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Long term survival and growth performance of selected seedling types in Cedar (*Cedrus libani*) afforestation in Turkey

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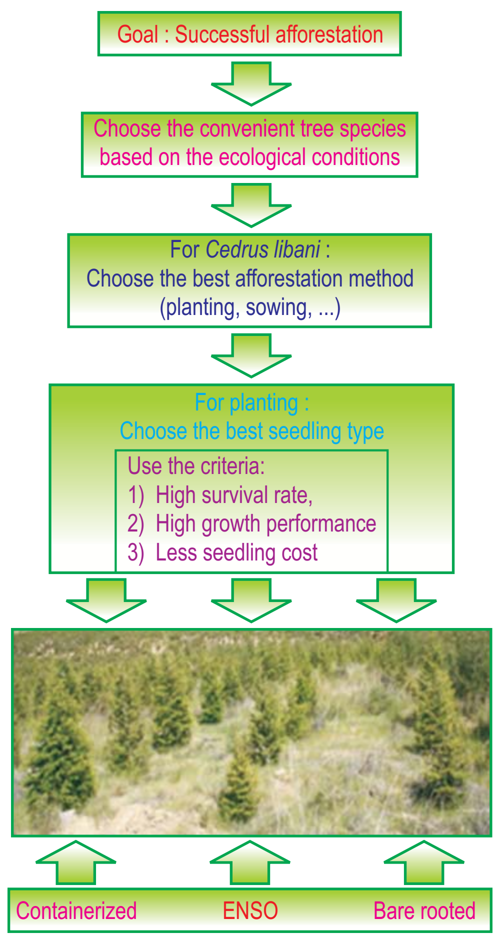
Abstract

Aim: Three different seedling types that are bare rooted, ENSO and polyethylene containerized seedlings are mainly used for Cedar afforestation in Turkey, however research on long-term field performance of these seedling types is meagre. The present study aims at comparing the survival and growth rate in order to determine the best seedling types for afforestation and also exploring their economic value at different sites.

Methodology: The study was carried out at two different experimental sites in Burdur-Bucak-Urkutlu and Antalya-Korkuteli-Yelten. A randomized block design with six blocks and three seedling types was applied at each site. One-year-old seedlings were planted within the sites and observed for 13 years. Data collected in the last seven years were used for statistical analyses. Analysis of variance was performed at each site and different seedling types were compared through Duncan's multiple range tests.

Results: Results showed that there were significant differences between the seedling types at $P<0.05$ level for survival and $P<0.01$ level for growth rate. At both sites, the containerized seedlings had higher survival rates than the other seedling types. At Yelten, the containerized seedlings had 39% and 28% higher growth rates than ENSO and bare rooted seedlings. These rates were 21% and 17% at Urkutlu site, respectively. Afforestation investment costs for the containerized seedlings were also 23.9% and 15.4% higher than for the bare rooted and ENSO stock at Yelten and 27.6% and 20.6%, respectively, in Urkutlu.

Interpretation: The results showed that containerized seedlings can be suggested for afforestation at similar sites considering their higher growth performance, even if the costs are higher than those of other types.



Introduction

Cedar (*Cedrus libani* A. Rich.) is distributed naturally in Anatolia, Lebanon and Syria. It has been exploited throughout the history for its valuable wood, and today it exists only in limited areas (Boydak and Calikoglu, 2008;Yaltirik and Akkemik, 2011). Its widest distribution is in Turkey with 463,000 ha of pure and mixed stands, which accounts only 2.1% of Turkey's total forest area (GDF, 2016). Cedar is commonly used for afforestation outside its natural distribution range not only in Turkey but also in Italy, Iran and Bulgaria especially in areas with poor ecological conditions due to its tolerance to water scarcity and high adaptation ability (Boydak *et al*., 1990; Erkan, 2006). However, its survival and growth rate might be low outside its natural distribution areas, especially with low annual precipitation and long dry summer season. Therefore, in such arid or semiarid areas, some additional precautions such as deep soil cultivation, selection of suitable seed provenances and better seedling material should be taken in order to increase the success of afforestation.

The success of afforestation depends on seedling type to some extent. Indeed, properly selected seedling types can enhance afforestation success considerably through increased survival and growth rate after out planting (Pinto *et al*., 2011). Barerooted and containerized seedlings grown in ENSO pot trays or polyethylene bags are the common seedling types used in Turkish forestry. However, there are conflicting observations about the field performance of these seedling types after establishment. Some of the scientists suggest containerized seedlings which perform better at most of the sites, but not ENSO type; while the others recommend bare rooted seedlings. Therefore, there is a need for new applied research studies to resolve the issues related to the performances of the seedling types in Turkish afforestation (Hizal *et al*., 2006; Kucukkaya, 2010).

Newly planted seedlings can survive at reforested site only if they have access to available soil water to meet their atmospheric demand of water. The ability of a seedling to take up water is affected by its root system, root-soil contact and root hydraulic conductivity. Newly planted seedlings have restricted root placements, low root system permeability and poor root-soil contact, which can limit water uptake from the soil (Burdett, 1990; Grossnickle, 2005). Root-soil contact is also related to the seedling type. Bare rooted and containerized seedlings have different root systems, therefore, their contact with the surrounding soil also varies. For that reason, under stressful conditions such as dryland areas, containerized seedlings have more advantages than bare rooted seedlings (Barnett and McGilvray, 1993).

Several observations and research studies have been performed on the initial survival rate of the seedling types of other conifers (TSF, 2015), however, there is no satisfactory information about the long-term survival and growth rate of cedar afforestation. Seedling type affects not only the field performance of the planted seedlings but also the establishment costs of afforestation. The price of seedlings, planting and seedling transfer costs can vary considerably depending on the seedling type. Therefore, cost-benefit should also be taken into account for afforestation investments.

In the present study, three seedling types (bare rooted, ENSO and containerized) were tested for survival and growth rates of cedar afforestation at two different sites (Yelten and Urkutlu) for past 13 years. Moreover, seedling and establishment costs were analysed in details by seedling type for each test site.

Materials and Methods

One-year-old bare rooted, ENSO type and contain erized seedlings, which are commonly used by the Forest Service, were tested at 13 years. ENSO is a seedling type raised in plastic pot trays with different number of cells and different dimensions using peat growth medium. Pot trays with 9×5=45 cells and each cell of dimension of 4×5×10 cm were used. These seedlings were initially grown in greenhouses in spring and early summer, after which the seedlings were acclimatized to open areas for the rest of the summer. Containerized seedlings were grown in cylinder shaped polyethylene bags with a diameter of 10 cm and height of 25 cm. These dimensions are preferred for afforestation. The seeds were collected from natural forest stands in Antalya-Elmali provenance and all seedlings were grown under operational conditions with conventional nursery culture. Bare rooted and polyethylene container seedlings were produced in Egirdir Forest Nursery, while ENSO seedlings were grown in Denizli Forest Nursery.

Test sites were established in the winter (February) of 2003 prior to the growing season at two ecologically different sites that were Yelten and Urkutlu. Experimental sites were located in the area where Cedar was identified as one of the indicator tree species by Negiz *et al.* (2015).

The annual precipitation of study area was 673 and 382 mm and elevation of 1245 and 955 m soil was sandy-loam and loam. According to Walter diagrams,Yelten and Urkutlu sites suffered from water deficiency during May-October and June-September, respectively.

Experimental design : Randomized complete block planting was carried out at each site and the seedlings were planted at a spacing of 2.0m x 3.0m. Each test site contained 6 blocks (replications) with each block undergoing three seedling type treatments. Each seedling type treatment within each block was represented by 30 observation trees, which were applied as three line parcels (3 parcels x 10 observations). Each parcel containing 10 observations was randomly distributed on each block and plantation was applied in the way usually performed by Forest Service.

Height (cm) was measured every year in the last seven years starting from 7 to 13 years of age. Diameter at ground level [d_0 (mm)] was also measured at 13 years. The data of last 13 year was collected and used for statistical analyses.

Analysis of variance (ANOVA) was performed to investigate the effect of seedling type on survival rates, height and d_0 growth rate by General Linear Models (GLM) in SPSS statistical software v. 22.0 (SPSS, 2014). Duncan's multiple range test was applied to test the differences between the treatments when they were found to be significantly ($P< 0.05$) different in the main model of ANOVA. Survival rate data were transformed using arc-sin transformer before statistical analyses.

Economic evaluations were conducted on the basis of the calculation of the seedling cost and afforestation investment cost by seedling types, taking account of the unit price of nursery and afforestation activities of the General Directorate of Forestry (GDF). Costs were calculated considering the current components of seedling production activities and afforestation investment. Afforestation investment costs were based mainly on the following components of activities: ground clearance, soil cultivation, planting, maintenance, protection and fencing, transportation of seedlings and seedling cost. Costs were calculated in US$ according to the conversion rate of 1 US$ = 2.127 Turkish Lira effective on 15th July 2014.

Results and Discussion

Statistical analyses showed that there were differences at $P<0.05$ level between the survival rates of the seedling types at both sites for the last 13 years. As shown from the Duncan's multiple range test results in the Table 1, the survival rates for bare rooted, ENSO and containerized seedlings were 81%, 73% 91% at Yelten and 94%, 98%, 97% at Urkutlu site, respectively. Containerized seedlings had significantly higher survival rates than bare rooted seedlings at both the sites than ENSO seedlings in Yeltensite, where precipitation was less than the precipitation in Urkutlu.

The survival rates found in this study are consistent with the previous studies carried due to the fact that covering roots, container and growth medium provide a more suitable environment for seedling roots and help to overcome the summer drought and competing vegetation, especially in the first two years after planting (Mcdonald, 1991; Barnett and McGilvray, 1993; Wilson *et al.*, 2007; Li *et al*., 2013). Grossnickle *et al.* (1987) measured greater new root development in containerized seedlings compared to bare rooted seedlings after field planting of jack pine.

Texas A&M Forest Service (TFS) also evaluated the advantages and disadvantages of containerized and barerooted seedlings. They underlined that the advantages of containerized seedlings mainly included production at any time of the year, use of limited number of seeds, higher growth performance, higher survival rates and extended planting season. Consequently, they suggested the use of containerized seedlings despite of their high cost, arguing that some of the costs could be compensated by higher survival rate (TFS, 2015).

Water availability (water content of soil and root hydraulic conductivity) is one of the most important variables that contribute to the successful establishment and growth of seedlings (Burdett, 1990; Grossnickle, 2005; Pinto *et al*., 2011;Nath *et al*., 2016). In this context, rainfall in the months after planting is important for survival rates. In our study area, precipitation was higher than the long-term average during those months just after planting at all sites. GDM (2015) records showed that monthly precipitation for March, April, May and June 2003 for Korkuteli meteorological station close to Yelten was 89, 63, 76 and 74 mm, while the long-term average for the same months were 38, 43, 37 and 25 mm, respectively. It was 65, 246, 65 and 20 mm for Burdur station close to Urkutlu while long-term averages were 45, 46,44 and 28 mm for the same months, respectively. This implies that survival rates would have been lower than the ones indicated above if

Table 1 : Effect of seedling type on survival, height and ground diameter at 13 years

		Survival (%)	**Height (cm)**	**Ground diameter (mm)**
		ANOVA sig.		
Site	**Seedling type**	***P< 0.005***	***p< 0.001***	***p< 0.001***
Yelten	Bare rooted	81.1 a	132.4 a	29.4 a
	ENSO	73.4 a	121.9 a	27.1 a
	Containerized	91.2 b	170.4 b	38.3 b
Urkutlu	Bare rooted	93.9 a	212.0 a	47.2 a
	ENSO	98.8 ab	205.3 a	46.7 a
	Containerized	97.2 b	249.1 b	57.5 b

values with the same letter are not significantly different

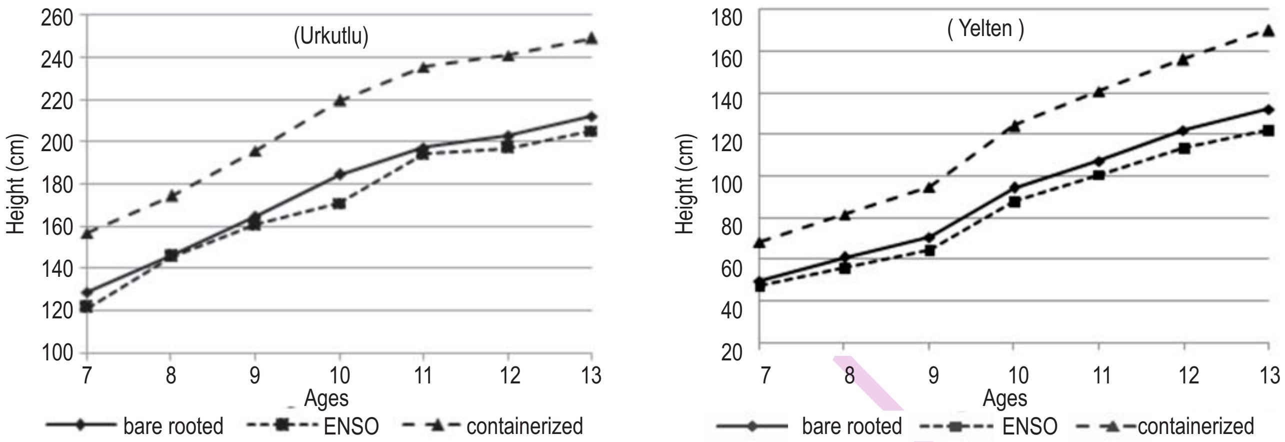


Fig. 1 : Height growth of seedling types of last seven years at experimental sites

Table 2 : Afforestation establishment cost per hectare by seedling types for two experimental sites

Activities	Cost (US$ ha^{-1})					
	Yelten site			Urkutlu site		
	Bare rooted	ENSO	Containerized	Bare rooted	ENSO	Containerized
Service road	148.74	148.74	148.74	79.36	79.36	79.36
Site preparation						
Ground clearance	369.10	369.10	369.10	293.13	293.13	293.13
Soil cultivation (by tractor)	332.79	332.79	332.79	286.08	286.08	286.08
Planting	428.27	335.74	699.92	428.27	355.74	699.92
Maintenance (two years)						
Replacementplanting	92.32	115.23	65.50	36.93	7.638	25.19
Weed and shoot control	463.11	463.11	463.11	463.11	463.11	463.11
Fencing	345.04	345.04	345.04	345.04	345.04	345.04
Seedling transfer	22.57	37.61	56.42	22.57	37.61	56.42
Seedling cost	74.81	279.11	341.86	74.81	279.11	341.86
Total	**2276.77**	**2446.49**	**2822.49**	**2029.30**	**2146.87**	**2590.12**

precipitation had been identical to the long-term mean values and the differences between the seedling types would have been clearer.

Results revealed significant differences at P<0.01 level between the total height growth of the seedling types in favour of the containerized seedlings at both the sites and the total height of the containerized seedling type was higher than that of the other types both the sites (Table 1). The mean height of the containerized seedlings was 28% and 39% greater than those of the bare rooted and ENSO seedling types, respectively, in Yelten site (Fig. 1). These proportions were 17% and 21%, respectively, at Urkutlu. Similar results were observed for diameter at both the sites.

Ortel (1995) reported similar findings in *Pinus brutia* plantations. He compared height growth of bare rooted and containerized seedlings of last 25 years and found significantly higher values in favour of the containerized seedlings. Urgenc (1990;1998a) compared the bare rooted and containerized seedling types and suggested that containerized seedlings could be used in arid and semi-arid areas, underlining higher survival rates and longer planting periods throughout the year. Similarly, Ayan and Bahadir (1995) suggested the use of containerized seedlings rather than bare rooted seedlings for successful afforestation, especially in areas where ecological conditions were unfavourable. Indeed, during initial years of afforestation, larger seedlings can compete and protect themselves from weedy vegetation (Cicek *et al*., 2010). Pinto *et al.* (2011) underlined the advantageous of containerized seedlings providing longer planting season and higher survival rates for reforestation and restoration projects with unique planting conditions like dry, extremely rocky with little topsoil.

Another result of our study was that even though ENSO type seedlings were a kind of containerized seedling, their growth rate was significantly lower than that of the polyethylene containerized seedlings. This might be because of their different growth media and depth and volume of the containers. ENSO type seedlings had peat growth medium while polyethylene containers had a mixture of soil and humus. ENSO trays also had smaller cell width and depth, resulting in about a 10 fold difference in container volumes (200 cm^3 vs 1962 cm^3). Chirino *et al*. (2008) found higher above-ground and below-ground biomass of the seedlings cultivated in the containers that had a higher volume.

The economic evaluation was performed on the basis of the data gathered in this study. In this framework, seedling costs and afforestation investment cost per hectare with sub components was calculated (Table2). Cost per seedling was calculated as 0.045 US$, 0.167 US$ and 0.205 US$ for bare rooted seedlings, ENSO and containerized seedling types, respectively. Seedling costs per hectare were also calculated considering that 1666 seedlings would be planted for one hectare (3 × 2 m spacing).

Afforestation investment cost per hectare was calculated as 2276.76 US$, 2446.49 US$ and 2822.49 US$ for bare rooted stock, ENSO and containerized seedlings at Yelten. These costs were calculated as 2029.30 US$, 2146.87 US$ and 2590.12 US$, respectively, at Urkutlu site (Table 2).

Afforestation investment cost of the containerized seedlings were found to be 23.9% and 15.4% higher than those of the bare rooted seedlings and ENSO types, at Yelten. These amounts were calculated as 27.6% and 20.6%, respectively, at Urkutlu site. As for the rate of the seedling costs in the total afforestation establishment costs, they varied depending on the seedling type but did not exceed 13% (for bare rooted, ENSO and containerized seedlings; 3.3%, 11.4% and 13.1% at Yelten site and 3.7%, 13.0% and 13.2% at Urkutlu, respectively). In the light of these rates, we underline that the containerized seedling types have superior growth performance. Therefore, at the end of the rotation period, plantations with containerized seedlings may easily tolerate the seedling cost differences.

Based on the evaluation of survival rate and total height growth of seedling of last 13 years, it can be concluded that containerized seedling type has advantage for a successful afforestation even if 15.4%-27.6% more investment cost in calculated for it, compared to the bare rooted and ENSO seedling types.

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