Field performance of Austrian pine bareroot seedlings in comparision to seedlings pattern and density in the nursery

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Abstract

The Austrian pine (*Pinus nigra* Arnold) is a species often used in afforestation/reforestation programs in Serbia and region. Seedlings quality has a great role in outplanting survival and growth. Nursery cultural practice has a central influence on seedlings morphological attributes, so we tested seedlings quality from different seedbed densities and seedlings patterns and their outplanting success. Two-year-old bareroot seedlings were grown in very high densities (110 seedlings m^{-1} in rows and 750 seedlings m^{-2} across all seedbed space) and high densities (65 seedlings m^{-1} in rows and 450 seedlings m^{-2} across all seedbed space). Morphological attributes (root collar diameter - RCD, height - H, sturdiness coefficient - SQ, root length – Rl, dry weight of shoot - SDW and root - RDW, shoot to root ration - S:R and quality index - QI) of seedlings from different densities were tested in the nursery before outplanting and compare with seedlings survival and growth (root collar diameter – RCD1 and height – H1) one year after field growing. Seedlings from different densities had accepted RCD (>3 mm) for field planting and there were significant differences in their morphological attributes, except Rl and S:R. The best survival was recorded at seedlings from highest seedbed densities (93.33%), opposite with many previous researches. Seedlings grown across all seedbed space (450 seedlings per m^{-2}) keep their advantage in growth after first year, although survival was lowest (46.67%).

Keywords

Austrian pine seedlings; Morphological attributes; Seedbed density; Outplanting performance; Survival

Contents

1 Introduction

Austrian pine (*Pinus nigra* Arnold) is species with discontinuous geographical distribution across Europe and Asia Minor, mostly presented on mountains range and in artificially forests. It is native species in western and central Serbia where growth in pure or mixed forests (Cvjetićan and Perović 2000). Some features as modest nutrients and water requirements, broad tolerance to soil conditions, tolerance to hot, dry and hard frost etc. made him as desirable required species in many afforestation programs in Serbia (Tomić et al. 2011; Ranković et al. 2007) and region (Diaci et al. 2019; Portoghesi et al. 2013; Cseresnyés and Tamás 2014) in last 50 years. The need for Austrian pine seedlings do not decrease in Serbian forest practice up today. More than 6 millions Austrian pine seedlings were planted in Serbia in last ten years, which covers about a third from all planted coniferous seedlings (SORS, 2021).

Survival and growth of seedlings after planting on the field is conditioned by many factors, but morphological attributes and general quality of seedlings have great role. Different site conditions require different approach to seedlings quality (Rose et al. 1990; Dumroese et al. 2016). Diameter is considered as most useful morphological attribute of seedlings quality (Mexal and Landis 1990). Number of seedlings per square has a great role in nursery operations and costs of production. In this research, we tested survival and growth of two-year-old Austrian pine bareroot seedlings from different seedbed density in the nursery, in first growing season. We observed seedlings quality from different seedbed densities and compared with their outplanting growth and success.

2 Material and method

2.1 Nursery

Austrian pine bareroot seedlings were growth in seedbeds in different densities for two years. Total of 4 sample plots consisted from 2 plots where seedlings growth in rows (R1 and R2) and 2 plots were seedlings growth across total seedbed space (S1 and S2). Higher density was at R1 and S1 plots (110 seedlings m^{-1} at R1 and 750 seedlings m^{-2} at S1) than R2 and S2 plots (65 seedlings m^{-1} at R2 and 450 seedlings m^{-2} at S2). Nursery cultural practice was conducted commonly and included irrigation and weeding control (Stilinović 1987). At the end of growing season, sample of 100 seedlings per plot were measured for root collar diameter (RCD - mm) and height (H - cm). Sample of 10 seedlings per plot were pull out (Figure 1) for measurement of seedlings dry weight of shoot (SDW - g) and root (RDW - g) and root length (Rl - cm), according simplified protocols described by Ivetić (2013). Shoot to root ratio (S:R) was calculated as ration between SDW and RDW. The sturdiness coefficient (SQ) was calculated according to Roller (1977) and the quality index (QI) was calculated using Dickson et al. (1960) method.

Figure 1. Seedlings from S2 plot.

2.2 Field

Lifting and pulling of seedlings in the nursery were performed manually, 10 days before field planting. Seedlings were placed in field containers with soil and transported on the planting site. Sample of 30 seedlings per plot were marked with different color ribbon (R1-red; S1-black; R2-green; S2-white; Figure 2). Seedlings were planted in second week of April 2018.

Figure 2. Seedlings from different plots marked and planted on the field.

Planting site was artificial Austrian pine forest which was partially destroyed by ice storms (N 43° 34' 11'', E 20° 39' 43'', 850 m a.s.l.). Planting was done in dug holes prepared by shovels. Weed control during first growing season was not carried out. Temperature during spring season was extremely high with low precipitation, while summer was very rainy with normal temperature regime for this area (Annual Buletin for Serbia, 2018). Next spring, survival was recorded, when measurement of RCD1 and H1 of each survival seedling were performed. Increasing of RCD and H was calculated as percentage in growth in comparison to initial RCD and H.

2.3 Statistical analysis

Seedlings from the nursery and after first year on the field were rated for average RCD, H, SDW, RDW, Rl, S:R, SQ and QI, also as standard deviation of sample and minimal and maximal values. Analysis of variance was used to test differenced between seedlings from different plots (OneWay ANOVA, p<0.05) and post-hoc LSD Fishers test to mark groups. For calculations STATGRAPHICS Centurion XVI.I software was used.

3 Results

3.1 Seedlings morphological attributes

Seedlings from S2 plot showed highest values of RCD, H, SDW, RDW, Rl, S:R ration and QI, while lowest values of same attributes (except Rl) was at seedlings from R1 plot. In the same time SQ was lowest at the seedlings from S2 and highest at seedlings from R1. Seedlings from rows (R1 and R2 plot) had similar Rl, while lowest Rl was at seedlings from S1. Differences between seedlings from different plots are proved (ANOVA, p<0.05) in all observed characteristics except Rl and S:R ration (Table 1).

Table 1. Morphological characteristics of two-year-old Austrian pine seedlings measured in the nursery (RCD – root collar diameter, H – height, SDW – shoot dry weight, RDW – root dry weight, Rl – root length, S:R – shoot to root ratio, SQ – sturdiness coefficient, QI – quality index; Sd – standard deviation; n – number of samples).

	RCD n=110		H n=110		SDW n=10		RDW n=10	
	mean value (Sd)	min-max value	mean value (Sd)	min-max value	mean value (Sd)	min-max value	mean value (Sd)	min-max value
R1	3.17[a](0.81)	1.4-5.1	8.56[a](2.07)	4.0-15.0	1,08[a](0,54)	0,6-2,2	0,56[a](0,26)	0,2-0,9
S1	3.92[b](1.24)	1.9-8.0	9.68[b](2.42)	4.7-17.0	1,81[ab](1,25)	0,3-3,5	0,61[a](0,29)	0,3-1,1
R2	3.88[b](1.19)	2.0-8.3	9.37[b](2.85)	1.0-18.0	2,77[b](1,32)	0,9-5,5	1,05[a](0,94)	0,3-3,4
S2	6.11[c](1.89)	2.4-10.0	12.12[c](3.31)	6.0-19.0	5,50[c](2,36)	3,1-10,6	2,05[b](1,20)	0,3-3,8
Total	4.27(1.73)	1.4-10.0	9.93(3.00)	1.0-19.0	2,79(2,23)	0,3-10,6	1,07(0,97)	0,2-3,8
F-ratio	99.44		35.58		16.34		7.74	
p-value	0.0000		0.0000		0.0000		0.0004	
	Rl n=10		S:R n=10		SQ n=110		QI n=10	
	mean value (Sd)	min-max value	mean value (Sd)	min-max value	mean value (Sd)	min-max value	mean value (Sd)	min-max value
R1	65.52(24.23)	27.5-104.5	2.23(1.29)	0.88-5.33	2,81[c](0,81)	1,54-6,43	0,38[a](0,21)	0,12-0,73
S1	49.82(24.48)	22.0-102.9	2.90(1.73)	0.60-6.75	2,62[bc](0,82)	1,08-5,00	0,44[a](0,23)	0,22-0,89
R2	64.55(21.22)	33.8-93.5	3.66(2.25)	1.12-9.33	2,50[b](0,73)	0,21-4,42	0,63[a](0,49)	0,18-1,73
S2	80.84(28.82)	41.6-126.5	3.93(3.21)	1.24-12.33	2,07[a](0,54)	1,25-4,38	1,47[b](0,87)	0,25-2,70
Total	65.18(26.32)	22.0-126.5	3.18(2.26)	0.60-12.33	2,50(0,78)	0,21-6,43	0,73±0,67	0,12-2,70
F-ratio	2.6		1.17		19.95		9.49	
p-value	0.0669		0.3360		0.0000		0.0001	

*group by LSD Fishers test

3.2 Seedlings survival and growth on the field

Survival of seedlings was in the range 93.33% (R1) to 46.67% (S2). Generally, better survival was recorded at seedlings which were growth in high seedbed density (R1 and S1), more than 80%. Seedlings from R2 showed better survival (53,33%) than seedlings from S2 (Figure 3).
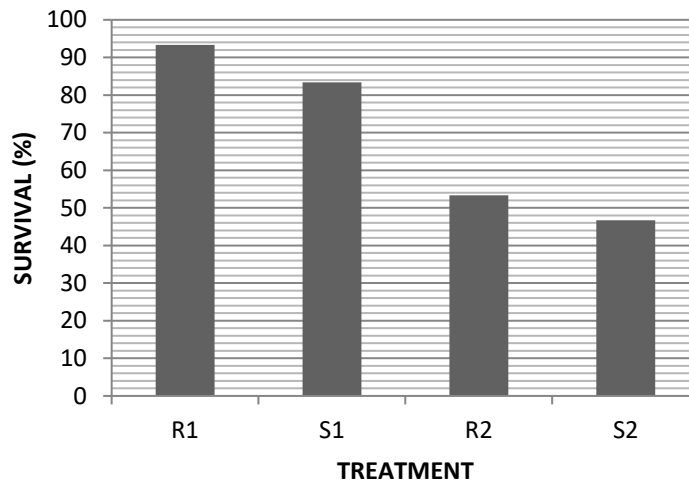

Figure 3. Survival of seedlings from different plots in the first growing season on the field.

After first growing season on the field, RCD1 and H1 were in the same range as in the nursery. Seedlings from S2 had the greatest growth (RCD1, H1), while seedlings from R1 were the smallest. Differences between seedlings from different plots were retained (ANOVA, p<0.05), (Table 2).

Table 2. Morphological attributes of the seedlings from different plots after first growing season on the field (RCD1 – root collar diameter after fires growing season on the field, H1 – height after first growing season on the field; Sd – standard deviation).

	RCD1		H1	
	mean value (Sd)	min-max value	mean value (Sd)	min-max value
R1	4.23[a](0.86)	2.80-6.90	11,49[a](3,27)	6,60-19,00
S1	4.86[b](0.85)	4.00-7.00	14,78[b](2,21)	10,00-19,00
R2	6.43[c](1.01)	5.00-8.40	17,64[c](3,43)	12,00-27,00
S2	8.08[c](2.05)	6.20-13.00	18,32[c](2,73)	15,00-25,00
Total	5.49(1.81)	2.80-13.00	14,82(3,96)	6,60-27,00
F-ratio	39.73		23.68	
p-value	0.0000		0.0000	

*group by LSD Fishers test

Seedlings from R1 were growing uniformly in height and diameter (34% and 33%), while other seedlings were growing strongest in height. Relative highest growth in H (88%) and RCD (65%) were recorded at seedlings from R2 (Figure 4 and 5).
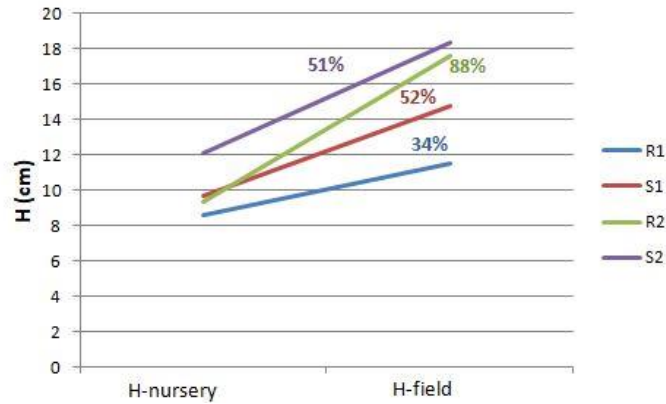
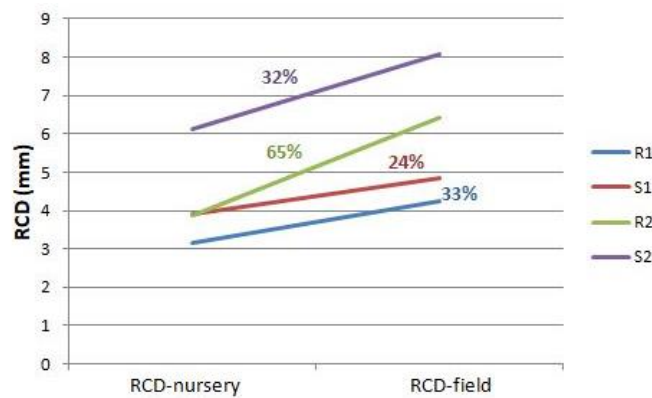Figure 4. Increasing of H in the first year after outplanting at seedlings from different nursery plots.

Figure 5. Increasing of RCD in the first year after outplanting at seedlings from different nursery plots.

4 Discussion

4.1 Seedlings morphological attributes

Two-year-old bareroot Austrian pine seedlings had acceptable RCD according The Serbian Standard for Coniferous Seedlings Quality SRPS D.Z2.110 (>3 mm), while their H were bellow recommended values for field planting, except seedlings from S2 (average H 12.12 cm). Commonly, pine bareroot seedlings grow in densities 300 per m^2 or even bellow 200 per m^2 (South 1993), so modest values of RCD and H of seedlings from this study can be expected especially if consider the luck of fertilization. Seedlings pattern in seedbed, also as density had a great influence on morphological attributes. Seedlings from rows were weaker than seedlings which were grown across all seedbed space (R1 in comparison to S1 and R2 in comparison to S2) in all observed attributes except Rl (R1>S1). Increasing of RCD and shoot and root biomass with increasing space for one seedling is well documented for southern pines (Mexal and South 1991). It was expected to competition in higher densities (especially in rows) should caused intensive growth in height, but Benson and Shepard (1976) reported less affected H growth than RCD and root growth relative to seedbed density. Ivetić and Škorić (2013) reported similar H and S:R ration for two-years-old bareroot seedlings from three Serbian provenances in seedbed density 500 seedlings per m^2,

while their seedlings were spindly (SQ – 3,55) and with lowest RCD (about 3 mm). In this study wasn't recorded significant differences between seedlings from different plots in Rl and S:R ration, but S:R ration can be evaluated as positive (Bernier at al. 1995).Increasing of RCD should be affected on increasing root biomass (Mexal and Landis 1990; Grossnickle 2012), but it is opposite in this study (R2 seedlings had lowest Rl). According Dickson et al. (1960) seedlings from S2 can be consider as "good" and "fair" from each plot.

4.2 Seedlings survival and growth on the field

According average survival of Austrian pine bareroot seedlings in Serbia which is 59.16 % (Ivetić 2015), seedlings from R1 and S1 plots were successful, but seedlings from R2 and S2 were below average. Decreasing of seedbed density was increasing outplanting survival at two-year old *Pseudotsuga menziesii* seedlings (Driessche 1982) and *Pinus taeda* seedlings (South 2000). Ivetić et al. 2016 reported very high survival rate of one-year-old Autrian pine bareroot seedlings from seedbed density 500 seedlings per m^2, three years after field planting (>95%). In this study we were planted two-year-old bareroot seedlings, so lower survival rate probably was caused by root damaged because top pruning was missed. Root system fibrosity have a great role in root growing after planting (Grossnickle 2012), so survival was higher at seedlings with lower level of root damages during lifting (R1 and S1). Survival was highest at weakest seedlings according RCD and H (R1) which is contradictory with many previous researches. However, some researchers reported negative effect of H on survival of pine seedlings (Tuttle et al. 1988; McTague and Tinus 1996; Ivetić et al. 2016). Seedlings had satisfactory values of S:R, SQ and QI, but generally low survival after first year on the field. Seedlings growth was more intense in H than RCD, probably as a result of competition to site vegetation. Seedlings from higher seedbed densities had a weaker growth, than seedlings from low seedbed densities which is in correlation to previous researches (Benson and Shepard 1976; Driessche 1982; South 2000). Strongest seedlings from S2 plot keep their advantage in H and RCD during first growing season, although survival was lowest.

5 Conclusions

Seedlings density and pattern in seedbed have a great influence on seedlings morphological attributes. Decreasing density and increasing space per one seedling result by increasing RCD, H, SDW, RDW, S:R ration and QI, while SQ decrease. Influence of density and pattern in seedbed on root development did not observed completely in this study and it is recommended for future research. Best survival rate (>80 %) were at seedlings from the highest seedbed densities. Seedlings survival was highest at weakest seedlings according H and RCD, while strongest seedlings keep their advantage in dimensions but with lower survival rate.

6 Acknowledgements

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