FORESTRY IDEAS, 2015, vol. 21, No 2 (50): 359–373

ASSESSMENT OF SOME PERFORMANCE INDICATORS FOR BLACK PINE (*PINUS NIGRA* ARN.) PROVENANCE TRIALS IN PETROHAN TRAINING AND EXPERIMENTAL FOREST RANGE, NORTH WEST BULGARIA

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Received: 25 November 2015 Accepted: 16 January 2015

Abstract

Black pine (*Pinus nigra* Arn.) provenance trials were established in North West Bulgaria in 1978 to study the hereditary potential of selected offspring of some of the most valuable populations in Bulgaria. Given the planting interval of 2 × 2 m, 13 provenances are assessed through three performance indicators including survival rate, quality of stems and general health status. At the age of 36, the average survival rate of the plantation is 68 %, varying between 38 % and 92 % for the different plots, without specific linkage to the altitude of origin. The impacts of wet snowfalls have played a primary negative role on the status of the plantation. Competition has also been an important factor for the survival rates as expected, with the most significant losses endured during the early life of the plantation. The field data reveals that there are no definite evidences on the influence of the provenance on mortality, quality and general health of the stands. Thus, the considerations on the provenance selection in afforestation practices may not have such a significant role and visible effect within the established plantations. A possible reason for this is that nature conditions of the specific site, although outside the natural range of distribution of Black pine, are relatively favourable but not within the range limits for its survival.

Key words: hereditary potential, impact, origin, plantation.

Introduction

The increasing demand of modern society for timber and other forest products worldwide inevitably leads to excessive use of natural forest resources resulting into a continuous loss of forest cover and irreversible loss of biodiversity. This calls for placing a stronger emphasis on the establishment of forest plantations, which have substantial potential for maximized yields of raw material, in terms of quantity and quality, on one hand, and easing off the pressure on natural forests and biodiversity on the other hand (Evans 1999b, 2001; Kanowski 1997; Milev 2013; Savill et al. 1997; Sedjo and Botkin 1997; Stephens and Wagner 2007). There is abundant evidence that plantation forests can even provide valuable habitat, even for some threatened and endangered species, and may contribute to the conservation of biodiversity by various mechanisms (Brockerhoff et al. 2008). Although artificially established forests account to only about 7 % of all forests in the world

(Evans 1998), they provide about 27 to 35 % of the industrial wood demand and under certain scenarios plantation share of industrial roundwood production is estimated to increase up to 64 % in 2050 (FAO 2001). The role and interrelationship between forest plantations and climate change is also noted (Pawson et al. 2013). So the adequate treatment of the issues related to the establishment of sustainable forest plantations would also contribute to reducing CO_2 concentrations, as plantations are part of the broader package of measure of reducing harmful emissions (van Minnen 2008).

In order to be successful, forest plantations need to be, above all, sustainable (Milev 2013, Milev et al. 2015). Historically, Bulgarian afforestation practices have not always adapted differentiated approaches, which take into consideration site conditions, the influence of the origin and the hereditary qualities of the sawing materials as major factors, for ensuring sustainability and desired phenotypic showing of the plantations. As a result, coupled to a large extent with the untimely implementation of the tending and thinning operations, part of the established plantations – predominantly composed of coniferous species including Black pine (*Pinus nigra* Arn.), deteriorate in general, have reduced growth characteristics, unfavourable environmental and commercial effect, which places serious questions over their future use.

Competition as a rule is the chief factor influencing survival, growth and regeneration of forest plantations (Keddy 1989, Schoener 1983). Taking this into account, researchers place a substantial emphasis on the issue of initial and optimal planting density. For the establishment of intensive plantations of Black pine, data in this respect is not straightforward. Some authors point that a maximum profitable stock in long rotation periods without active management could be achieved with initial planting density of 2500–3400 seedlings per hectare (Stankova 2006), but the application of statistical modelling does not exclude optimum management regimes with initial density of around 9000–10000 seedlings per hectare (Stankova and Zlatanov 2010) although the latter are not fully substantiated by practice.

Pests and diseases, as wetll as damages caused by storms and forest fires, are also among the key factors for sustainability of forest plantations in a global scale (Evans 1999a). As for the Black pine, a number of authors point out its vulnerability to snow as a key risk (Hatzistathis 1985, Kostov 1971, Schütz 1999, Wheeler et al. 1976, Varelides et al. 2001). The threat here depends mainly on the climatic conditions, geographic location and topography on one hand, and the stand characteristics on the other. Of the latter, the most significant role is given to stem taper and crown characteristics (Nykanen et al. 1997). The opinions about the impact of density on stand stability found in various sources are also diverging (Stankova 2010). Some authors point out that denser stands are less stable (Nykanen et al. 1997), while other authors offer proof of the opposite (Schütz 1999).

Specialists are uniform though (Evans 1999a, Evans 1999b, Fussi et al. 2015, Zahariev 1977), that to great extent sensitivity towards unfavourable factors, sustainability respectively, is determined by the specific biological features and ecological requirements inherent in the different geographic variations. As a rule, it is considered that local variations of the species are most sustainable. Local populations are a result of a long standing natural selection in the course of which nature sustainability comes first. Longevity and productivity of established plantations, but also value of stands and individual trees such as straightness, self-pruning, wood characteristics and other features are all dependent on the geographic origin. Desired results can be achieved only if sawing materials are taken from a source, which matches the nature conditions of the sites to be afforested. Obviously, the knowledge on the influence of the geographic origin is of substantial importance, and this should be taken as a basis for developing and optimizing the zoning of seed sources and the conditions for using these sources for securing reproductive materials. It is why a number of countries have enforced regulations, as is the case with the EU (Council Directive 1999/105/EC 2000), to guarantee observation of this rule. Bulgaria moved towards maintaining an electronic register of sources of forest reproductive material in 1998 (Milev et al. 2015). In compliance with this EU requirement, the regions of provenance were defined in 2012 and a Map of the Regions of Provenance (EFA 2012) was developed using the forest vegetation zoning of the country. In 2013, Rules and Specific Exceptions for Moving forest Reproductive Material within or between Regions of Provenance (EFA 2013b) were adopted. A National List of the Approved Basic Material (EFA 2014) is being maintained with updates published on an annual basis.

The provenance trials (geographical, ecological plantations) network established throughout the world and Europe in particular form a good basis for studying the abovementioned topics. Taking into account Black pine's ecological plasticity and above all drought resistance (Mataruga et al. 2010, 2012), the species will continue to play an important role in afforestations and reforestations in part of the lower and the middle (in terms of altitude) forest zone in South-Eastern Europe.

Through the methods of selection, some 650 ha (EFA 2013a) of Black pine provenance trials have been established in Bulgaria since the beginning of XX century, where some of the most valuable local provenances, as well as some foreign were represented. Provenance trials abroad prove also useful. While the purpose of some of these 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 (Gökdemir et al. 2012, von Röhrig 1966, Varelides et al. 2001, Wheeler et al. 1976) as is the current study. Gökdemir et al. (2012) report for Turkey that from 36 Turkish provenances of *P. nigra* ssp. *pallasiana* tested in 6 sample plots per year, 25 did not show differences for height, diameter and volume but there were considerable differences among provenances for stem form. Provenances differed for survival percentage at one out of the six sites (Gökdemir et al. 2012). Varelides et al. (2001) studied the performance of 17 provenances (from Greece, Turkey, Corsica and Calabria) on 3 sites in Northern Greece to reveal, at year 9, differences in height, diameter and survival on two of the sites with varying results per site. The analysis of 12 provenances common to the two sites where differences were identified showed significant site-provenance interactions (Varelides et al. 2001). In Germany, von Röhrig studied 18 European provenances of the species on 4 sites, where by year 7 significant differences in frost resistance were observed for two of the sites and only minor differences in growth in height (von Röhrig 1966).

In order to further enhance selection work, along with the general importance of the geographic origin, it is also necessary to reveal and assess the individual characteristics (those of the genotype). Valuable information in this relation could be obtained from the provenance trials, containing the offspring of tracked mother trees.

This current study sets itself the objective to assess some of the performance indicators having direct impact on sustainability, as well as to add to the criteria for assessing the success of the forest plantations. What is useful in this case is the possibility to analyse the impact of provenance on these indicators for the particular site conditions and thus provide a site specific provenance selection in Black pine afforestations.

Materials and Methods

Site characteristics

Subject to research is a plantation, which is part of series of provenance trials from Bulgaria's main coniferous species, established in the 1970s. The plantation, located in the Training and Experimental Range (TER) "Petrohan" of the University of Forestry – Sofia (Fig. 1), was established in 1978 with a main objective to study the hereditary potential of selected offspring and provenances at the existing environmental conditions, through testing sustainability, growth and productivity of the most valuable natural Black pine populations in Bulgaria. The initial concept included the idea, that after some additional selection, plantations may be used also as a source of reproductive material

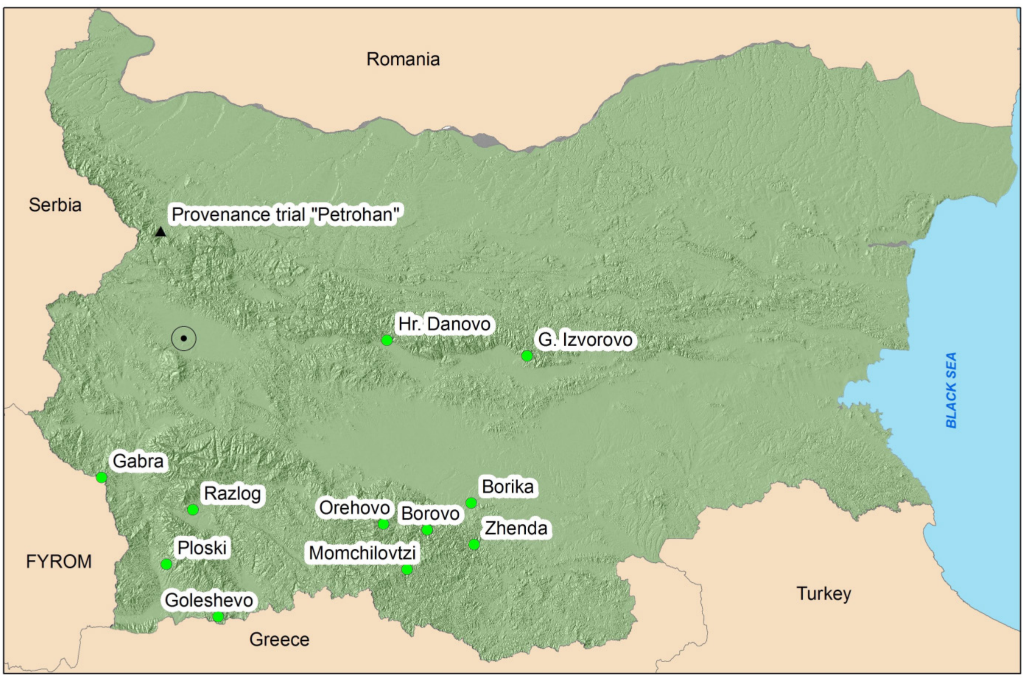

Fig. 1. Location of the provenance trial and provenances used.

with improved qualities – form the categories “selected” and “qualified” (Bogdanov and Dakev 1982) as per the provisions of National Ordinance No 12 of 12.11.2012 on the conditions and order for determination, approval, registration and cancellation of sources from the forest seed production base, collection and yield of forest reproductive material, their grading, trade and import (MAF 2012).

For the establishment of the provenance trial, seedlings were produced from reproductive material derived from plus trees selected within the best autochthonous Black pine stands in Bulgaria. The planting was carried out in the spring of 1978 in an area known as Kolchova polyana (N 43°11’38”, E 23°82›18» at 600 m altitude) formerly used as a pasture with scattered low-stem trees of *Carpinus betulus* L. and *Fagus sylvatica* L. Applying a permanent 2 × 2 m planting intervals, 11 provenances of the species (where reproductive material of one of the provenances is derived from two different altitudes) were introduced, represented by generative offspring of 28 plus trees and 12 provenance aggregations.

The scheme used is in line with the common methodology developed under the auspices of IUFRO, providing opportunities for comparison of results with other similar trials (Lines 1965). The original location of the provenances used, sorted down per altitude and the features of the mother plus trees, are presented in Table 1.

The trial is composed of 26 rectangular plots (cells). Most of these consist of 12 rows each with 13–14 seedlings, making 156–168 seedlings in total per cell. Depending on the availability of

Table 1. Provenances used and their basic features of origin.

Provenance		Altitude, m	Mother trees, number	Age, years	Mean height, m	Mean diameter, cm
Name	App. coordinates					
Hristo Danovo – lower	N 42°43’ E 24°35’	400	2	60	14.5	22
Borika (Haskovo)	N 41°54’ E 25°09’	400	1	150	12.5	35
Borovo	N 41°50’ E 23°16’	590	2	60	19.2	32
Ploski	N 41°39’ E 24°51’	700	3	60	23.5	43
Zhenda	N 41°47’ E 25°10’	740	5	70	20.7	32
Tzarvaritza (Gabra)	N 42°01’ E 22°50’	980	12	120	34.4	47
Gorno Izvorovo	N 42°39’ E 25°28’	750	5	-	-	-
Razlog	N 41°53’ E 23°24’	1050	5	85	29.2	43
Momchilovtzi	N 41°37’ E 24°45’	1000	5	75	29.0	41
Orehovo	N 41°52’ E 24°35’	1100	5	90	31.9	47
Goleshevo (Petrodan)	N 41°24’ E 23°35’	1100	7	120	24.5	41
Hristo Danovo – upper	N 42°45’ E 24°35’	1200	3	90	20.7	34

Note: The popular names of the geographic provenances are given in brackets.

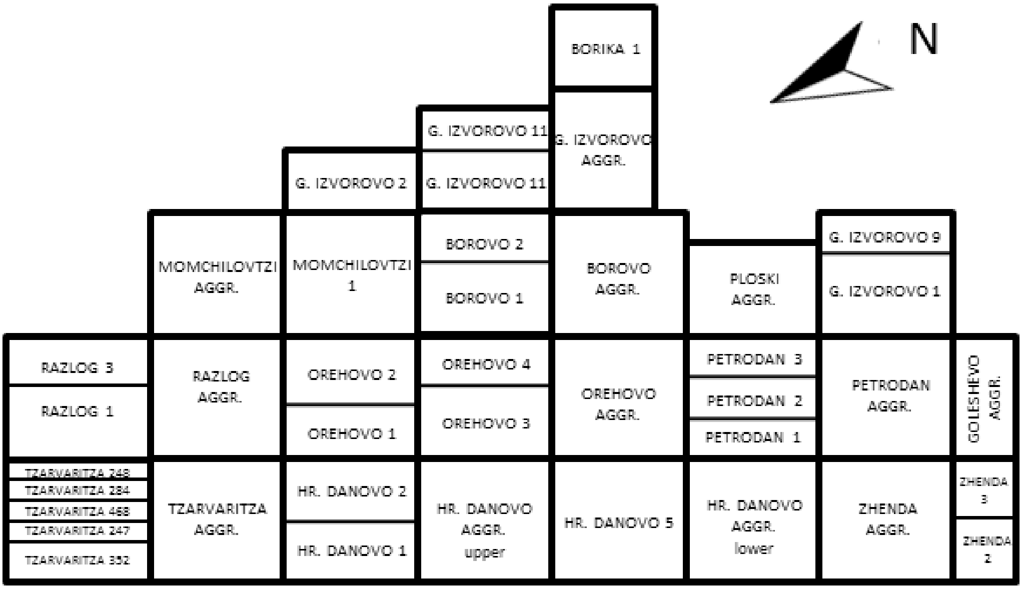

Fig. 2. Composition (design) of the experimental scheme.

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 (Fig. 2).

For clear distinction of the plots, isolation rows of *Picea abies* (L.) Karst. were planted among them, using the same density of 2 m. This has guaranteed good clarity of the adopted scheme and avoids mistakes during observations and measurements. The pure area of the Black pine (without the spruce isolations) in the provenance trial is 1.4 ha, and the total area of the site is 1.7 ha (Fig. 3).

Fig. 3. Aerial photo of the investigated plantation.

Methods

The field work was implemented using an adapted methodology for forest plantations analysis (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. To assess the damages of wet snowfalls, the 4 categories described by Nykanen et al. (1997) were used. Diameter measurements at breast height with 1 cm accuracy were also taken. Field investigations were carried out in the autumn of 2007 and the autumn of 2013, which gave the opportunity to extract trends in the main sustainability indicators. On this basis, analysis of the dynamics of mortality was carried out by comparing data about three conditional periods: 1) the early life of the plantation or until its 20th year (mortality during this period is determined via the number of empty planting spots counted in 2007); 2) mid-term – 20–30 years of age (calculations based on the number of dry, but still present trees in 2007); and 3) for the last 6 years - 30-36 years of age (based on the number of died out trees in the period 2007-2013).

To determine the studied factors, the statistical package of MS Excel was used, while for assessing the impact of the origin, field data were subject to ANOVA.

Results and Discussion

The results of the survey regarding survival and quality of stems are summarized in Table 2 below.

Of all 3654 seedlings planted at the trial, 2501 trees have survived in 2013. Thus, at the age of 36, the average survival of the plantation is 68.4 %, varying between 38.1 % (Zhenda 2) and 91.9 % (Gorno Izvorovo 11) for the different plots. The results reveal a weak correlation with the altitude of the provenance, however a slight trend is observed where provenances originating from higher altitudes show relatively better resistance (Fig. 4). Most preserved are the variants of G. Izvorovo 11, Momchilovtzi and Hr. Danovo 2, while highest mortality is revealed for Zhenda 2, Hr. Danovo 1 and 5, which are peripheral for the scheme. If calculations for these three latter provenances omit the data for the outer row on the edge of the plantation, because it has been subject to highest external impacts, including human interventions, the survival rates improve but do not change the status of these three weakest provenances.

The general picture for the 13 provenances shows that the most sustainable, if sustainability is measured through survival, are the provenances from Momchilovtzi, Petrodan, Borovo, Goleshevo and Razlog. No clear trend showing differences in survival between the offspring of plus trees and the provenance aggregations could be observed.

The analysis of variance applied does not provide clear evidence on the influence of provenance on the survival rate. This in general supports the findings of Varelides et al. (2001), Nicolic and Tucic (1983), that differentiations among Black pine provenances are primarily related to heterogeneity and the site conditions within the natural distribution of the species. These results also indicate that plasticity and heterozygosity of the planting material exists within the studied provenances, because of the wide variation among parent trees within each provenance (Mataruga et al. 2012).

Table 2. Data on survival and stem quality.

Provenance with plus tree No	Seedlings planted initially, number	Living trees, number		Survival, %			Normal, %	Bifurcated, %	Curved, %	Bent, %	With side shoots, %
		2007	2013	2007	2013	Δ	2013	2013			
Tzarvaritza 352	34	25	24	73.5	70.6	2.9	91.7	4.2	0.0	0.0	4.2
Tzarvaritza 247	26	20	17	76.9	65.4	11.5	82.4	5.9	11.8	0.0	0.0
Tzarvaritza 468	42	30	28	71.4	66.7	4.8	25.0	10.7	64.3	0.0	0.0
Tzarvaritza 284	42	36	33	85.7	78.6	7.1	63.6	9.1	27.3	0.0	0.0
Tzarvaritza 242	14	10	9	71.4	64.3	7.1	77.8	0.0	22.2	0.0	0.0
Tzarvaritza – total for + trees	158	121	111	76.6	70.3	6.3	64.0	7.2	27.9	0.0	0.9
Tzarvaritza	139	98	84	70.5	60.4	10.1	70.2	14.3	15.5	0.0	0.0
Razlog 1	98	81	70	82.7	71.4	11.2	60.0	17.1	21.4	0.0	1.4
Razlog 3	70	58	52	82.9	74.3	8.6	57.7	25.0	15.4	0.0	1.9
Razlog – total for + trees	168	139	122	82.7	72.6	10.1	59.0	20.5	18.9	0.0	1.6
Razlog	156	123	113	78.8	72.4	6.4	62.8	21.2	15.9	0.0	0.0
Momchilovtzi 1	156	117	109	75.0	69.9	5.1	71.6	23.9	4.6	0.0	0.0
Momchilovtzi	156	137	131	87.8	84.0	3.8	71.8	20.6	7.6	0.0	0.0
Hristo Danovo 1	78	48	43	61.5	55.1	6.4	76.7	0.0	23.3	0.0	0.0
Hristo Danovo 2	78	66	65	84.6	83.3	1.3	72.3	6.2	21.5	0.0	0.0
Hristo Danovo 5	156	100	86	64.1	55.1	9.0	59.3	20.9	19.8	0.0	0.0
Hristo Danovo – total for + trees	312	214	194	68.6	62.2	6.4	67.5	11.3	21.1	0.0	0.0
Hristo Danovo – upper	156	109	96	69.9	61.5	8.3	50.0	17.7	31.3	0.0	1.0
Hristo Danovo – low	156	100	97	64.1	62.2	1.9	57.7	28.9	13.4	0.0	0.0
Orehovo 1	65	45	45	69.2	69.2	0.0	44.4	42.2	13.3	0.0	0.0
Orehovo 2	91	61	59	67.0	64.8	2.2	66.1	11.9	16.9	0.0	5.1
Orehovo 3	104	68	65	65.4	62.5	2.9	60.0	23.1	16.9	0.0	0.0
Orehovo 4	52	42	37	80.8	71.2	9.6	73.0	13.5	13.5	0.0	0.0
Orehovo – total for + trees	312	216	206	69.2	66.0	3.2	60.7	22.3	15.5	0.0	1.5
Orehovo	156	134	111	85.9	71.2	14.7	51.4	14.4	34.2	0.0	0.0
Gorno Izvorovo 1	95	62	62	65.3	65.3	0.0	75.8	9.7	14.5	0.0	0.0
Gorno Izvorovo 9	65	54	43	83.1	66.2	16.9	44.2	11.6	44.2	0.0	0.0
Gorno Izvorovo 2	89	69	65	77.5	73.0	4.5	78.5	18.5	1.5	0.0	1.5
Gorno Izvorovo 10	104	82	75	78.8	72.1	6.7	74.7	14.7	9.3	0.0	1.3
Gorno Izvorovo 11	37	34	34	91.9	91.9	0.0	64.7	17.6	17.6	0.0	0.0
Gorno Izvorovo – total for + trees	390	301	279	77.2	71.5	5.6	69.9	14.3	15.1	0.0	0.7

Gorno izvorovo	120	83	75	69.2	62.5	6.7	58.7	10.7	18.7	12.0	0.0
Borovo 1	91	80	73	87.9	80.2	7.7	79.5	8.2	12.3	0.0	0.0
Borovo 2	65	52	46	80.0	70.8	9.2	78.3	15.2	6.5	0.0	0.0
Borovo – total for + trees	156	132	119	84.6	76.3	8.3	79.0	10.9	10.1	0.0	0.0
Borovo	156	133	112	85.3	71.8	13.5	60.7	15.2	24.1	0.0	0.0
Ploski	117	91	75	77.8	64.1	13.7	54.7	18.7	26.7	0.0	0.0
Zhenda 2	42	20	16	47.6	38.1	9.5	93.8	0.0	6.3	0.0	0.0
Zhenda 3	30	23	18	76.7	60.0	16.7	61.1	33.3	5.6	0.0	0.0
Zhenda – total for + trees	72	43	34	59.7	47.2	12.5	76.5	17.6	5.9	0.0	0.0
Zhenda	156	111	91	71.2	58.3	12.8	72.5	15.4	12.1	0.0	0.0
Goleshevo	72	56	55	77.8	76.4	1.4	80.0	18.2	1.8	0.0	0.0
Petrodan 1	52	45	38	86.5	73.1	13.5	68.4	18.4	13.2	0.0	0.0
Petrodan 2	52	42	39	80.8	75.0	5.8	74.4	10.3	15.4	0.0	0.0
Petrodan 3	52	46	39	88.5	75.0	13.5	56.4	23.1	20.5	0.0	0.0
Petrodan – total for + trees	156	133	116	85.3	74.4	10.9	66.4	17.2	16.4	0.0	0.0
Petrodan	156	125	117	80.1	75.0	5.1	71.8	14.5	13.7	0.0	0.0
Total	3654	2776	2501	76.0	68.4	7.5					

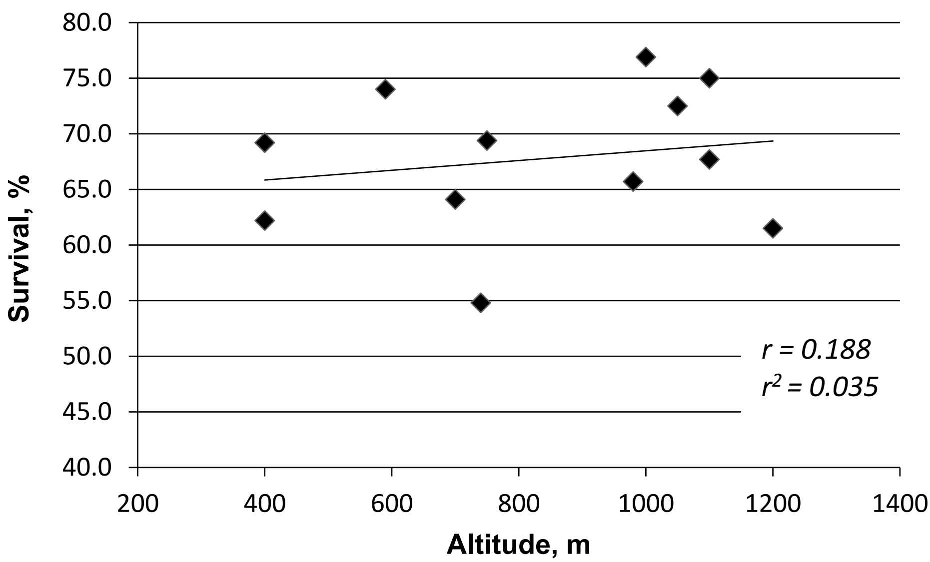

Fig. 4. Correlation between survival rates and altitude of provenances (data aggregated per provenance).

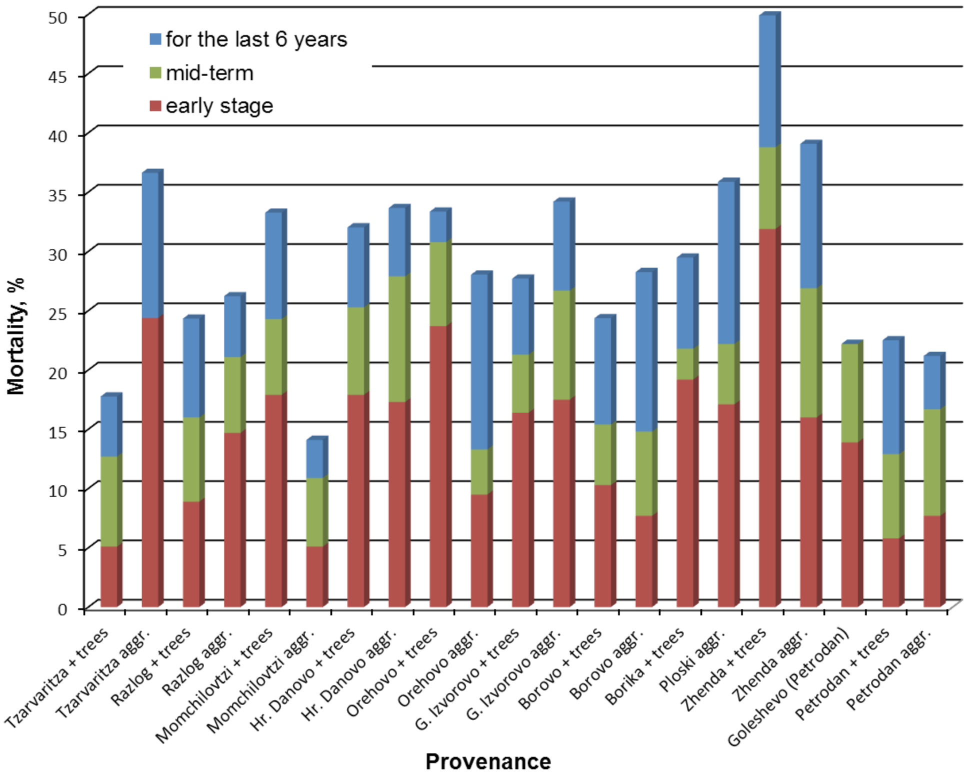

Fig. 5. Dynamics of mortality in 3 stages – early stage (3–20 years), mid-term (20–30 years) and for the last 6 years (30–36 years).

The dynamics of mortality (Fig. 5) reveals that it has been relatively constant – more intensive during the early life of the plantation but with no indications of decline for the moment. During the 6-year period between the two investigations, no new dead trees have been observed for three of the provenances – Orehovo 1, Gorno Izvorovo 1 and 11, thus maintaining survival rates of 96.2 %, 65.3 % and 91.9 % respectively. Most dramatic changes occurred for Zhenda 3 (16.7 %) and Orehovo (difference of 14.7 %). For the first mentioned, falling out of trees lagging in their growth is observed with survival currently at 60.0 %, while for Orehovo falling out of trees with different defects (mainly curvatures) is recorded thus reducing survival to 71.2 %. Averaged by provenances (but differentiated between the offspring of plus trees and aggregations), between 2.6 % (Orehovo plus trees) and 13.7 % (Ploski) of the trees within the plantation have been lost for the last 6 years. A specific note should be taken of Borovo, where the 13.5 % mortality rate in the last period is almost two times higher than during the early stages (by 20th year) and mid-term (by 30th year).

Regarding quality of stems, if taken as a criterion for sustainability, the following became evident: normally developed without defects and curvatures are about 66 % of the trees (Fig. 6). The biggest share of such trees is observed for the offspring of the plus trees of Zhenda 2 (but as mentioned, the relatively higher mortality rate in this cell seems to have provided a larger living space for the remaining trees) and Tzarvaritza 352 (over 90 %), while lowest figures are recorded for Tzarvaritza 468 (25 %, Fig. 7), Gorno Izvorovo 9 and Orehovo 1 – under 44.5 %. Generalized per provenance, the provenances of Goleshevo, Borovo, Zhenda and Momchilovtzi excel in a positive aspect.

Observations through the years confirm that wet snowfalls have been the key negative factor for the plantations, thus confirming the findings of a number of authors studying the sensitivity of the species to this factor. Recorded in our case are 3 out of all 4 types of damages described by Nykanen et al. (1997) with the only exception being uprooting. The effects here result mainly in stem bending, which is very common in spots within the plantation with changing slope, as is the case with Orehovo 1. A more rare case is crown breakage, smaller scale curvatures and bifurcation. Of all defects most common in general are the curvatures – 17 % on average and bifurcation – about 15 %. The presence of curvatures varies between 0 and 64 % (Fig. 7). For two of the variants, steeply bent trees are observed – Gorno Izvorovo (12 % of the living trees) and Borika 1 (7.4 %). Bifurcation among the different trials varies between 0 and 42 % (in most of the cases observed in the upper part of the stem), which confirms the importance of this factor for Black pine plantations revealed by Kostadinov (1975) and Thanasis et al. (2007). For 7 of the trial variants, strongly developed side shoots are common, mainly as a result of biotic factors. The highest percentage in this respect is recorded for Orehovo 2

Fig. 6. Straight stems of Gorno Izvorovo 2.

Fig. 7. Curvatures caused by wet snow in Tzarvaritza 468.

where over 5 % of the living trees have this shortcoming.

The overall health status of the plantation could be defined as very good, with no severe impacts of pests and diseases.

Conclusion

With over 68 % survival and over 66 % of quality trees within the different variants, the provenance trial plantation shows relatively favourable signs of sustainability. The main factor having negative impact is wet snowfalls, causing different types of curvatures. Comparable data from consecutive field observations provide sufficient ground to consider that once affected by the wet snow, the sustainability of the trees weakens, resulting in higher mortality afterwards (even towards the 36th year of the trials). Among the other factors having impact on mortality is competition (evidenced by the remaining dry trees) although the 2 × 2 m planting intervals used has provided a relatively good living space until this age and some anthropogenic impacts. The biggest share of the fall out had occurred in the early life of the trials, but processes at the moment do not show indications for it ceasing.

At this stage there are no definite evidences, supported statistically, on the influence of the provenance on mortality and quality of the stands. This comes to show that the factors having impact on sustainability relate mainly to internal competition, individuality and micro conditions, and not so much with the ecological specifics of the geographic provenances and their offspring. These findings should be interpreted additionally, once data from the tree measurements for determining growth rates get included in the analysis.

A more general assessment, combining all observed indicators, reveals that the provenances of Gorno Izvorovo, Goleshevo, Momchilovtzi and Borovo demonstrate best performance at the particular site conditions based on the observed and measured properties.

As a whole, a greater remoteness of the geographic provenance does not result in lower sustainability. The species is ecologically plastic enough or the represented populations are homogenous. In this sense, provenance selection in afforestation practices may not have the most significant role and visible effect regarding sustainability of the Black pine plantations under local nature conditions. A possible reason for this is that nature conditions at the specific site, although outside the natural range of distribution of the species, are relatively favourable but not within the range limits for its survival.

A more distinct impact of the geographic origin and the use of enhanced reproductive material (from the best populations and their plus trees) could be expected with regard to growth and productivity.

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