% in Ankara and Eskişehir, and this rate might be considered high enough for semi-arid areas. This result indicated that *C. libani* was well adapted to the semi-arid ecological conditions of Central Anatolia. Konya was significantly different from the other 2 locations in terms of mean survival. This difference might be mainly due to the higher water deficit and heavy soil texture in Konya. After 5 growing seasons, the mean height of seedlings was highest in Ankara and significantly different from that in the other 2 locations. This height difference might be mainly due to the lower water deficit and more favorable north aspect with better soil moisture conditions and lower solar radiance compared to the other aspects in Ankara. Similarly, Akgül and Yılmaz (1987) showed that growth of *C. libani* trees was affected mainly by annual precipitation and soil characteristics outside its natural distribution areas.

In the present study, initial seedling height and root collar diameter sizes had no effect on survival after 5 growing season in the 3 locations. This result corresponds well with the findings reported by Eler et al. (1993), and Eler and Keskin (2003). They observed that the size of seedlings had no effect on the survival of *C. libani* after 3 and 14 years in a sub-Mediterranean region of Turkey. The present study and previous studies on the Taurus cedar (Eler et al., 1993; Eler and Keskin, 2003) support the ideas that (1) morphological characteristics alone are not a reliable indicator of seedling survival (Van den Driessche, 1976; Sutton 1979; Puttonen, 1997); (2) the physiological characteristics of seedlings have a strong influence on seedling survival and growth potential (Ritchie, 1984); and (3) comparisons of seedling performance based upon morphological traits are valid only when seedlings are in the same physiological

Table 4. Effects of initial seedling height categories and root collar diameter categories on seedling height 5 years after planting.

Seedling height categories	Mean heights of root collar diameter categories, (cm)		Average[1] (cm)
	Large	Small	
1	69.8	68.1	69.0a
2	64.1	63.5	63.8ab
3	63.3	59.3	61.3b
4	58.6	53.7	56.2bc
5	52.1	44.0	48.1c
Average[2]	61.6 A	57.7B	

[1]Values in a column with the same letter(s) are not significantly different ($P < 0.001$).
[2]Values in a row followed by the same capital letter are not significantly different ($P < 0.05$).

conditions at planting time (Ritchie, 1984). Similar to the present study, seedling size did not affect seedling survival in *Pinus nigra* subsp. *pallasiana* (Kızmaz, 1993), *Pinus sylvestris* (Tosun et al., 1993), *Fagus orientalis* (Özpay and Tosun, 1993) or transplanted *Picea orientalis* (Genç et al., 1995). However, the absence of a seedling size effect on survival in *C. libani* is inconsistent with some previous studies on other tree species, which show a relationship between seedling sizes and survival (Bacon et al., 1977; Larsen et al., 1986; Tuttle et al., 1987; Shiver et al., 1990; Dirik, 1991; Long and Carrier, 1993). This inconsistency might be due to differences in species and evaluation ages of seedlings after planting in each study. First-year survival results in this study were evaluated in another study by Semerci (2001), and he stated that seedling size has an effect on survival. Survival was positively correlated with initial height in Ankara but there was a negative correlation in Eskişehir and Konya in Taurus cedar at the end of the first year. However, this study showed that the effects of morphology on first-year survival had disappeared by the end of the fifth year.

Initial root collar diameter of seedlings had significant effects on their height growth after 5 growing seasons (Table 3). The large root collar diameter seedlings grew more than the smaller seedlings did (Table 4), and this result partially supported the findings of Eler et al. (1993). In their study, the largest seedlings (root collar diameter > 6 mm and height > 24 cm) were the best performing seedlings in 2+0, *C. libani*. Those 2 studies in Taurus cedar agree well with the general idea that root collar diameter is a good predictor of field growth (Chavasse, 1980; Mexal and Landis, 1990; Mattsson, 1997).

Height differences among different height categories were maintained but had not expanded at the end of 5 years (Table 4). A similar result was observed in Norway spruce (*Picea abies)*. In that study, morphologically graded seedlings (small, medium, and large) were planted in the field and the differences in mean height among graded seedlings were still detectable after 40 years (Puttonen, 1989). The result of the present study agrees partially with the study by Long and Carrier (1993), who reported that initial seedling diameter was significantly associated with seedling performance. The survival and height growth of seedlings 3-5 years after planting were positively correlated with seedling sizes at planting. Height differences among different sized stocks were still significant after 5 years (Long and Carrier, 1993).

According to the Turkish Forest Tree Seedling standards (TSE, 1988), classes I and II 2+0 Taurus cedars should be over 10 and 12 cm in length, respectively. Their root collar diameter should be over 2 mm. However, the fifth seedling height category in our study (Table 4) indicated that seedlings with 3.0-3.9 mm root collar diameter are 4.5 cm taller than those with 2.0-2.9 mm diameter. For this reason, as before, Genç et al. (1999) stated that minimum seedling root collar diameter should be 3 mm for 2+0 Taurus cedar, and the Turkish Forest Tree Seedling standards should be revised without delay, taking the Standards of the European Commission into consideration.

In conclusion, initial height and root collar diameter of seedlings had no effect on survival. This suggests that seedling morphology is not a perfect predictor of field survival. The 2+0 seedlings with large diameters grew faster in the early years at 3 experiment areas, and initial height differences among different sized stocks were still significant after 5 years. These results show that root collar diameter is a good indicator of growth potential after planting for *C. libani* seedlings. For this reason, using seedlings with large diameters in planting might be preferable for the establishment of new plantations to reduce establishment cost. Since large diameter seedlings compete well with other vegetation and may gain more biomass volume in a shorter period than smaller seedlings may gain, the root collar diameter of seedlings should be increased by diverse methods (undercutting, wrenching, top pruning, growing in a wider space etc.) in nurseries for producing high quality seedlings.

Acknowledgments

I wish to express my gratitude to Dr. Fahrettin TİLKİ and Dr. Aydın TÜFEKÇİOĞLU, from the Faculty of Forestry, University of Kafkas, for their valuable advice and for reviewing the English of the paper.

References

Akgül, E. and A. Yılmaz. 1987. Doğal yayılış alanı dışında yapılan ağaçlandırmalarda yörenin ekolojik özellikleri ile Toros sedirinin (*Cedrus libani* A. Rich.) gelişimi arasındaki ilişkiler (Relationship between characteristics of Taurus cedar and the ecological properties of reforestation areas outside the natural stands). Ormancılık Araştırma Enstitüsü Yayınları. Teknik Bülten Serisi: 188, Ankara.

Atalay, İ. 1987. Sedir (*Cedrus libani* A. Rich.) Ormanlarının Yayılış Gösterdiği Alanlar Ve Yakın Çevresinin Genel Ekolojik Özellikleri ile Sedir Tohum Transfer Rejyonlaması (General Ecological Properties of Natural Occurrence Areas of Cedar (*Cedrus libani* A. Rich.) Forests and Regioning of Seed Transfer of Cedar in Turkey). Orman Genel Müdürlüğü Yayını. Yayın No: 663, Ankara.

Atalay, İ. 1990. Türkiye'de sedir (*Cedrus libani* A. Rich.) tohum transfer rejyonlaması (Regioning of seed transfer of cedar (*Cedrus libani* A. Rich.) in Turkey). In: Proceedings of the International Cedar Symposium, Ormancılık Araştırma Enstitüsü Yayını. Muhtelif Yayın No: 59, Ankara, pp. 166-179.

Bilir, N. 1997. Doğu Karadeniz Bölgesinde Toros Sediri (*Cedrus libani* A. Rich.) Orijin Denemeleri Fidanlık Aşaması. Master Tezi. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, p. 90.

Bilir, N. 2002. Doğu Karadeniz Bölgesi'nde Kurulan Toros Sediri (*Cedrus libani* A. Rich.) Orijin Denemelerinin İlk Sonuçları. Doktora Tezi. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, p. 98.

Bacon, G.J., P.J. Hawkins and D. Jermyn 1977. Morphological grading studies with 1-0 slash pine seedlings. Australian Forestry, 40: 293-303.

Boydak, M., H.F. Bozkuş and C.Ü. Alptekin. 1990. Türkiye'de özellikle doğal yayılış alanları dışındaki sedir (*Cedrus libani* A. Rich.) ağaçlandırmalarının silvikültürel açıdan değerlendirilmesi (Silvicultural evaluation of the *Cedrus libani* plantations located out of its occurrence in Turkey). In: Proceedings of the International Cedar Symposium, Ormancılık Araştırma Enstitüsü Yayını. Muhtelif Yayın No: 59, Ankara, pp. 180-192.

Boydak, M. and H. Dirik. 1990. Lübnan Sediri (*Cedrus libani* A. Rich.) fidanlarında su stresi ile koşullandırmanın dikim sonrasındaki su durumu ve kök rejenarasyonuna etkileri (The effects of preconditioning by restricted watering on the water status and root regeneration of transplanted *Cedrus libani* plants). In: Proceedings of the International Cedar Symposium, Ormancılık Araştırma Enstitüsü Yayını. Muhtelif Yayın No: 59, Ankara, pp. 193-202.

Boydak, M. 1996. Toros Sedirinin (*Cedrus libani* A. Rich.) Ekolojisi Silvikültürü ve Doğal Ormanlarının Korunması (Ecology and Silviculture of Cedar of Lebanon (*Cedrus libani* A. Rich.) and Conservation of Its Natural Forest). Orman Bakanlığı Yayını, No: 012, Ankara.

Boydak, M. 2003. Regeneration of Lebanon cedar (*Cedrus libani* A. Rich.) on karstic lands in Turkey. Forest Ecology and Management. 178: 231-243.

Bryant, E.C. 1966. Statistical Analysis. McGraw-Hill Book Company, New York.

Chavasse, C.G.R. 1980. Planting stock quality: a review of factors affecting performance. New Zealand Journal of Forestry, 25: 145-171.

Demirci, A. and N. Bilir, 2001. Yaşı 3-0 olan Toros sediri (*Cedrus libani* A. Rich.) fidanlarında orijinler arası farklılıklar. Turk. J. Agric. For. 25: 217-223.

Dirik, H. 1990. Dikim şoku. İstanbul Üniversitesi, Orman Fakültesi Dergisi. Seri B 40: 105-116.

Dirik, H. 1991. Kızılçam (*Pinus brutia* Ten.)da Bazı Önemli Fidan Karakteristikleri ile Dikim Başarısı Arasındaki İlişkiler. Doktora Tezi, İstanbul Üniversitesi, Fen Bilimleri Enstitüsü, p. 116.

Duryea, M.L. and K.M. McClain. 1984. Altering seedling physiology to improve reforestation success. In: Seedling Physiology and Reforestation Success (Eds., M.L. Duryea and G.N. Brown). Martinus Nijhoff/Dr. W. Junk Publishers, Boston, pp. 77-113.

Düzgüneş, O. 1963. Bilimsel Araştırmalarda İstatistik Prensipleri ve Metotları. Ege Üniversitesi Matbaası, İzmir.

Edwards, C. 1998. Testing plant quality. Forestry Commission Research Information Note: 011. Forestry Commission, Edinburgh.

Eler, Ü., S. Keskin and E. Örtel. 1993. Toros sediri (*Cedrus libani* A. Rich.) fidanlarında kalite sınıflarının belirlenmesi (Determination of quality classes of Lebanon cedar (*Cedrus Libani* A. Rich.) seedlings). Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten Serisi: 240. Ankara.

Eler, Ü. and S. Keskin. 2003. Farklı falite sınıflarına ait Toros sediri (*Cedrus libani* A. Rich.) fidanlarının 14 yaşındaki gelişme durumları (Growing trait of 14 year old Taurus cedar seedlings of quality classes.). Batı Akdeniz Ormancılık Araştırma Müdürlüğü Dergisi. 5: 3-14.

Genç, M. 1992. Doğuladini (Picea orientalis (L.) Link.) Fidanlarına Ait Bazı Morfolojik ve Fizyolojik Özelliklerle Dikim Başarısı Arasındaki İlişkiler. Doktora Tezi. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, p. 268.

Genç, M., A.Ö. Üçler, İ. Turna and N. Bilir. 1995. Doğu ladininde fidan kalitesi-dikim başarısı etkileşimleri: 5 yıllık sonuçlar. I. Ulusal Karadeniz Ormancılık Kongresi, Trabzon, pp. 134-141.

Genç, M., T. Güner and A. Şahan. 1999. Eskişehir, Eğirdir ve Seydişehir orman fidanlıklarında 2+0 yaşlı Karaçam fidanlarında morfolojik incelemeler (Morphological studies of 2+0 Anatolian black pine stocks grown in Eskişehir, Eğirdir and Seydişehir forest nurseries). Turk. J. of Agric. and For. 23: 517-525.

Goor, A.Y. and C.W. Barney. 1976. Forest Tree Planting in Arid Zones. The Ronald Press Company, New York.

Hobbs, S.D. 1984. The influence of species and stocktype selection on stand establishment: an Ecophysiological perspective. In: Seedling Physiology and Reforestation Success (Eds.: M.L. Duryea and G.N. Brown). Martinus Nijhoff/Dr. W. Junk Publishers. Boston, pp. 179-224.

Jaramillo, A. 1980. Review of techniques used to evaluate seedling quality, In: Proceedings of Intermountain Nurseryman's Association and Western Forest Nursery Association. U.S.D.A. Forest Serv., Intermountain Forest and Range Exp. Sta., Gen. Tech. Rep. INT-109, Ogden, Utah, pp. 84-95.

Kalıpsız, A. 1988. İstatistik Yöntemler. İstanbul Üniversitesi, Orman Fakültesi Yayınları, No: 394, İstanbul.

Konukçu, M. 2001. Ormanlar ve Ormancılığımız (Forests and Turkish Forestry). DPT Yayınları, No: 2630, Ankara.

Kızmaz, M. 1993. Karaçam fidanlarının kalite sınıflarının belirlenmesi üzerine araştırmalar (Research on the determination of quality classification of Crimean pine seedlings). Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten Serisi: 238. Ankara.

Larsen, H.S., D.B. South and J.M. Boyer. 1986. Root growth potential, seedling morphology and bud dormancy correlate with survival of loblolly Pine seedlings planted in December in Alabama. Tree Physiology, 1: 253-263.

Long, A.J. and B.D. Carrier. 1993. Effect of Douglas-fir 2+0 seedling morphology on field performance. New Forests, 7: 19-32.

Mattson, A. 1997. Predicting field performance using seedling quality. New Forests, 13: 227-252.

Mexal, J.G. and T.D. Landis. 1990. Target seedling concept: height and diameter. In: Proceedings of Combined Meeting of the Western Forest Nursery Associations (Eds.: R. Rose, S.J. Campbell and T.D. Landis), USDA Forest Serv., Gen. Tech. Rep. RM-200, Roseburg, Oregon, pp. 17-35.

Munson, K. R. 1985. Principles, procedures, and availability of seedling quality test. In: Proceedings of the Intermountain Nurseryman's Association Meeting (Eds.: T.D. Landis and J.W. Fisher), U.S.D.A. Forest Serv., Gen. Tech. Rep. RM-125, Fort Collins, Colorado, pp. 71-83.

OGM, 1980. Türkiye Orman Envanteri. Orman Genel Müdürlüğü Yayını. Yayın No: 13/160, Ankara.

Özpay, Z. and S. Tosun. 1993. Kayın (*Fagus orientalis* Lipsky.) fidanlarının kalite sınıflarının belirlenmesi üzerine araştırmalar (Researches on the determination of quality classification of Oriental beech (*Fagus orientalis* Lipsky.) seedlings. Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten Serisi: 241. Ankara.

Puttonen, P. 1989. Criteria for using seedling performance potential tests. New Forests, 3: 67-87.

Puttonen, P. 1997. Looking for the 'Silver bullet'-can one test do it all? New Forests, 13: 9-27.

Quézel, P. 1979. La région méditerranéenne francaise et ses essesence forestières. Signification écologique dans le contexte circum-mediteranéen. Foret Méd. 1 (1): 7-18.

Quézel, P. 2000. Taxonomy and biogeography of Mediterranean pines (*Pinus halepensis* and *P. brutia*). In: Ecology, Biogeography and Management of *Pinus halepensis* and *P. brutia* Forest Ecosystem in the Mediterranean Basin. (Eds: G. Ne'eman and L. Trabaud). Bachuys Publishers, Leiden, pp. 1-12.

Ritchie, G.A. 1984. Assessing seedling quality. In: Forest Nursery Manual Production of Bareroot Seedlings (Eds.: M.L. Landis and T.D. Landis). Martinus Nijhoff/Dr. W. Junk Publishers. Boston, pp. 243-259.

Savil, P., J. Evans, D. Auclair and J. Falck. 1997. Plantation Silviculture in Europe. Oxford University Press, New York.

Sarvas, M. 2001. The influence of physiological activity on the rate of electrolyte leakage from Beech and Oak planting stock. Journal of Forest Science. 47: 174-180.

Semerci, A. 2001. Toros Sediri (*Cedrus libani* A. Rich.) Fidanlarına Ait Bazı Morfolojik ve Fizyolojik Karakteristikler İle İç Anadolu'daki Dikim Başarısı Arasındaki İlişkiler Doktora Tezi. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, p. 125 (Yayınlandı).

Shiver, B.D., B.E. Borders, H. Page and S.M. Raper. 1990. Effect of some seedling morphology and planting quality variables on seedling survival in the Georgia Piedmont. Southern Journal of Applied Forestry, 14: 109–114.

Sutton, R.F. 1979. Planting stock quality and grading. Forest Ecology and Management, 2: 123-132.

Şimşek, Y. 1987. Ağaçlandırmalarda kaliteli fidan kullanma sorunları (Fragen Der Planzenqalitaet in der Aufforstungsarbeit), Ormancılık Araştırma Enstitüsü Dergi Serisi. 3: 7-29.

Şimşek, Y., S. Tosun, H. Atasoy, H.Z. Usta and S. Uğurlu. 1996. Türkiye'de çoğul amaçlı ağaçlandırmalarda kullanılabilecek yapraklı türlerin tespiti üzerine araştırmalar (a study on determination of the broad leaved-tree species to be used in multipurpose plantations in Turkey). Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten Serisi: 260. Ankara.

Tosun, S, Z. Özpay and M. Tetik. 1993. Sarıçam (*Pinus sylvestris* L.) fidanlarının kalite sınıflarının belirlenmesi üzerine araştırmalar (Researches on the determination of quality classifications of Scotch pine (*Pinus sylvestris* L.) seedlings). Ormancılık Araştırma Enstitüsü Yayınları, Teknik Bülten Serisi: 239. Ankara.

Tuttle, C.L., D.B. South, M.S. Golden and R.S. Meldahl. 1987. Relationship between initial seedling height and survival and growth of Loblolly pine seedlings planted during a droughty year. Southern Journal of Applied Forestry, 11: 253-263.

Türkeş, M. 1990. Türkiye'de Kurak Bölgeler ve Önemli Kurak Yıllar. Doktora Tezi. İstanbul Üniversitesi, Deniz Bilimleri ve Coğrafya Enstitüsü, p. 195.

TSE, 1988. Türk Standartları Enstitüsü, İğne Yapraklı Ağaç Fidanları Standardı, TS 2265/ Şubat, p. 14.

Van den Driesshe, R. 1976. How far do seedlings standards reflect seedling quality. In: Proceedings of XVI IUFRO World Congress, Division II, Norway, pp.50-52.

Vidakovic, M. 1991. Conifers Morphology and Variation. Graficki Zavod Hrvatse, Zagrep.

Yahyaoğlu, Z. 1986. Orman ağacı fidanlarının kalite özellikleri, Scholander tekniği yardımı ile su potansiyelini ölçülmesi ve önemi. Karadeniz Üniversitesi, Orman Fakültesi Dergisi, 9: 140-151.

Yahyaoğlu, Z. and M. Genç. 1990. Sedir (*Cedrus libani* A. Rich.)'de ıslah çalışmaları (Genetic improvement studies on the Taurus cedar (*Cedrus libani* A. Rich.). In: Proceedings of the International Cedar Symposium, Ormancılık Araştırma Enstitüsü Yayını. Muhtelif Yayın No: 59, Ankara, pp. 325-341.