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Full Length Research Paper

The effects of different pot length and growing media on seedling quality of Crimean juniper (*Juniperus excelsa* Bieb.)

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The aim of this study was to determine appropriate pot length and growing medium for Crimean Juniper seedlings (*Juniperus excelsa Bieb*.), which will be used for afforestation of extreme areas. For this purpose, polyethylene pots of 11 cm width and 20, 25 and 30 cm lengths were used. As growing medium, 13 different treatments were used, containing different ratios of forest soil, pumice, creek sand and humus collected from the species' natural forest environments. The experimental design was a randomized block with 3 replications under open field conditions. Some morphological properties of the seedlings, such as seedling height, root collar diameter, shoot and root fresh and dry weights and shoot/root ratios (fresh and dry weights) were measured on 1 + 0 year old seedlings. Statistical analyses indicated that when pot length increased, the seedling quality improved. The seedlings with the best quality in terms of the measured criteria can be grown in 11 cm x 30 cm pots. In respect to the growing media, 70% forest soil + 15% humus + 15% pumice or creek sand should be used.

Key words: Growing media, pot length, *Juniperus excelsa* Bieb, Crimean juniper, seedling quality.

INTRODUCTION

Approximately, 5.3% of forest areas of Turkey (1100000 ha) is covered with juniper species (Davis, 1965; Kayacık, 1980; Anonymous, 1987). Especially small fruited juniper (*Juniperus oxycedrus* L.) is one of the most common maquis species in destroyed forest areas of Lake Region (Unaldi, 1990) and Isparta province (Gul et al., 2006a). Junipers can grow in poor soils and karstic areas and can tolerate extremely high and low temperatures in comparison to other forest tree species. In addition, they are the last species that abandon areas in the process of deforestation (Pamay, 1955). Crimean juniper has the second widest distribution, after small fruited juniper (*Juniperus oxycedrus* L.) in Turkey. Crimean juniper is distributed in north, west, central and southern Anatolia, particularly in arid and infertile slopes of the Taurus and Antitaurus Mountains, as single trees or in a group. The natural distribution of this species varies between 300-3500 m altitudes uprightly (Eliçin, 1977; Kayacık, 1980; Yaltırık and Efe, 2000). Within this wide distribution area the natural growing medium of Crimean juniper shows great variety in different soil and climatic conditions. For example, annual average rainfall varies between 200-700 mm.

Stands of this species are considerably damaged, crown closures are deteriorated, stand structures are damaged and stem qualities are extremely low. These stands were deprived of the opportunity for natural regeneration, due to their damaged structure. Due to various factors related to seed germination, it was not possible to grow junipers in Turkey's forest nurseries until recently. Therefore, juniper forests could not be managed and attempts were made to conserve existing juniper stands in their natural environment. However, it is not possible to conserve these forests in the long term. Heart rot starts to develop in mature Crimean juniper after 80

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years of age (Eler, 1991). These unproductive forests should be converted to productive forests again by afforestation and should be made use of economically. Successful and economical afforestation activities in these areas, many of which are problematic in terms of climate and growing medium, depends upon the use of high quality, hardy seedlings and plantation survival.

In recent years, important developments occurred in Turkey regarding the growing of juniper species in nurseries and planting in afforestation areas (Gültekin and Öztürk, 2002; Gültekin, 2003; Gültekin and Gültekin, 2003a, b; Gültekin et al., 2003; Gültekin, 2004; Gültekin et al., 2004a,b). Preliminary afforestation studies produced successful results. Therefore, starting in 2007, the Ministry of Environment and Forest carried out afforestation, improvement and natural regeneration studies across the country, over an area of approximately 15000 ha. Due to the above-mentioned qualities, Crimean juniper was given priority in these studies. However, due to the large variation in soil and climatic characteristics across these areas, the most appropriate type of juniper seedlings for successful afforestation is not known.

Potted seedlings have the highest survival rate and initial growth in plantations. In addition, they can be used in wider areas or in areas having different characteristics (Duryea and Brown, 1984). Recent economic analyses indicated that potted seedlings can be as economical as bare-root seedlings for attaining similar or better survival rates or growth (Guldin, 1982). Due to continuous mass production techniques, the most important advantages of using potted seedlings are time savings and reduced seedling loss (Duryea and Brown, 1984). Consequently, the use of potted seedlings would be appropriate in planned Crimean juniper afforestation areas that are problematic in terms of soil and climatic characteristics.

In afforestation studies with this species, particularly in arid areas, potted seedlings with dense capillary roots lateral roots of maximum 3 - 4 cm around a long tap root are preferred (Gültekin and Gültekin, 2006; Gültekin, 2007). However, no comprehensive study has been conducted on the appropriate pot length and growing medium for the pot filling material.

The aim of the present study is to investigate the effects of pot length and different growing media on morphological seedling characteristics of *Juniperus excelsa*.

MATERIALS AND METHODS

The study was conducted at Eğirdir Forest Nursery located in the southwestern part of Turkey at an altitude of 950 m. This area have characteristics continental and Mediterranean climate (Gul et. al., 2006b). Annual average temperature, maximum temperature and annual average rainfall of the nursery were 12 - 13°C, 38°C and 763 mm, respectively. The growth pots were filled with different ratios of forest soil, Crimean juniper humus, pumice and creek sand. In previous studies carried out on some other tree species and in general practice, growth medium is mainly composed of forest soil (Ayık, 1987; Sayman et al., 2002; Gülcü and Gültekin, 2005). For this reason, each treatment was prepared using a minimum of 50% forest soil.

Since Crimean juniper seedlings are mainly planted in areas which are problematic in terms of soil and climate, their roots are expected to be mycorrhizal and rich in hairy roots. Therefore, to encourage mycorrhizal hairy root development, different ratios of Crimean juniper humus, pumice and creek sand were used in the growth medium in some treatments. 13 different growth media were used in the study (Table 1). Some physical and chemical properties of the growth media are given in Table 2. A Bouyoucos hydrometer method was used in soil texture analysis (Tüzüner, 1990). A glass electrode pH meter was used to determine soil reaction (pH) and electrical conductivity (EC) was determined using an EC meter (Jackson, 1958). The loss on ignition (LOI) method was used to determine the soil organic matter content in the 5th treatment, and the wet oxidation (Walkley-Black) method was used in other treatments (Kaçar, 1995). The semi-micro Kjeldahl method was used to determine total nitrogen content.

Each growth medium was used to fill 20, 25 and 30 cm long pots. The study was carried out under open field conditions according to a randomized block design with 3 replications. The treatments were represented by a 30 pots for each pot length at each replication.

To overcome germination inhibition, before sowing, the seeds were subjected to the following pre-treatments, respectively: soaking in 20% ashy water for 5 days + soaking in 4°C water for 15 days + drying in shadow for 5 days + floating the seeds in 25000 ppm NaCl solution + soaking in 5000 ppm citric acid ($C_6H_8O_7$) for 3 days + hot-wet stratification for 30 days at 15 - 20°C + hot-wet stratification for 30 days at10°C.

1 + 0 year old seedlings were uprooted in February, 2008 and seedling lengths (cm), root collar diameters (mm), shoot and root fresh weights (g), shoot/root fresh weight ratios, shoot and root dry weights (g) and shoot/root dry weight ratios were measured. The statistical model used in comparison of tested pot lengths and growth media is given below.

$$Y_{ijkm} = \mu + R_i + T_j + G_{k(j)} + TG_{k(j)} + RT_{ij} + RG_{k(j)} + RTG_{ik(j)} + e_{m(ijk)}$$

Where Y_{ijkm}= value of mth seedling grown at ith replication of kth treatment of jth pot; μ = general mean; R_i = effect of ith replication; T_j = effect of jth pot; $G_{k(j)}$ = effect of kth treatment (growing media) of jth pot; RT_{ij} = effect of interaction between ith replication and jth pot; $RG_{k(j)}$ = effect of interaction between ith replication and kth treatment; $RTG_{ik(j)}$ = effect of interaction between ith replication and jth pot and kth treatment; and $e_{m(ijk)}$ = experimental error.

RESULTS AND DISCUSSION

The treatments of the tested pot lengths and growth media were different in terms of all measured characteristics. The differences observed among other sources of variation were not statistically significant (Table 3). The seedlings grown in 30 cm pots were 11.4 and 6.8% longer than those grown in 20 and 25 cm pots, respectively. In terms of root collar diameter, the seedlings grown in 30 cm pots were respectively, 15.6 and 4.5% thicker than those grown in 20 and 25 cm. Shoot fresh weights of the seedlings grown in 30 cm pots were 10.5% heavier; dry shoots were 16.1% heavier than those of the seedlings grown in 25 cm pots; fresh root weights were 16.4% heavier and dry roots were 27.0% heavier than those of the seedlings grown in 25 cm pots.

Table 1. Growth material mixtures and their volumetric participation rates (%).

Treatments	Forest Soil	Humus	Pumice	Creek Sand
1	50	20	30	-
2	50	20	-	30
3	50	30	20	-
4	50	30	-	20
5	50	50	-	-
6	50	-	50	-
7	50	-	-	50
8	70	15	15	-
9	70	15	-	15
10	70	30	-	-
11	70	-	30	-
12	70	-	-	30
13	100	-	-	-

Table 2. Physical and chemical analysis results of growth media for each treatment.

Treatments	Physical analysis				Chemical analysis				
	Sand (%)	Dust (%)	Clay (%)	Soil type	WC (%)	pH (1/2.5)	OM (%)	TN (% N)	S(ms /cm)
1	-	-	-	-	45.8	6.60	5.30	0.24	0.567
2	-	-	-	-	40.4	6.87	3.09	0.21	0.481
3	-	-	-	-	46.0	6.59	7.88	0.31	0.488
4	-	-	-	-	42.4	6.71	4.86	0.27	0.508
5	-	-	-	-	50.6	6.43	19.08	0.49	0.519
6	-	-	-	-	35.0	6.96	2.08	0.10	0.409
7	-	-	-	-	38.8	7.49	1.32	0.10	0.381
8	-	-	-	-	47.2	6.53	4.92	0.19	0.388
9	-	-	-	-	47.4	6.53	3.40	0.20	0.403
10	-	-	-	-	47.8	6.49	5.30	0.29	0.345
11	-	-	-	-	43.6	6.52	2.33	0.11	0.349
12	69.64	18.09	12.27	sandy clay	36.2	7.27	1.58	0.09	0.378
13	50.22	17.40	32.38	sandy clay silt	40.1	6.17	2.96	0.18	0.347

WC, Water capacity; OM, organic matter; TN, total nitrogen; S, salinity EC10 at 25ºC.

Table 3. Results of analysis of variance.

SV	DF	SH	RD	SFW	RFW	SDW	RDW	S/R(F)	S/R(D)
R_i	2	1.86 ns	0.27 ns	0.417 ns	0.18 ns	0.09 ns	0.03 ns	0.04 ns	0.26 ns
T_j	2	714.72***	61.43***	123.69***	428.19***	34.35***	41.43***	51.09***	29.95***
$G_{k(j)}$	12	185.33***	2.61***	18.78***	7.83***	1.74***	0.52***	2.24***	1.56***
$TG_{k(j)}$	24	13.47 ns	0.45 ns	0.93 ns	1.07 ns	0.16 ns	0.09 ns	0.37 ns	0.47 ns
RT_{ij}	4	0,70 ns	0.34 ns	0.19 ns	0.61 ns	0.05 ns	0.04 ns	0.19 ns	0.22 ns
$RG_{k(j)}$	24	6.36 ns	0.22 ns	0.50 ns	0.41 ns	0.10 ns	0.04 ns	0.23 ns	0.44 ns
$RTG_{ik(j)}$	48	5.97 ns	0.27 ns	0.46 ns	0.36 ns	0.09 ns	0.05 ns	0.16 ns	0.27 ns
$e_{m(ijk)}$	2462	10.20	0.33	0.67	0.86	0.11	0.07	0.28	0.33

SV, Source of variation; DF, degrees of freedom; SH, seedling height; RD, root collar diameter; SFW, shoot fresh weight; RFW, root fresh weight; SDW, shoot dry weight; RDW, root dry weight; S/R(F), shoot/root ratio (fresh weight); S/R(D), shoot/root ratio (dry weight).

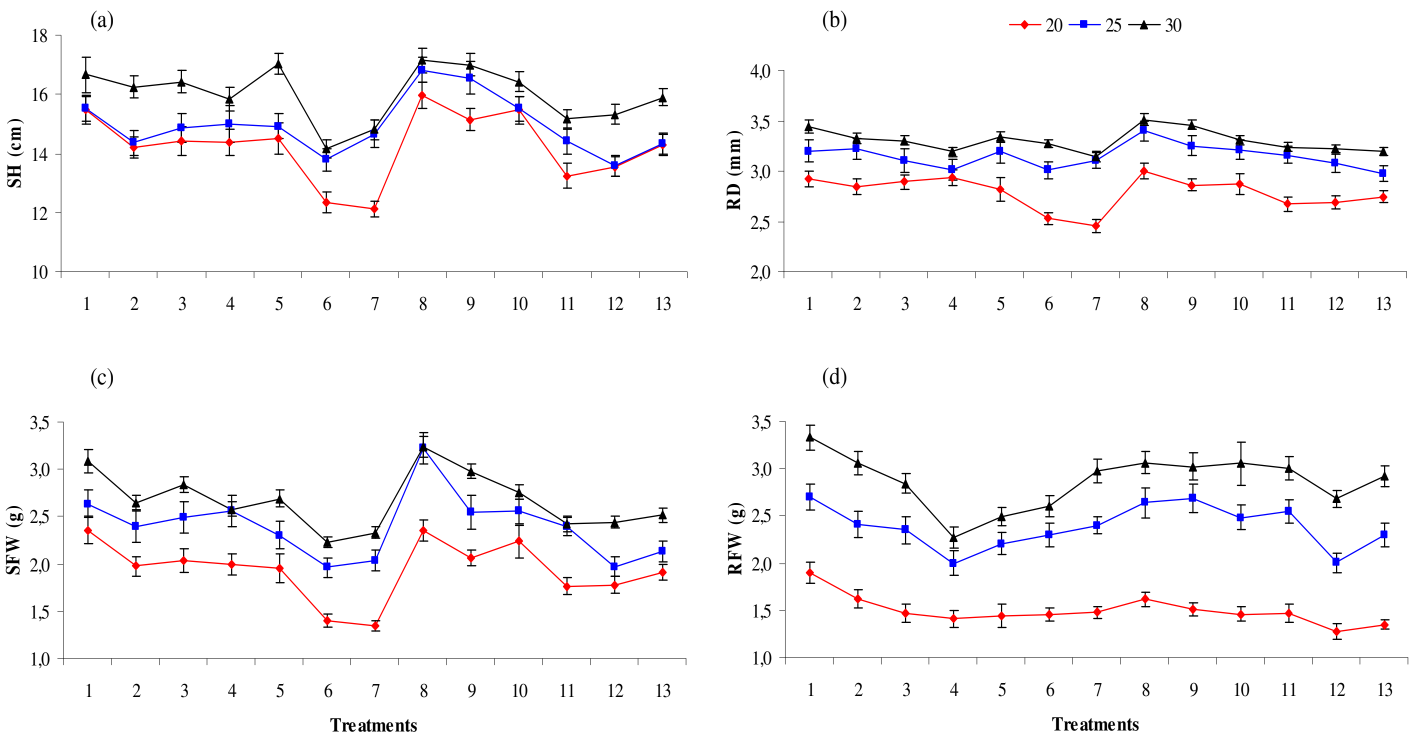

Figure 1. General means of seedling height (a), root collar diameter (b), shoot fresh weight (c), root fresh weight and (d) for each treatment.

When compared to the seedlings grown in 20 cm pots, these differences were greater (Figures 1 and 2).

The seedlings grown in 30 cm pots were observed to have the lowest ratio of fresh and dry shoot/root ratios, followed by the seedlings grown in 25 and 20 cm pots, respectively. In other words, the seedlings grown in 30 cm pots had better morphological properties than those grown in 20 and 25 cm pots. Seedling height and root collar diameter have an important effect on survival percentage and seedling development after planting. Therefore, long and thick seedlings have better survival and growth than others (Bacon, 1979; Rose et al., 1990; Yahyaoğlu and Genç, 2007). In areas where summer temperatures are high, which is a particular characteristic of the Mediterranean climate, seedlings with a long root system are better able to reach deeper soil layers containing sufficient moisture (Blade and Vallejo, 2008).

Regardless of the pot dimension, longer and thicker seedlings were obtained in the growth medium used in treatments 8 and 9. These treatments were followed by treatments 1, 2, 3, 4, 5 and 10, in which different ratios of humus were mixed into the growth media (Figure 1). Thus, it is clear that the addition of humus to the growth media had a positive effect on seedling properties. This can be explained by the contribution of humus to physical and chemical properties of the soil as an organic substance. Another important advantage of humus is that the seedlings are inoculated with natural mycorrhizae.

This will have a positive effect on the survival and growth of the seedling in the afforestation area. Mycorrhiza takes in nutrients, which are difficult to acquire from the soil, moving elements and distant nutrients using the hypha and increase plant growth (O'Keefe and Sylvia, 1991). George (2000) reported that, under controlled condition, mycorrhiza increased the P, Zn, Ca, Cu, Mn, Fe and Mg uptake of the plant. Therefore, in preparation of growth media in pot Crimean juniper seedling growing studies, in sandy mud texture, 15% humus should be mixed into the soil. Where the soil lacks mineral nutrients, the ratio of humus to be mixed into the growth medium can be increased. However, the effect of humus on seedling cost should be taken into account. Previous studies on juniper species drew attention to the importance of humus, particularly in growing potted seedlings and reported that, as the ratio of humus and creek sand increases in pot filling, seedling growth accelerates and capillary root ratio increases (Gültekin, 2007).

In treatments 8 and 9, 70% forest soil and 15% Crimean juniper humus was used. In addition to these, 15% pumice was used in treatment 8; 15% pumice was replaced by 15% creek sand in treatment 9. Humus, pumice and creek sand improve the physical properties of soil and enhance root respiration of the seedlings. They enable better wrapping of the pot filling material and enhance capillary root growth. Therefore, 15% pumice or 15% creek sand should be mixed into the growth medium.

It was found that, in treatment 13 (100% forest soil),

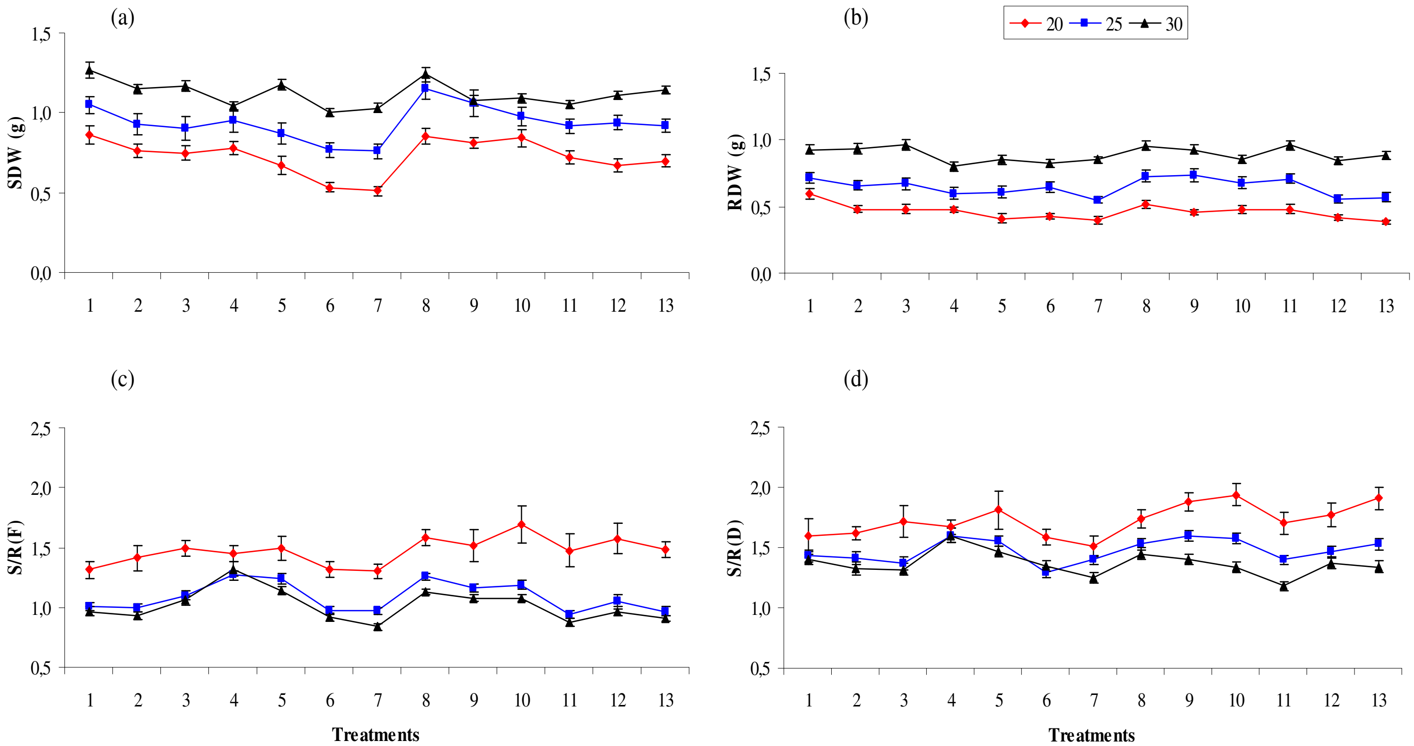

Figure 2. General means of shoot dry weight (a), root dry weight (b), shoot/root ratio (fresh weight) (c), shoot/root ratio (dry weight) and (d) for each treatment.

root collar diameter was small; however, seedling length was moderate. It can be stated that the soil in sandy clayey mud texture had sufficient mineral nutrients and therefore the growth of vegetative parts of the seedlings was normal or close to normal. It is known that mineral nutrients and particularly, dominant ammonium nitrogen, are important for good growth in conifer species (van den Driessche, 1984). However, particularly for root growth and balanced growth, the physical properties of the soil should also be good. This affects sufficient respiration by the roots and the degree of ventilation in the growth medium. For this reason, in the preparation of growth medium or pot filling material, certain ratios of humus, creek sand or pumice should be mixed into the soil to improve the physical properties. Thus, preparing a growth medium with adequate aggregated structure will improve root growth, grown roots will better wrap around the pot material and higher quality seedling will be produced in terms of shoot/root ratio.

Particularly in afforestation of areas with extreme climatic and soil characteristics, shoot/root ratio is important for biological success. Seedlings which will be planted in arid or semi-arid areas should have a developed root system that can absorb the water lost from the soil in shoots and leaves (Hermann, 1964; Baer et al., 1977; Hobbs et al., 1980). In addition, previous afforestation studies reported that seedlings with low shoot/root fresh or dry weight gave better results, particularly in arid areas (Yahyaoğlu and Genç, 2007; Gültekin, 2007). However, weight ratio does not always correctly indicate the root structure of the seedling. When a seedling with a thick tap root and another with a thin or dense hairy root were compared in terms of root weights, it was found that the results were in favor of the seedling with a tap root. It was reported that a seedling with a heavy root which lacks capillary roots is not higher in quality than a seedling with a light root, rich in capillary roots (Bacon, 1979).

Conclusion

The results of the present study indicated that pot length and growth medium had an effect on seedling quality. Longer growth-pots resulted in higher quality seedlings in terms of the seedling properties measured in the study. In other words, no matter what treatment is applied, the average length of seedlings grown in 30 cm pots was higher than those grown in 20 and 25 cm pots. However, the shoot/root ratio of the seedlings grown in 30 cm pots was lower. For example, the seedlings grown in 30 cm pots were 11.4 and 6.8% longer, respectively, than the seedlings grown in 20 and 25 cm pots. Similarly, the root collar diameter showed differences of 15.6 and 4.5%, respectively. Considering that the seedlings will be planted into areas with problematic in terms of climatic and soil properties, the results of the study indicate that seedlings of this species should be grown in 30 cm pots.

Growth medium should be composed of a minimum of 50% forest soil. In the present study, the growth media used in treatments 8 and 9 provided optimal conditions. These mixtures contained 70% forest soil + 15% humus + 15% pumice or 15% creek sand. In terms of seedling quality, treatments 8 and 9 were followed by treatments 1, 2, 3, 4, 5 and 10, into which different ratios of humus was mixed. This indicates that humus has a significant effect on seedling quality. Therefore, humus should be mixed into seedling growth media. This is also important for mycorrhizae inoculation to the roots of the seedlings and survival and growth performance in the afforestation area. This species will be planted in arid, infertile and problematic areas. Therefore, the physical properties of the growth medium should be improved and root development should be encouraged. It is therefore, recommended that 15% pumice or creek sand should be used to enable the roots to better wrap around the pot filling and to produce higher quality seedlings in terms of shoot/root ratio. Of these appropriate growth media, the most economical mixture should be used.

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