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THE DYNAMICS OF GERMINATION AND MORPHOMETRICS PROPERTIES OF AUSTRIAN PINE (*Pinus nigra* Arnold) SAPLINGS IN TERMS OF EARLY INDICATORS OF TOLERANCE TOWARD THE DROUGHT

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Genetic markers, from morphological to molecular, in function with early indicators of tolerance toward drought, have been an object of research and scientific papers for many years. It starts with the hypothesis that seedlings produced from seeds that were collected from population of extremely different site conditions, on the level of open pollinated families, will have different results concerning drought tolerance. By tracking the

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dynamics of germination and morphological parameters of saplings, we are researching the interdependence of these parameters with the survival and growth of two-year-old seedlings in conditions where there is a lack of water. Austrian Pine seeds were collected from forty trees, distributed over five provenances on the Balkan Peninsula. Within each provenance a group is assigned to an extremely harsh and dry habitat, while also another group is assigned to prosperous (the most productive) habitat. The analysis of the twenty-one-day-old seedlings (saplings) is performed in the laboratory, while the tolerance test of the two-year-old seedlings is performed in the field. Seedlings that are exposed to conditions in which there is lack of water, have the coefficient of water formation evaluation 22.59 times bigger than sandy-clay soil with fraction of sand bigger than 60 percent.

The results show significant and positive correlation between some parameters of saplings and the dynamics of growth (high increments) of the seedlings in drought, but no correlation with the survival of the seedlings.

Key words:dynamics of germination, indicators of drought, *Pinus nigra* ,properties of seedling

INTRODUCTION

Disjunct area and specific environmental characteristics of isolated populations of black pine (*Pinus nigra* Arnold) caused a high degree of its interspecies variability, due to the effects of specific genetic mechanisms (MATARUGA and ISAJEV 1998; ISAJEV *et al.* 2004; LUČIĆ *et al.* 2008). However, research concerning the germinative behavior among ecotypes, provenances, or populations within the same species is very limited (MATARUGA *et al.* 2010a; 2010b). FALUSI et al. (1983) showed that germination energy, germination rate, and root growth of *Pinus halepensis* seed under a range of moisture conditions varied among seed sources. Similarly, significant differences were found in germination of *Pinus sylvestris* seed from six provenances placed under varying water potential conditions with those from the southern most provenances showing less susceptibility to water stress (TILKI 2005). BOYDAK *et al.* (2003) also found that germination rates of *Pinus brutia* seed from provenances of humid regions were most susceptible to moisture stress and could be attributed to intraspecific variations resulting from natural selection.

The first step in creating a plant is the adoption of water and seed swelling. Then come the activation and synthesis of ferments, hydrolize of reserve materials and their transportation to places of growth, synthesis of new metabolites and tissues. Division, lengthening and differentiation of cells in various structures of sapling creates a plant, which later reaches maturity and takes the characteristics of a species, (TUCOVIĆ and ISAJEV, 1984). In woody plants “sapling” (or young seedling) is considered to be a young plant in the first/initial period of its development, usually from establishing the first, more or less, characteristic/typical leaves (ANIĆ, 1983).

Each plant species in the phase of saplings is mostly and easily susceptible to elimination in both the natural (stands), as well as artificial (nurseries) conditions. Therefore, a lot of authors are conviced (TUCOVIĆ and ISAJEV 2000) that it is of special significance to get to know more variabilities of morphological traits and youngest characteristics of the ontogenetics development, considering the large differences that can be observed at that age, which are largely the consequence of genetic variability (polymorphism*)*. Age variability was of no significance until it was realized that an individual is exposed to natural selection in each time (at each phase, on each level) of the life cycle. In the cycle of development of each species the number of sapling is the largest, compared to adult individuals, both in natural and cultivated (artificial) conditions. The number of genotypes is the largest at this stage of development of trees, and they contain the highest level of gene pool of parent trees. With the age, their number becomes smaller/decreases, diminishes, often only to a few trees, which significantly reduced genetic variability compared to the starting variability of sapling. The first and strongest natural selection actually happens when the plants are in the stage of germination. Therefore, comprehensive studies that show significant interdependence between the properties of cotyledons, hypo-and epicotil, and roots with subsequent characteristics of adult trees.

With the above mentioned, the variability of sapling is, generally speaking, significantly less studied in woody plants. Not many works which study black pine sapling have been found (MATARUGA *et al.* 2003; 2007) while sapling of *Amorpha fruticosa* were studied more (TUCOVIĆ and ISAJEV 2000, KNEŽEVIĆ and TUCOVIĆ, 2004); *Platanus x acerifolia* (TUCOVIĆ and OCOKOLJIĆ 1998); *Picea omorka* (TUCOVIĆ and ISAJEV 1984); *Ailanthus altissima* (TUCOVIĆ 1995, TUCOVIĆ *et al* 1997); *Fagus silvatica* (ŠIJAČIĆ-NIKOLIĆ *et al.* 2007); *Celtis occidentalis* (ŠIJAČIĆ-NIKOLIĆ *et al.* 2008); *Paulownia elongata* (ŠIJAČIĆ-NIKOLIĆ *et al.* 2009); *Abies alba* (BALLIAN, 2000) and others.

One of the major problems of early testing is to identify features or combinations of features of juvenile material, which is in a strong correlation with the significant features of adult plants (ERIKSSON and EKBERG 2001). This problem is especially prominent when analyzing quantitative traits of plants, whose heredity/genetics and stability of expression over the life cycle are affected by a large number of minor genes, where a completely different set of alleles may be responsible for their expression in the juvenile and mature development stage. Physiological processes as a result of the influence of environmental factors and inheritance are very complex, and their knowledge and understanding are necessary for the purpose of predicting the success of the establishment of forest plantations, and the survival and growth of seedlings after planting.

Starting from the general well-known fact that the black pine is the species that occurs in extremely dry habitats where it creates native populations, the interest for using this species for reforestation and the establishment of new forests on degraded and shallow soils affected by erosion, has always existed. Interspecies variability (inter- and intra- populations) is proved in the tolerance of seedlings under different water deficit conditions (MATARUGA 2003; 2006).

Finding interdependencies between the features of saplings and survival of seedlings in the conditions of water deficit is a complex approach to the study of the degree of variability in components of growth and development of Austrina pine in various early stages of the life cycle. That creates a substantial basis for genetic improvement of production technology of high quality planting materials for pre-defined purpose.

MATERIALS AND METHODS

All research is based on a study of the dynamics of seed germination, morphological traits of saplings, two-year-old seedlings of Austrina pine in different conditions of water deficiency and the analysis of the interdependence and correlation of the properties listed above.

In the context of the above mentioned, Austrian pine seed was collected from trees that are on the rocky (harshest) habitats which are, in most cases, only inhabited by Austrian pine. For the purpose of comparing sapling properties and reactions of plants to water deficiency, besides the seeds from these trees, we collected the seed from the trees in the best habitats on which there is Austrian pine. Site conditions of populations are given in Table 1. Five provenaces were included (Sutjeska, Tara, Teslić, Višegrad and Durmitor). Two populations were allocated within each provenance (extremely harsh habitat-where the seeds were collected from 5 trees, and the best habitat (where the seeds were collected from 3 trees).

Table 1. Site conditions of populations where a seeds were collected

Provenance	Habitat	Trees	Latitude	Longitude	Altitude (m)	Geological substrate	Soil type
Sutjeska	rocky	1-5	43 19’20’’	18 42’46’’	1400	limestone	no surface soil
	control	6-8	43 19’19’’	18 39’33’’	1300	limestone	colluvium
Višegrad	rocky	1-5	43 45’20’’	19 24’04’’	550	limestone	no surface soil
	control	6-8	43 51’26’’	19 14’24’’	475	serpentinite	eutric cambisol
Tara	rocky	1-5	43 52’50’’	19 24’20’’	800	limestone	no surface soil
	control	6-8	43 53’20’’	19 32’40’’	1050	serpentinite	eutric cambisol
Teslić	rocky	1-5	44 34’30’’	17 43’28’’	510	serpentinite	eutric leptosol
	control	6-8	44 34’03’’	17 43’34’’	470	serpentinite	Albeluvisol – (Pseudogley)
Durmitor	rocky	1-5	43 09’12’’	19 15’53’’	1240	limestone	Leptosol -
	control	6-8	43 00’29’’	19 25’29’’	1320	limestone	Calco-cambisol

Immediately after collecting and processing the seeds (spring, 2000) they were tested applying the direct method of testing germination. Germination of seeds was done according to ISTA standards. The number of seeds which start to germinate and the number of normal germinated seeds were observed every 4 days. The dynamics of germination is presented based on the total number of germinated seeds ie. number of seeds that began to germinate plus the number of normal germinated seeds. The number of germinated seeds is presented as absolute germination, ie the number of germinated seeds according to the number of full seeds, ie. the formula:

$$\text{Absolute germination} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds-Number of empty seeds}}$$

The length of hypocotyls, roots, cotyledons (in millimeters) and number of cotyledons (in pieces) were measured at 21-day-old seedlings

The "Duneman beds" were built according to standard principles (STILINOVIĆ, 1987). One-year seedlings were transplanted in them. As walls of Duneman beds we used boards 30 cm wide, 4.5-5 cm thick. The length of bed was 12.5 meters, the width 1.3 meters, and the depth 0.3m. Below the surface of the bed and the paths we put a grid, and on it a layer of larger crushed stone, which had the function of preventing rodents from entering the bed, and stopping the movement of water from the lower layers to the substrat in beds.

The substrate in beds was made to improvise a variety of living conditions in terms of water regime and quantity of available water to planted seedlings. In that respect, Duneman beds were filled with substrate, which was a mixture of rock (the skeleton) and soil in a variety of ratios (the ratio of stone:soil was- in bed 1 = 80%: 20%; in bed 2 = 67%: 33% and bed 3 = 33%: 67%). The properties of humus and skeleton are given in table 2.

The seedlings were planted in rows perpendicular to the length of the bed, with 12 seedlings in each row with a distance between seedlings 0.1 m. Forty half-sib lines were placed on a length of 12 meters through three repetitions. 108 seedlings were transplanted from each half-sib lines (a total of 12 seedlings x 40 half-sib lines x 3 repetitions x 3 beds = 4320). Measurements of seedling height and observations of survival were carried out 6 times during the vegetation period, which means that for these properties a total of 25,920 measurements and 25,920 observations of survival (or dying) were made.

In order to define the differences between the beds in terms of water permeability, and therefore the difference in the availability of water, we made tests for water permeability of the substrate. As you can see the permeability of water in bed 1 (80% of stones: 20% of soil) was 22.59 times higher than in the used soil whose properties are described in the first part of the table.

Table 2. Properties of the soil that was used for the substrate in Duneman beds

Water-air properties of used soil

Specific weight [gr/cm^3]	Density [gr/cm^3]	Retention capacity for water vol.%	The total porosity of soil vol. %	The capacity for air vol. %	Dry soil
2,70	1,37	35,30	49,26	13,96	9,87

Mechanical composition of used soil

Sand particles 2,0-0,06 %	Powder particles 0,06-0,002 %	Clay particles <0,002 %	Class of texture
60,18	29,99	9,83	Sandy loam

The chemical composition of used soil

pH u H_2O	pH u KCl	Humus %	P_2O_5 [mg/100gr.]	K_2O [mg/100gr.]
8,36	7,51	0,75	4.6	6,00

Permeability of water at different substrates and beds

	Bed-1-80:20	Bed –2-67:33	Bed-3-33:67	Soil-0:100
Permeability coefficient "K" in m/day	19,43	9,70	1,52	0,86
The difference in permeability compared to used soil	22,59 x	11,28 x	1,77 x	1 x
Evaluation of hydraulic conductivity	very fast	very fast	moderately fast	moderate

In order to define the dynamics of growth as an indicator of when during the vegetation period is the height growth the most intensive, and highlight the progeny that has growth in the first part of vegetation period, the formula applying the principle of calculating medium duration of germination was used*:*

$$Dvp = \frac{l_1(T-t_1)+l_2(T-t_2)+\ldots+l_m(T-t_m)}{l_1+l_2+\ldots+l_m}$$

where the following are:

-Dvp- height growth dynamics,

-l_1, l_2, l_m-periodic height increment between two measurements

-t_1, t_2, t_m- number of days from the date when the seedlings were planted

-T-total number of days from planting to the final measurements of height growth.

Permanently during the vegetation period the observations of seedlings that were starting to die and began to change color from green to yellow, were carried out. These seedlings were recorded. The number of seedlings that started to dry were observed 6 times during the vegetation period from April, 3rd to September, 23rd. Twenty days after the seedlings were planted, all the seedlings that have died and all the seedlings that started with high increment were recorded. The seedlings which did not initiate vegetation were excluded from the calculation and further characterized as dried, which could be due to improper planting.

All the measurements were carried out on a randomly selected sample, and the experiments were done based on the statistical principle of reducing the experimental error, ie, by the planned trials, which included the necessary conditions: repetition, random distribution of land and local control.

In order to simplify the presentation and explain the significant differences inside and between the populations, the F-tests were done (analysis of variance) and that from the simplest (one factor) to the most complex (four factors). To confirm the significance of the difference between the arithmetic mean of individual factors, multiple interval-Duncan test was used. The interdependence of all analyzed properties was proved through regression coefficient (r^2) (HADŽIVUKOVIĆ, 1991).

RESULTS AND DISCUSSION

The dynamics of germination

As early as 3 days after placing the seeds to germinate, the half-sibe line vis/2 had 100% germination. In 21 days 6 half-sibe lines which had 100% germination (sut/6, vis/2, tar/3, tar/6-7, dur/7) were located. The lowest germination at the start had a tar/2, and later throughout the period vis/6 had the lowest value, and on the twenty-first-day the total germination was only 53.31%.

Mean values at the level of the population are shown in Figure 1. As the first indicator it should be pointed out that all the populations with rock provenance had a lower percentage of germination except the provenance of Visegrad. The lowest differences between the mean values of populations and within individual provenances, were measured at Durmitor, Teslic and Sutjeska, while large differences among populations within the provenances of Visegrad and Tara. The significance of the differences was confirmed by the analysis of variance and Duncan tests (Table 3 and 4). Also, a significant difference between the test trees in the same population was observed, which is the indicator of the great individual variability.

On the basis of mean values of the percentage of germinated seed, 3 days after being posted on germination, significant differences in favor of lines with rocky populations were also noted, because on average they had about 5% higher germination than the trees from the control populations. This may indicate the larger dynamics of germination and seed germination ability in a faster (shorter) period, which is certainly caused by the habitat conditions and water availability as a limiting factor in the process of germination in rocky habitats. Later, the difference increases in favor of the provenances, and disappears depending on the site (habitat) conditions where the test trees grow.

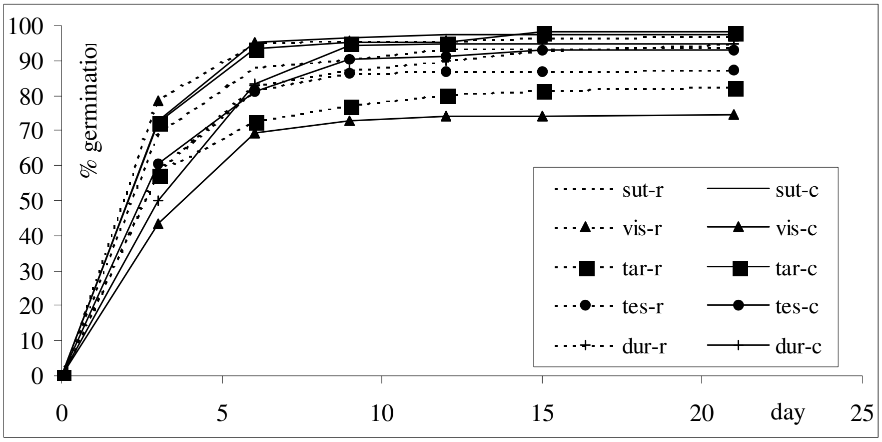

Figure 1. The dynamics of seed germination at the level of population

Table 3. Analysis of variance for the dynamics of seed germination

Factors	Number of factor	3rd day	6th day	9th day	12th day	15th day	21st day
provenance (1)	5	2,577 ^{ns}	3,380*	4,109**	5,863**	5,171**	5,672**
half-sib (2)	8	4,206**	2,974*	5,161***	4,890***	3,269**	2,827*
interaction (1 x 2)		3,672***	6,750***	9,135***	8,466***	9,146***	8,636***
population (1)	10	4,433***	7,735***	10,853***	11,542***	12,618***	12,781***
half-sib (2)	3-5	4,764**	3,003*	5,488**	5,897**	3,596*	2,984*
interaction (1 x 2)		3,335***	5,479***	7,154***	6,388***	6,571***	6,045***
habitat (1)	2	4,950*	,123^{ns}	1,644 ^{ns}	,375 ^{ns}	,508 ^{ns}	,163 ^{ns}
half-sib (2)	25–15	4,711***	7,293***	9,013***	8,044***	8,265***	7,936***
interaction (1 x 2)		1,991*	3,449**	6,373***	7,176***	7,173***	6,688***

Table 4. Duncan test for the dynamics of seed germination

3rd day		6th day		9th day		12th day		15th day		21st day	
viš-k	a	viš-k	a	viš-k	a	viš-k	a	viš-k	a	viš-k	a
dur-k	a	tar-s	ab	tar-s	a	tar-s	a	tar-s	b	tar-s	b
tar-s	ab	tes-k	bc	tes-s	b	tes-s	b	tes-s	bc	tes-s	bc
tes-s	ab	tes-s	bc	dur-s	bc	dur-s	bc	tes-k	cd	tes-k	cd
dur-s	ab	dur-s	c	tes-k	bcd	tes-k	bcd	dur-s	cd	sut-s	d
tes-k	ab	dur-k	c	sut-s	bcd	sut-s	bcd	sut-s	cd	dur-k	d
sut-s	bc	sut-s	cd	dur-k	cd	dur-k	cd	dur-k	d	dur-s	d
tar-k	bc	tar-k	d	tar-k	d	tar-k	cd	viš-s	d	viš-s	d
sut-k	bc	viš-s	d	viš-s	d	viš-s	cd	sut-k	d	sut-k	d
viš-s	c	sut-k	d	sut-k	d	sut-k	d	tar-k	d	tar-k	d

Despite the fact that in most cases the measured values of germination in populations on a rock in comparison with the control population are smaller/lower, and the fact that only the provenance of Visegrad measured higher germination in the population on rocks, leads to the conclusion that the living conditions in which the analyzed populations are found, does not affect the dynamics of seed germination, but the very characteristics of the populations, as well as the inter-lines variability, have the greatest impact on the dynamics and energy of germination.

Features of seedlings (sapling) 21 days old

The highest values of the properties of the length of hypocotyls, root length and the length of cotyledons had a half-sib line vis/3. The length of hypocotyls ranged from 5.33 cm (vis/6) to 7.55 cm (vis/3), the length of root from 1.93 cm (sut/4) to 4.64 cm (vis/2), the number of cotyledons from 6.33 (tes/2) to 9.00 (vis/7) and the length of the cotyledons from 2.62 cm (sut/1) to 4.43 cm (vis/3). The largest range of variations for all 40 tested half-sib lines was measured in root length, but the lowest in the number of cotyledons. The saplings of seed trees that are on the rocks, had almost all the features more prominent than saplings of half-sib lines from the control population (Figures 2-6). The most significant difference is reflected in the size of the root, and also in the length of the cotyledons, where significant differences are proved. Also a larger length of hypocotyls(60.77 mm> 60.21 mm) was measured, but the results of the analysis of variance does not show that this difference is significant (Table 5).

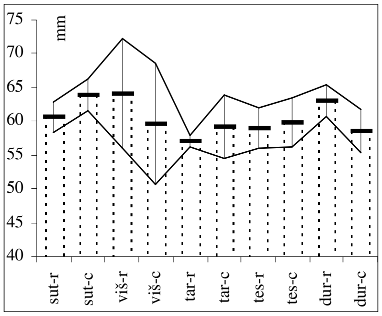

Figure 2. Hypocotyl length [mm]

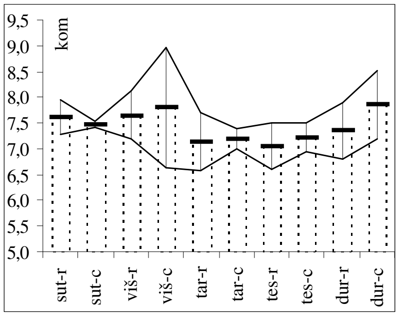

Figure 3. Number of cotyledons [piece]

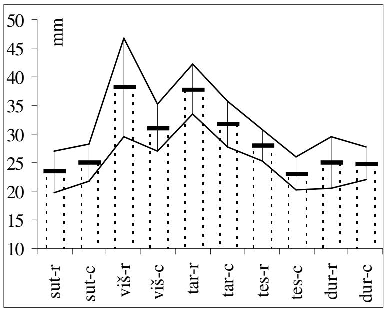

Figure 4. Root length [mm]

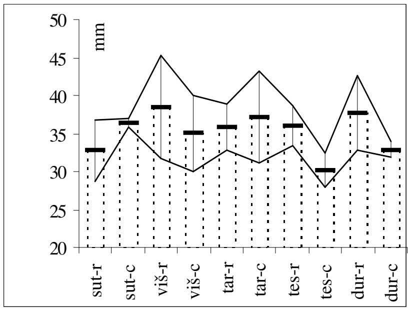

Figure 5. Cotyledon length [mm]

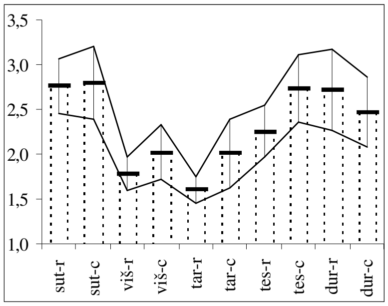

Figure 6. Relation between hypocotyl length and cotyledon length

It is important to emphasize that the roots of half-sib line from vis/2 and 3 (44.42 mm) had the greatest length which, in further tests, showed the largest percentage of growth and survival of two-year-old seedlings in exposure tests in conditions of water deficiency.

Table 5. Analysis of variance of the traits of 21-day-old saplings

Factor	Number of factors	Hypocotyl	Root	Ratio hypoc./root	Number of cotyledons	Cotyledon length
population (1)	10	7,726***	41,111***	25,513***	4,449***	13,593***
half-sib (2)	3-5	12,293***	15,888***	4,771**	2,555*	14,060***
repetation (3)	4	,769^{ns}	3,390^{ns}	3,599^{ns}	,133^{ns}	,520^{ns}
interaction (1 x 2)		4,678***	4,611***	2,981***	4,250***	8,730***
provenance (1)	5	8,167***	75,118***	50,589***	8,086***	8,580***
half-sib (2)	8	7,202***	13,582***	4,336***	3,556**	11,677***
repetation (3)	4	3,559^{ns}	2,738^{ns}	3,165^{ns}	,999^{ns}	1,111^{ns}
interaction (1 x 2)		5,362***	5,300***	3,433***	3,750***	10,177***
habitat (1)	2	,310^{ns}	75,796***	29,713***	,213^{ns}	6,868**
half-sib (2)	25–15	5,859***	15,229***	9,005***	3,498***	10,389***
repetation (3)	4	2,294^{ns}	1,655^{ns}	2,088^{ns}	,487^{ns}	2,014^{ns}
interaction (1 x 2)		6,552***	10,614***	7,367***	5,372***	9,686***

By analyzing the differences between the populations in different provenances based on the variance analysis tests and Duncan tests (Table 5 and 6), we can conclude the following:

- For the root and cotyledon lengths, as well as the ratio of the length of hipokotil/root for rocky populations, significantly higher values were confirmed.

-There is no significant difference in the length of hypocotyls, although half-sib lines from the rocks had somewhat higher values. (It should be noted that the populations from rock provenances Durmitor and Visegrad had significantly higher values, while in the provenances Sutjeska significantly lower values of this population were measured, and the values for Tara and Teslic were not significantly lower),

-The differences in site conditions in which test trees are situated, have the least influence on the properties of saplings, and the highest influence on the features of individual trees.

-The length of cotyledons is distinguished as the property in which significant differences between populations in all provenances were observed (except for Tara). On the other hand, the number of cotyledons differed only between the habitats within the provenance Durmitor.

Table 6. Duncan test for 21-day-old saplings

Hypocotyl		Root		Ratio hypoc./root		Number of cotyledons		Cotyledon length	
tar-s	a	tes-k	a	tar-s	a	tes-s	a	tes-k	a
dur-k	ab	sut-s	a	viš-s	ab	tar-s	a	sut-s	b
tes-s	ab	dur-k	a	tar-k	bc	tar-k	a	dur-k	b
tar-k	ab	sut-k	a	viš-k	bc	tes-k	ab	viš-k	c
viš-k	ab	dur-s	a	tes-s	cd	dur-s	abc	tar-s	cd
tes-k	ab	tes-s	b	dur-k	de	sut-k	abcd	tes-s	cd
sut-s	bc	viš-k	c	dur-s	ef	sut-s	bcd	sut-k	cde
dur-s	cd	tar-k	c	tes-k	ef	viš-s	cd	tar-k	cde
sut-k	d	tar-s	d	sut-s	f	viš-k	d	dur-s	de
viš-s	d	viš-s	d	sut-k	f	dur-k	d	viš-s	e

The dynamics of growth and survival of seedlings in extremely different substrates (water regimes)

Mean values on the population level are shown on Figure 7. In all populations a significantly higher growth rate in bed number 3 was measured, ie. the bed with 33% of stone. Within bed 3 in all provenances (except Tara where the values are almost the same), the stronger dynamics of growth of controlled populations was measured. In bed 1 (substrate with 80% of stone) the control population from provenances Sutjeska, Visegrad, Teslic had higher values, while the tar-r and dur-r had higher values. The control population inside Durmitor provenance had the largest difference in the dynamics of growth between 1. and 3. beds, where the rock population had greater success in bed 1, while the control population had greater success in bed 3.

Figure 8 shows the percentage of survival of seedlings at the end of vegetation period on the level of the studied populations and beds (with different degrees of water deficit). First, it can be concluded that the ratio of populations within the same provenance was always the same, ie. if the population of the rocks had a smaller percentage of survival in bed 1, then it also had a smaller percentage in the third bed. Only the provenance of Visegrad recorded a higher percentage of survival of rock population in all beds. It can be also noted that the population dur-c had a slightly smaller percentage of survival in bed 3 than in bed 1, while the population dur-r had a significantly higher percentage of survival in the third bed. All half-sib lines had a higher percentage of survival in the third bed.

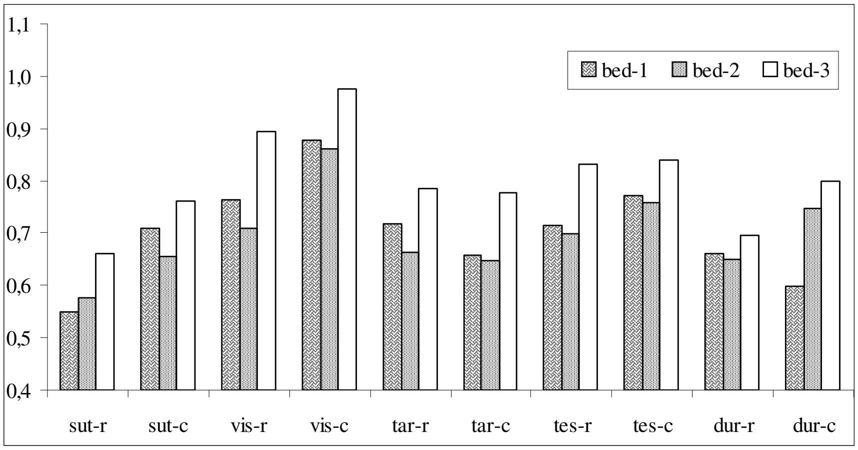

Figure 7. Mean value of the dynamics of height growth for populations in three beds

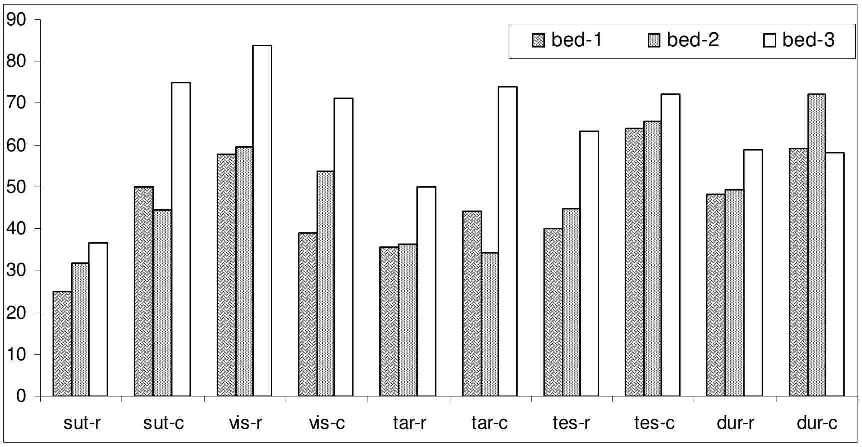

Figure 8. Mean value percentage of survival at the end of vegetation period

In all provenances (except Visegrad), half-sib lines from the most productive populations had a higher percentage of survival, ie. half-sib progeny originating from the rocks had a lower percentage of survival in all conditions of water deficit (beds 1, 2 and 3). Only the rocky population from the provenance of Visegrad recorded a higher percentage of survival in all beds. This dynamics of survival percentage of seedlings at the population level fully follows the dynamics of germination of fresh seeds. Besides the fact that at the population level lower percentage of survival at half-sib progeny originating from the rocks was measured, at the same time higher coefficients of variation in these populations were recorded, which speaks in favor of greater genetic diversity of progeny from these habitats. Also, in most of the analyzed properties the extremes belonged to the half-sib progeny from these populations (the greatest percentage of survival have vis/2, vis/3, and the lowest dur/ 2; sut/2). All these facts point to the validity of individual selection on these habitats, while for the commercial production of planting material, until the synthesis of sorts, mass selection of the best and most productive populations of black pine could be carried out.

Interdependence of the dynamics of germination and the characteristics of saplings with the dynamics of growth and survival of seedlings in extremely different substrates

Regression coefficients are shown in Table 8.demonstrate significant dependencies of a small number of analyzed properties. The most important are shown in Figure 9.

Based on the results of morphometric properties of sapling it can be stated that they have high importance for nursery production technology. For this reason it is recommended to control and monitor the characteristics and variability of saplings, based on which we can predict successful production of planting material and its use in establishing the plantations of special purpose. As we have proved that there is a significant correlation of root length and seedling traits in drought conditions, we can also recommend tests to check the germination of seeds that would also include measurements of root length.

Although significant interdependence of these properties with seedling survival and growth in different habitat conditions were not recorded, these properties (primarily the length of the root) give good guidelines in the early selection of lines.

Table 8. Interdependence of the dynamics of germination, characteristics of sapling with height growth dynamics and survival of seedlings in conditions of water deficit (regression coefficients)

	Dynamics of growth-bad/1	Dynamics of growth-bad/2	Dynamics of growth-bad/3	% survival 23.9.01-bed/1	% survival 23.9.01-bed/2	% survival 23.9.01-bed/3
Germination/3 days	0,05	-0,14	0,03	-0,01	-0,06	0,14
Germination/6 days	-0,06	-0,14	-0,04	0,08	0,04	0,09
Germination/9days	-0,08	-0,09	-0,06	0,14	0,12	0,05
Germination/12 days	-0,12	-0,10	-0,10	0,14	0,10	0,02
Germination/15 days	-0,13	-0,12	-0,13	0,18	0,09	0,02
Germination/21 days	-0,14	-0,14	-0,15	0,20	0,09	0,01
Hypokotyl length	0,17	0,09	0,05	0,22	0,26	0,24
Root length	**0,41***	0,23	**0,35***	0,04	0,01	0,11
Ratio Hypokotyl/Root	**-0,35***	-0,24	**-0,37***	0,05	0,09	-0,02
Number of cotyledons	0,02	0,26	0,12	0,13	0,29	-0,01
Cotyledons length	0,26	0,17	0,14	0,01	-0,01	0,15

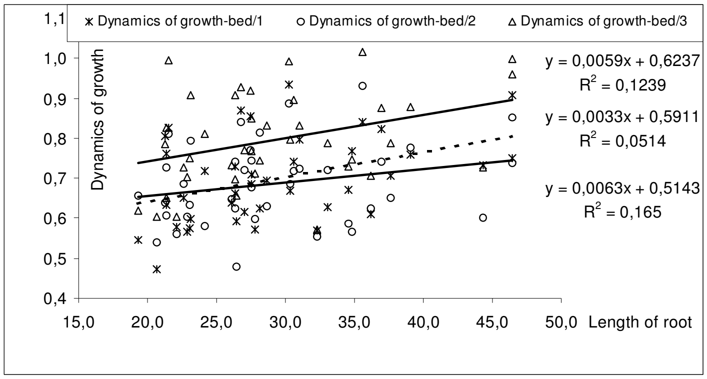

Figure 9. Dependence of the length of root and growth dynamics of two-year-old seedlings in conditions of water deficit

CONCLUSIONS

Based on the analysis of the dynamics of germination of seeds from different provenances and populations with extremely different site conditions, it can be concluded that site conditions (where mother trees grow) do not affect the germination of seeds, but inter-lines variability has the greatest impact on the dynamics and energy of germination.

Saplings (21day old seedling) from seeds trees which are on the rocks had almost all the features higher than saplings from the control populations. The most significant difference is reflected in the size of the root, and also in the length of the cotyledons. Considering the significant correlations, particularly the length of the roots with the dynamics of height growth in conditions of water deficit, in future research and in testing the quality of seeds we should analyze the characteristics of saplings which would enable forecasting the success of the production of planting material and its use in the planting of plantations for special purposes.

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DINAMIKA KLIJAVOSTI I MORFOMETRIJSKA SVOJSTVA KLIJAVACA CRNOG BORA (*Pinus nigra* Arnold) KAO RANI POKAZATELJI TOLERANTNOSTI NA SUŠU

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Izvod

Pored činjenice da crni bor ulazi u grupu najistraženijih drvenastih vrsta, istraživanja koja se odnose na dinamiku klijanja različitih ekotipova, provenijencija ili populacija crnog bora su veoma skromna. Praćenjem dinamike klijanja i morfometrijskih parametara klijavaca istraživana je međuzavisnost ovih svojstava sa opstankom i razvojem dvogodišnjih sadnica u uslovima vodnog deficita.Seme crnog bora je sakupljano u 5 provenijencija na Balkanskom poluostrvu. Unutar svake provenijencije izdvojena je populacija na ekstremno surovom staništu i populacija na najproduktivnijem staništu. jeme je ukupno sakupljano sa 40 stabala. Dinamika klijanja je praćena u trajanju od 21 dan, dok su osobine klijavaca – dužina epikotila, hipokotila, kotiledona i broj kotiledona mereni na klijavcima starim 21 dan. Kasnije proizvedene dvogodišnje sadnice na nivou testiranih stabala su izlagane vodnom deficitu u poljskim uslovima gde je evidentiran procenat preživljavanja i dinamika visinskog prirasta u toku jednog vegetacionog perioda.Klijavci dobijeni od sjemena koje je sakupljano sa stabala na ekstremno surovim staništima gotovo uvjek su imali veće morfometrijske vrijednosti. Najveće razlike su se manifestovale u veličini korena i dužini kotiledona. Dobijeni rezultati pokazuju pozitivnu korelaciju između nekih parametara klijavaca (dužina koreena) i dinamike rasta (visinski prirast) dvogodišnjih sadnica u uslovima vodnog deficita. Nisu dokazane međuzavisnosti osobina klijavaca i opstanka dvogodišnjih sadnica tj. preživljavanja u uslovima vodnog deficita.

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