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PERFORMANCE OF BLACK PINE (*PINUS NIGRA* ARN.) PROVENANCES IN WEST BULGARIA

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Abstract

Fourteen provenances of *Pinus nigra* Arn. from the best autochthonous populations in Bulgaria were tested on two sites in West Bulgaria. Data of the 36–37th year of the plantations on tree diameter, height, survival and stem quality show varying results per site but provide grounds for recommending Goleshevo (Petrodan) and Razlog provenances and avoiding the use of Hristo Danovo provenance in similar conditions. Significant site-provenance interactions are confirmed. The source for the seeds – be it from mother plus trees or seed aggregations seems to matter and plus tress shall be preferred. Showing of different ecotypes and edophotypes is also discussed indicating better performance of the low-mountain ecotype and the calcareous edaphotype for similar conditions although not statistically substantiated for the two sites.

Key words: performance, productivity, provenance trials, site-provenance interactions.

Introduction

Black pine (*Pinus nigra* Arn.) has been extensively used for reforestation and land restoration in South-Eastern Europe, the Mediterranean basin and other parts of the world since the late 19th century. The species presently covers more than 3.5 million hectares (Isajev et al. 2004) making it one of the most widespread conifer species in the Balkans and Asia Minor (Enescu et al. 2016). For example, Black pine is the most used species in Anatolia for afforestration (Öner et. al. 2016). Within Bulgaria, Black pine occupies circa 275,000 ha with a growing stock of around 74 million m³ and annual harvesting levels of about 700,000 m³ per annum (EFA 2016) with potential for further increase of the area (Kostov and Rafailova 2009). Natural Black pine forests have been historically reduced to approximately 20,000 ha occupying scattered patches (Zlatanov et al. 2010) as is the case throughout the natural range of distribution of the species, thus leaving a considerably larger proportion to artificially established plantations. Some of the latter have been established exclusively for erosion control purposes on dry and poor sites while others targeted purely commercial objectives replacing natural broadleaved vegetation. In both cases, advantages of some important features of the species were sought which, as summarized by Matziris (1985) include:

- it is well adapted to a wide range of environmental conditions, forming different ecotypes;
- it is highly tolerant and grows well even on degraded lands;
- plantations are easily established re-

quiring minimum cultivation;

- grows fast, producing high quality and resistant timber.

Given the increasing demand for timber and other forest products and the resulting pressure on natural forests, commercial plantations will continue playing an important role in satisfying the needs of timber (Kanowski 1997; Savill et al. 1997; Evans 1999, 2001; Milev 2013). Taking into account Black pine's ecological plasticity and above all drought resistance (Mataruga et al. 2010, 2012), the species can well serve this role in the afforestations and reforestations in part of the lower and the middle (in terms of altitude) forest belt in South-Eastern Europe.

Bulgarian afforestation practices however, have not always taken into consideration the site conditions, the influence of the origin and the hereditary qualities of the sowing materials. As a result, coupled to a large extent with the untimely implementation of the tending and thinning operations, part of the established Black pine plantations deteriorate in general, have reduced growth characteristics, unfavourable environmental and commercial effect, which places serious questions over their future use (Bardarov and Milev 2015), although not as serious as for other species that face similar challenges such as the Scots pine.

Provenance trials provide good opportunity to actively seek answers to some of the most pressing issues related to sustainability and improving the production potential of plantations. Experience within Europe is already generated but Black pine provenance trials are not unknown even at places far from the natural range of distribution of the species including USA (Wheeler at al. 1976) and New Zealand (Wilcox and Miller 1975). While the purpose of some of the trials was to further clarify the taxonomy of the species or its morpho-anatomical features (Arbez and Millier 1971; Matziris 1984; Matziris 1989a, 1989b; Matziris 1994; Sıvacıoglu and Ayan 2010; Ayan et al. 2011) others serve for obtaining data on provenance performance in nursery production (Ivetić and Škorić 2013) and on-site (von Röhrig 1966, Wheeler et al. 1976, Varelides et al. 2001, Gökdemir et al. 2012) although data on the productivity of the provenances within the trials is scarce.

Through the methods of selection, some 650 ha (EFA 2013) of Black pine provenance trials have been established in Bulgaria since the beginning of XX century. These encompass all known national natural populations as well as some foreign. Subject to testing are both distinct ecotypes – low-mountainous (occurring at altitudes of up to 800–1000 m) and mid-mountainous (above 1000 m) (Zahariev 1977) as well as the three known edaphotypes (depending on the parent material) – "silicate", "calcareous" and "rocky" (Dobrinov et al. 1982). The studies conducted in these trials cover mainly the early stages of the plantations including initial survival, canopy formation and differentiation as well as the stages of the intensive growth and culmination in height increment. Thus, the current study is to build-up this existing knowledge by adding information related to a more mature stage for two of the trials, where differentiation in diameter is more distinct.

Materials and Methods

Site characteristics

Subject to research are two plantations, which are part of series of provenance trials from Bulgaria's main coniferous species, established in the 1970s. The first plantation (Site 1 – provenance trial "Petrohan") is located in the Training and Experimental Forestry "Petrohan" of the University of Forestry – Sofia (N43°11'38", E23°08'22"), while the second on the territory of State Forestry Unit "Ihtiman" (Site 2 – provenance trial "Ihtiman"; N42°29'05", E23°42'01") (Fig. 1). Both trials were established in 1978 (except for two of the provenances in Site 2 which were introduced 2 years earlier) with a main objective to study the hereditary potential of selected offspring and provenances of the most valuable natural Black pine populations in Bulgaria at the given environmental conditions. The initial concept also included the idea, that after some additional selection, plantations may also be used as a source of reproductive material with improved qualities (Bogdanov and Dakev 1982) – from the categories "selected" and "qualified" as per national regulations.

For the establishment of the provenance trials, three year old seedlings were produced from seeds derived from individual pre-selected plus trees or from provenance aggregations from the best autochthonous Black pine stands in Bulgaria. Thus, provenance trial "Petrohan" holds 11 provenances represented by the generative offspring of 28 plus trees and 12 provenance aggregations, while provenance trial "Ihtiman" tests 13 provenances represented by the offspring of 34 plus trees and 15 aggregations (one of the provenances represented in the two sites is derived from two different altitudes). In

Fig. 1. Location of the provenance trials and used provenances.

addition, one provenance from Adana, Turkey was introduced in 1975 but this is not subject to the current study. Eleven of the provenances are common for both sites. The original location of the provenances used, sorted down per altitude and the features of the mother plus trees, are presented in Table 1.

Table 1. Provenances used in the trial.

Provenance		Altitude, m	Longi-tude	Latitude	Represented at	
Name*	Code**				"Petrohan"	"Ihtiman"
Melnik	Mk	280	23°24'	41°31'		✓
Hristo Danovo – lower	HD (d)	400	24°35'	42°43'	✓	✓
Borika (Haskovo)	Has	400	25°09'	41°54'	✓	✓
Vodenicharsko (Kardjali)	Vd (Kj)	420	25°15'	41°29'		✓
Borovo	Br	590	23°43'	41°35'	✓	✓
Ploski	Pl	700	24°51'	41°39'	✓	✓
Zhenda (Kardjali)	Zh (Kj)	740	25°10'	41°47'	✓	✓
Tzarvaritza (Gabra)	Gbr	980	22°50'	42°01'	✓	
Gorno Izvorovo	GI	750	25°28'	42°39'	✓	✓
Teshel	Ts	1000	24°23'	41°38'		✓
Razlog	Rz	1050	23°24'	41°53'	✓	✓
Momchilovci	Mc	1000	24°45'	41°37'	✓	✓
Orehovo	O	1100	24°35'	41°52'	✓	✓
Goleshevo (Petrodan)	Pd (Gol)	1100	23°35'	41°24'	✓	✓
Hristo Danovo – upper	HD (g)	1200	24°35'	42°45'	✓	✓

Note: * The popular names of the geographic provenances are given in brackets.
**The ID of the mother plus tree is annotated as a number to the code; aggregations are annotated as OS in the text.

The trial layouts are of block design where each treatment represents a rectangular plot – cells (Fig. 2). Site 1 is composed of 26 cells most of which consist of 12 rows each with 13–14 seedlings, making 156–168 seedlings in total per cell. Site 2 has 35 cells composed, in the general case, of 15 rows with 14 seedlings each. Depending on the availability of planting material, some of the variants were reduced and formed smaller cells, while for others the offspring of different plus trees, but from one and the same provenance, were combined into a single cell. For clear distinction of the plots, isolation rows of *Picea abies* (L.) Karst. were planted among them, using the same interval of 2 m. This has guaranteed good clarity of the adopted scheme and avoids mistakes during observations and measurements. Permanent 2×2 m planting intervals are used in both sites allowing for adequate comparison. However, no replication of each variant is available.

The altitudes of the provenance trials are 600 m (Site 1) and 750 m (Site 2) respectively, both falling within lower part of the mid-mountain belt. Locations of sites are selected to have uniform conditions throughout the site. Both plantations have north-eastern aspect and clay-sandy soils – *Cambisols* and *Leptosols* respectively, with average depth. The mean annual temperature for both site is 8–9 °C the highest being in July (around 15 °C) and lowest in January (2–3 °C). Annual precipitation is 500–700 mm, higher for "Petrohan". Natural vegetation for the lat-

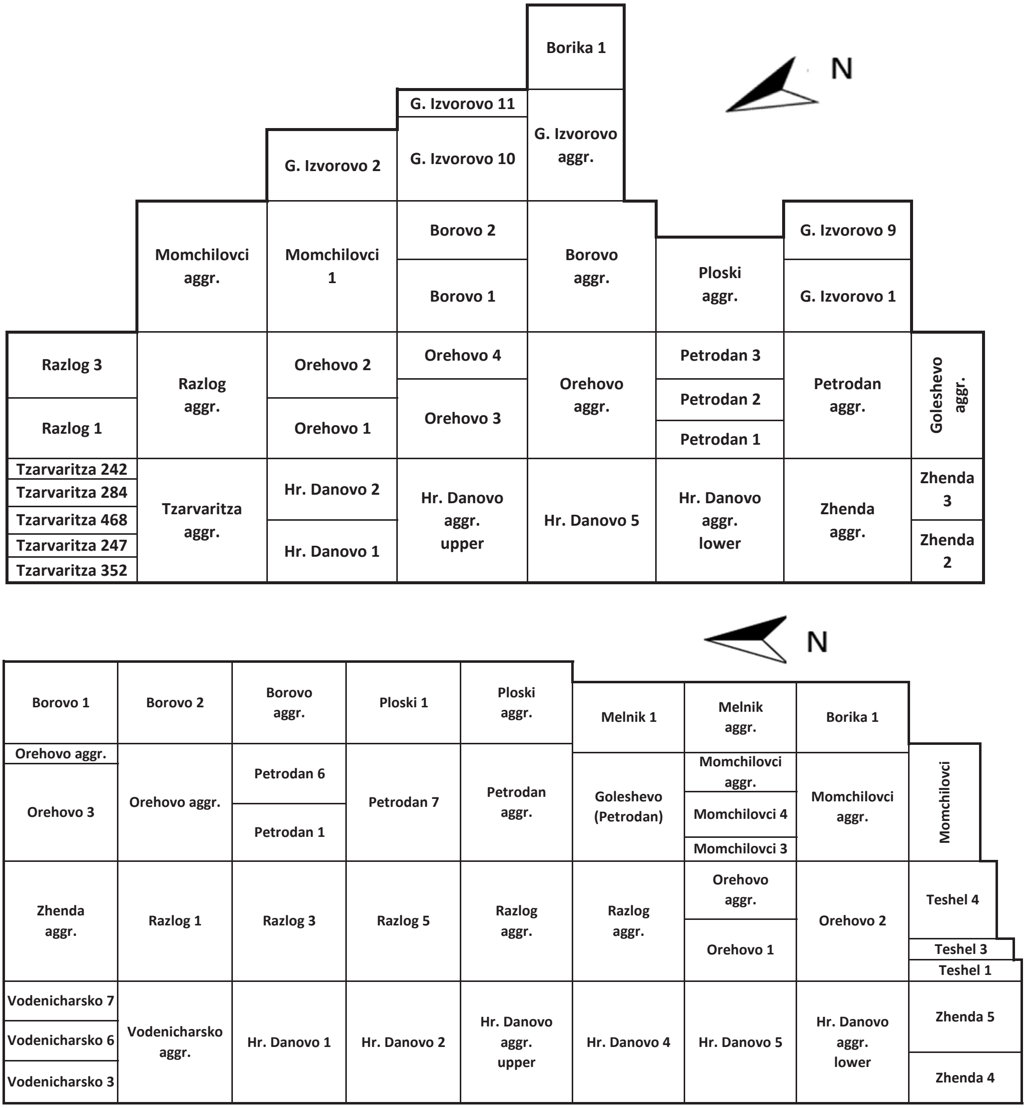

Fig. 2. Layout of the experimental plots – "Petrohan" (top) and "Ihtiman" (bottom).

ter is represented by *Carpinus betulus* L. and *Fagus sylvatica* L. while in "Ihtiman" by *Quercus frainetto* Ten., *Quercuss cerris* L. *and Carpinus betulus* L. Both sites are considered favourable for the Black pine.

Methods

Field measurements were carried out in the autumn of 2013 ("Petrohan") and in spring of 2015 ("Ihtiman") using an adaptation of the methodology for analysis of forest plantations (Milev 2013). A detailed inventory of the site was carried out, where presence (taking note of normal, dry, died out and cut trees) and condition (including curvatures, bifurcation, damages) of every individual tree was evaluated. Diameter at breast height (DBH) and height were measured.

Collected field data was introduced to MS Excel environment, where some basic indicators of each trial were calculated including: survival; share of normal, curved, bifurcated and bent trees or trees with highly developed side-shooting; site index, basal area, basal area per hectare, mean and dominant diameter, increment.

Based on initial comparative analysis of the DBH, survival and percentage of quality trees within each trial, best performing variants were determined and a 'model' tree for these was selected on the field. Each model tree selected was felled, measured in length and cut to sections (1 cross-section disc from base, breast height and every 2 m taken for processing). Stem analysis for each model tree was subsequently carried out using the specialized "STA.13" software (Poryazov and Radulov 2007). Twelve model trees for each site were analyzed.

Data were analyzed statistically using the free R Software (R Development Core Team 2008). Given the age of the plantations and the stage of differentiation, diameter was considered a better indicator for the growth and productivity of the plantations than height (as opposed to young stands when height is a more secure indicator). Thus, the statistical analysis took the diameter as the main variable.

Data were tested for homogeneity of variances using the Fligner-Killeen test (Conover et al. 1981) from R's 'car' library. Variances for "Petrohan" proved homogenous but those for "Ihtiman" heteroscedastic which was also confirmed using Levene's test (Fox and Weisberg 2011). This is most probably due to the large number of observations. In order to further proceed with the application of ANOVA for "Ihtiman", power transformation of data was tested for stabilizing the variance, returning an estimated transformation parameter close to 1 (1.034653) meaning unchanged data and possibility for application of the analysis of variance. On a similar note, the variance using medians through a non-parametric Kruskal-Wallis rank sum test (Myles and Wolfe 1973) was applied (p-value < 2.2e-16).

Subsequently, ANOVA was applied to test: the influence of provenance including testing for significant differences among each variant; the influence of the origin of the reproductive material – plus trees versus provenance aggregations; the influence of the ecotype – low versus mid altitude; as well as the influence of the edaphotype – provenances originally growing on silicate parent material versus calcareous versus rocks.

Where statistically significant differences were returned, a post-hoc pair comparison to evaluate pair means was conducted using the LSD test (Steel et al. 1997) from R's 'agricolae' library.

Data on survival and implications on sustainability of the "Petrohan" trial were reported by the authors in a separate study (Bardarov and Milev 2015).

Results

The plots included in "Petrohan" trial recorded an average survival of 68.4 %, varying between 38.1 % (Zhenda 2) and 91.9 % (Gorno Izvorovo 11) for the different plots. Most preserved are the variants of G. Izvorovo 11, Momchilovci aggr. and Hristo Danovo 2, while highest mortality is revealed for Zhenda 2, Hristo Danovo 1 and 5. Generalizing data for the represented provenances shows that the most sustainable, if sustainability is measured through survival, are the provenances Momchilovci, Petrodan, Borovo and Razlog. A similar status is observed for “Ihtiman” trial, where of 7508 seedlings initially planted, 5247 have survived, making an average survival of 68.0 %, varying between 33.3 % (Vodenicharsko 6) and 87.7 % (Borika aggr.). In terms of provenance generalization, 6 provenances manage a survival above the 70 % mark (Borika, Razlog, G. Izvorovo, Ploski, Petrodan and Hristo Danovo) while Melnik provenance ranks lowest with 57.3 %. Comparison between survival rates generalized per provenance is presented on Fig. 3.

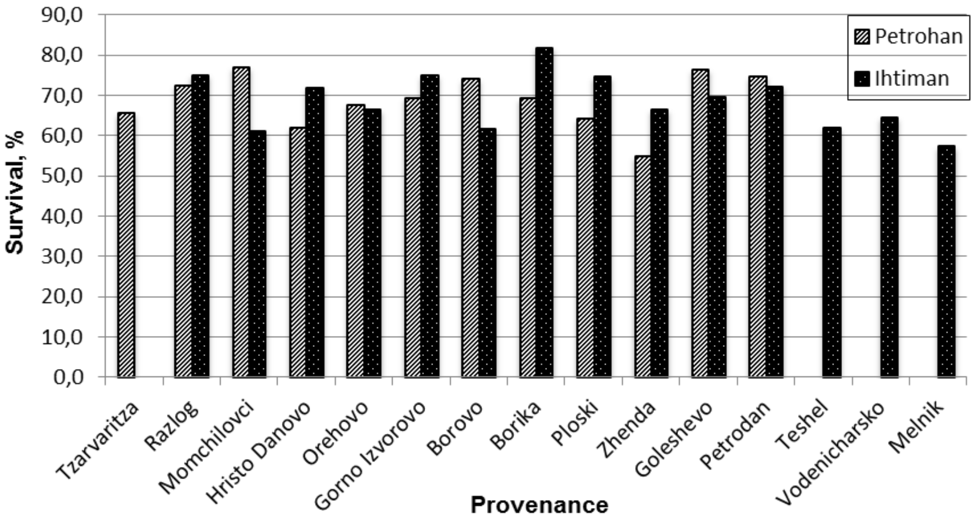

Fig. 3. Survival rates generalized per provenance for the two trials.

Survival percentages could have been even higher if trees had not been deliberately cut as result of illegal activities or for the purposes of previous studies. Taking this into account, the theoretic survival could have been as high as 79 % in average or between 66 and 90 % for the different provenances (94.8 % as the case for Razlog aggr. plot).

The site indexes assessment reveal good growth showing of the offspring and provenances in both trials favored by the unified environmental conditions of the site. The height was measured as mean for each plot and the average for “Petrohan” is calculated to 18 m, varying from 17.4 m (Petrodan) to 19.0 m (Momchilovci and Ploski). Looking at the comparison between the different variants, an interesting fact represents the difference in the mean height for Goleshevo aggr. (19.5 m) and Petrodan aggr. (17.0 m) which are in fact one and the same provenance but from different locations. Given the data on the mean height, all plots record grade I of the site index (as compared to the results of a study carried out in 2007 where 4 variants recorded grade II). The mean annual increment in height is 47–54 cm/annum, or 51 cm/annum.

The mean height of the trees in "Ihtiman" trial is calculated to 15.0 m, varying from 13.3 m for Teshel provenance and 16.8 m for Vodenicharsko (in more absolute terms the variance of the mean height among the plots is between 12.8 m – G. Izvorovo aggr. and 17.0 m – Vodenicharsko 6 and 7). The average site index is grade II, with only one provenance (G. Izvorovo) graded III. Here, the mean annual increment is 38 cm/annum, varying between 33 and 43 cm/annum taking the aggregated data for the provenances.

The dynamics of the periodic annual increments, reconstructed through the stem analysis of model trees from the two trials is presented on Fig. 4. Similar trends are observed for the two sites, with relatively steady increment rates between year 15 and 30, with good signs that growth in height slows down afterwards.

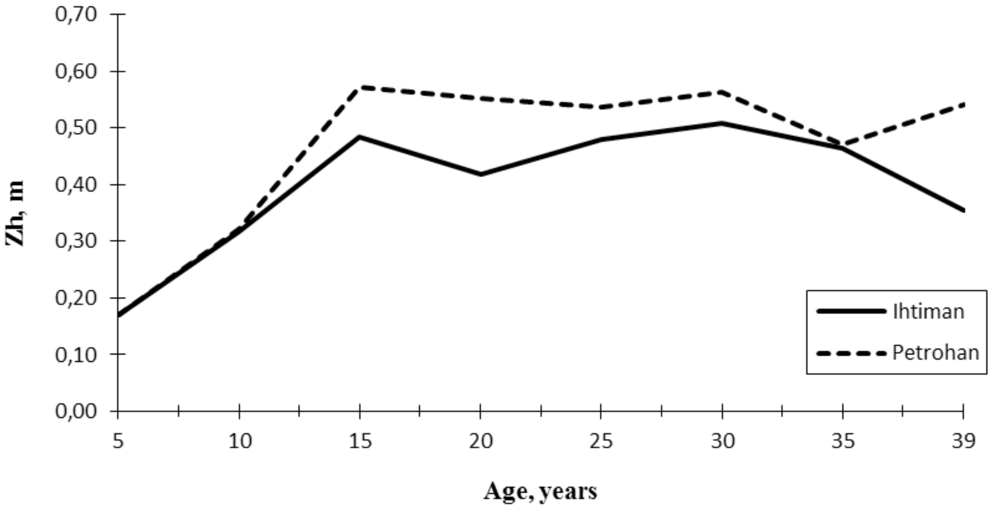

Fig. 4. Periodic annual increments in height for the two provenance trials.

The mean diameter, calculated through the basal area, in "Petrohan" trial is estimated to 21.1 cm, varying between 17.9 cm (Tzarvaritza 352) and 22.9 cm (Borovo 2) or between 20.0 cm (Hristo Danovo) and 21.9 cm (Razlog) when aggregating the data per provenance. As for the diameter of the dominant trees this varies between 28.6 cm (Hristo Danovo) and 33.4 cm (Goleshevo) or 30.3 cm on average. The mean annual increment in diameter is estimated to 0.59 cm/annum (0.56–0.61 cm/annum). "Ihtiman" provenance trial shows visibly lower figures, with mean diameter estimated to 19.0 cm, highest for Borika (20.6 cm) and lowest for Hristo Danovo (17.6 cm) provenances. The mean annual increment in diameter for "Ihtiman" is 0.48 cm/annum (0.43–0.53 cm/annum). The dynamics of the periodic annual increments in diameter, reconstructed through the stem analysis of model trees from the two trials is presented on Fig. 5.

Within "Petrohan" trial, we determined significant variation for the basal areas given that no thinnings have been carried out so far: between 32.1 m^2/ha (Zhenda

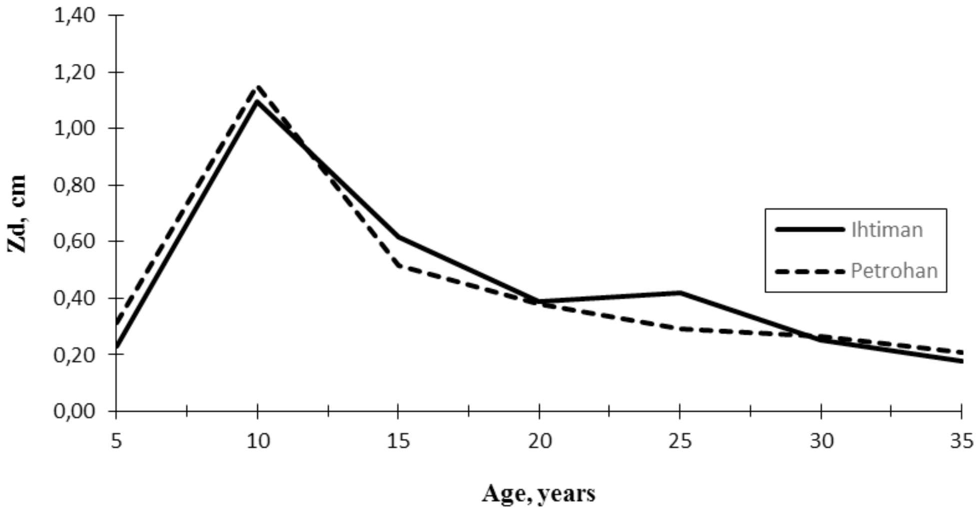

Fig. 5. Periodic annual increments in diameter for the two provenance trials.

2) and 92.9 m²/ha (G. Izvorovo 11) or 60.9 m²/ha on average. When aggregating the data per provenance highest ranked are Goleshevo (69.2 m²/ha) and Razlog (68.2 m²/ha). In comparison, the average value on this indicator for "Ihtiman" trial is 48.7 m²/ha, varying between 35.2 m²/ha (Momchilovci 4) and 58.0 m²/ha (Razlog 5). Overall, Razlog, Zhenda and Borika provenances rank highest.

Using the standard growth models for determining the growing stock revealed differences from the data obtained from the stem analysis. In order to avoid distortion of the results, productivity in terms of volumes was calculated only for the variants from which model trees were taken thus indicating the potential of the plantations. For "Petrohan" this potential could be as high as 683 m³/ha (Goleshevo aggr.) or around 450 m³/ha on average (12.6 m³/ha). Given the lower values for the mean height and diameter, the growing stock for "Ihtiman" is lower as expected but still in the region of 340 m³/ha (highest for Razlog 5 – 423 m³/ha).

General grouping of provenances per "regions of provenance" for "Petrohan" trial shows that the influence of the provenance on performance (diameter) is a trend (*p*-value=0.0542) and statistically significant variances could be expected. The application of the LSD test for grouping of the means, shows that data are clustered in 3 groups where highest ranked are Rila mountain provenances and lowest are the provenances from Stara Planina Mountain. This was further confirmed when testing the performance of the 11 provenances included in the trial where the applied ANOVA revealed highly significant influence of the provenance on performance (*p*-value=0.000195) – Fig. 6. The post-hoc analysis identifies 3 groups of equivalent performance where Razlog (Rz) provenance ranks highest while Momchilovci (Mc) and Hristo Danovo (HD) rank lowest.

ANOVA "Petrohan"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Provenance	10	741	74,14	3,404	0,000195 ***
Residuals	2490	54232	21,78		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

LSD test "Petrohan"

Mean	CV	Mserror
20,45902	22,89893	21,77978

$parameters

Df	ntr	bonferroni	alpha	test	name.t
2499	11	3.32125	0,05	bonferroni	Prov

$groups

trt	means	M
Rz	21.36596	a
Has	21.01852	ab
Gl	20.92938	ab
Pl	20.78667	ab
O	20.67192	ab
Kj	20.64000	ab
Pd	20.49653	ab
Gbr	20.40000	ab
Br	20.38095	ab
Mc	19.85417	b
HD	19.52713	b

Note: Means annotated with the same letter do not differ at p<0.05

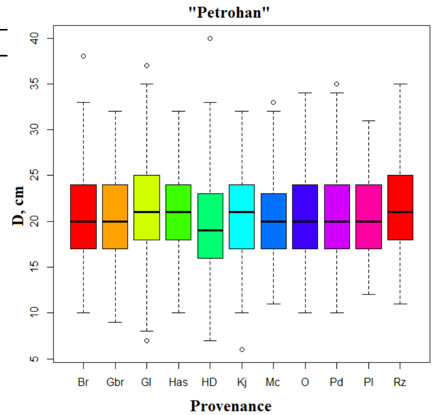

Fig. 6. Analysis of variance and pos-hoc test for tree diameter (D) for 11 provenances in “Petrohan” trial.

Similar procedure was applied at the level of a single variant, where the LSD test excels Razlog 3 and Borovo 2 trials, and ranks lowest Hristo Danovo aggr.-low and Tzarvaritza 352 (which however is represented by only 24 trees).

The analysis of the data for “Ihtiman” also reveals highly significant differences resulting from the influence of the provenance on performance. Here, data are separated into five groups: group 1 comprising the provenances of Teshel, Momchilovci, Kardjali and Orehovo (all from the Rhodopi mountain); group 2 – Borovo, Razlog, Melnik, Haskovo and Petrodan; group 3 – Gorno Izvorovo; group 4 – Ploski; and group 5 – Hristo Danovo (Fig. 7).

The results of the statistical analysis on the influence of the origin of the reproductive material – plus trees versus provenance aggregations, are presented on Fig. 8 and Table 2. Significant differences were identified only for “Petrohan” trial (p-value=0.0174) where variants growing from seeds derived from pre-selected individual plus trees show better performance in diameter than trees originating from provenance seed aggregations.

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ANOVA "Ihtiman"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Provenance	11	2825	256,79	22,44	<2e-16 ***
Residuals	5263	60218	11,44		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

LSD test "Ihtiman"

Mean	CV	Mserror
18,44152	18,34213	11,44176

$parameters

Df	ntr	bonferroni	alpha	test	name.t
5263	12	3,369823	0,05	bonferroni	Prov

$groups

trt	means	M
Ts	19,50467	a
Mc	19,43131	a
Kj	19,34964	a
O	19,21655	a
Br	18,6426	ab
Rz	18,6114	ab
Mk	18,43448	ab
Has	18,41841	ab
Pd	18,40099	ab
Gl	17,94821	b
Pl	17,84332	bc
HD	17,22851	c

Note: Means annotated with the same letter do not differ at p<0.05

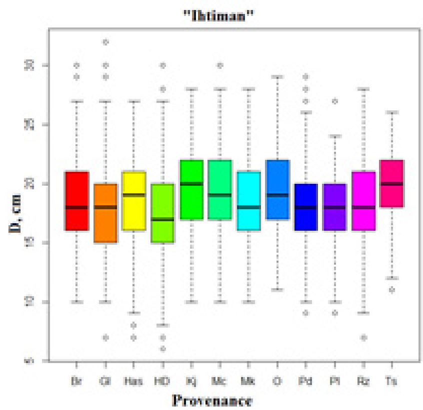

Fig. 7. Analysis of variance and pos-hoc test for tree diameter (D) for 12 provenances in "Ihtiman" trial.

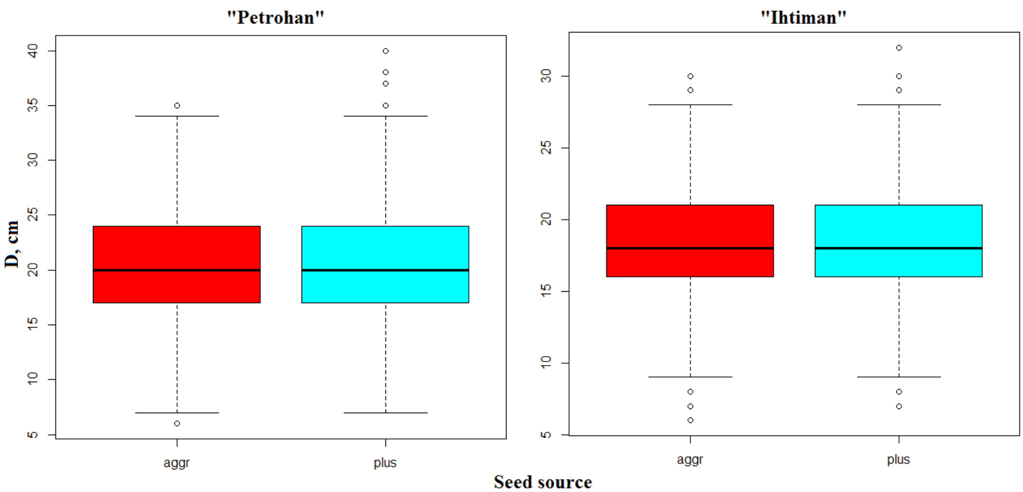

Fig. 8. Box-plots on the growth in diameter depending on the seed source.

Table 2. Analysis of variance and post-hoc test on the influence of the seed source.

ANOVA "Petrohan"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	1	124	124,37	5,667	0,0174
Residuals	2499	54849	21,95		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

ANOVA "Ihtiman"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	1	1	0,823	0,069	0,973
Residuals	5273	63042	11,956		

LSD test "Petrohan"

Mean	CV	Mserror
20,45902	22,89893	21,94825

$parameters

Df	ntr	bonferroni	alpha	test	name.t
2499	2	1,960914	0,05	bonferroni	Seed source

$means

	Diam	std	r	LCL	UCL	Min	Max
aggr	20,21867	4.705853	1157	19,94859	20,48875	6	35
plus	20,66592	4.666782	1344	20,41534	20,91651	7	40

$groups

trt	means	M
1 plus	20,66592	a
2 aggr.	20,21867	b

Trials were also grouped per ecotypes of origin – low-mountain (occurring at altitudes of up to 800–1000 m) and mid-mountain (above 1000 m) (Zahariev 1977). Applied analysis of variance reveals that significant differences (*p*-value=0.0308), although close to the critical value, are observed only in “Ihtiman” plantation where provenances representing the low-mountain ecotype perform slightly better (Fig. 9 and Table 3).

An interesting case represents the results of the statistical analysis on the influence of the soil of origin (in broader terms depending on the parent material) on growth in diameter or in other terms, the performance of the different edaphotypes in both sites. While the “silicate” and “calcareous” provenances only are represented in the “Petrohan” plantation, “Ihtiman”

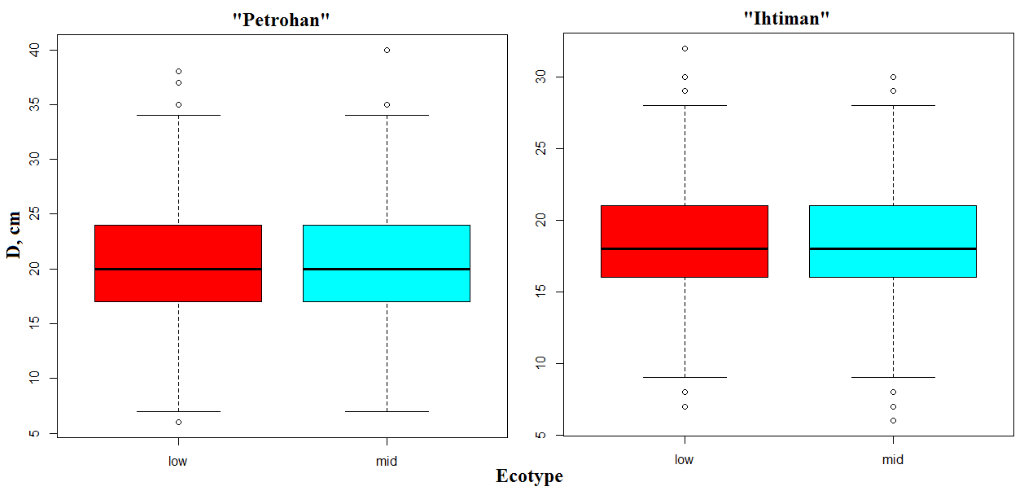

Fig. 9. Box-plots on the growth in diameter depending on the ecotype of origin.

Table 3. Analysis of variance and post-hoc test on the influence of the ecotype of origin.

ANOVA "Petrohan"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	1	3	2,921	0,133	0,716
Residuals	2499	54970	21,997		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

ANOVA "Ihtiman"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	1	56	55,76	4,668	0,0308
Residuals	5273	62987	11,95		

LSD test "Ihtiman"

Mean	CV	Mserror
18,44152	18,7413	11,94518

$parameters

Df	ntr	bonferroni	alpha	test	name.t
5273	2	1,960414	0,05	bonferroni	Ecotype

$means

	Diam	std	r	LCL	UCL	Min	Max
low	18,5664	3,586579	2131	18,41963	18,71318	7	32
mid	18,35687	3,364938	3144	18,23603	18,47771	6	30

$groups

trt	means	M
1 low	18,5664	a
2 mid	18,35687	b

holds all three types including the "rocky" edaphotype, although in actual terms this is only one provenance – Teshel. No significant differences on performance were revealed in Site 1, but highly significant variance was determined for "Ihtiman". There, "rocky" and "calcareous" soil types show significantly better performance than the "silicate" soil type, having also in mind that the "rocky" type is in fact also "calcareous" in its essence (Fig. 10 and Table 4).

The complex picture for the offspring showing shall be completed with the data on stem quality and the occurrence of different deficiencies resulting from various biotic and abiotic factors. These deficiencies include among all bifurcation and cur-

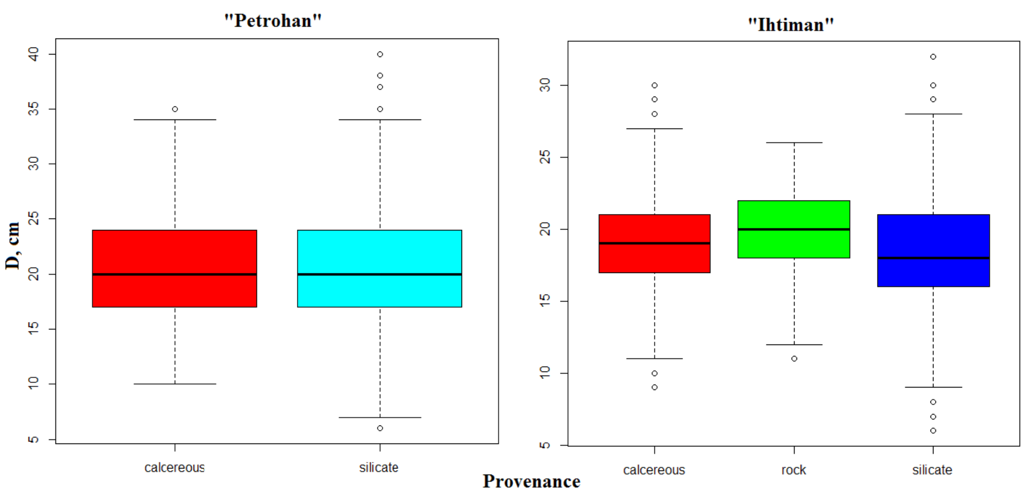

Fig. 10. Box-plots on the growth in diameter depending on the parent material of origin.

Table 4. Analysis of variance and post-hoc test on the influence of the parent material of origin.

ANOVA "Petrohan"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	1	3	3,076	0,14	0,708
Residuals	2499	54970	21,997		

ANOVA "Ihtiman"

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Seed source	2	474	237,22	19,99	2.25e-09 ***
Residuals	5272	62568	11,87		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

LSD test "Ihtiman"

Mean	CV	Mserror
18,44152	18,68068	11,86803

$parameters

Df	ntr	bonferroni	alpha	test	name.t
5272	3	2,394744	0,05	bonferroni	Soil

$means

	Diam	std	r	LCL	UCL	Min	Max
calcereous	18,79108	3,220022	1704	18,62747	18,95469	9	30
rock	19,50467	3,291997	107	18,85178	20,15757	11	26
silicate	18,23672	3,554854	3464	18,12197	18,35147	6	32

$groups

trt	means	M
rock	19,50467	a
calcereous	18,79108	a
silicate	18,23672	b

vatures but also breakages and bending. Data for "Petrohan" trial and the influence of wet snowfalls have been reported by the authors in a previous survey (Bardarov and Milev 2015). "Ihtiman" trial records better percentages of the normally developed trees – 74 % (as opposed to "Petrohan" where the share is 66 %), highest for Teshel 3 plot – 100 % and lowest for Hristo Danovo 4 plot – 38 %. Aggregated per provenance, best showing have Teshel and Vodenicharsko while Ploski, Orehovo and Momchilovci the worst – just short of 70 %. Observed shortcomings are also common for the "Ihtiman" trial but again with better values than for Site 1. Bifurcation, attributed to attacks of *Rhyacionia* (*Evetria*) *buoliana* Schiff. in previous studies of the plantation is common, with around 15 % on average for the different provenances, mostly occurring in Hristo Danovo provenance – 21.5 % and least for Teshel – 8.4 %. Curvatures are around 16 % which is common for both trials. Of the other observed indicators it is worth mentioning the occurrence of trees with strongly developed side shooting – mostly common for the provenances of Orehovo (6.0 %), G. Izvorovo (4.8 %), Hristo Danovo and Ploski (4.6 %).

Discussion

Differences in growth, mainly early, among *Pinus nigra* provenances have been almost always observed in trials (Wheeler et al. 1976, Zahariev 1983, Alptekin 1986, Varelides et al. 2001, Gökdemir et al. 2012), with different results depending on the sites. Consequently, judging by early growth, different provenances should be selected for different environments, depending on the soil and climatic conditions of the site (Varelides et al. 2001). Statistically significant differences in growth (judged by the growth in diameter) were also observed in the two trials subject to our research even at an age higher than the reported in literature. Three and five groups of behavior are formed in the respective sites but provenances doing statistically better in one site do not maintain their better performance in the other trial. One exception is Hristo Danovo provenance which is lowest ranked in both plantations. The varying results per site, in general confirms that the site-provenance interactions are prevailing, which has often been attributed to the broad natural distribution of the species in a wide range of environments, leading to distinct races. Evidences for this are also apparent within the sites as for example with the difference in the mean height for Goleshevo aggr. (19.5 m) and Petrodan aggr. (17.0 m) which are in fact one and the same provenance but from different locations. Our results come also in support of the suggestion of Nicolic and Tucic (1983) that the differentiation of *Pinus nigra* provenances is possibly due to heterogeneity of environments over the areas of its natural distribution, where gene frequencies are controlled by the local environment through selection.

The existence of clear track record for both trials on the process of selection of provenances and their progenies to be included: from mother trees/ stands selection and their passportization to seed collection, seedlings production and planting, presents some unique opportunities to study the influence of different factors on the offspring showing. One such question is what the influence of the seed source is – be it mother plus trees with desired qualities or seed aggregations from a whole stand but also with targeted quantitative and qualitative features. References on the issue were not found to make more substantiated conclusions, but our study shows that the offspring grown from seeds from mother plus trees show better performance than the offspring derived from seed mixtures and aggregations from a whole stand or forest. This however, shall be taken as a trend as statistically significant differences were recorded only for the “Petrohan”. Taking into consideration the existing information, one area that could be further studied is to reveal the extent to which the characteristic of the mother plants are inherited by the offspring given that the source of the pollen is not known but very likely from the same or nearby stands.

Better performance in early growth of the low-mountain ecotype has already been reported by Zahariev (1983) in another provenance trial, and our research could confirm that in both studied cases, variants representing the low-mountain ecotype show better performance in general than the mid-mountain ecotype. This again shall be taken with some cautious as statistically significant differences are revealed only for “Ihtiman” trial and the fact that there are some distinct exceptions as is the case with Goleshevo (Petrodan) provenance.

The existence of soil ecotypes has been suggested in other provenance trials (Nicolic and Tucic 1983, Varelides et al. 2001) and that it might be possible that performance of the provenances is influenced by the site soil factors and the inherited ability of certain provenances to exploit those factors (Varelides et al. 2001). The analysis of the performance of the three edophotypes described in Bulgarian literature is not straightforward. There, “rocky” and “calcareous” soil types show significantly better (statistically proven) performance than the “silicate” soil type in “Ihtiman”, while the “silicate” type is slightly better but not statistically different for “Petrohan” (where the “rocky” type was not tested). Taking into consideration that both trials are established on a “silicate” parent material, it could be suggested that “calcareous” type is more prominent in harsher conditions as are the conditions within natural populations where this type occurs.

Conclusions

The complex assessment of the provenance showing in the two trials taking into consideration survival, share of normally developed trees and growth in height and diameter, reveals that no recommendations on the choice of provenance can be safely made, because of the strong site-provenance interaction. However, Goleshevo and Razlog provenances show good performance in both trials and could be recommended. Momchilovci and Gorno Izvorovo also record reasonable values for “Petrohan” as are Kardjali and Borika for “Ihtiman” but these results are strictly specific to the respective site. One thing that is statistically proven is the modest performance of Hristo Danovo provenance so its use should be avoided in plantations in similar conditions.

Observed growth trends reveal that culmination in growth – both in height and diameter comes around the age of 10–15, maintaining relatively good increment until the age of 30, showing signs of decrease afterwards. So this age could be cautiously considered for obtaining reasonable volumes if plantations are to be managed more intensively in shorter rotations in similar conditions.

Proper selection of provenance taking into account the seed source, ecotype and edaphotype may grant of up to 3 times larger growing stock per hectare in more favorable conditions and 1.6 times more in less favorable ones but still not within the limits for survival.

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