

NORWAY SPRUCE (*Picea abies* (L.) Karst.) SEEDLINGS SURVIVAL IN PROGENY TEST “DRINIĆ”

PREŽIVLJAVANJE SADNICA SMRČE (*Picea abies* (L.) Karst.) U TESTU POTOMSTVA “DRINIĆ”

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Abstract

This paper presents the results of survival in progeny tests in the Republic of Srpska (Bosnia and Herzegovina). Four progeny tests of Norway spruce on sites: Drinić, Derventa, Nevesine and Srebrenica were established on the territory of the Republic of Srpska in 2009. These progeny tests consist of six populations: Han Pijesak 1 and 2, Foča, Potoci, Olovo and Kneževo. The total number of half-sib lines was 36.

In this paper, the data collected during 2014 were analyzed and they refer to the survival of Norway spruce seedlings in the progeny test in Drinić. The data were processed in order to determine which populations and half-sib lines are best adapted to ecological conditions of Drinić area.

The results indicate a significant variability of survival among the tested populations and half-sib lines. They also indicate a higher adaptability of population originating from geographically more distant provenances from progeny test, in comparison with closer populations. The results can be used for the purpose of transferring the spruce reproductive material from Bosnia and Herzegovina to Drinić area, as well as the sites which are characterized by similar ecological conditions.

Keywords: Norway spruce, progeny test Drinić, survival

1. INTRODUCTION / UVOD

Forestry, nursery, seed and seedling production are facing new challenges which most often occur in the form of climate changes and the changes in the natural range of species due to the controlled and uncontrolled transfer of seeds and planting materials. The transfer of seeds and planting material carries risks of insufficient adaptation to new environmental conditions. In order to assess adaptability, field tests needs to be established and monitored.

Scientist around the world and Europe have been working on many experiments referring the adaptability and morphological variability of Norway spruce (Lagercrantz & Ryman, 1990; Morgante & Vendramin, 1991; Ujvari-Jarmay & Ujvari, 2006). More about the impact of climate changes on Norway spruce can be found in the numerous papers (Matyas, 1994; Schmidtling, 1994; Gömöry et al., 2010; Kapeller et al., 2012; Gömöry et al., 2012).

Numerous experiment plots of Norway spruce, established in 13 countries by IUFRO in the period from 1964 to 1968, indicate the importance of the species (Kruttsch, 1974; Lindgren & Werner, 1989; Klapster et al., 2007). In the territory of Serbia, three provenance tests were established. They consist of Norway spruce populations from ex-Yugoslavia (Isajev & Tucović 1992; Šijačić-Nikolić, 1995; Šijačić-Nikolić et al., 2000; Ivetić, 2004; Isajev et al., 2009 and others).

For the Republic of Srpska and Bosnia and Herzegovina (B&H) forestry, Norway spruce is one of the most important tree species and, according to Mataruga et al. (2012), has the largest number of produced seedlings with a share of about 60% of total nursery production. Previous research in B&H was related mainly to its genetic character-

ization (Ballian et al., 2007; Ballian et al., 2009; Ballian, 2010; Mataruga et al., 2014). In order to achieve genetic gain in terms of qualitative and quantitative traits, it is necessary to carry out research in progeny tests of Norway spruce. The first steps were made in 2005 (Mataruga et al., 2005), when seed stands were designated in RS.

The second step included the establishment of four progeny tests in Drinić, Derventa, Nevesinje and Srebrenica in 2009. Two of them: Derventa and Nevesinje are not suitable for investigation due to low survival rate. The first published paper pointed out the initial adaptation of 6 populations of spruce to local conditions (Mataruga et al., 2012). The latest research in Drinić was conducted during 2014 and the results of seedlings survival are presented in this paper.

2. MATERIAL AND METHOD / MATERIJAL I METOD

2.1 Origin of planting material / Porijeklo sadnog materijala

Spruce progeny from almost the entire B&H was examined for the response to environmental influences in progeny tests. It was necessary to encompass its entire gene pool in B&H.

The basic information about the populations is shown in Table 1. More detailed description of the work on the selection of initial populations, mother trees, and other tests which preceded the progeny test establishment can be found in Mataruga et al. (2010).

Table 1. Locations where seed was collected / **Tabela 1.** Lokacije sakupljanja sjemena

Provenance	Latitude	Longitude	Altitude [m]	Mark of seed stand	Eco-vegetation district	Habitat
Han Pijesak 1	44° 08' 13,3"	18° 50' 01"	1000-1100	S.S. 010-030.1210.06	Internal Dinaric	<i>Piceo-Abieti-Fagetum</i>
Han Pijesak 2	44° 02' 08,8"	19° 00' 11,4"	960-1040	S.S. 010-030.1213-1212.06	Internal Dinaric	<i>Piceo-Abieti-Fagetum</i>
Foča	43° 24' 58,4"	18° 52' 38,7"	1000 - 1126	S.S. 030.1214.22	Transitional Moesiatic-Iliric	<i>Abieti - Piceetum</i>
Olovo	44° 07' 43"	18° 34' 54"	900-1000	It is not a seed stand	Internal Dinaric	<i>Piceo-Abieti-Fagetum</i>
Potoci	44° 23' 12,4"	16° 39' 39,5"	850-950	S.S. 030.1316.17	Internal Dinaric	<i>Piceo- Abieti Fagetum</i>
Kneževo	44° 28' 59,6"	17° 24' 45,9"	1010-1030	S.S. 030.1214.42	Internal Dinaric	<i>Piceo-Abieti-Fagetum</i>

2.2 Progeny test / Test potomstva

Progeny test in Drinić represents a unique experimental plot set in the vertical zone of spruce, fir

and beech forests (*Piceo-Abieti-Fagetum*), at an altitude of 650 m. It is located on a gentle slope. Information about the characteristics of the site are given in Table 2.

Table 2. Characteristics of the location where progeny test is set up / **Tabela 2.** Karakteristike lokacije na kojoj je osnovan test potomstva

Locality	Latitude	Longitude	Altitude [m]	Habitat	Eco-vegetation district	Soil
Drinić	44° 31' 10"	16° 36' 04"	690	<i>Piceo-Abieti Fagetum</i>	Internal Dinaric	Calkomelansol and luvisol

Progeny test consists of 4 blocks (repetitions), but only 3 of them were analyzed: 2nd, 3rd and 4th. The omission of the first block is the result of doubts about the representativeness of the 1st block, so it was temporarily suspended in

research. Each block consists of six populations and 36 half-sib lines, where the number of half-sib lines is different for each population. The names of the population and half-sib tag lines are given in Table 3.

Table 3. Populations and half-sib lines in progeny test in Drinić / **Tabela 3.** Populacije i linija polusrodnika u testu potomstva u Driniću

No.	Population	Half-sib lines
1	Han Pijesak 1 (Locality „Kusače“)	HP1/1, HP1/3, HP1/4, HP1/5, HP1/6, HP1/7, HP1/9
2	Han Pijesak 2 (Locality „Radojevac“)	HP2/1, HP2/3, HP2/4, HP2/8, HP2/10
3	Foča	F1, F2, F3, F5, F6, F7, F9, F10
4	Potoci	P8, P9
5	Olovo	O1, O2, O3, O9, O10
6	Kneževo	K1, K2, K3, K5, K6, K7, K9, K10, K11

2.3 Data collecting and processing / Prikupljanje i obrada podataka

During 2014, at the end of the vegetation period, the survival of seedlings in the field was recorded. Besides the seedlings survival, their physiological condition (damage and the presence of disease) was also recorded. In doing so, the surviving seedlings include those seedlings whose performance could not be classified as promising (Figs. 1–3).

Data were statistically analyzed by using the appropriate software packages: Microsoft Excel (ver. 2010) and Statistica (StatSoft Inc, ver. 7.0). The basic statistical parameters were calculated: arithmetic mean and standard deviation at the level of: blocks, population and half-sib lines. The differences among the survival rates at the level of blocks, populations and half-sib lines were tested by ANOVA ($p < 0.05$), and post-hoc Duncan's multiple range test.

**Figure 1.** Damaged seedlings / **Slika 1.** Oštećene sadnice (© B. Cvjetković)



Figures 2-3. Damaged seedlings / Slike 2-3. Oštećene sadnice (© B. Cvjetković)

3. RESULTS AND DISCUSSION / REZULTATI I DISKUSIJA

Testing seedlings survival in the field, 5 years after planting, aimed at indicating the particular population and half-sib lines which are promising for the transfer into new habitats in conditions that are similar to the conditions prevailing in Drinić. The research done on the adaptive potential of tested populations and half-sib populations provides guidance to potential sources of reproductive materials which are able to withstand the impact of the environment and suitable for the transfer of reproductive material (Rehfeldt et al., 1999; Rehfeldt, 2004; O'Brien et al., 2007; Vitt et al. 2010; Ukrainetz et al. 2011).

The survival of seedlings at the half-sib line level in progeny test Drinić points to a strong gene-ecological potential of the two half-sib lines from the population of Han Pijesak 2, and half-sib lines HP2/4 and HP2/8. It is also noticeable that most of half-sib lines from Han Pijesak had

a survival rate greater than 50%, while no half-sib lines from Olovo and Kneževo had a survival rate greater than 50% (Table 6).

Consequently, the listed half-sib lines are considered desirable (with the stress on the survival of seedlings) to be introduced into the habitats that have, in a broader sense, similar environmental characteristics as in the progeny test. These half-sib lines are suitable for so-called "assisted migration". That can sustain productivity in spite of the changes in environmental conditions (Gray et al., 2011; Kreyling et al., 2011).

Half-sib lines F6 and K9 had below 40% of the survival rate (Fig. 4). They cannot be considered promising appropriate for further work on the transfer of reproductive material due to a very low survival rate.

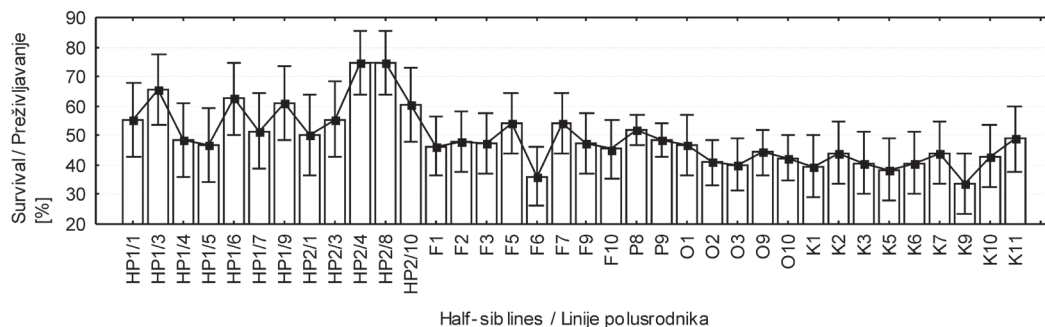


Figure 4. Seedlings survival in progeny tests in Drinić at half-sib lines level / **Slika 4.** Preživljavanje sadnica u testu potomstva u Driniću na nivou linija polusrodnika

Seedlings survival at the population level indicated the superiority of the population from the area of Han Pijesak (population Han Pijesak 1 and Han Pijesak 2). The populations are located about 200 km from the progeny test, while other populations with lower survival rate, except the population of Foča, are much closer to the

progeny test. The survival of seedlings population “Han Pijesak 2” is 63%, while the survival of the population “Han Pijesak 1” is 56%. Local populations “Potoci”, had a survival rate of 50% (Fig. 5). The survival rate at the block level was: 53% for 2nd block, 52% for 3rd block and 40% for 4th block.

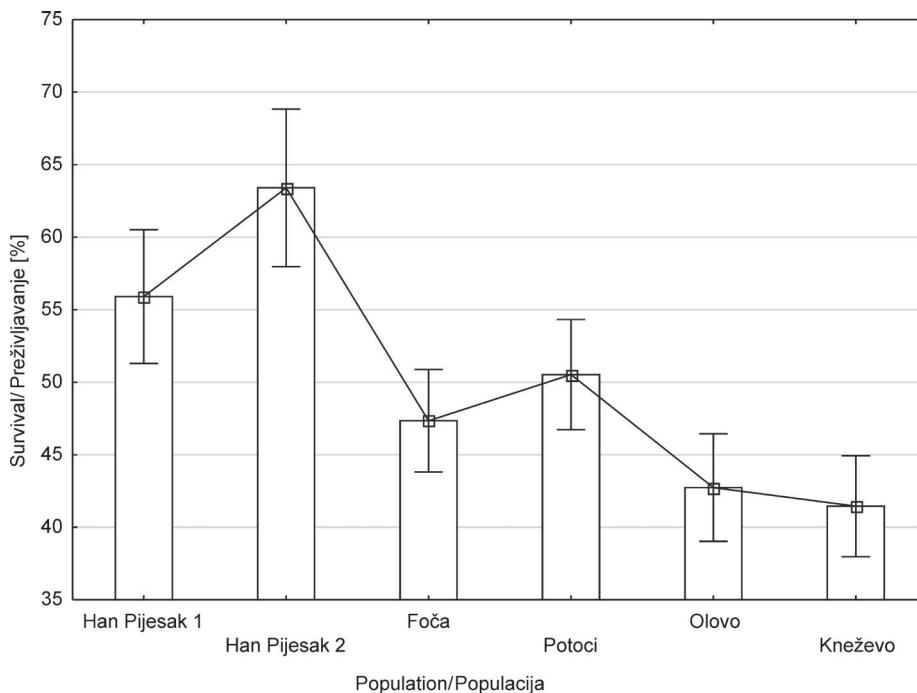


Figure 5. Seedlings survival at the level of populations / **Slika 5.** Preživljavanje sadnica na nivou populacija

ANOVA was performed to determine the difference among the blocks, populations, half-sib

lines and their interaction (table 4). It indicated significant differences for all tested levels.

Table 4. ANOVA for „Survival rate“ / **Tabela 4.** Rezultati analize varijanse za obilježje „preživljavanje sadnica“

Variation source	df	F	p
Blocks	2	27.361	0.0000
Population	5	12.794	0.0000
Half-sib lines	36	2.910	0.0000
Blocks *Population	10	9.834	0.0000
Blocks *Half-sib lines	70	2.109	0.0000

For three analyzed blocks in progeny test, the existence of significant differences among them was determined. Duncan's test indicates the existence of two homogeneous groups. One of them comprised only the fourth block – the block with the lowest percentage of survived seedlings (table 5). The results confirmed what was visible in the field to the “naked eye”: due to microsite conditions in block 4, where the site was drier, the percentage of surviving seedlings was lower.

Table 5. Results of Duncan's test for seedlings survival on block level / **Tabela 5.** Rezultati Dankan testa za preživljavanje sadnica na nivou blokova

Block	Survival	Homog. groups	
		1	2
4	40		****
3	52	****	
2	53	****	

The survival rate at the population level was different, as determined by ANOVA, and the results were grouped into four homogeneous groups (table 6). The population “Han Pijesak 2” clearly distinguished with the highest survival rate and it grouped itself in one homogeneous group. The local population “Potoci” was in the 3rd homogenous group together with the population “Han Pijesak 1” and achieved a survival rate greater than 50%. It was expected that the local population “Potoci” would show better survival rate results due to its position. The population “Potoci” is 35 km south-east from the site where the progeny test had been established. However, the obtained results were different. The reproductive material from populations “Han Pijesak 1” and “Han Pijesak 2” can be taken into

account when the transfer of reproductive material is planned to be done in habitats similar to Drinić progeny test.

Table 6. Results of Duncan's test for seedlings survival at population level / **Tabela 6.** Rezultati Dankan testa za preživljavanje sadnica na nivou populacije

Population	Survival [%]	Homogenous groups			
		1	2	3	4
Kneževo	41	****			
Olovo	43	****			
Foča	47	****	****		
Potoci	51		****	****	
Han Pijesak 1	56			****	
Han Pijesak 2	63				****

The results obtained at the half-sib lines level indicate the superiority of half-sib lines and the populations “Han Pijesak 1” and “Han Pijesak 2”. Half-sib lines HP2/8 and HP2/4 were separated into one homogeneous group (table 7). This can be the basis for the rapid realignment of reproductive material production from the level of populations to the individual level. It would be necessary to do the analysis of the seedlings development dynamics as well as the genetic markers to determine the relatedness of the populations and half-sib lines originating from two localities from Han Pijesak.

Compared with the data obtained by Mataruga et al. (2012), in the first survey conducted in 2010, it can be concluded that a significant number of seedlings did not survive. Also, there are some discrepancies caused by number of blocks that are included in the analysis. In a study from 2012, research has been conducted in 4 blocks and in 2014, three blocks were studied. There are differences in microhabitat conditions which caused less disharmony between two studies. The biggest losses suffered half-sib lines K9 and F6. These were half-sib lines that had the smallest percentage of survival. Most stable and most resistant were two half-sib lines from Han Pijesak: HP2/4 and HP2/8. These half-sib lines had the highest percentage of survival and the smallest loss in 4 year period. For them to be counted in further breeding of species in BiH.

Table 7. Results of Duncan's test for seedlings survival at the half-sib line level / **Tabela 7.** Danka test za preživljavanje na nivou linija polusrodnika

Half-sib lines	Survival [%]	Homogenous groups					
		1	2	3	4	5	6
K 9	34	****					
F 6	37	****	****				
K 5	38	****	****				
K 1	40	****	****				
O 3	40	****	****				
K 3	41	****	****				
K6	41	****	****				
O 2	41	****	****				
O 10	42	****	****	****			
K 10	43	****	****	****			
K 33	44	****	****	****	****		
K 2	44	****	****	****	****		
O 9	44	****	****	****	****		
F 10	45	****	****	****	****		
F 1	46	****	****	****	****		
O 1	47	****	****	****	****		
HP1/5	47	****	****	****	****		
F 9	47	****	****	****	****	****	
F 3	47	****	****	****	****	****	
F 2	48	****	****	****	****	****	
HP1/4	48	****	****	****	****	****	
P 9	49	****	****	****	****	****	
K 11	49	****	****	****	****	****	
HP2/1	50	****	****	****	****	****	
HP1/7	52	****	****	****	****	****	
P 8	52	****	****	****	****	****	
F 5	54		****	****	****	****	
F 7	54		****	****	****	****	
HP1/1	55		****	****	****	****	
HP2/3	56		****	****	****	****	
HP2/10	60			****	****	****	****
HP1/9	61			****	****	****	****
HP1/6	63				****	****	****
HP1/3	66					****	****
HP2/8	75						****
HP2/4	75						****

4. CONCLUSION / ZAKLJUČAK

The seedlings originating from two locations in the wider area of Han Pijesak had the best survival rate in progeny test Drinić. In subsequent analyses it is necessary to take into account the results which would be related to the assessment of the production potential of the population and half-sib lines in this area. It presents a possibility to get the overview of the potentials of spruce from different areas for the introduction in new habitats.

Also, the results may indicate the appropriate norm of reaction of populations and half-sib lines. This will be particularly important if the current trend of climate changes continues. The results of survival rates of seedlings might direct the pro-

ducers of forests seeds and planting materials to promising populations as potential seed recourses in the form of provenance region or seed stands.

After entering the maturity phase progeny test could be categorized as a potential source of reproductive material for further work on breeding through the re-selection process followed by hybridization. At the same time, it can be a seeds source for the production of planting material for reforestation. Progeny test which has been established in Drinić is a form of ex situ conservation of a large part of Norway spruce gene pool in B&H, which gives it a special value and requires additional engagement of the forestry profession and science.

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Sažetak

Testovi potomstva imaju nezamjenjivu ulogu u istraživanju potencijala šumskih vrsta drveća. Analize uticaja promjena životne sredine i njihovog uticaja na populacije i linije polusrodnika predstavlja osnovu za usmjereno korišćenje i transfer reproduktivnog materijala drveća.

Iako je jedna od ekonomski najvažnijih vrsta drveća, smrča nije do sada imala značajniju ulogu u poljskim oglecima u Bosni i Hercegovini. Jedan od prvih testova potomstva osnovan je u Driniću. Po svojim bioekološkim karakteristikama, test predstavlja zapadni dio Bosne i Hercegovine u kojem se smrča vrlo često koristi za pošumljvanje. U takvim uslovima, smrča porijeklom iz 6 populacija iz Bosne i Hercegovine pokazala je različit procenat preživljavanja sadnica što je bitno za definisanje zona sigurnog transfera reproduktivnog materijala.

Najbolje rezultate pokazale su populacije Han Pijesak 1 i Han Pijesak 2. Najlošije rezultate pokazala je populacija Kneževo, a zatim populacija Olovo. Na nivou linija polusrodnika najbolje rezultate pokazale su linije polusrodnika HP2/4 i HP2/8 dok su najlošije rezultate pokazale linije F6, K5 i K9.

Dalja istraživanja će se usmjeriti na istraživanja najproduktivnijih populacija i linija polusrodnika kao i na njihove proizvodnje karakteristike. Na osnovu broja preživjelih sadnica i proizvodnih karakteristika, moće će se sa odgovarajućom sigurnošću definisati siguran transfer reproduktivnog materijala na području Bosne i Hercegovine.

Ključne riječi: preživljavanje, smrča, test potomstva Drinić