INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 12, Issue 3, July-September 2021: 1139-1152 www.ijcs.ro

IN SITU CONSERVATION OF NARROW CROWNED NORWAY SPRUCE IDEOTYPE (*PICEA ABIES PENDULA* FORM AND *COLUMNARIS* VARIETY) IN ROMANIA

Marius BUDEANU[1], Ecaterina Nicoleta APOSTOL[1*],
Lucian DINCĂ[1], Ioana Maria PLEȘCA[1]

[1] National Institute for Research and Development in Forestry 'Marin Drăcea', Voluntari,
128 Eroilor Boulevard, 077190, Ilfov County, Romania.

Abstract

The study aims to identify Norway spruce populations with narrow crown form, within each provenance regions across the Romanian Carpathians, and to evaluate the stability of the narrow-crowned spruce compared with the classical crown form under different environmental conditions. Narrow crowned Norway spruce ideotype may presents superior resistance to wind and snow breaks compared with the classical crown form of spruce (pyramidalis). The existence of pendula and columnaris trees in 25 populations was investigated and the compliance of the necessary criteria for inclusion in FGR's Catalogue was checked. The selected populations were mapped, the narrow crown trees were described and cores were collected for determination of the wood density. The narrow crown trees present favourable results for growth traits, tree slenderness, crown diameter and wood density, compared with the trees reported with normal crown form, while natural pruning was the only unfavourable trait. For wood density, narrow crowned trees were superior in all plots but only one time the differences were significant ($p < 0.05$). For the first time in Romania, seven populations comprising 249 narrow crowned spruce trees were selected for their inclusion in the Romanian FGR's Catalogue with the aim of in situ conservation of this ideotype.

***Keywords**: Breeding strategy; Carpathian forests; Dynamic conservation; Forest genetic resources; Phenotypic traits; Spruce adaptability; Wood resistance.*

Introduction

Norway spruce (*Picea abies* (L.) Karsten) is one of the most important tree species in Europe, highly influenced by the environmental changes of the last period [1-8]. Numerous studies have been carried out to analyse the influence of climatic changes on trees' growth and wood properties and for selection of the best adapted provenances to be included in the next generations of the breeding programmes [9-14]. Numerous authors consider wood density as the most significant predictor of wood quality [15-17]. The tree ideotype concept was used for the first time by Karki, in 1985 [18], in Finland, and implemented for the first time in Romania by Enescu, in 1987 [19]. Tree ideotypes depict the 'ideal tree' with characteristics based on superior growth (high yield), high wood density and high genetic variation, conferring adaptability. The superior adaptability of narrow crown spruce (*Picea abies pendula* form and *columnaris* variety) to more dense planting schemes is the conclusion reached by Finnish

* Corresponding author: ecaterina.apostol@icas.ro

research [20-22]. Molecular genetics analyses have indicated that the narrow crown type is controlled by a single dominant gene [23], which favours the cloning of this ideotype. The strong genetic control observed for crown architecture of Norway spruce has been previously revealed in Germany [24].

Because of the highly variable climatic characteristics of the species' natural range distribution across Romania, it was necessary to divide the country into 11 provenance regions, 5 for the mountain area (Eastern Carpathians, Curvature Carpathians, Southern Carpathians, Banatului Mountains and Western Romanian Carpathians) and to ensure the forest reproductive materials in each region, avoiding transfer between regions [25]. Because the Norway spruce is affected by the combined action of abiotic factors (wind and snow), it is very important to find the species variety with superior resistance. One action may be aimed at promoting the narrow crown ideotype of Norway spruce. Recent research conducted in Romania [25-27] has highlighted the superiority of this ideotype in different site conditions of open-pollinated half-sib and full-sib comparative trials.

The aims of the study were to identify Norway spruce populations with narrow crown trees in each mountain provenance region and to evaluate the stability of the narrow-crowned spruce compared with the classical crown form (pyramidal and wide crown) in different environmental conditions to promote the *in situ* conservation of the spruce narrow crown ideotype. The working hypotheses of the article were:

- Analysis of the 25 populations described by *Pârnuţă* [19], selection of representative ones and mapping of the narrow crown trees.
- Comparative analysis of the growth and wood quality for the two spruce crown forms.
- Comparing the wood density for the two spruce crown forms inside the populations.

Experimental part

Materials

In Romania, representative populations for bioaccumulation capacity, wood quality and resistance to disturbing factors were selected and included in the National Catalogue of Forest Genetic Resources (FGR), for each provenance region. Each FGR consists of a core and a buffer area. The core represents the strictly protected area and any kind of cuttings (except conservation and hygienically cleaned cuttings) are excluded. In the case of the main species, the requirement was that the core has a minimum area of 10 ha. The buffer area includes the plots that surround the core and has the role to protect it. A decrease of the core area under 10 ha was accepted for marginal peripheral populations and for those where valuable biotypes, from a scientific and/or economic point of view, are present [28]. The dynamic FGR conservation strategy [29, 30] was implemented in Romania, as in many other European countries (at least 33).

In Romania, research for promotion of the narrow crown Norway spruce ideotype began in 1987 with the selection of 455 Norway spruce trees with narrow crown (*pendula* form and *columnaris* variety) in 25 populations located in all branches of the Romanian Carpathians, most of them placed in the Apuseni Mountains (Table 1). Unfortunately, these populations were not included in a conservation program. In 1994, two half-sib comparative trials were established for testing the stability traits of narrow and normal crown spruce trees and in 1996 five full-sib trials for testing the two forms and their hybrids in a complete diallel mating design were established [19].

Thirty-one years after the implementation of the breeding selection, the present research was carried out to identify populations for the *in situ* conservation of narrow crown ideotype. All 25 populations were investigated and the best representatives of *pendula* and *columnaris* trees were selected (Figs. 1 and 2).

Table 1. Location of the studied populations [19]

Carpathian region	County	Coordinates Lat./Long./Altitude	Population's name	No. of narrow crown trees identified in 1991
Apuseni Mountains	Bihor	46˚22'/22˚40'/1200m	Stâna de Vale I	37
Apuseni Mountains	Bihor	46˚22'/22˚40'/1175m	Stâna de Vale II	11
Apuseni Mountains	Bihor	46˚22'/22˚40'/1225m	Stâna de Vale III	13
Apuseni Mountains	Cluj	46˚38'/22˚58'/1250m	Cheile Someşului	30
Apuseni Mountains	Cluj	46˚38'/22˚58'/1200m	Izbuc I	30
Apuseni Mountains	Cluj	46˚38'/22˚58'/1275m	Izbuc II	30
Apuseni Mountains	Bihor	46˚30'/22˚38'/1050m	Cetăţile Ponorului	52
Apuseni Mountains	Alba	46˚28'/23˚09'/1250m	Pârâul Pânzelor	20
Apuseni Mountains	Alba	46˚35'/22˚45'/1200m	Vulturu	5
Apuseni Mountains	Cluj	46˚33'/23˚10'/1600m	Dumitreasa	39
Apuseni Mountains	Cluj	46˚34'/23˚12'/1515m	Dobrinu	30
Banatului Mountains	Caraş-Severin	44˚55'/22˚00'/600m	Bozovici	15
Southern Carpathians	Hunedoara	45˚25'/23˚05'/1700m	Stâna de Râu	5
Southern Carpathians	Alba	45˚40'/23˚50'/1600m	Stânişoara	14
Southern Carpathians	Sibiu	45˚35'/23˚55'/1700m	Onceşti	21
Southern Carpathians	Argeş	45˚25'/25˚07'/1310m	Clăbucet	1
Southern Carpathians	Argeş	45˚25'/25˚13'/1175m	Dealul Sasului	1
Curvature Carpathians	Braşov	45˚28'/25˚33'/1100m	Poliştoaca	9
Curvature Carpathians	Dâmboviţa	45˚23'/25˚25'/1675m	Horoaba	6
Curvature Carpathians	Dâmboviţa	45˚23'/25˚25'/1625m	Peştera	3
Eastern Carpathians	Mureş	46˚50'/25˚12'/1160m	Şandra	46
Eastern Carpathians	Suceava	47˚27'/25˚04'/935m	Cucureasa	12
Eastern Carpathians	Suceava	47˚22'/25˚40'/1075m	Slătioara	5
Eastern Carpathians	Maramureş	47˚36'/24˚53'/1250m	Prislop	3
Eastern Carpathians	Maramureş	47˚40'/24˚54'/1400m	Cislişoara	17

Lat. = North latitude, Long. = East longitude.

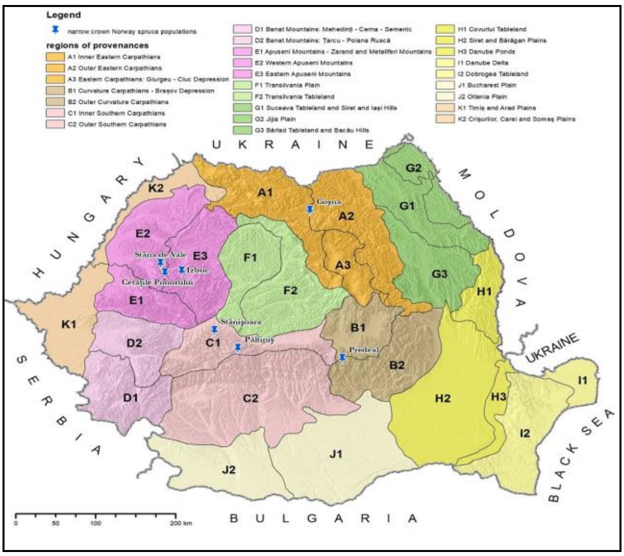

Fig. 1. Locations of the narrow crown Norway spruce populations on the Romanian FGR's map

Fig. 2. *Pendula* trees selected in the seven FGRs

Methods

The *pendula* trees are reported to the sixth and twelfth crown types, *columnaris* to the fourth type, while the normal crown form (*pyramidalis*) is reported to the first type, according to *Schmidt-Vogt* [31]. The crown diameter of narrow crowned trees is lower than *pyramidalis* and the first-order branches of *pendula* are pendent and descend along the trunk. Usually, the branches of the *pendula* trees are thinner [26].

In each of the selected populations, some of the narrow-crowned trees (not all were chosen to ensure a minimum distance of 30 m between trees) have been mapped and marked in the field using yellow paint and for those the main traits of growth, quality and stability of trees were measured, such as:

- Diameter at breast height (Dbh), using forest calliper;
- Trees height (Th) and pruning height (Ph, from the ground to the first green whorl) were taken using a Vertex IV instrument;
- Crown diameter (Cd) projection was taken using a telemeter;

The following traits were calculated based on field measurements:

- Tree slenderness (Ts) was calculated using the formula: Ts = Th/Dbh.
- Trees volume, calculated using the regression equation method developed by Giurgiu *et al*. [32].
- Pruning height ratio: Phr = (Ph/Th) x 100.
- Crown slenderness: Cs = Th/Cd.

In four populations, representative for three different Romanian Carpathian regions, cores were collected using the Pressler increment borer, at breast height (1.3 m above ground). For determination of conventional wood density (Cwd) the methodology proposed by Dumitriu-Tătăranu *et al.* [33] was used.

The data obtained for all traits were processed using the STATISTICA 10.0 software [34]. The Kolmogorov–Smirnov test was applied to check normal distribution and the assumptions of analysis of variance (ANOVA) were verified using Levene's test. The level of significance between forms was checked with ANOVA model [35], depending on the overall average value, crown forms and random error.

The simple Pearson correlations between phenotypic traits were also calculated.

Results

Eastern Carpathians populations

From the five populations identified by Pârnuţă in the Romanian Eastern Carpathians (Table 1), only one fulfilled the necessary criteria for inclusion in the Romanian National Catalogue of Forest Genetic Resources. In the 31 years that passed since the original identification, three populations were regenerated and in one population, a minimum of 10–15 trees with narrow crowns could not be identified.

In the Coşna population (Slătioara in Table 1), 40 spruce trees with narrow crown form were identified, 20 of them being marked in the field (Figs. 1 and 2). In all populations, the field selection took into account the condition of ensuring a distance of at least 30 m between the trees, avoiding inbreeding and promoting a uniform distribution to ensure the highest possible genetic diversity. In the Coşna population, there were selected trees belonging to the *pendula* crown form, but also four trees with a columnar crown. At an average age of 150 years, the narrow crown trees registered a Th of 34 m, Dbh was 55 cm, resulting in a volume of 3.61 m^3 (Table 2). The Ts, Cd and Cs values ensure the stand stability (Cd is 52% lower than the value registered for *pyramidalis* trees) while the Phr was below the previous results registered for Norway spruce in Romania (≈50%), with negative effects on the wood quality [36, 37]. The average Cd registered in the Coşna population was one of the lowest (Fig. 3), while the Cwd, a very important trait for stand stability [38], registered the highest value in Coşna, the northernmost population, both for *pendula* and normal crown trees (Fig. 4).

Table 2. Mean (± standard deviation) of the traits for narrow crown trees selected in the seven populations (up) and for the trees with normal crown form (down)

Carpathian region	Population	No. of trees	Trees' age (years)	Trees' height (m)	Breast height diameter (cm)	Trees' volume (m3)	Trees' slend. index	Pruning height ratio (%)	Crown diameter (m)	Crown slend.
Eastern	Coşna	20	150	34±2.8 33±3.0	**55**±11 50±10	**3.61**±1.3 2.64±1.4	65±12 66±11	30±13 **60**±15	**2.4**±0.5 5.0±0.7	**14.2**±3.5 6.6±3.0
Curvature	Predeal	14	145	35±2.7 34±2.9	**68**±11 57±10	**5.30**±1.8 3.24±1.6	**52**±7 60±7	21±8 **55**±10	**3.0**±0.6 5.6±0.8	**11.7**±1.8 6.1±2.0
Southern	Păltiniş	20	125	25±1.8 25±1.9	36±5 36±7	1.24±0.4 1.24±0.4	70±9 70±10	19±7 **55**±10	**2.3**±0.4 5.0±0.8	**10.9**±1.8 5.0±2.2
Southern	Stânişoara	20	115	30±3.4 30±3.5	40±9 40±10	1.87±0.9 1.87±0.9	75±11 75±12	30±11 **60**±12	**2.3**±0.2 5.5±0.8	**13.0**±1.2 5.5±2.2
Western R.C.	Stâna de Vale	15	130	33±2.2 33±2.2	56±11 56±13	3.65±1.3 3.65±1.4	61±10 61±10	17±5 **50**±10	**3.1**±0.4 5.0±0.8	**10.6**±1.4 6.6±2.0
Western R.C.	Cetăţile Ponorului	25	130	34±5.3 32±3.9	48±10 50±12	2.96±1.3 2.77±1.5	71±8 **61**±8	41±12 40±11	**2.8**±0.4 5.0±0.9	**12.1**±2.3 6.4±2.1
Western R.C.	Izbuc	30	140	**29**±5.3 25±5.1	**42**±12 36±13	**2.06**±1.2 1.72±1.1	70±11 69±12	34±16 **50**±13	**2.6**±0.4 5.0±0.8	**11.2**±2.2 5.0±2.0

Significant differences between crown form are bolded. It is ideal to have superior values for Th, Dbh, Tv, Phs, Cs and inferior for Ts, Cd. R.C.= Romanian Carpathians

Curvature Carpathians populations

One population (of the three described by *Pârnuţă* [19]) was selected in the Curvature Carpathians with only 14 narrow crown trees (10 *pendula* and 4 *columnaris*). In the other two populations, spruce trees with narrow crowns could not be identified. The Predeal population is situated at 1100 m altitude above sea level (a.s.l.) on a slope with north-west exposure and an inclination of 13°. This time, the selected population presents a fairly advanced age (145 years), a reduced stand density (0.6), a 50% spruce participation (mixed with silver fir and European beech) and the stand is the superior productivity class.

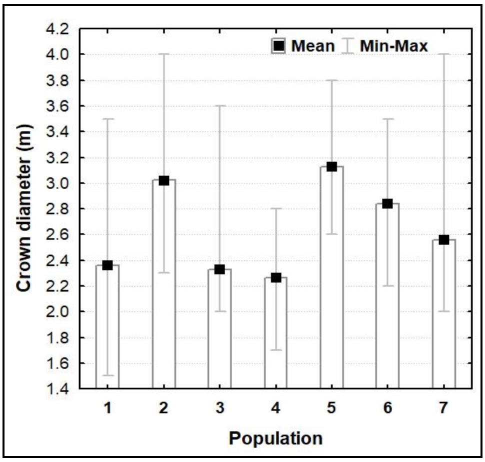

Fig. 3. Crown diameters of narrow crown spruce trees selected in the seven populations (1-Coşna, 2-Predeal, 3-Păltiniş, 4-Stânişoara, 5-Stâna de Vale, 6-Cetăţile Ponorului, 7-Izbuc)

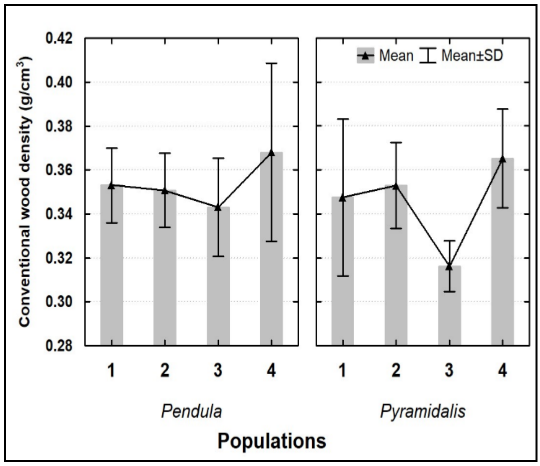

Fig. 4. Wood density of *pendula* vs. *pyramidalis* trees in different Carpathian regions (Populations: 1-Izbuc, 2-Stâna de Vale, 3-Păltiniş, 4-Coşna)

The 14 narrow crown trees present highest Dbh (68 cm) of all selected populations (Table 2) but, at the same time, a high value for Cd (Fig. 3), the latter being, however, inferior by 46% to the Cd value registered for the spruce trees reported as the normal crown form (*pyramidalis*). Once again, the Dbh and Th are superior (significant for Dbh, $p < 0.05$) for narrow crown trees compared with the normal crown ones. This time, the worrying value is related to the Phr, the mean value, 21%, indicating the presence of an increased number of wooden knots, with negative effects on wood quality [39, 40].

Southern Carpathians populations

In the Southern Carpathians, the Păltiniş (Onceşti in Table 1) and Stânişoara populations were selected, both of them located at the upper altitudinal limit of the natural distribution of Norway spruce in Romania, reaching a maximum altitude of 1690 m. In the Păltiniş population, 42 spruce trees with narrow crowns were identified, 20 of them (13 *pendula* and 7 *columnaris*) being marked in the field. Within the Stânişoara stand, 38 spruce trees with narrow crowns were identified, 20 of them (14 *pendula* and 6 *columnaris*) being marked in the field. The data from the literature indicated as favourable areas for narrow crown spruce in Apuseni Mountains and Obcinile Bucovinei, located in the north of the Romanian Eastern Carpathians [41]. However, the two populations of the Southern Carpathians are distinguished by the productivity of the trees but also by the diameters of their crowns, the lowest of all seven selected populations (Table 2, Fig. 3). In the previous research, the *columnaris* variety of spruce was identified especially in high altitude populations [19, 41]. Although the Stânişoara population is 10 years younger (the youngest of all seven selected) than the Păltiniş population, the values recorded for Th and Dbh are higher by 20% and 11%, respectively (Table 2). In addition, more favourable results were obtained in the Stânişoara population for Phr and Cs. The average Cd of narrow crown trees was lower by 54% and 58% compared with normal form, in the Păltiniş and Stânişoara populations, respectively. The Cwd were determinate only in the Păltiniş population, located at highest altitudinal level, where the lowest values among all four populations were registered, for both crown forms of spruce, especially for normal crown form (Fig. 4). Păltiniş was the only population where significant differences (p = 0.003) between narrow and normal crown forms of Norway spruce have been registered for Cwd.

Western Romanian Carpathians populations

Almost half of the populations selected by *Pârnuţă* [19] were located in the Western Romanian Carpathians, especially in the Apuseni Mountains (Table 1). The only one population selected in the Banat Mountains was replanted in the last few years. Of the eleven populations selected in 1991, only three fulfil the necessary conditions for inclusion in the Romanian FGR's Catalogue. The last four populations from table 1 were regenerated and from the first three and the next three it has been established, together with the managers of forest districts which administrate those forests, the selection of the most representative, Stâna de Vale I and Izbuc I (named Stâna de Vale and Izbuc in Table 2). The third selected population is Cetăţile Ponorului (Table 2).

In the Stâna de Vale population, 20 narrow crown trees were identified, 15 of them being marked in the field (all belonging to *pendula* form). In the Cetăţile Ponorului population, 25 narrow crown trees were selected (out of the 52 identified trees), mostly in relation to the *pendula* form (two trees present columnar crown). In the Izbuc population, the most spruce trees with narrow crown (30) were selected, out of the 43 identified trees. Most of the trees selected in the Izbuc population are related to the *pendula* form, but there are also three trees belonging to the *columnaris* variety. In the Izbuc population, narrow crown trees present lower values for Th and Dbh than in the other two populations (Table 2), but the more favourable Cd average value, 16% lower than the Stâna de Vale population (Fig. 3). The average Cd of narrow crown trees was lower by 38–48% than the normal form in these populations, while Cs was higher by 61–124% (Table 2), the results for both traits indicating the superior stability of narrow crown ideotype of Norway spruce. Only the Cetăţile Ponorului population registered a superior natural pruning of narrow crown compared with normal crown form trees. Cwd presents medium values in the Apuseni Mountains (superior to Păltiniş and inferior to Coşna) with slight differences between averages of the two populations (Fig. 4).

Correlations between analysed traits

In all populations, positive and significant correlations ($p < 0.05$) were registered between Th and Dbh, and, in most of the populations, a favourable influence of both traits on Ph and Ts. Only the positive correlations between growth traits and Cd (significant in three populations) obstruct the simultaneous breeding selection for all traits (Table 3).

Table 3. Correlations between analysed traits in the seven populations

Var.	Coşna/Predeal					Var.	Păltiniş/Stânişoara				
	Th	Dbh	Ts	Ph	Cd		Th	Dbh	Ts	Ph	Cd
Th	-	**0.50**	0.03	0.10	0.17	Th	-	**0.59**	-0.17	0.08	-0.06
Dbh	**0.77**	-	**-0.93**	0.21	0.15	Dbh	**0.84**	-	**-0.89**	-0.03	0.26
Ts	-0.5	**-0.90**	-	-0.19	-0.15	Ts	**-0.53**	**-0.88**	-	0.06	-0.34
Ph	0.26	-0.05	0.15	-	0.17	Ph	-0.17	**-0.49**	**0.64**	-	-0.28
Cd	**0.66**	**0.63**	-0.47	0.02	-	Cd	**0.64**	**0.64**	**-0.58**	-0.21	-
Var.	Stâna de Vale/Izbuc					Var.	Cetăţile Ponorului				
	Th	Dbh	Ts	Ph	Cd		Th	Dbh	Ts	Ph	Cd
Th	-	**0.76**	**-0.66**	0.33	0.17	Th	-	**0.90**	**-0.43**	**0.53**	0.17
Dbh	**0.88**	-	**-0.98**	**0.58**	0.13	Dbh	x	-	**-0.77**	**0.46**	0.26
Ts	**-0.54**	**-0.85**	-	**-0.61**	-0.16	Ts	x	x	-	-0.25	-0.30
Ph	**0.56**	0.28	0.07	-	-0.21	Ph	x	x	x	-	-0.32
Cd	**0.42**	**0.53**	**-0.55**	0.09	-	Cd	x	x	x	x	-

Var. = variables, Th = trees' height, Dbh = breast height diameter, Ts = trees' slenderness index, Ph = pruning height, Cd = crown diameter. The significant correlations are bolded.

However, selection in favour of *pendula* trees that present the highest values for Th and Dbh, removes this inconvenience. At the same time, the chosen trees must have a Ts around 80 and a natural pruning as good as possible (around 50%).

Discussion

Climate predictions for the coming years are worrying and these will affect the Norway spruce stands' resistance to wind and snow. In Romania, an increased frequency of windthrow has been observed during the last decades in the Norway spruce stands [19, 27, 42]. In this context, the identification, selection and promotion of tree ideotypes presenting higher resistance to the perturbing action of abiotic factors (wind and snow), is an important challenge for the geneticists.

For the first time in Romania, stands located in different provenance regions were selected for in situ conservation of narrow crown Norway spruce ideotype, which is considered more resistant to windfalls and specially to snow break. At the same time, the forest reproductive materials collected from these stands will be used for promotion of this ideotype in afforestation. In fact, only 28% of the populations identified by Pârnuţă (in 1991, not included in a conservation program) fulfil the criteria to be included in the Romanian FGR's Catalogue. The seven populations present old ages (134 years on average), in this context, selection and conservation procedures are required. At the same time, an action for cloning the narrow-crowned trees selected in these populations is required, too.

Comparative analyses of the narrow and normal crown trees for the most important productivity traits (Th, Dbh and Tv) in the seven populations revealed a superiority of narrow crown Norway spruce ideotype in four of the populations while in the other three populations the same average results were obtained for the two crown forms (Table 2). The average results of narrow crown trees, for Th, exceed the potential offered by the environment in which these populations grow: the trees are reported to the high productivity level while the biotope potential (expressed by soil, rocks, climate and relief) is medium.

The Phr of the 144 selected Norway spruce with narrow crown trees was 27.4%, inferior by 45% to the average Phr of Romanian spruce stands [36, 37] but rather close to the Swedish results (22%), registered at the age of 66 years [43]. In the present research, the spruce trees related to the normal crown form (*pyramidalis*) registered 55% for Phr. The very low value for Phr is the only weakness of the narrow crown ideotype (especially for wood quality) and can be compensated by a denser planting scheme, when *pendula* trees perform better than *pyramidalis* [21].

Ts trait (Th/Dbh) is of certain importance to assess the stability of Norway spruce stands. In Romania, *Popa* [42] proposed a threshold for Ts < 80, to manage stability of stands against wind and snow. In the selected populations, all narrow crown trees and the majority of normal crown trees satisfy this condition. Compared with the average Ts result recorded in 1991 [19], the present average Ts (66) is higher by 6.5% for narrow crown form. In the Romanian Carpathians, Ts decreases with age [36]. In Germany, at the age of 100 years, Ts increased with stand productivity and also with the increase in the number of trees/hectares [44]. In Finland, at the age of 52 and 60 years the Ts were 89 and 85, respectively [45, 46].

The Cd of narrow crown trees is lower by 38–58% than the normal crown form of spruce (significant differences in all populations, $p < 0.05$), which ensures the strength of the trees by the lower amount of snow retained in the canopy [47]. The distances between trees in the seven populations is, on average 1.5 m x 1.5 m, while in the north of Europe the research recommended a more dense planting scheme for narrow crown spruce, 1.0x1.0m, which provides increased production per hectare and also reducing thinning interventions in stands [4, 21, 22].

The Cwd, an important indicator of the resistance of spruce trees to wind and snow [38], increased with latitude, the lowest average value being registered in Southern Carpathians (0.33 g/cm^3) and the highest (0.367g/cm^3) in the Eastern Carpathians. The neighbouring populations (Stâna de Vale and Izbuc) present almost the same results, intermediate between the two extreme populations, as well as their intermediary locations on north latitude. The same trend is also observed if we analyse separately the two spruce forms, with a higher variation for the pyramidal spruce. For the two populations located in the Western Romanian Carpathians (Stâna de Vale and Izbuc) the present average Cwd (0.352g/cm^3) is 3% higher than the average result recorded in 1991 [19], for the trees reported as the narrow crown form, while for the Southern population the Cwd is the same after 27 years. In addition, in 1991 the highest difference between the two crown forms in the Southern population was registered (Păltiniş), in favour of the narrow crown form, while in the Apuseni Mountains the results were almost the same [19]. Cwd also showed considerably lower variation than the growth traits, which is in line with earlier findings [48, 49].

The phenotypic correlations between traits are in accordance with previous studies conducted in comparative half-sib and full-sib trials of narrow crown Norway spruce [26, 50]. The classical correlation between Th and Dbh, described in numerous studies [19, 49, 51] was registered ($r = 0.50–0.90$). A direct and significant correlation between Th and Ph was obtained also in the north of Europe [52]. In the present research, the simultaneous breeding selection could not be recommended because of the positive correlation of Th and Cd, likely with negative impact on the stand's stability. In Norway, because of the high correlation between tree height and the number of damaged trees, it is recommended that the breeding selection according to Th to be carefully adopted [53]. The wood resistance of the two crown forms of Norway spruce, analysed in Stâna de Vale population (Budeanu and Porojan, unpublished data), showed a highly significant superiority ($p < 0.001$) of *pendula* trees for the flexural strength (+32%), resistance to wood compression parallel to fibers (+45%) and for the resistance to wood radial shear (+17%). These results confirm the superiority of *pendula* ideotype obtained for phenotypic traits and wood density, in the seven natural populations.

The seven natural populations in which the narrow crown spruce ideotype (*pendula* form and *columnaris* variety) will be preserved in situ are added to the seven trials in which are conserved *ex situ* the narrow crown spruce trees as well as hybrids obtained through full diallel mating design between *pendul*a and *pyramidalis* (classical crown form) spruces [19, 26, 50]. The research will continue with identification of the gene involved in the inheritance of the narrow crown character, the analysis of environmental conditions that favour the manifestation of this character, establishment of a seed orchard for cloning the seven populations that reached an advanced age as well as for the production of seeds to promote this ideotype. In addition, a working protocol for the in vitro multiplication of narrow crown spruce will be established.

Conclusions

In seven natural populations a total number of 249 narrow crowned Norway spruce trees were identified and selected for inclusion in the Romanian National Catalogue of Forest Genetic Resources with the aim of in situ conservation of this ideotype considered more resistant to windthrow and heavy snows. In these stands, with an average age of 134 years, the narrow crown trees present favourable results for growth traits (Th and Dbh), tree slenderness, crown diameter and wood density compared with the trees reported as the normal crown form of spruce, while natural pruning was the only unfavourable trait.

In the future, the breeding selection strategy in favour of narrow crown trees will neutralize the positive correlations between growth traits and crown diameter (significant in three populations) with high impact on the stand's stability.

Acknowledgments

This article is dedicated to the forest geneticist, dr. Gheorghe Pârnuţă, the promotor of this grandiose experiment and the mentor of MB and ENA. We want to thank to our devoted colleagues: Dan Pepelea, Ștefan Tănasie and Gabriela Lupu, for their help in the field measurements and laboratory analysis.

The Romanian Ministry of Research and Innovation financed the research, in the frame of Nucleu Programme contracted with National Institute for Research and Development in Forestry "Marin Drăcea" (Project PN19070302).

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Received: July 15, 2020
Accepted: July 5, 2021