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Effects of Seedbed Density on Seedling Morphological Characteristics of four Broadleaved Species

C. Yücedağ[1, 2, *], and O. Gailing[2]

[1] *Bartın University, Engineering Faculty, 74100, Bartın, Turkey*
[2] *Michigan Technological University, School of Forest Resources and Environmental Science, Michigan, 49931, Houghton USA*

Abstract

The aim of this study was to investigate the effects of seedling spacing on morphological characteristics of one year-old *Amygdalus communis* L., *Prunus avium* L., *Pyrus elaeagnifolia* Pall. and *Eriolobus trilobatus* (Poiret) Roemer seedlings under nursery conditions. Seedlings were grown in completely randomized blocks with four replications. Seedbeds were 1.2 m wide with 5 rows each 20 cm apart. Within-row spacings were chosen as 4, 8 and 12 cm to analyze the effect of seedlings density on growth performance. Seedling spacing significantly affected root collar diameter, shoot height, tap root length and number of fine roots in *A. communis* and *P. avium*, but not in *P. elaeagnifolia* and *E. tribolatus*. Additionally wider seedling spacings resulted in larger seedlings in *A. communis* and *P. avium*. In conclusion, it would be beneficial to use wider seedling spacing in order to obtain better seedling growth in *A. communis* and *P. avium*. Larger seedlings could also provide significant advantages because of reduced cultural activities and an expected higher growth and survival rate.

Key words: *Amygdalus communis*; *Eriolobus trilobatus;* Morphology; *Prunus avium; Pyrus elaeagnifolia*; Seedling performance; Seedling spacing.

Resumen

Efectos de la densidad del semillero sobre las características morfológicas de las plántulas de cuatro especies de frondosas

El objetivo de este estudio fue analizar el efecto del espaciamiento de plántulas en las características morfológicas de brinzales de un año de edad de *Amygdalus communis L., Prunus avium L., Pyrus elaeagnifolia Pall y Eriolobus trilobatus (Poiret) Roemer* bajo condiciones de vivero. Las plantas se cultivaron en bloques completos al azar con cuatro repeticiones. Los semilleros son de 1,2 m de ancho con 5 filas cada 20 cm de distancia. Para analizar el efecto de la densidad de plántulas en el crecimiento se eligieron espaciamientos entre filas de 4, 8 y 12 cm. El espaciamiento de las plántulas afectaba significativamente el diámetro del cuello de la raiz, la altura de tallo, la longitud de la raíz y el número de raíces finas en *A. communis* y *P. avium*, pero no en *P. elaeagnifolia* y *E. tribolatus*. Adicionalmente amplios espaciamientos de plántulas produjeron grandes plántulas en *A. communis* y *P. avium*. En conclusión, sería beneficioso utilizar un mayor espaciamiento de plántulas con el fin de obtener un mejor crecimiento de las plántulas en *A. communis* y *P. avium*. Las plantas más grandes también pueden proporcionar ventajas significativas a causa de la reducción de las actividades culturales y un mayor crecimiento y tasa de supervivencia.

Palabras clave: *Amygdalus communis; Trilobatus eriolobus;* Morfología; *Prunus avium; Pyrus elaeagnifolia;* rendimiento de plántulas; espaciamiento de plántulas.

* Corresponding author: yucedagc@gmail.com
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Abbreviations used: FRN (fine root number); RCD (root collar diameter); SH (shoot height); SPSS (Statistical Package for the Social Sciences); TRL (tap root length); TSI (Turkish Standards Institution).

Introduction

Amygdalus communis L., *Prunus avium* L., *Pyrus elaeagnifolia* Pall., and *Eriolobus tribolatus* (Poiret) Roemer are commercially important tree species of the Rosaceae family native to different parts of Turkey (Davis, 1978; Anşin and Özkan, 1997). *A. communis,* a small tree, is widely cultivated for its edible seeds. This species has long been grown in Turkey, mostly along the coast of the Aegean, Marmara and Mediterranean regions (Yapar *et al*., 2006). *P. avium* is a vigorous tree with strong apical control and an erect pyramidal canopy shape (Naderiboldaji *et al*., 2008). It is mostly cultivated in temperate regions of the world (Webster, 1996). *P. elaeagnifolia* is a thorny tree producing small edible fruits and has been cultivated for about 3000 years (Hummer and Postman, 2003; Birinci, 2008). *E. trilobatus* (syn. *Sorbus trilobata* Labll., *Malus trilobata* Schneid) is an erect tree of about 6m with edible fruits and rowan-like five to seven lobed leaves (Davis, 1978). It is distributed in the Eastern Mediterranean Region and North East Greece (Hillier and Sons, 1973).

All taxa occur in the wild, but are also cultivated as valuable ornamental, and timber plants (Dirr, 1998). Their fruits are also processed into traditional products (Gültekin *et al*., 2007) and used in pharmaceutical and chemical industrial applications (Baytop, 1999). Moreover, these species are fast-growing plants and resistant to drought, pest and diseases and show high biological adaptation to different climate and soil conditions in their distribution range (Bell *et al*., 1996; Dirr, 1998). In addition to these irrefutable benefits, they have been used for afforestation in semi-arid regions of Turkey for eight years owing to resistance to drought. The species are widespread in Turkey, yet no scientific studies have been published to date regarding best nursery practices.

Qualified seedlings are described as superior seedlings in terms of their morphological, physiological and genetic characteristics in comparision with even-aged seedlings from the same seed origin that are grown at similar sites and conditions with regard to irrigation, weed control, hoeing and manuring (Gezer and Yücedağ, 2006). Seedling spacing is known as one of the important nursery practices used to obtain qualified seedlings. Namely, unless the proper seedling spacing of the species in nursery activities is used the morphological characteristics of the seedlings could be negatively affected due to severe competition among seedlings for light above ground or for nutrients below ground. Hence, the aim of the present study is to investigate the effects of seedling spacing on morphological characteristics of one-year-old *A. communis*, *P. avium*, *P. elaeagnifolia*, and *E. tribolatus* seedlings under nursery conditions.

Materials and Methods

Fruits were collected from natural populations of the species in the Isparta Forest District Directorate in Turkey between July and October of 2005 (*A. communis*-37°51’ N, 30°47’ E, 1050 m asl.; *P. avium*-37°51’ N, 30°57’ E, 1,200 m asl.; *P. elaeagnifolia*-37°43’ N, 30°49’ E, 1,250 m asl. and *E. tribolatus*-38°01’ N, 30°48’ E, 1,000 m asl.). They were obtained from 20 individuals per species keeping a minimum distance of 30m between trees. Seeds from the fruits of individual trees were mixed and randomly selected for each experiment. These seeds were kept at 4 ± 1°C in a refrigerator before sowing them in the field in November of 2005. The study was conducted in the Eğirdir Forest Nursery-Turkey (37°53’ N, 30°52’ E, 926 m asl). The nursery soil was sandy clay loam with a soil pH of 6.8-7.8 in the rooting zone (Özçelik and Özkan, 1997). Annual precipitation average is about 76.3 cm with an average temperature of 13°C (Anonymous, 2006). The growing season is about 210-220 days long.

The study was laid out using a completely randomized block design with four replications by using marked sticks in April 2006. Sowing depths used for *A. communis*, *P. avium*, *P. elaeagnifolia* and *E. tribolatus* were 20, 10, 20 and 4 mm, respectively. The distance between two rows was constant (20 cm). Each seed-bed was oriented in east-west direction in the nursery and had five rows and a standard width of 1.2 m. Three seedling spacings were investigated by varying the number of plants within rows (Table 1). Cultivation activities such as irrigation (twice a day by sprinkling) and weed control (manually once a month) were regularly performed for each seed-bed in the nursery during the growing season of 2006. In November of 2006 a total of 240 seedlings (60 seedlings for each experimental treatment) were uprooted from each species without harming the roots. The hand-lifted seedlings were examined in terms of morphological traits, such as shoot height (SH), root collar diameter (RCD), tap root length (TRL) and fine root number (FRN, diameter < 2 mm). Assessments of cull seedling (root collar diameter < 4 mm and shoot height < 30 cm) ratios were also performed in accordance with the Turkish Standards Institute (TSI) guidelines (Anonymous, 1988). The survival rate after one year was 100 % for each treat-

Table 1. Seedbed density treatments

Seedbed density treatments	Seedbed density (seedlings/m²)	Row density (seedlings/m)	Seedling spacing (cm)
D1	40	8	12
D2	65	13	8
D3	125	25	4

ment and species. Statistical analysis was carried out by using SPSS (SPSS Inc., 2002). Before analysis, square-root transformation was performed for fine root number. An ANOVA was performed to determine whether or not the means of treatments were all equal. The means were compared by using the adjusted Duncan's multiple range test ($p < 0.05$). In addition, correlations between pairs of the measured seedling traits for each component were evaluated by using Pearson's correlation coefficients.

Results

In *A. communis*, lowering seedbed density increased SH and RCD, while TRL and FRN were not affected (Table 2). The highest values for SH and RCD were observed for treatment D1 (lowest seedling density). Only minor differences in mean values were recorded between treatment D2 and D3. In *P. avium*, significant differences among treatments were found for SH, RCD, and FRN but not for TRL (Table 2). Increasing seedling space had positive effects on SH, RCD, and FRN but no effect on TRL. The highest values in SH and RCD were found for treatment D2 (intermediate seedling density). Mean values of FRN were significantly higher for treatments D1 and D2 than for treatment D3 (high density). For *P. elaeagnifolia*, there were no significant differences between treatments in SH, TRL and FRN (Table 2). A negative effect of higher seedling density was only detected for RCD ($p < 0.05$). The highest values for all the variables were detected in the D1 treatment. Although there was no statistically significant difference among treatments for most traits, all the characteristics were positively affected by increasing seedling space. In *E. tribolatus,* increasing seedling space had no positive effect on any of the morphological variables, but a negative effect on TRL ($p < 0.05$, Table 2). Pearson's correlation coefficients among pairs of characters (Table 3) revealed positive correlations

Table 2. Effects of seedbed density on various seedling morphological characteristics of species (RCD: root collar diameter, SH: shoot height, TRL: the tap root length, FRN: fine root number)

Species	Treatments	SH (cm)	RCD (mm)	TRL (cm)	FRN²
		ANOVA sig.			
		$p < 0.05$	**$p < 0.001$**	**$p > 0.05$**	**$p > 0.05$**
Amygdalus communis L.	D1	79.20a[1]	4.24a	28.97a	3.50a
	D2	72.92ab	3.66b	27.64a	3.60a
	D3	72.17b	3.68b	26.64a	3.59a
		$p < 0.05$	**$p < 0.01$**	**$p > 0.05$**	**$p < 0.01$**
Prunus avium (L.) L.	D1	77.05ab	7.54ab	29.72a	3.76a
	D2	79.82a	8.04a	31.41a	3.70a
	D3	71.75b	6.97b	30.92a	3.46b
		$p > 0.05$	**$p < 0.05$**	**$p > 0.05$**	**$p > 0.05$**
Pyrus elaeagnifolia Pall.	D1	65.33a	7.41a	31.42a	3.12a
	D2	61.17a	6.74ab	30.80a	3.03a
	D3	60.57a	6.43b	29.38a	2.98a
		$p > 0.05$	**$p > 0.05$**	**$p < 0.05$**	**$p > 0.05$**
Eriolobus trilobatus (Poiret) Roemer.	D1	47.55a	3.87a	24.56b	2.19a
	D2	44.80a	3.75a	24.05b	2.32a
	D3	48.90a	3.71a	26.87a	2.18a

[1] Means within each column followed by the same letter are not significantly different ($p < 0.05$); 2: Transformed data (logged) was used for mean separations.

Table 3. Pearson coefficient of correlation between pairs of characteristics of the seedlings by species

		SH[1]	RCD	TRL	FRN
	SH	1.000			
Amygdalus communis L.	RCD	0.512***	1.000		
	TRL	0.666***	0.303^{***}	1.000	
	FRN	0.344^{***}	0.456^{***}	0.177^{**}	1.000
	SH	1.000			
Prunus avium (L.) L.	RCD	0.761^{***}	1.000		
	TRL	0.508^{***}	0.249^{***}	1.000	
	FRN	0.449^{***}	0.464^{***}	0.048^{ns}	1.000
	SH	1.000			
Pyrus elaeagnifolia Pall.	RCD	0.734^{***}	1.000		
	TRL	0.627^{***}	0.273^{***}	1.000	
	FRN	0.429^{***}	0.670^{***}	0.072^{ns}	1.000
	SH	1.000			
Eriolobus trilobatus (Poiret)	RCD	0.808^{***}	1.000		
Roemer.	TRL	0.650^{***}	0.459^{***}	1.000	
	FRN	0.287^{***}	0.482^{***}	0.168^{**}	1.000

[1] SH: Seedling height; RCD: Root collar diameter; TRL: Tap root lenght and FRN: Fine root number; Correlation is significant at 0.01 (**) and 0.001 (***) levels (2-tailed). ^{ns} Correlation is non-significant.

($p \leq 0.05$) between the investigated seedling characteristics for each species. Specifically, strong and significant correlations were observed for all species between SH and RCD (see also Bilir *et al*., 2010).

Discussion

For all four species strong positive correlations were found between root characters TRL and FRN on the one hand and SH and RCD on the other hand. TRL showed the highest correlation with SH, and FRN the highest correlation with RCD. Deep tap-rooted species are advantaged in terms of water uptake, since they can deploy fine-roots in deeper parts of the soil (Yamada *et al*., 2005). Also some hardwood seedlings with larger lateral roots had better survival (Ponder Jr., 1997).

All growth characteristics, except for *E. trilobatus*, were negatively affected by decreasing seedling spacing. In *A. communis* and *P. avium*, spacing within rows significantly affected RCD, SH, TRL and FRN, but not in *P. elaeagnifolia* and *E. tribolatus*. This study showed that several growth characteristics of seedlings were negatively affected as seedling density increased. This can be explained by the increasing competition among the seedlings for light, water, and nutrition with increasing seedling density. In general, increasing seedling space resulted in more qualified seedlings. Similar results have been found previously for other tree species such as *Pinus brutia* Ten. (Keskin, 1992), *Ailanthus altissima* (Miller) Swingle (Cengiz and Şahin, 2002), *Fraxinus angustifolia* Vahl. (Çiçek *et al*., 2007), *Robinia pseudoacacia* L. (Semerci *et al*., 2008) although some exceptions such as for *Pyrus* spp. (Palmer *et al*., 1994) and *Quercus* spp. (Mishra and Feret, 1996) have been reported.

TSI standards are available only for *A. communis*. Thus, these standards were also used for assessing variables of the other studied species. When the cull seedlings for *A. communis* were investigated according to TSI standards, it was observed that the closest seedling spacing yielded cull seedlings in terms of their root collar diameter. However, all the seedlings of *P. avium* and *P. elaeagnifolia* were found suitable for the category of the first seedling grade class indicated by TSI standards, and they contained no cull. Regardless of the seedbed density, all the seedlings of both species grown were suitable for planting according to TSI standards. On the other hand, even *E. trilobatus* seedlings produced with the highest seedling spacing did not satisfy TSI requirements. In addition, larger seedlings produced in lower density seedbeds could provide significant advantages since expensive cultural activities are reduced. Furthermore, higher survival rates and a better growth are expected for larger seedlings (see also Özpay and Tosun, 1993). As a conclusion, it would be beneficial to use wider seedling spacing in order to obtain qualified seedlings in *A. communis* and *P. avium*.

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