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SEEDLING MORPHOLOGY AND QUALITY IN CRIMEAN JUNIPER (*JUNIPERUS EXCELSA* BIEB.)

SUMMARY

Junipers (*Juniperus* sp.) have 1.56 million ha natural distribution which of total 23.3 million ha Turkish forest area. However, 1.1 million ha (71%) of junipers and 9.6 million ha (41%) of Turkish forest area is unproductive. Seedling quality and morphology is one of the important tools in conversion of unproductive forest to productive forest.

Seedling quality and morphology were investigated based on seedling height and root-collar diameter, and sturdiness index of 2+0 years containerized and bare-root seedlings of Crimean juniper (*Juniperus excelsa* Bieb.) grown at Forest Nursery from southern Türkiye. For the purpose, 150 seedlings were sampled randomly from each seedling type in a forest nursery to collect seedling height and root-collar diameter data. Sturdiness index was calculated by ratio between the height and diameter.

Collected data was performed for comparison of the seedling types for the characteristics by one-way analysis of variance, and to be determined relations among the characteristics by correlation analysis. The seedlings were distributed to quality classes of Turkish Standard Institute and Sturdiness index.

Studied bare-root seedlings (16.3 cm) showed higher height growth performances than containerized (14.5 cm) seedlings opposite to root-collar diameter (2.04 mm and 1.86 mm), while the seedlings showed large differences within seedling type for the characteristics. Averages of sturdiness index were 72.5 and 88.5 in containerized seedlings and bare-root seedlings, respectively.

Seedling types indicated significant ($p \leq 0.05$) differences for the characteristics. Positive and significant ($p \leq 0.05$) phenotypic relations were estimated among the characteristics in seedling types. Distribution of seedlings to quality classes varied for the characteristics, classes and seedling type.

Results of the study were discussed based on nursery practices and plantation forestry of the species.

Keywords: Afforestation, Diameter, Height, Nursery, Variation.

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INTRODUCTION

Junipers (*Juniperus* sp.) are one of the largest taxa by 8 species at 1.6 million ha natural distribution which of 1.1 million ha (~71%) is unproductive in total 23.4 million ha Turkish forest area which of 9.7 million ha is unproductive (OGM, 2024). However, Crimean juniper (*Juniperus excelsa* Bieb.) has 82% natural distribution in Turkish junipers (OGM, 2014). Crimean juniper is also native in Albania, Greece, North Macedonia, Bulgaria, Cyprus, Syria, Lebanon, Azerbaijan, Crimea, Russia at 500 and 2700 m (Farjon, 2005, Figure 1). Crimean juniper has drought, heat and cold tolerant characteristics. It is getting importance based on climate change and adaptation ability to different ecological conditions. The species is used widely in afforestation, rehabilitation and other forestry and landscape practices because of these advantages at different ecological conditions (Eser, 2021a).

Figure 1. Natural distribution of Crimean juniper in the world

Seedling quality and morphology is one of the important tools in conversion of unproductive forest to productive forest, and also forestry and landscape practices. While seedling quality and morphology have important roles in these practices, there are limited studies carried out on seedling quality and morphology of Crimean juniper (i.e., Gülcü and Gültekin, 2005; Eser and Gülcü, 2019; Eser, 2021a). In these studies, morphology of seedling type at the same age and sturdiness index have not yet been compared. It is also known that many abiotic and biotic factors could impact on morphology and quality of seedlings such as seedling type or seed source (Yücedağ *et. al*., 2010; Eser, 2021b; Uslu and Bilir,

2020; Yücesan and Yıldırım, 2021; Öye and Bilir, 2024), and nursery conditions and practices (i.e., Dewald and Feret, 1987; Bilir, 2019 and 2021). It is getting importance of new studies carried out on different seed sources, nurseries and morphological attributes.

Quality and morphology of containerized and bare-root seedlings of Crimean juniper, produced in Beyler-Antalya Forest Nursery from southern Türkiye, were examined to estimate variation, correlation and distribution of seedlings to quality classes based on seedling height and root-collar diameter, and sturdiness index to contribute nursery practices and plantation forestry of the species in this study.

MATERIAL AND METHODS

In this study, 150 seedlings of the species were sampled randomly from each 2+0 years containerized (**CS**) and bare-root (**BRS**) seedlings (Figure 2) called also seedling type in the study. The seedlings were grown originated from natural forests selected phenotypical of the species (30°31' N latitude and 29°44' E longitude, and 1350 m) in Beyler- Antalya Forest Nursery (30°39' N latitude and 29°51' E longitude, and 1035 m) established at 85.4 decare at southern part of Turkey. Averages of annual temperature and total precipitation were 11.3 °C and 636 mm. Average of P^H was 8.02 at the nursery. Seedling height (**SH**) and root-collar diameter (**RCD**) of the sampled seedlings were measured at end of growing period of 2023.

The collected data was performed by following model of ANOVA for comparison of seedling types at SAS Package (SAS, 2004).

$$Y_{ij} = \mu + P_j + e_{ij} \quad (1)$$

Where Yij is the observation from the jth seedling of the ith type, μ is overall mean, Pi is the random effect of the ith type, and eij is random error.

Figure 2. A view from sampled seedlings

The seedlings were classified according to the Seedling Quality Classification of Turkish Standard Institute for the Seedling height (**SH**) and root-collar diameter (**RCD**) (Anonymous, 1988, Table 1). The seedlings were also classified for Sturdiness index (**SI**) (Aphalo and Rikala, 2003) as (Table 1):

$$\mathrm{SI} = \frac{SH(mm)}{RCD(mm)} \quad (2)$$

Table 1. Seedling quality classes of Turkish Standard Institute in the species

Quality classes	Seedling height (SH, cm)	Root collar diameter (RCD, mm)	SI
First class	8≤	2 ≤	SI≤50
Second class	8> SH ≥6	-	50<SI≤60
Cull	6>	-	SI>60

The characteristics were related by Pearson' phenotypic correlation analysis (SAS, 2004).

RESULTS AND DISCUSSION

Characteristics

Bare-root seedlings (16.3 cm) showed higher height growth performances than that of containerized (14.5 cm), while it was opposite in root-collar diameter (2.04 mm and 1.86 mm) (Table 2, Figure 3). Similar growth performances were also reported in Stinking juniper by Eser (2021a), while containerized seedlings of Taurus cedar and Brutian pine had higher growth performances than bare-root seedlings for seedling height and root-collar diameter (Çetinkaya and Bilir, 2019; Bilir, 2019; Eser, 2021b). Averages of seedling height and root-collar diameter were found 21.9 cm and 5.2 mm in 1+1-year containerized seedlings, and 24.7 cm and 3.7 mm in 2+0 year bare-root seedlings of Crimean juniper, respectively in another forest nursery and seed source (Eser, 2021a).

Table 2. Averages ($\bar{x}$) and coefficient of variation (CV%) for the characteristics in the containerized (**CS**) and bare-root (**BRS**) seedlings

	CS		BRS		Total	
	$\bar{x}$	CV	$\bar{x}$	CV	$\bar{x}$	CV
SH (cm)	14.5	19.6	16.3	18.2	15.4	19.7
RCD (mm)	2.04	19.6	1.86	17.6	1.95	19.2
SI	72.5	18.7	88.5	17.0	80.5	20.3

Many abiotic such as seedling type, nursery conditions, nursery practices, soil characteristics (i.e., Dewald and Feret, 1987; Dilaver *et al*., 2015; Yılmazer and Bilir, 2016; Yazıcı and Turan, 2016; Yazıcı, 2018; Eser and Gülcü, 2019), and biotic such species and seed source (i.e., Parker and Niejenhuis, 1994; Ivetić, and

Škorić, 2013) could impact on seedling morphology and quality in forest tree species. These results emphasized importance of these factors in nursery practices.

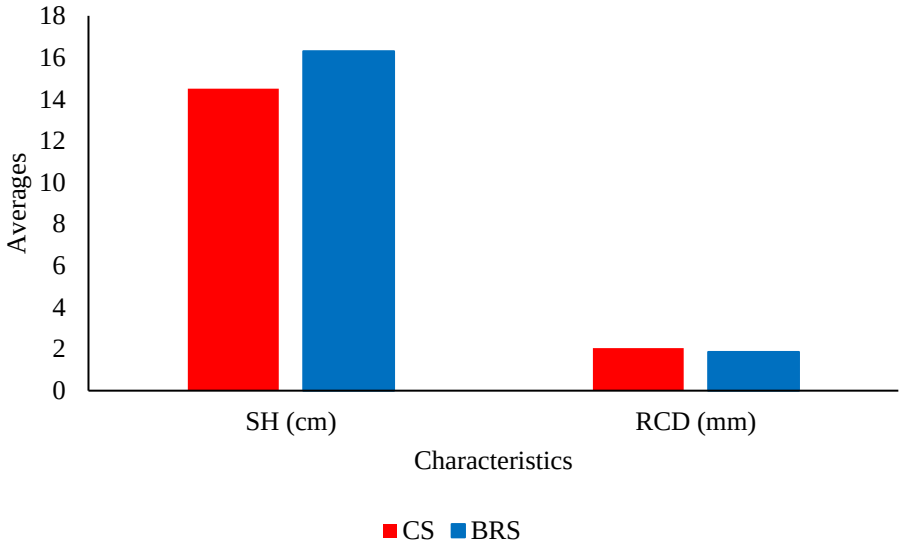

Figure 3. Averages of the characteristics for the seedling types

Averages of sturdiness index were 72.5 in containerized seedlings and 88.5 in bare-root seedlings. Besides, individual seedlings had large difference for the characteristics within seedling type (Table 2, Figure 4). For instance, seedling height ranged from 8.5 cm to 24.0 cm in containerized seedlings, while it was between 9.5 cm and 24.7 cm in bare-root seedlings. Sturdiness index had the lowest variation in seedling types (18.7% and 17.0%) opposite to the pooled types (20.3%) based on coefficient variation. Similar variations were also reported in different forest tree species (i.e., Dilaver *et al*., 2015; Çetinkaya and Bilir, 2019; Eser, 2021a, b). The variations indicated importance of individual selection in seed harvesting and tending in nursery practices for higher growth performance in the species.

Significant ($p \leq 0.05$) differences were found between seedling type for the characteristics according to results of analysis of variance. Significant ($p \leq 0.05$) differences between seedling types were also found in Crimean and Stinking junipers (Eser, 2021a), and in different forest tree species (i.e., Dilaver *et al*., 2015; Yılmazer and Bilir, 2016; Çetinkaya and Bilir, 2019; Öye and Bilir, 2024). The result emphasized importance of seedling type for afforestation practices and plantation forestry.

Significant ($p \leq 0.05$) and positive correlations were also reported between seedling height and root-collar diameter in Crimean and Stinking junipers by Eser (2021a, b), and in different forest tree species (i.e., Dilaver *et al*., 2015; Çetinkaya

and Bilir, 2019; Uslu and Bilir, 2020). The correlations could be used in nursery practices of the species such as tending.

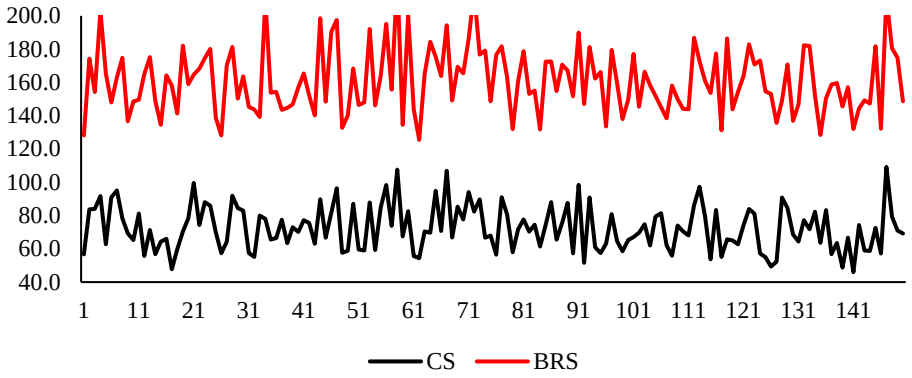

Figure 4. Individual sturdiness index for the seedling types

Table 3. Phenotypic correlations among the characteristics in the seedling type

	r	SH	RCD
CS	**RCD**	.549**	-
BRS		.567**	-
Total		.446**	-
CS	**SI**	.420**	-.505**
BRS		.450**	-.460**
Total		-.520**	.507**

**; Correlation is significant at the 0.01 level.

Seedling quality

Distribution of seedlings to quality classes changed for the characteristics, classes and seedling type (Table 4). The results were well accordance with results of early studies carried out in different forest tree species (i.e., Dilaver *et al*., 2015; Yılmazer and Bilir, 2016; Çercioglu and Bilir, 2016; Bilir, 2019; Uslu and Bilir, 2020). All seedlings of seedling types were in first class (8 cm ≤ SH) for seedling height. Containerized seedlings (56% in first class) had better quality than bare-root seedlings (45.7% in first class) for root-collar diameter, and also for sturdiness index (Table 4, Figure 5).

Seedling height and root-collar diameter were different quality criterions, while they were combined in sturdiness index. Sturdiness index could also be accepted as balancing of above and under parts of seedlings. However, quality classes of sturdiness index have not been tested in the field, yet. The results of seedling quality showed importance of quality characteristics and classes.

Table 4. Distribution of seedlings to quality classes of Turkish Standard Institute (SH and RCD) and sturdiness index (SI) in seedling types

	Quality classes	SH	RCD	SI
CS	**First class**	100	56.0	2.7
	Second class	-	-	20.0
	Cull	-	44.0	77.3
BRS	**First class**	100	35.6	-
	Second class	-	-	2.0
	Cull	-	64.4	98.0
Total	**First class**	100	45.7	1.3
	Second class	-	-	11.0
	Cull	-	54.3	87.7

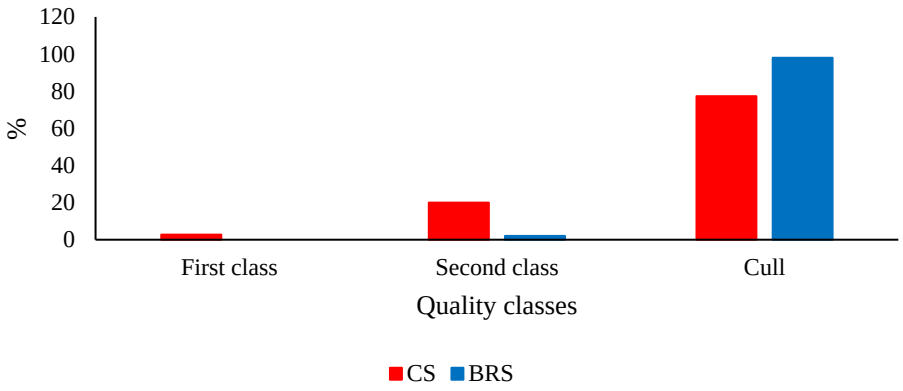

Figure 5. Distribution of seedlings to quality classes of sturdiness index for the seedling types

CONCLUSIONS

Averages height and sturdiness index of bare-root seedlings were higher than containerized seedlings, while containerized seedlings had higher root-collar diameter. Seedling types showed significant ($p \leq 0.05$) differences for the characteristics. The results indicated importance of seedling type and selection criterions in afforestation, plantation and other forestry practices of the species. All seedlings of the seedling types were in first class for seedling height, while containerized seedlings had better quality than bare-root seedlings for root-collar diameter, and also for sturdiness index. However, quality classes of sturdiness index have not yet tested in the field. The quality classes should be tested at field. There were positive and significant ($p \leq 0.05$) correlations among the characteristics of the seedling types. The relations could be used in nursery practices of the species.

The present study was carried out only one nursery and seed sources. Future studies should be carried out by new characteristics such as survival, fresh and dry weights in different forest nurseries on the species.

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