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Influence of Container Type and Growing Media on Seedling Growth of *Pinus sylvestris* in the Nursery

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Abstract
Type of container and growing media are two important factors that affect seedling quality. The present study aimed to evaluate the effects of the growing media (local peat sources and Finnish peat) and Enso tube containers (type with vertical slits and rocket type) on the morphological attributes of two-year-old container-grown *Pinus sylvestris* L. seedlings using a completely randomised block experimental design in the nursery. Both container types and growing media significantly affected some seedling morphological attributes such as seedling height (SH), root collar diameter (RCD), the Dickson quality index (DQI), shoot and root dry weights (SDW and RDW, respectively), and sturdiness quotient (SQ) of *P. sylvestris* seedlings. When the containers were evaluated, the fixed Enso container type with greater volumes, which has vertical slits on the sidewalls, gave better results in terms of most measured seedling morphological characteristics than the Enso-rocket container type with smooth walls. It was also determined that the growing media significantly affected *P. sylvestris* seedlings' morphological indices, and low growing media acidity because high local peat pH decreased some morphological quality attributes of *P. sylvestris* seedlings. The results suggest that lowering local peat pH can increase the potential of local peat as a Finnish peat substitute in container growing media for *P. sylvestris* seedling production.

Keywords: acidity, morphological attributes, peat, Scots pine, seedling quality

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INTRODUCTION

Nursery management practices affect seedling quality attributes (Aphalo and Rikala 2003, Aghai et al. 2014), and assessment of seedling quality characteristics at the seedling stage could help to predict their field growth and survival (Mattsson 1996, Aytas and Tilki 2012, Tian et al. 2017, Grossnickle and MacDonald 2018).

Several parameters are used to determine seedling morphological and physiological qualities in relation to field performance. Most of the parameters are based on seedling morphological attributes and are well correlated with outplanting performance (Thompson 1985, Aphalo and Rikala 2003, Tsakaldami et al. 2013).

Seedling height and root collar diameter are commonly used criteria to classify seedling quality. They are easily measurable and have a significant impact on field performance (Mexal and Landis 1990, Dey and Parker 1997, Haase 2008, Tsakaladami et al. 2013). Total seedling dry weight is a fundamental measure of growth, and high dry weight values of seedlings are better. Shoot/root ratio and sturdiness quotient are also important parameters for seedling growth and survival. Low values of these parameters may be favorable for dry sites (Thompson 1985, Aphalo and Rikala 2003, Close et al. 2010, Ivetic et al. 2016). The Dickson quality index (DQI) indicates plant field performance, and high DQI values indicate better performance (Manas et al. 2009, Tsakaldimi et al. 2013, Grossnickle and MacDonald 2018).

Many studies show that container variables, such as shape, color, size, and design characteristics influence seedling attributes in nursery (South et al. 2005, Close et al. 2010, Aghai et al. 2014, Kolevska et al. 2020). The morphology and design of a container are also important because they determines the seedling quality, primarily in terms of their root systems (Landis et al. 1990, Rune 2003, Dominguez-Lerena et al. 2006, Sanchez-Aguilar et al. 2016, Tian et al. 2017).

Container volume significantly affected plant morphology of several species. Consequently, seedlings grown in containers with larger rooting volume had significantly larger heights and diameters in nursery, and larger container volumes usually correlate better with field performance (Sutherland and Day 1988, Dey and Parker 1997, Aphalo and Rikala 2003, South et al. 2005).

Container growing media are very important for seedling quality, and peat is the most important of the materials used for making container medium in nurseries, either alone or mixed with other materials (Landis et al. 1990, Manas et al. 2009, Blok et al. 2021). However, as a result of an increase in sphagnum peat costs, a decrease in the amount of sphagnum peat, and increasing concern about over extraction of peat (Landis et al. 1990, Manas et al. 2009, Heiskanen, 2013, Barrett et al. 2016), seedling producers are seeking more locally available growing media in many countries including Türkiye. As a result, various alternative materials, including local peat, sawmill residues, biosludge, chicken manure, rice husks, wood fiber, bark, natural zeolit, and compost have been tested as components of nursery substrates in different proportions (Kahraman and Guclu 2001, Ayan and Tilki 2007, Manas et al. 2009, Tilki and Doganay 2015, Tian et al. 2017, Heiskanen et al. 2024).

Since growing media and container type have great impact on seedling quality, the objectives of this study are to: (1) evaluate the suitability of local peats from Türkiye (Patnos-Agri and Karacoban-Erzurum) as components of container media for two-year-old *Pinus sylvestris* L. (Scots pine) seedlings, and (2) assess the influence of container type on seedling morphological characteristics during nursery culture.

MATERIALS AND METHODS

The experiment was carried out in Erzurum Forest Nursery, Türkiye, using Finnish-style greenhouses to grow *P. sylvestris* seedlings, one of the important tree species raised in containers in that nursery. The nursery is located at 1850 m above sea level, with a general orientation to the northwest. The seeds were collected from the seed collection areas determined by the Forest Nursery Directorate in the central districts of the Erzurum province.

In the study, 15 different growing media were created from Karacoban (Erzurum-Türkiye), Patnos (Agri-Türkiye) and low-humified Finland's sphagnum peat with 25% mixture ratios (0, 25, 50 or 100% by volume). After preparing the growing media, their chemical and physical properties were determined. Variations in the measured characteristics of the growing medium arise from the differing plant species involved in peat formation at the source of the indigenous peat, which consequently alter the rate of decomposition (Table 1).

Organic matter content using the Walkley-Black method was determined (Nelson and Sommers 1996). Brayl procedure was used to determine phosphorus content (Kalra and Maynard 1991), and pH of the growing medium was measured in a soil water suspension (soil-solution ratio 1:2.5) using a *pH*-meter. Exchangeable cations were measured by using atomic absorption spectrophotometer (Kacar 1996).

Containers were filled with 15 different growing media mixes. Three seeds were sown per cell in two types of circular-section container tubes (Enso and Enso-rocket), differing in design and volume. The first of the container types were used is the Enso type container. One plastic tray contains 45 fixed cells with a volume of 0.220 dm^3 (height: 5 cm, upper diameter: 16 cm) with vertical slits in the sidewalls to improve root structure. The second container type model used in the research was Enso-rocket tube type. In this container type, seedling tray contains 45 cells without internal vertical groove with a tube volume of 0.172 dm^3 (height: 5 cm, upper diameter: 12 cm). Tubes are hard plastic and have a smooth inner surface. A total of 95% of *P. sylvestris* seeds were germinated in containers. The germlings were thinned to allow only the most vigorous seedling per cell to grow after the germination of the seeds.

Seedlings were watered as needed to maintain sufficient moisture for continuous growth. A total of 135 g of NPK compound fertilizers was applied per m^2 (15 g m^{-2} in August, 70 g m^{-2} in September, 50 g m^{-2} in October), containing macronutrients and micronutriens (Table 2). After 45 days of growing, containers were put on the overhead wire grid for air pruning outdoors. During the nursery stage, normal management practices (irrigation, fertilization, weeding) were carried out.

Table 1 The properties of substrates used in the experiment.

Growing medium	pH	Organic matter	Water holding capacity	Ca	Mg	P	K
	-	%	%	me/lt	me/lt	ppm	ppm
p0k1f3	6.59	31.64	0.185	54.64	11.59	59.86	98.79
p0k0f4	5.27	36.31	0.145	58.81	14.74	72.57	75.72
p0k4f0	7.53	27.59	0.184	61.59	11.86	34.78	58.41
p0k3f1	7.70	38.17	0.182	61.39	24.50	23.88	49.97
p0k2f2	6.56	38.49	0.182	49.17	10.63	53.89	110.77
p1k1f2	7.05	32.26	0.166	44.01	17.70	70.95	86.99
p1k2f1	7.55	26.97	0.177	49.67	12.84	82.93	95.46
p1k0f3	7.51	27.59	0.180	46.89	7.59	62.46	89.01
p1k3f0	6.46	24.79	0.137	39.24	10.93	78.08	90.71
p2k1f1	7.20	24.48	0.185	47.48	11.21	92.6	83.69
p2k2f0	7.60	29.15	0.186	38.35	20.35	87.45	125.62
p2k0f2	6.80	21.06	0.188	31.19	17.47	34.48	97.66
p3k1f0	7.44	26.66	0.186	38.25	19.75	99.78	84.90
p3k0f1	7.20	27.59	0.190	29.21	19.16	85.27	94.44
p4k0f0	7.35	21.99	0.191	28.91	18.25	78.11	92.12

Which: p: Patnos peat, k: Karacoban peat, f: Finland peat, 0: 0%, 1: 25%, 2: 50%, 3: 75%, 4: 100%.

Ten seedlings at random from each replication of each treatment were sampled and root collar diameter (RCD, ±0.01 mm) and seedling height (SH, ±0.1 cm) of fresh seedlings were measured. Then, the shoot and roots were separated (cut) at root collar, and shoot and root dry weights (SDW and RDW, respectively) were determined after the end of the second growing season. After carefully washing root systems free of all media, SDW and RDW were measured with accuracy of 0.001 g after drying the plant material for 24 h at 105°C. Using these measurement values, sturdiness quotient (SQ) and the Dickson quality index (DQI) were determined.

Sturdiness quotient (SQ) was quantified as the ratio of height (cm) to root collar diameter (mm) (Aphalo and Rikala 2003). The Dickson quality index (DQI) was calculated according to Dickson et al. (1960) using the formula: DQI = total dry weight, g / [(shoot height, cm / root collar diameter, mm) + (shoot dry weight, g / root dry weight, g)].

The experiment followed a randomized complete block design (RCBD) with two container types and 15 growing media treatments, each replicated three times. Data were analyzed using analysis of variance (ANOVA), and treatment means were compared using Duncan's multiple range test at a significance level of $p \leq 0.05$ (Zar 1996).

RESULTS

Table 2 Treatment of dose and application times of NPK-compound fertilizer.

Application time	Chemical content
May–June	NPK (13:40:13) + micronutrient
July–August	NPK (20:20:20) + micronutrient
September	NPK (19:6:20) + micronutrient
October–until the end of the vegetation season	NPK (0:25:36) + micronutrient

Effects of Container Type and Growing Media on SH and RCD

Analysis of variance showed that both container type and growing media significantly affected SH and RCD of the seedlings. However, there was not a significant interaction between container type and growing medium for seedling height and root collar diameter. When the container types were analyzed, higher average SH of *P. sylvestris* was obtained in Enso tube containerized seedlings (15.60 cm) compared to the average of 15 different media. *Pinus sylvestris* seedlings grown in Enso tube containers were about 10% taller (Table 3). Among growing media, the seedling height was the greatest (20.33 cm) when seedlings were grown in p0k0f4 growing medium, followed by p1k0f3 and p0k1f3, with the shortest seedlings grown in p0k4f0 (12.86 cm).

When RCD was evaluated, the Enso tube containerised seedlings had a higher average RCD when averaged over 15 different treatments (3.84 mm). Growing media also significantly affected ($p < 0.05$) RCD, and the highest RCD was measured as 4.74 mm in p0k0f4 growing medium followed by the p2k0f2 growing medium (4.53 mm), while the lowest RCD was found in the p4k0f0 and p3k0f1 growing media (3.93 and 3.86 mm, respectively) (Table 3).

Effects of Container Type and Growing Media on SDW and RDW

Statistical analysis showed that the type of container and growing media significantly affected ($p < 0.05$) SDW and RDW (Table 4). SDW was 9.5% greater and RDW was 10.2% greater for the *P. sylvestris* seedlings grown in Enso tube containers compared to the seedlings in Enso-rocket tube containers.

There was a significant interaction between types of container and growing media for these parameters. Among

Table 3 Effects of container type and growing media on SH and RCD.

Growing medium	SH (cm)			RCD (mm)		
	Enso	Enso- rocket	Mean	Enso	Enso- rocket	Mean
p0k1f3	19.77	18.56	19.17 b	4.37	4.06	4.22 d
p0k0f4	20.92	19.74	20.33 a	4.86	4.61	4.74 a
p0k4f0	13.59	12.12	12.86 h	3.50	3.25	3.38 g
p0k3f1	14.04	12.79	13.42 g	3.38	3.08	3.23 h
p0k2f2	16.87	15.97	16.42 c	3.95	3.54	3.75 f
p1k1f2	15.82	14.56	15.19 e	4.45	4.02	4.23 d
p1k2f1	14.46	12.58	13.52 g	3.47	3.09	3.28 h
p1k0f3	20.96	17.63	19.30 b	4.73	3.98	4.36 c
p1k3f0	14.74	13.57	14.16 f	2.93	2.69	2.81 j
p2k1f1	15.82	13.59	14.71 e	3.11	2.77	2.94 i
p2k2f0	15.31	13.47	14.39 ef	3.19	2.81	3.00 i
p2k0f2	15.07	14.00	14.54 ef	4.72	4.33	4.53 b
p3k1f0	14.12	12.17	13.15 gh	3.28	2.82	3.05 i
p3k0f1	16.88	16.18	16.53 c	3.92	3.80	3.86 e
p4k0f0	16.61	15.13	15.87 d	4.10	3.75	3.93 e
Mean	15.60 A	14.19 B		3.84 A	3.50 B	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly ($p \leq 0.05$).

container types, higher average SDW of the seedlings (2.07 g) was obtained in the Enso container type, averaged over 15 different growing media. Considering the seedling growing environments, the highest SDW was measured as 3.17 g in p0k0f4, followed by the growing media of p1k0f3, p0k2f2, p3k0f1 and p4k0f0, while the lowest SDW was measured as 1.57 g and 1.53 g in p1k3f0 and p1k2f1 growing medium, respectively, according to the average of two different container types (Table 4).

Considering the container types, higher average RDW was obtained in the Enso containerized seedlings, averaged over growing media (1.29 g). Among the growing media, according to the average of two different container types, the highest RDW was measured as 2.10 g in p0k0f4 growing medium followed by the p1k0f3 growing medium, while the lowest RDW was measured as 0.72 g in the p0k4f0 growing medium (Table 4).

Table 4 Effects of container type and growing media on SDW and RDW.

Growing medium	SDW (g)			RDW (g)		
	Enso	Enso- rocket	Mean	Enso	Enso- rocket	Mean
p0k1f3	2.31	2.16	2.24 bc	1.69	1.59	1.64 b
p0k0f4	3.25	3.09	3.17 a	2.16	2.04	2.10 a
p0k4f0	1.29	1.15	1.22 g	0.76	0.68	0.72 h
p0k3f1	1.56	1.42	1.49 f	0.94	0.87	0.91 g
p0k2f2	2.51	2.38	2.45 b	1.47	1.39	1.43 bc
p1k1f2	2.09	1.88	1.99 cd	1.32	1.20	1.26 de
p1k2f1	1.63	1.43	1.53 f	1.00	0.91	0.96 fg
p1k0f3	2.61	2.19	2.40 b	1.85	1.55	1.70 b
p1k3f0	1.63	1.51	1.57 f	1.07	0.99	1.03 fg
p2k1f1	1.82	1.60	1.71 e	1.27	1.11	1.19 de
p2k2f0	1.81	1.59	1.70 e	1.45	1.28	1.37 cd
p2k0f2	1.89	1.74	1.82 de	1.13	1.03	1.08 ef
p3k1f0	1.84	1.58	1.71 e	1.46	1.26	1.36 cd
p3k0f1	2.35	2.28	2.32 b	1.22	1.18	1.20 de
p4k0f0	2.48	2.26	2.37 b	1.20	1.12	1.16 ef
Mean	2.07 A	1.89 B		1.29 A	1.17 B	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly ($p \leq 0.05$).

Effects of Container Type and Growing Media on SQ and DQI

SQ of *P. sylvestris* seedlings was not affected by container type, while growing media significantly affected SQ value of the seedlings. Considering the growing media, the highest SQ was measured as 5.05 and 5.01 in p1k3f0 and p2k1f1 growing media, respectively, followed by the p2k2f0 growing medium (4.80), while the lowest SQ value was 4.06 in the p4k0f0 growing medium, according to the average of two different container types (Table 5).

Container type and growing media significantly affected ($p < 0.05$) DQI of the seedlings. *Pinus sylvestris* seedlings grown in the Enso type container had greater DQI (0.83) according to the average of 15 different growing media compared to the seedlings grown in the Enso-rocket tube containers. DQI was 10.6% greater for the seedlings grown in Enso tube containers compared to seedlings in Enso-rocket tube containers. With regard to growing media, according to the average of the two different container types, the highest DQI was measured as 1.23 in the p0k0f4 growing medium, while the lowest DQI was measured as in the range of 0.51–0.58 in p0k4f0, p0k3f1, p1k2f1 and p1k3f0, p2k1f1, p2k2f0 growing media, according to the average of two different container types (Table 5).

Table 5 Efects of container type and growing media on SQ and DQI of seedlings

Growing medium	SQ			DQI		
	Enso	Enso- rocket	Mean	Enso	Enso- rocket	Mean
p0k1f3	4.54	4.59	4.56 c	0.89	0.82	0.85 c
p0k0f4	4.30	4.28	4.29 de	1.26	1.20	1.23 a
p0k4f0	3.91	3.75	3.83 g	0.53	0.49	0.51 e
p0k3f1	4.18	4.18	4.18 ef	0.60	0.55	0.58 e
p0k2f2	4.28	4.51	4.40 cd	0.93	0.83	0.88 b
p1k1f2	3.57	3.63	3.60 h	0.96	0.85	0.91 b
p1k2f1	4.18	4.09	4.13 ef	0.63	0.58	0.60 e
p1k0f3	4.43	4.43	4.43 cd	1.01	0.85	0.93 b
p1k3f0	5.05	5.05	5.05 a	0.54	0.49	0.52 e
p2k1f1	5.10	4.92	5.01 a	0.61	0.55	0.58 e
p2k2f0	4.81	4.79	4.80 b	0.68	0.60	0.64 de
p2k0f2	3.20	3.24	3.22 i	0.95	0.86	0.90 b
p3k1f0	4.31	4.32	4.31 de	0.77	0.66	0.71 cd
p3k0f1	4.32	4.26	4.29 de	0.83	0.82	0.82 bc
p4k0f0	4.07	4.05	4.06 f	0.91	0.84	0.87 b
Mean	4.14 A	4.13 A		0.83 A	0.75 B	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly ($p \leq 0.05$).

DISCUSSION

Determination of seedling quality attributes is very important in forest practice, as seedling morphology at lifting would be a good predictor of seedling performance in field (Mattsson 1996, Dey and Parker 1997, Bayala et al. 2009, Aytas and Tilki 2012, Tsakaldimi et al. 2013). In the present study, container shape and volume affected morphological attributes of *P. sylvestris* seedlings. Similar findings were reported for *Pinus pinea* L. (Dominguez-Lerena et al. 2006), *Cupressus sempervirens* L. (Topic et al. 2009), *Larix occidentalis* Nutt. (Aghai et al. 2014), *Pinus halepensis* Mill. (Singh et al. 2018), *Pinus occidentalis* Sw. (Hubbel et al. 2018), *Quercus robur* L. (Mijatovic et al. 2022), and *Ulmus glabra* Huds. (Er and Tilki 2023).

When comparing larger fixed Enso container type to Enso-rocket tube type with smooth walls, the larger Enso container type with vertical slits, which potentially deters root spiralling and forces the seedling roots to grow downward, increased height, diameter, root dry weight and DQI of the seedlings. The type and size of the container determine not only the roots' development, but also nutrient and water availability.

Morphological parameters of the two-year-old seedlings of *P. sylvestris* were also affected by growing media. Although peat is the most popular component in both greenhouse and nursery mixes, seedling growers have been trying to create their own media using locally available growing media components in many countries and also in Türkiye, and some previous research have shown that some organic and inorganic compounds (fine quartz, sewage sludge, sawmill residues, compost, diatomite, wood chips, perlite, local peat and many other substitutes in different proportions) can be substituted for peat (Landis et al. 1990, Ingelmo et al. 1998, Manas et al. 2010, Heiskanen 2013, Memisoglu and Tilki 2014, Hubbel et al. 2018, Kose et al. 2020).

In the present study, the highest SH, RCD, dry weight and DQI of *P. sylvestris* seedlings were found in pure sphagnum peat (p0k0f4 growing media). The pH of 5.27 of the p0k0f4 growing medium may have contributed to increased seedling attributes. Growing media acidity has been shown to be very important to successful conifer growth (Gilmore 1972, South 2017), and most studies showed that pH higher than 6.0 is not optimal for growing most pine species as well as Scots pine seedlings in nurseries (Carter 1987, Marx 1990, South 2017). The domestic peat with high pH reduced the morphological quality attributes of *P. sylvestris* seedlings significantly in this study. Lowering local peat pH with sulphur or ammonium sulphate can increase container-grown seedling quality of *P. sylvestris*, and domestic peat with pH around 5.5 can mix with imported Finnish peat. Er and Tilki (2023) found that the use of domestic peat from Türkiye with pH higher than 5.5 mixed with imported Finnish peat in proportion of up to 50% had positive results in terms of container seedling production of *Ulmus glabra*, as found in previous studies that most container-grown hardwoods grew best at pH higher than 5.5 (Salifu et al. 2006, Zhang et al. 2016).

CONCLUSIONS

The present study showed that both container types and growing media had a significant effect on the seedling growth attributes of *P. sylvestris* (two-year-old). Since higher seedling height, root collar diameter, total dry weight and the Dickson quality index may be an indication of high seedling quality, the results in this study suggest that the larger fixed Enso container type, which has vertical slits on the sidewalls, produced higher-quality seedlings that can perform better, especially in adverse environmental conditions of plant establishment. In terms of growing media, high pH of the growing media mixes decreased the morphological quality of *P. sylvestris* seedlings. Thus, the results suggest that the pH of domestic peat should be lowered to around 5.5 with ammonium sulphate or sulphuric acid to increase the ratio of local peat in the growing media mixes for *P. sylvestris* seedling production.

REFERENCES

- Aghai, M.M., J.R. Pinto, A.S. Davis, 2014: Container volume and growing density influence western larch (*Larix occidentalis* Nutt.) seedling development during nursery culture and establishment. New Forests 45: 199–213. https://doi.org/10.1007/s11056-013-9402-8
- Aphalo, P., R. Rikala, 2003: Field performance of silver-birch planting-stock grown at different spacing and in containers of different volume. New Forests 25: 93–108. https://doi.org/10.1023/A:1022618810937
- Ayan, S., F. Tilki, 2007: Morphological attributes of oriental spruce [*Picea orientalis* (L.) Link.] seedlings grown in peat-based media amended with natural zeolite. Acta Agronomica Hungarica 55 (3): 363–373. https://doi.org/10.1556/AAgr.55.2007.3.13
- Aytas, V., F. Tilki, 2012: Effects of seedling type and planting time on field performance of Scots pine (*Pinus sylvestris* L.) seedlings in Tortum-Erzurum. Artvin Coruh Universitesi Orman Fakultesi Dergisi 13: 13–24.
- Bayala, J., M. Dianda, J. Wilson, S. Ouedraogo, K. Sanon, 2009: Predicting field performance of five irrigated tree species using seedling quality assessment in Burkina Faso, West Africa. New Forests 38: 309–322. https://doi.org/10.1007/s11056-009-9149-4
- Blok, C., B. Eveleens, A. van Winkel, 2021: Growing media for food and quality of life in the period 2020–2050. Acta Horticulturae 1305: 341–356.https://doi.org/10.17660/ActaHortic.2021.1305.46
- Carter, M.R., 1987: Seedling growth and mineral nutrition of Scots pine under acidic to calcareous soil conditions. Soil Science 144: 165–180. https://doi.org/10.1097/00010694-198709000-00003
- Close, D.C., S. Paterson, R. Corkrey, C. McArthur, 2010: Influences of seedling size, container type and mammal browsing on the establishment of *Eucalyptus globulus* in plantation forestry. New Forests 39: 105–115. https://doi.org/10.1007/s11056-009-9158-3
- Dey, D.C., W.C. Parker, 1997: Morphological indicators of stock quality and field performance of red oak (*Quercus rubra* L.) seedlings underplanted in a central Ontario shelterwood. New Forests 14: 145–156. https://doi.org/10.1023/A:1006577201244
- Dickson, A., A.L. Leaf, J.F. Hosner, 1960: Quality appraisal of white spruce and white pine seedling stock in nurseries. The Forestry Chronicle 36 (1): 10–13.
- Dominguez-Lerena, S., N.H. Sierra, I.C. Manzano, L.O. Bueno, J.P. Rubira, J.P. Mexal, 2006: Container characteristics influence *Pinus pinea* seedling development in the nursery and field. Forest Ecology and Management 221: 63–71. https://doi.10.1016/j.foreco.2005.08.031
- Er, O., F. Tilki, 2023: Influence of container type and growth medium on morphological attributes of *Ulmus glabra* seedlings. In: Proceeding Book of the 14th International Conference on Applied Sciences, Batumi, Georgia, October 13–15, 2023, pp. 227–238.
- Gilmore, A.R., 1972: Liming retards height growth of young shortleaf pine. Soil Science 113: 448–452.
- Grossnickle, S., J.E. MacDonald, 2018: Seedling quality: history, application, and plant attributes. Forests 9: 283. https://doi.org/10.3390/f9050283
- Haase, D.L., 2008: Understanding forest seedling quality: measurements and interpretation, Tree Planters' Notes 52 (2): 24–30.
- Hanson, P.J., R.K. Dixon, R.E. Dickson, 1987: Effect of container size and shape on the growth of northern red oak seedlings. HortScience 22: 1293–1295.
- Heiskanen, J., 2013: Effects of compost additive in sphagnum peat growing medium on Norway spruce container seedlings. New Forests 44: 101–118. https://doi.org/10.1007/s11056-011-9304-6
- Heiskanen, J., H. Ruhanen, K. Himanen, M. Kivimaenpaa, N. Silvan, 2024: Growth of Nordic container forest tree seedlings in some peatless and peat-reduced growing media. New Forests 55: 1499–1517. https://doi.org/10.1007/s11056-024-10048-8
- Hubbel K.L., A.L. Ross-Davis, J.R. Pinto, O.T. Burney, A.S. Davis, 2018: Toward sustainable cultivation of *Pinus occidentalis* Swartz in Haiti: effects of alternative growing media and containers on seedling growth and foliar chemistry. Forests 9 (7): 422. https://doi.org/10.3390/f9070422
- Ingelmo, F., R. Canet, M.A. Ibanez, F. Pomares, J. Garcia, 1998: Use of MSW compost, dried sewage sludge and other wastes as partial substitutes for peat and soil. Bioresource Technology 63: 123–129. https://doi.org/10.1016/S0960-8524(97)00105-3
- Ivetic, V., S. Grossnickle, M. Škoric, 2016: Forecasting the field performance of Austrian pine seedlings using morphological attributes. iForest 10: 99–107. https://doi.org/10.3832/ifor1722-009.
- Kahraman, I.M., K. Guclu, 2001: The research on usage probabilities of some peat materials placing in Erzurum and environments as growing medium in pot plants. Atatürk Universitesi Ziraat Fakultesi Dergisi 32: 189–195.
- Kolevska, D.D., A. Dimitrova, K. Cokoski, M. Basova, 2020: Growth and quality of *Pinus nigra* (Arn.), *Pinus sylvestris* (L.) and *Pinus pinaster* (Aiton) seedlings in two container types. Reforesta 9: 21–36. https://doi.org/10.21750/Refor.9.04.78
- Kose, M., C. Ugurlu, O. Oncul, F. Demirci, I. Angin, 2020: The use of sewage sludge and diatomite as growing medium in Scots pine (*Pinus sylvestrıs* L.) seedling production and evaluation of its land performance. Šumarski list 144 (11–12): 559–564. https://doi.org/10.31298/sl.144.11-12.3
- Landis, T.D, R.W. Tinus, S.E. McDonald, J.P. Barnett, 1990: Containers and growing media. The Container Tree Nursery Manual. Vol. 2. USDA, For. Serv., Agriculture Handbook 674. Washington DC.
- Manas, P., E. Castro, J. De las Heras, 2009: Quality of maritime pine (*Pinus pinaster* Ait.) seedlings using waste materials as nursery growing media. New Forests 37: 295–311. https://doi.org/10.1007/s11056-008-9125-4
- Manas, P., E. Castro, P. Vila, J. De las Heras, 2010: Use of waste materials as nursery growing media for *Pinus halepensis* production. European Journal of Forest Research 129: 521–530. https://doi.org/10.1007/s10342-009-0349-4

- Marx, D.H., 1990: Soil pH and nitrogen influence *Pisolithus* ectomycorrhizal development and growth of loblolly pine seedlings. Forest Science 36: 224–245.
- Mattsson, A. 1996: Predicting field performance using seedling quality assessment. New Forests 33: 223–248. https://doi.org/10.1023/A:1006590409595
- Memisoglu, T., F. Tilki, 2014: Growth of scots pine and silver birch seedlings on different nursery container media. Notulae Botanicae Horti Agrobotanici 42 (2): 565–572. https://doi.org/10.15835/nbha4229551
- Mexal J.G., T.D. Landis, 1990: Target seedling concepts: height and diameter. In (Rose, R., S.J. Campell, T.D. Landis, eds.): Proceedings of the Target Seedling Symposium: Combined Meeting of Western Forest Nursery Associations, USDA For. Serv. GTR-RM-200, Roseburg, OR, August 13–17, 1990, pp. 17–35. http://www.fcanet.org/proceedings/1990/mexal.pdf
- Mijatović Lj., S. Pavlović, L. Jović, J. Devetaković, D. Vilotić, 2022: Potential of new planting container in *Quercus robur* seedlings production – first report. Reforesta 14: 1–8. https://doi.org/10.21750/refor.14.01.96
- Rose, R., J.S. Ketchum, 2003: Interaction of initial seedling diameter, fertilization, and weed control on Douglas-fir growth over the first four years after planting. Annals of Forest Science 60: 625–635. https://doi.org/10.1051/forest:2003055
- Rune, G., 2003: Slits in container wall improve root structure and stem straightness of outplanted Scots pine seedlings. Silva Fennica 37: 333–342.
- Salifu, K.F., M.S. Nicodemus, D.F., Jacobs, A.S. Davis, 2006: Evaluating chemical indices of growing media for nursery production of *Quercus rubra* seedlings. HortScience 41: 1342–1346. https://doi.org/10.21273/hortsci.41.5.1342
- Sanchez-Aguilar, H., A. Aldrete, J. Vargas-Hernandez, V. Ordaz-Chaparro, 2016: Influence of container type and color on seedling growth of pine in nursery. Agrociencia 50: 481–492.
- Singh, A., M. Husain, S.R. Ali, 2018: Effect of container type and growing media on germination and seedling growth parameters at nursery stage in allepo pine in Kashmir Valley, India. Flora and Fauna 24: 211–217. https://doi.org/10.33451/florafauna.v24i2pp211-217
- South, D.B., S.W. Harris, J.P. Barnett, M.J. Hainds, D.H. Gjerstad, 2005: Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, USA. Forest Ecology and Management 204: 385–398. https://doi.org/10.1016/j.foreco.2004.09.016
- South, D., 2017: Optimum pH for growing pine seedlings. Tree Planter's Notes 60: 49–62.
- Sutherland, D.C., R.J. Day, 1988: Container volume affects survival and growth of white spruce, black spruce and jack pine seedlings: a literature review. Northern Journal of Applied Forestry 5: 185–189. https://doi.org/10.1093/njaf/5.3.185
- Thompson, B.E., 1985: Seedling morphological evaluation: What you can tell by looking. In (Duryea, M.L., ed.): Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. Forest Research Lab., Oregon State Univ., Corvallis, OR, pp. 59–72.
- Tian, N., F. Shengzuo, Y. Wanxia, S. Xulan, F. Xiangxiang, 2017: Influence of container type and growth medium on seedling growth and root morphology of *Cyclocarya paliurus* during nursery culture. Forests 8: 237. https://doi.org/10.3390/f8100387
- Tilki, F., K. Doganay, 2015: Container media affect nursery growth of *Fraxinus excelsior* seedlings. In: The Abstract book of the International Conference on Science, Ecology and Technology I, Vienna, Austria, 25–28 August, 2015, p. 13.
- Topić, V., L. Butorac, Z. Đurdević, B. Kekelić, G. Jelić, 2009: Effect of container type on growth and developtment of seedlings of common cypress (*Cupressus sempervirens* var. *pyramidalis* Nyman) in nurseriers and forest cultures. *Šumarski* list 133 (3–4): 132–134.
- Tsakaldimi, M., P. Ganatsas, D.F. Jacobs, 2013: Prediction of planted seedling survival of five Mediterranean species based on initial seedling morphology. New Forests 44: 327–339. https://doi.org/10.1007/s11056-012-9339-3
- Zar, J., 1996: Bio statistical Analysis, 3rd edition. Prentice-Hall, Inc., Upper Saddle River, NJ.
- Zhang, W., J.J. Zwiazek, 2016: Effects of root medium pH on root water transport and apoplastic pH in redosier dogwood (*Cornus sericea*) and paper birch (*Betula papyrifera*) seedlings. Plant Biology 18: 1001–1007. https://doi.org/10.1111/plb.12483