



Growth and quality of *Pinus nigra* (Arn.), *Pinus sylvestris* (L.) and *Pinus pinaster* (Aiton) seedlings in two container types

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Abstract

In this study we investigated the dynamics of growth and quality features of 1+0 Austrian Pine (AP; *Pinus nigra* Arn.), Scots Pine (SP; *Pinus sylvestris* L.) and Maritime Pine (MP; *Pinus pinaster* Aiton) seedlings in containers Yukosad (YS; hard plastic, 75cm³, 610 seedlings m⁻²) and Siset (SS; gray cardboard with white coating, 128 cm³, 589 seedlings m⁻²). The experiment, for all Pine species, was conducted in randomized blocks in four replications. Each replication contained 10 multipots of each container type. After the seed germination, every 15 days, i.e. 10 times during the vegetation season, 10 seedlings of each of 4 replications, i.e. 40 seedlings of each container and Pine species, were analyzed. The following morphological characteristics were measured: shoot height (SH), root collar diameter (RCD), shoot dry weight (SDW), number, length and dry weight (RDW) of I, II and III order lateral roots (FOLR, SOLR and TOLR) and of the central root. Quality ratios and indexes were calculated. The dynamics of growth of selected features during the vegetation season was expressed as trend lines. AP and SP seedlings, grown in containers YS had higher values of almost all measured traits (SH, RCD, SDW, number, length and dry weight of FOLR, SOLR and TOLR). However, in AP, the SS seedlings had better values of quality indexes and ratios (SQ, DQI, SDW/RDW and RDW/SDW ratio), than YS seedlings. SP seedlings, except for SQ, had better quality indexes in YS container. MP seedlings, with some exceptions, have better above ground quality features in SS containers, while root systems don't differ significantly in both containers. Root quality indicators (root intensity and root bound indexes) are more favorable in SS containers in all Pine species. The polynomial trend lines in AP and SP grow in similar way and intensity in both containers, gradually increasing during the vegetation season. MP seedlings differ in much more intensive growth of above ground features, especially in the half of the vegetative period in both containers, while during this period root quantity and length stagnates. Generally, the quality of AP and SP seedlings is more or less equal and satisfactory in both containers, while MP seedlings show slightly better results in SS container.

Keywords

Austrian pine; Scots pine; Maritime pine; Quality; Seedlings; Containers; Dynamics of growth

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1 Introduction

Austrian Pine (AP) and Scots Pine (SP), as autochthonous species, represent the most common species for afforestation and reforestation in the R. North Macedonia. Maritime Pine (MP) was introduced some 50 years ago and is used in rather limited range for afforestation on dry sites up to 500-600 m above sea level (a.s.l.).

During 2010-2018, in North Macedonia a total area of about 12760 ha was reforested, i.e. annually about 1420 ha, of which coniferous species were planted on 961 ha (68%). In this period, of totally reforested area, AP stands represent in average 34.5% and SP stands 6.2% (Statistical Yearbook of the R. of North Macedonia 2019). MP new artificial stands occupy only a portion of forested area.

AP seedlings are planted in rather wide range of ecological conditions (300-1300 m a.s.l.), while SP is mostly planted in higher regions, above 800 m a.s.l. Annually, in the nurseries of the Public Enterprise (PE) "National forests" c/a 1.5 million AP seedlings are produced of which 53% are containerized, and c/a 250.000 SP seedlings, of which 85% as containerized (Kolevska, unpublished data). The MP seedlings are produced in small quantities (10.000-20.000 seedlings every few years).

Containerized seedlings have been produced in N. Macedonia for more than 4 decades (Popovski and Levkova 1977). Despite the differences in tree species and their biological characteristics, purpose of reforestation, site conditions, planting methods etc., forest seedlings are produced in few container types, generally as 1+0 or 2+0 (Kolevska et al. 2006). The most commonly used container, in term of long-term use, its durability and low production costs, is the hard plastic container Yucosad (Jukosad). Occasionally, some other container types (Paperpots, hard plastic Bosnaplast and Makosad, etc.) were used for seedlings production. The Yucosad container has been in regular use for over 40 years (Arsovski and Stankovski 1980), but, for its small volume (75 cm³) it was considered not suitable for dry and harsh sites and for fast-growing species. Seedlings grown in this container were predicted to develop root deformities which would lead to death of the stands at early stage of development (Popovski 1985, 1986). Investigations on Austrian Pine stands, raised with Yukosad and other stock type seedlings, however, didn't confirm this predictions (Šmit et al. 1985; Kitić et al. 1985; Kolevska 1995, 1997, 2012; Kolevska and Trajkov 2012).

After developing a new container Siset with a volume of 128 cm³ (Patent No ISBN: 9989-2009-0-4), we conducted an investigation on growing seedlings of three Pine species: Austrian Pine (*Pinus nigra* Arn.), Scots Pine (*Pinus sylvestris* L.) and Maritime Pine (*Pinus pinaster* Aiton) in this new container, Siset, and compare their morphometrical features with seedlings grown in Yucosad containers.

In addition to the influence of the container on the quality features of the seedlings, we needed to observe the dynamics of growth and development of the seedlings during the vegetation season. Namely, the annual production plans for the seedlings production in nurseries operated by PE "National forests" are rather unstable

and inconsistent, in term of species structure and quantities. Often, in the same greenhouse, seedlings of different species which require specific nursery procedures are grown together and due to organizational, technical and operational problems they are exposed to the same regime of irrigation, fertilization and pest protection. Therefore, by measuring of some of the seedlings traits in shorter intervals of time, we expect to get some insight into how the same production procedure reflex on the dynamics of growth of the seedlings.

2 Materials and methods

The experiment was conducted in the nursery of PE "National forests"- Forest Estate in the city Sveti Nikole, R. of North Macedonia. The nursery lies on flat terrain at 277 m a.s.l. (N41° 52.082', E21° 56.810'). The average year air temperature is 12.9°C, and the average for vegetation period (April-October) is 18.8°C. The average annual sum of precipitations is 472 mm.

One-year old seedlings of the three Pine species were grown in two container types:

1. Yukosad (Jukosad): hard-plastic, bullet-shape, h = 10 cm, upper d = 3.8 cm, bottom d = 1.2 (opening) cm, volume = 75 cm³; inside the container protrude 4 shallow ribs; one multipot contains 60 cells; 610 seedlings m⁻² (Figure 1, left).
2. Siset (Patent No ISBN: 9989-2009-0-4): made of gray cardboard with white coating, cut into stripes. The stripes of 59 x 8 cm and 38 x 8 cm have incisions (notches) of 4 cm which allow assemble a multipot of 135 containers; each 4.2 x 3.8 x 8 cm with open bottom, volume = 128 cm³. Assembled multipot is placed in a perforated plastic tray 59.5 x 38.5 x 8 cm; 592 seedlings m⁻² (Figure 1, right).

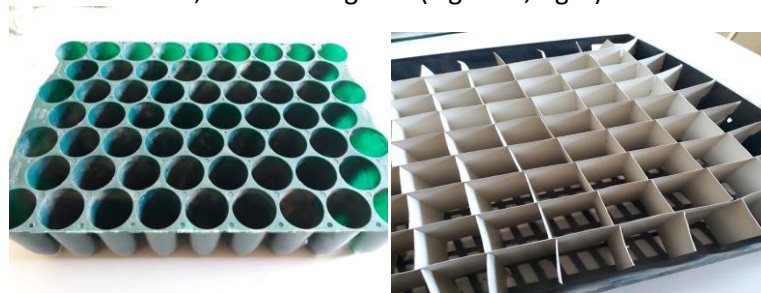


Figure 1. Multipot containers Yucosad (left) and Siset (right).

The seeds of AP and SP were collected from natural seed stands from Maleshevo Mountains, and the MP seeds from an artificially raised seed source near Sveti Nikole (trees of about 40 years of age) from an unknown provenance. Seed purity was: 95% (AP), 96% (SP) and 99% (MP); germination 82% (AP), 84% (SP) and 65% (MP).

The containers were filled with Lithuanian Sphagnum peat Novobalt (pH 3.5-4). Two-three seeds (previously soaked for 2 days in water) per cavity were sown during April and covered with thin layer of peat. The containers were placed on wooden construction about 10 cm high, to prevent growing roots into the ground, in a greenhouse covered with a shade cloth. During the vegetation period established nursery operations were conducted. Irrigation was performed on demand, 3-4 times per day, with small quantity. After emerging of the seeds (2-3 week later), from each

cavity the excess seedlings were pulled out, so only one seedling left. The seedlings were weeded manually. Foliar fertilization was executed 4-5 times per week, ones a day, from May to mid-August (MP), resp. to the end of August (AP and SP), with Folifertil T (NPK 11:3:5 with water soluble microelements Cu 0.008%, Fe 0.02%, Mn 0.01%), in concentration 0.02-0.2%. The seedlings were regularly treated against plant diseases and pests.

The experiment, for all Pine species, was conducted in randomized blocks in four replications. Within one species, each replication contained 10 multipots of each container type. During the vegetation season, every 2 weeks, i.e. since the age 8 (end of May) to 22 weeks (MP), resp. to 26 weeks (AP and SP), randomly of each container type 10 seedlings of 4 replications, i.e. 40 seedlings, were lifted for analysis. Total of 320 MP seedlings and 400 seedlings of AP and SP of each container type from all harvesting period were analyzed.

For the analysis, the root system was separated from the substrate, under a gentle water jet, using a sieve to collect any root fragments detached from the system (Tsakalimi et al. 2013). The shoot height (SH, ± 0.1 cm) and root collar diameter (RCD, ± 0.1 mm) of fresh seedlings were measured. Then the shoot and roots were separate (cut) at root collar and the fresh root system was divided on its parts and a destructive analysis was executed. The length of the central root (CR), number and length of first order lateral roots (FOLR; all roots at the junction with the CR), second (SOLR) and third order lateral roots (TOLR) were counted and manually measured. Only roots longer than 1 cm were taken into account. Then the shoot and separated roots were dried on 80°C for 24 hours and dry weight of shoot (SDW) and parts of the root system (CR, FOLR, SOLR and TOLR) were measured with accuracy of 0.01g.

Total roots dry weight (RDW) and total roots length were calculated as a sum of dry weight, i.e. length, of the parts of the root system (CR, FOLR, SOLR and TOLR).

Following coefficients and ratios were calculated:

- Sturdiness coefficient (SQ) as SH [cm]: RCD [mm], (Roller 1977),
- Dickson's Quality index (DQI, Dickson et. al. 1960) as:

$$\circ \text{DQI} = \frac{\text{SDW}[\text{g}] + \text{RDW}[\text{g}] / \text{SH}[\text{cm}]}{(\text{SH}[\text{cm}] / \text{RCD}[\text{mm}]) + (\text{SDW}[\text{g}] / \text{RDW}[\text{g}])}$$
- SDW [g]: RDW [g] ratio
- RDW [g]: SDW [g] ratio
- Rooting intensity (ROIN) as: roots dry weight [mg] per unit rooting volume [cm³] (Endean and Carlson 1975). The dry weight of the roots was divided by volume of the container (75cm³ in YS container, 128 cm³ in SS container).
- Root-bound indexes (RBI) as:
 - RBI diameter = (RCD [mm] ÷ container cavity diameter [mm]) x 100, and
 - RBI volume = (RCD [mm] ÷ container cavity volume [cm³]) x 100 (South and Mitchell 2005).

Data analyses were performed using SPSS program version 21.0 for Windows. One-way ANOVA was carried out to determine whether the means of seedlings' traits were equal. The trend lines, according to best fitting coefficient of determination (R^2) to express the dynamics of growth of selected features, were calculated using Excel 2010.

3 Results

In Table 1 are presented the results for the morphometrical quality features of the seedlings, and in Table 2 the results for the quality indicators and ratios.

Austrian Pine seedlings in YS container have better parameters, both on the shoot and roots, compared to SS container seedlings. The root features are significantly better in YS seedlings (number length and weight of roots). However, the roots structure, i.e. percent participation of roots in I, II and III order of branching, is relatively close in both container types (Table 1).

The seedling quality indicators (SQ, DQI, SDW:RDW and RDW:SDW) are more favorable in SS seedlings, even though the difference in DQI is very small. The root system fibrosity indicator, i.e. root system intensity (ROIN) is more favorable in SS seedlings (bigger volume). Indicators for root bounding (Root-Bound Index, RBI) also vary between the two containers. RBI-diameter differs slightly, since the diameter of both containers is equal (but with different cross section), while RBI-volume, due to differences in container volume, has more favorable values in SS seedlings (Table 2).

In **Scots Pine** seedlings, SS container produced slightly shorter seedlings, but with bigger RCD and shoot weight. All root morphology parameters, except of number of TOLR, however, are significantly bigger in YS seedlings. The root number, length and weight is almost twice bigger in YS seedlings, compared to SS seedlings. However, the percent participation of roots in I, II and III order of branching by number, length and weight, is relatively close in both container types (Table 1).

The seedling quality indicators and are equal (DQI) or better in YS seedlings (except SQ). Root fibrosity indicator (ROIN), and root bounding index by volume are better in SS seedlings (Table 2).

If in AP and SP the YS container produced seedlings with better traits, but less favorable root indicators, in MP we got "mosaic" results.

In **Maritime Pine** the SS seedlings are higher but thinner and with smaller weight. The root parameters, generally, are better in SS seedlings, with some exceptions. MP seedlings develop different root system compare to AP and SP seedlings. They develop less roots with much less length and weight than AP and SP seedlings. Also the root structure is different, because they have less FOLR, compare to AP and SP, but they participate in higher percent in the whole root system (Table 1).

The seedlings quality indicators are better in YS container, while ROIN and RBI by volume in SS seedlings (Table 2).

To present the dynamics of growth of the seedlings, every 2 weeks (starting the last week of May, at the age of 8 weeks of the seedlings) up to 22 weeks (MP), respectively 26 weeks (AP and SP), we measured all above mentioned parameters of the seedlings. An important point in the growth season is the mid-August, i.e. 18th week of age of the seedlings, when the fertilization was stopped for MP, i.e. end of August (20th week) for AP and SP.

Dynamics of growth of SH, RCD, SDW, number of all roots, total roots length and dry weight of the roots during the vegetation season, was expressed as trend lines (polynomial regression, according to highest value of coefficient of determination R^2 ; all $R^2 > 0.85$) in Figures 2a-2f. The trend lines reveal that SH, RCD and SDW (Figures 2a, 2b and 2c) in AP and SP in both containers grow slowly and gradually, during all the

vegetation season. In MP, the increase of SH, RCD and SDW follows slightly different pattern. After 12th-14th week of age, the SH and RCD grow more intensively in both containers, reaching 2-3 times bigger SH, comparing to AP and SP.

Table 1. Morphometrical quality features of the seedlings at the end of the vegetation period. YS = Yukosad, SS = Siset, SH = shoot height; RCD = root collar diameter; SDW = shoot dry weight; FOLR = first order lateral roots; SOLR second order lateral roots; TOLR =third order lateral roots; CR = central root; RDW = total roots dry weight. Means within column marked with * are significantly different at the $\alpha=0.05$ level. n=40.

Feature	Austrian Pine		Scots Pine		Maritime Pine	
	YS	SS	YS	SS	YS	SS
SH [cm]	13.05	11.18	10.29	10.01	27.51	29.03*
RCD [mm]	1.97	1.90	1.87	2.06*	2.56	2.44
SDW [g]	0.78*	0.57	0.49	0.63*	1.43	1.39
Number of roots						
FOLR (%)	15.88 (29.7%)	12.35 (29.6%)	16.5* (21.8%)	11.83 (24.2%)	8.03 (41.5%)	12.83 (52.7%)
SOLR (%)	23.9 (44.7%)	23.9 (57.3%)	47.8* (63.1%)	25.63 (52.3%)	9.68 (50.1%)	9.53 (39.2%)
TOLR (%)	13.7* (25.6%)	5.43 (13.0%)	11.43 (15.1%)	11.50 (23.5%)	1.63 (8.4%)	1.98 (8.1%)
Total lateral roots number	53.48* (100%)	41.68 (100%)	75.73* (100%)	48.96 (100%)	19.34 (100%)	24.34 (100%)
Length of roots [cm]						
FOLR + CR (%)	103.65* (44.1%)	85.48 (51.2%)	151.9* (44.5%)	66.94 (40.0%)	40.68 (62.8%)	82.37* (76.8%)
SOLR (%)	98.5* (41.9%)	72.1 (43.2%)	168.0* (49.2%)	75.89 (45.4%)	22.39 (34.6%)	22.3 (20.8%)
TOLR (%)	33.1* (14.1%)	9.46 (5.7%)	21.66 (6.3%)	24.42* (14.6%)	1.69 (2.6%)	2.56* (2.4%)
Total roots length	235.25 (100%)	167.04 (100%)	341.56 (100%)	167.25 (100%)	64.76 (100%)	107.23 (100%)
Dry weight of roots [g]						
FOLR (% without CR)	0.12 (54.5%)	0.12 (70.6%)	0.13* (61.9%)	0.07 (58.3%)	0.07 (58.3%)	0.07 (63.6%)
SOLR (% without CR)	0.07* (31.8%)	0.04 (23.5%)	0.06* (28.6%)	0.03 (25.0%)	0.04* (33.3%)	0.02 (18.2%)
TOLR (% without CR)	0.03* (13.6%)	0.01 (5.9%)	0.02 (9.5%)	0.02 (16.7%)	0.01 (8.3%)	0.02 (18.2%)
Total lateral roots weight (RDW) [g]	0.22 (100%)	0.17 (100%)	0.21 (100%)	0.12 (100%)	0.12 (100%)	0.11 (100%)
CR	0.09	0.11	0.06	0.07	0.12	0.12
Total roots weight [g]	0.31 (100%)	0.28 (100%)	0.27 (100%)	0.19 (100%)	0.24 (100%)	0.23 (100%)
Total seedling weight (SH + RDW) [g]	1.09	0.85	0.76	0.82	1.67	1.62

Table 2. Seedling quality indicators. YS = Yukosad, SS = Siset, SQ = sturdiness coefficient; DQI = Dickson’s quality index; SDW = shoot dry weight; RDW = roots dry weight; ROIN = rooting intensity. RBI diameter = root bounding index by container diameter; RBI volume = root bounding index by container volume. n=40.

Feature	Austrian Pine		Scots Pine		Maritime Pine	
	YS	SS	YS	SS	YS	SS
SQ	6.62	5.88	5.50	4.86	10.75	11.90
DQI	0.12	0.11	0.10	0.10	0.10	0.09
SDW:RDW	2.52	2.04	1.81	3.32	5.96	6.04
RDW:SDW	0.40	0.49	0.55	0.30	0.17	0.17
ROIN [mg cm ⁻³]	4.13	2.19	3.60	1.48	3.20	1.80
RBI diameter	51.8	47.5	49.2	51.5	67.4	61.0
RBI volume	2.6	1.6	2.5	1.7	3.4	2.0

Increasing of number of the roots (Figure 2d) is most intensive in SP seedlings in YS container, growing gradually during all the season, following by AP in YS and SS containers, and SP in SS container. MP develops smallest number of roots in both containers, and there is a trend of stagnation in developing roots after the 14th-16th week of age.

Intensive growth of some of the analyzed traits continues even when the fertilization of seedlings was stopped at the end of July.

Increasing of the length of the roots (Figure 2e) differs in all Pines and containers. Increasing of the length of the roots is most intensive in SP in container YS, from the early age of the seedlings. In other Pine species and container types, the roots grow in length gradually during all the season, except in MP in YS, where is obvious stagnation in growth after 14th-16th week of age.

Increasing of the total roots weight is presented in Figure 2f. In MP-YS seedlings the roots weight increases intensively from the middle of June (10th week of age), and this trend follows to the end of the growing season. In the other species and container types the roots weight increases more intensively at the beginning of July (14th week), and at the end of the vegetation, roots in SS container in AP and SP have the smallest weight.

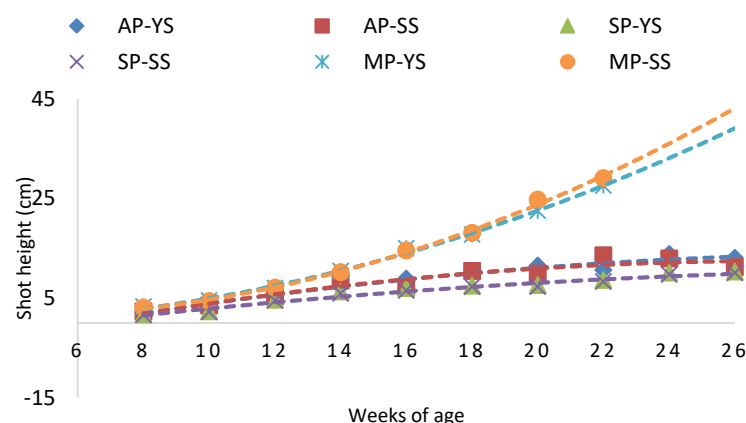


Figure 2a. Growth of SH.

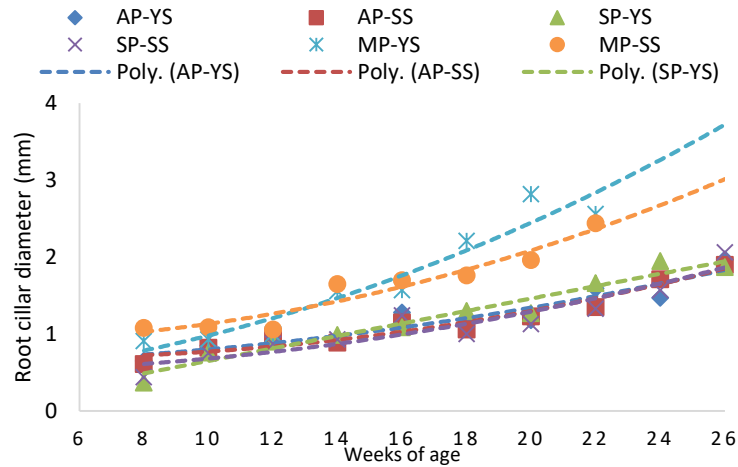


Figure 2b. Growth of RCD.

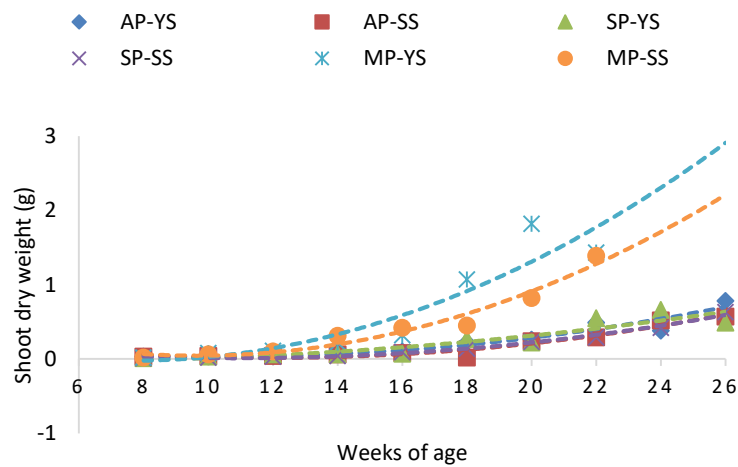


Figure 2c. Growth of SDW.

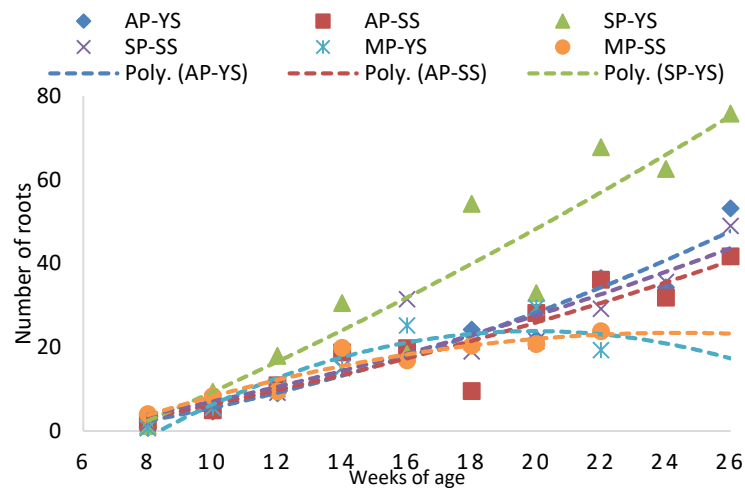


Figure 2d. Growth of total number (quantity) of the roots.

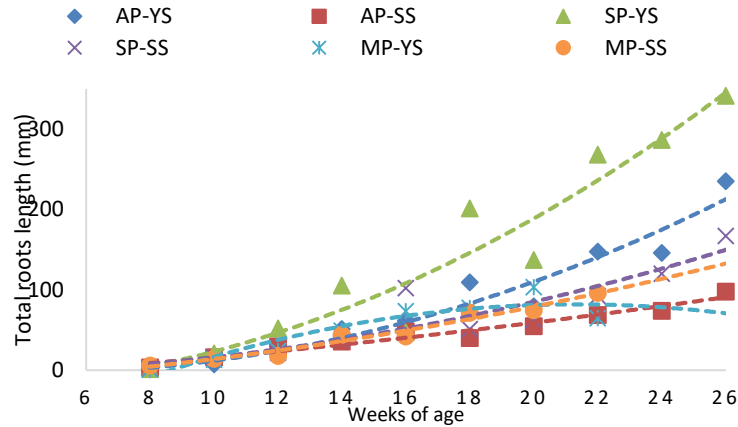


Figure 2e. Growth of the total length of the roots.

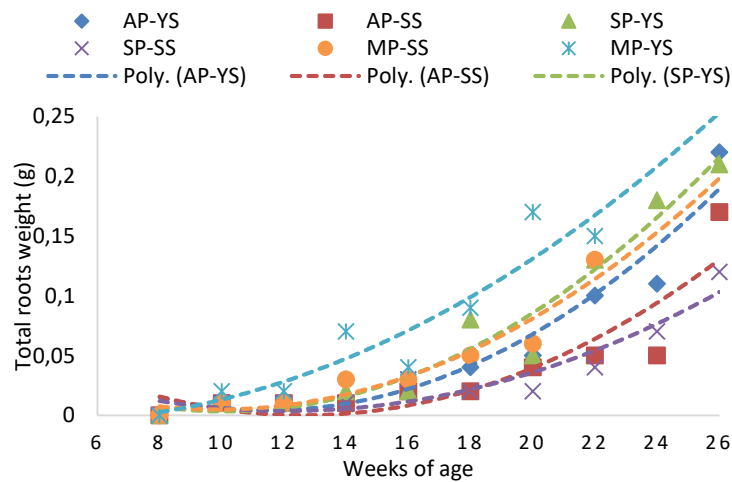


Figure 2f. Growth of total dry weight of the roots.

Figure 2(a-f). Growth of SH, RCD, SDW, number of all roots, total roots length and dry weight of the roots, during the growing period. AP =Austrian Pine, SP = Scots Pine, MP = Maritime Pine; YS = Yukosad, SS = Siset.

4 Discussion

Planting high quality seedlings does not guarantee successful seedling establishment, but it increases the chances for successful establishment and growth (Thompson 1985; Landis 1990; Davis and Jacobs 2005; Grossnickle 2012; Grossnickle and MacDonald 2018). But, “high quality” of the seedlings can be define in more aspects, depending on purpose of reforestation, site conditions, planting technique etc. (Thompson 1985; Duryea 1985; Grossnickle 2005a; Haase 2008; Tsakaldimi et al. 2013).

In our investigation, comparison between seedlings produced in YS and SS containers shows differences, but also similarities in quality features and dynamics of growth in all three investigated Pine species.

Austrian Pine and Scots Pine 1+0 seedlings grown in container YS with smaller volume (75 cm³) have better morphometrical characteristics than in SS containers (128 cm³). Even though the volume of YS is c/a 60% less than SS container, the seedlings

features in YS containers, with some exceptions, overcome those in SS containers. This is recordable especially in term of roots characteristics. Kolevska et al. (2006) reviewed that container types, which are used in North Macedonia, with different volume (75-160 cm³), materials (hard plastic, paperpot or cardboard) and shape (round, rectangle or hexagonal cross section, various height: diameter ratio), don't influence the quality of Austrian Pine seedlings, and the differences in seedlings features can be significant. Similar is the case in SP and MP (Kolevska, pers. comm.) The seedling features depend mostly on the production procedures, which are not consistent, but differ in each nursery. Findings of researchers, who investigated quality of AP and other Pines, in containers with the same or bigger volume and age: Fraysse and Crémière (1998) in MP, Jelić (2012) in MP, Ivetić and Škorić (2013) in AP, Devetaković et al. (2017) in AP, Lučić et al. (2012) in SP, expose a range of quality features of these species. The seedlings from their investigations, compared to ours, are mostly shorter, but thicker, with generally better quality indicators (SDW:RDW and DQI).

Most researchers, contrary to our results, found that quality parameters of the seedlings grow with increasing of the volume and density of the containers (Endean and Carlson 1975; Tinus and McDonald 1979; Landis 1990; Jinks and Mason 1998; Topić et al. 2006).

The importance of root system of seedlings is emphasized by many researchers (Burdett 1990; Chiatante et al. 2002; Jacobs and Seifert 2004; Davis and Jacobs 2005; Grossnickle 2005b, Tsitsoni et al. 2015). Successful seedling establishment is largely dependent on the capacity of seedlings to rapidly initiate new roots (Grossnickle 2005b).

Root systems of the seedlings in our investigation differ among species and container types. In AP and SP, more similarities can be observed between container type than between species. Seedlings grown in YS container develop more numerous, longer and heavier roots, than in SS container. We didn't measure thickness of the lateral roots, since in 1+0 small volume container seedlings they are very thin, therefore we consider these root systems as fibrous, eventhough definiton of fibrosity of root systems varies (Davis and Jacobs 2005). Thompson (1985) consider that total root length is a better measure of fibrosity or absorptive surface, than root mass and volume. In our investigation, despite differences in absolute values of measured root parameters, in AP and SP the root system structure, i.e. relative participation of I-III order lateral roots, is similar. The FOLR participate with highest percent in term of length and weight, while SOLR in quantity (number of roots). In MP seedlings, the participation of FOLR and SOLR is quite close in both containers, with lower number of TOLR.

The most operated indexes for better description and evaluation of the quality of the seedlings, as SQ, SDW:RDW, RDW:SDW and DQI, in our investigation vary between Pine species and container types, and generally are more favorable in SS seedlings, even though the difference in DQI is very small. Stjepanović and Ivetić (2013) state that optimum SDW:RDW ration for container seedlings is 2:1 or even less. Barnett and Brissette (1986) consider that RDW:SDW ratio between 0.45-0.65 appears to produce seedlings that achieve balanced root and shoot growth. These comparisons determine our seedlings with high (in MP) and thin shoot and low roots mass.

Tsakaldimi et al. (2013), in *Pinus halepensis* and *Pistacia lentiscus*, established that survival of seedlings was positively correlated to initial seedling root-collar diameter, total dry weight and Dickson's quality index, and can be reliably predicted by these variables.

Ivetić et al. (2016) examined morphological characteristics of AP seedlings for predicting survival and growth of stands up to 12 years of age. They established that SH, SQ and SDW:RDW were the best attributes for forecasting seedling survival.

Root systems of seedlings grown in containers, especially in hard-plastic, with round a smooth walls, are subject to various modifications and deformations, and were in focus of interes of many researchers, as Hiatt and Tinus (1974); Lokvenc (1980); Stilinović et al. (1980); Šmit et al. (1985); Girouard (1995); Mauer and Palátová (2004); Grossnickle and El- Kassaby (2016).

In this investigation we did not evaluated and described the root deformations, but we calculated indexes, proposed by Endean and Carlson (1975) and South and Mitchell (2005), to test differences in root systems between the two containers. According to Endean and Carlson (1975), a high root fibrosity of seedlings in containers with small volume means high root intensity (ROIN; roots dry weight expressed per unit container volume, [mg cm⁻³]). They found in container Lodgepole Pine seedlings that ROIN increases with the age (4-20 weeks) of the seedlings. The growth of seedlings was reduced significantly after reaching "critical" ROIN of 0.45 mg cm⁻³ (and bigger), when total dry weight was reduced. In comparison, the Pines from our investigation develop less fibrous root systems.

South and Mitchell (2005) state that field performance of pines (*P. pinaster* seedlings, *P. elliotii* x *P. caribaea* and *P. patula* cuttings) from container will be reduced before the roots become tangled or matted, and that nursery managers need a method to estimate when this begins to occur. They introduced two root-bound indexes (RBI) for estimating the percentage of root bound seedlings: RBI diameter and RBI volume. They analyzed the seedlings survival in dependence of RCD, RBIdia and RBivol. They tested these indexes for wide range of RCD and containers with different volumes, and they derived practical data for culling seedlings. In our investigation, values for RBIdia, since they derived from the same YS and SS container diameter, vary in rather close range within each Pine species. RBivol, due to differences in container volumes (75 and 128 cm³) varies wider. However, since we calculated root bounding indexes for the first time, for seedlings with very small differences in RCD, we can't extract conclusions about their applicability in the practice, but they can represent a base for future investigation of this topic.

Our investigation of the dynamics of growth and development of the Pine seedlings, subjected to the same regime of foliar fertilization during the vegetation season, reveals most similarities in development of above ground parts in AP and SP seedlings in both containers. MP grows much more intensively, reaching SH almost 3 times bigger than other two Pines, which caused that all quality indicators (except DQI) got worse values, comparing to AP and SP. The most intensive height and RCD growth in MP happens after the fertilization stopped (during the second part of the vegetation period). In AP and SP, after the fertilization stopped, the height growth slow down, while the RCD increment gradually continues. The roots development also differs between the Pines. In the second half of the vegetation period, after interrupting of fertilization, in MP, development and elongation of new roots stagnates, and only weight (thickness) of the roots increases. In the same time, in AP and SP, development of new roots happens during all the vegetative season, with various intensity. Most intensive growth is recorded in term of roots weight, even after the fertilization stopped. Similar results we confirmed in Arizona Cypress (Kolevska et al. 2015).

Seasonal growths of various species were investigated by Lyr and Hoffmann (1967), Boyer (1970), Baker (1988). Lyr and Hoffmann (1967), for *Picea abies* and *Pinus sylvestris*, determined a “Quercus type” of growth of shoot and roots, with various intensity and duration of growth for both species. In our investigation we established different patterns of growth in SH, and similar in roots development.

Differences in seasonal growth of five species found Baker (1988). He measured seasonal shoot growth of 1+0 Radiata pine and 2+0 Red beech, Corsican pine, Ponderosa pine and Douglas fir seedlings grown at New Zealand. He registers similarities in growth in Corsican pine and Ponderosa pine. Rapid shoot extension in Corsican and Ponderosa pine began soon after initial bud elongation and continued until bud set, when 70% of the total seasonal growth had been achieved. This growing dynamics differs from our investigation, where SH grows gradually during all the vegetation season.

Fertilization is one of the most important means to manage seedling quality and future field performance, as it, generally, increases growth in height and thickness, increasing of SDW and RDW, root growth potential (Landis 1985,1990; Fraysee and Crémère, 1998; Olet et al. 2009; Landis et al. 2010; Wang et al. 2015). In our investigation, the nutrients were not incorporated into the sphagnum peat, but we applied foliar fertilization as described in the methods, in a way as it is a regular practice in the nursery. We assume that changes in fertilizer composition in favor of higher participation of P and K in the second half of the fertilization period (July-August) would increase the RDC and the general quality of the seedlings. However, this should be subject to further investigation and tests.

As from our other previous works follows, differences in seedlings quality in various containers are common, and mostly depend on current nursery procedures (Kolevska et al. 2006, 2015). The reforestation success with small-volume container stock seedlings, used in N. Macedonia, depends mostly on the site conditions (Kolevska and Trajkov 2012; Načeski et al. 2012; Kolevska et al. 2018). In our previous investigations (Kolevska 1995; Kolevska and Trajkov 2012) we didn't record significant differences in field survival in Austrian Pine stands of age 4-17 years, between YS seedlings and Paperpots-508 seedlings (with the same container volume as the SS container), even though there are opposite finds (Tsakalimi et al. 2005).

5 Conclusions

Investigation of the quality of the seedlings of three Pine species, grown in containers YS and SS, confirmed similarities and differences in all Pine species.

AP and SP seedlings, grown in containers YS had higher values of almost all measured traits. However, in AP, the SS seedlings had better values of quality indexes and ratios, than YS seedlings. SP seedlings, except for SQ, had better quality indexes in YS container. MP seedlings, with some exceptions, have better above ground quality features in SS containers, while root systems don't differ significantly in both containers. Root quality indicators (root intensity and root bound indexes) are more favorable in SS containers in all Pine species. The AP and SP seedlings grow in similar way and intensity in both containers. MP seedlings differ in much more intensive growth of above ground features, especially in the half of the vegetative period in both containers, while during this period root quantity and length stagnates.

Generally, the quality of AP and SP seedlings is satisfactory in both containers, while MP seedlings show slightly better results in SS container.

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