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Analysis of Qualitative Indicators of Norway Spruce and Silver Fir Seed Stands in the Federation of Bosnia and Herzegovina

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ABSTRACT

The research aims to determine the quantity and quality of Norway spruce and silver fir seed stands in the Federation of Bosnia and Herzegovina and to recommend measures for their improvement to produce the highest quality reproduction material and achieve genetic gain in newly planted forests. For this research, four measured and 19 observed phenotypic traits were analyzed in 11 Norway spruce and 14 silver fir seed stands. The average age of the trees in Norway spruce seed stands was 70 years, and in silver fir stands 85 years. The average diameter of trees in Norway spruce seed stands was 49 cm, and 46 cm for silver fir. The average height of trees for both species was 26 m. In all seed stands of both species, there was a sufficient number of favorably shaped and straight trees. There was a small incidence of forkness and a high incidence of thin and medium-thick branches. The number of branches in the whorl was high in the seed stands of both species. There was a large number of trees growing poorly and trees with poor trunk clearance from dead branches. A small number of damaged trees in seed stands were also registered, and a low percentage of trees with moderate twisting. The appearance of mistletoe was registered in silver fir seed stands. Some of the analyzed seed stands have shown very good quality, and individual selection should be made in them. In some of the analyzed stands, activities of arrangement and removal of part of the trees are necessary. Considering the great ecological-vegetation diversity of Bosnia and Herzegovina, with four ecological-vegetation regions, 14 areas and 20 districts, most of which are also represented in the Federation of BiH, a higher number of seed stands is needed. When selecting new seed stands for spruce and fir, the focus should be on small stands that grow in extreme conditions.

Keywords: Seed stand; *Abies alba*; *Picea abies*; qualitative structure

INTRODUCTION

The quality of seed stands of Norway spruce and silver fir in the Federation of Bosnia and Herzegovina is not sufficiently known, although these are the most important facilities for the production of "normal forest seeds". Seed stands are selected by conducting mass selection as the basic method of breeding forest trees (Ballian 2008). Mass selection occurs through several stages: proposing, rating, and registration of seed objects. Using the prescribed selection method, the above-average parts of the forest are selected, which will be used for the production of normal or selected seeds (EC 2000, Law on seeds and seedlings of forest and horticultural trees and shrubs 2005) if the seed object is arranged and the surrounding forests are meliorated. This method of selecting the best parts of stands and removing trees with bad phenotypes achieves the primary goal of mass selection (Ballian 2008, Ballian and Kajba 2011).

These activities create the basis for further work on breeding, especially on individual selection. Considering the pronounced trend of forest devastation in the Federation of Bosnia and Herzegovina (Federation of BiH), and the dangers of drastic damage and loss of the gene pool of indigenous trees, the selection of quality seed stands in the coming period is imperative.

During the mass selection in the Federation of BiH, where a great variety of ecological conditions exist, it was necessary to select representatives of geographical, ecological, and seasonal subspecies. According to Vidaković and Žufa (1966), if there is not enough data on the existence of lower taxonomic categories, it is necessary to separate the best populations and individuals in the best habitats, and populations and individuals growing in ecologically extreme habitats. In this case, we focused on a larger scale and more detailed study of the starting material. Selection is normally performed by assessing the appropriate phenotypic properties, starting from the basic genetic laws of inheritance. Here the principle applies that a good phenotype is hypothetically a good genotype, although this is not always the case (Vidaković and Krstinić 1985, Ballian and Kajba 2011). However, with mass selection within the stands, it should be borne in mind that forest trees are cross-fertilized, and mostly heterozygous.

How many seed stands of one species will be separated depends on their genetic differentiation. This is often directly related to the distribution and diversity of ecological conditions prevailing in the distribution area. Thus, in species with a wider distribution, such as in the case of Norway spruce, differentiation is higher, while silver fir is less differentiated (Vidaković and Franjić 2004). Due to the great ecological diversity inherent in the Dinaric Mountains, a larger number of stands should be selected, so that the complete genetic structure of one area or one species could be represented in seed production (Ballian and Halilović 2016, Ballian and Božič 2018).

The area of seed stands is a matter of choice, whether to have a larger number of smaller stands or a smaller number of larger stands. However, the decision on the size of the stand is based on the quality parameters of the trees, whereby the stand must not contain less than 50 seed-bearing trees per ha on a minimum area of 2 ha. It should also be borne in mind that when selecting larger buildings in a mountainous area the difference in height between the lowest and the highest part should not exceed 200 m. If the height difference is greater than 200 m, in the case of spruce, two independent objects should be separated (Ballian et al. 2007).

This research aims to determine the quality of seed objects of Norway spruce and silver fir in the Federation of Bosnia and Herzegovina and to recommend measures for their improvement to produce the highest quality reproductive material of these species.

MATERIALS AND METHODS

In this research, the data on the assessment of all separated seed objects of Norway spruce and silver fir in the Federation of Bosnia and Herzegovina were analyzed (Table 1 and Table 2). Some of the separated seed stands were not registered because it was later established that they were in minefield zones and some were not registered due to non-compliance with legal decisions in the forestry of Federation of Bosnia and Herzegovina. Nevertheless, the assessed and nominated but not registered seed stands of Norway spruce and silver fir were also included in the analysis to represent better the quality of seed stands of these species (data from the authors' archive).

Spatial distribution of silver fir seed stands is shown in Figure 1a, and of Norway spruce in Figure 1b.

For the analysis, 23 phenotypic characteristics of the tree, i.e. the population of forest trees, were used. The basic properties measured are the diameter at breast height and the height of the trees. The age and the social status were also determined, which requires a lot of experience considering that the observed forests are of various ages. In dioecious species, the gender of trees was recorded, and in monoecious species, sexual functionality was recorded. Nineteen (19) descriptive properties that are key to quality were also evaluated. Some are qualitative and under high genetic control, while some are quantitative and under low genetic control. For this reason, when grading, the evaluator needs to know the basic rules of inheritance of each property. When it comes to the property of fruiting, it is conditioned by the fertility in the year of evaluation, and it is possible to estimate it based on the remains of cones under the evaluated tree.

According to Regulation on the content, form and manner of keeping the register of forest and horticultural seeds and forest and horticultural planting material , the following properties are measured and evaluated (Table 3).

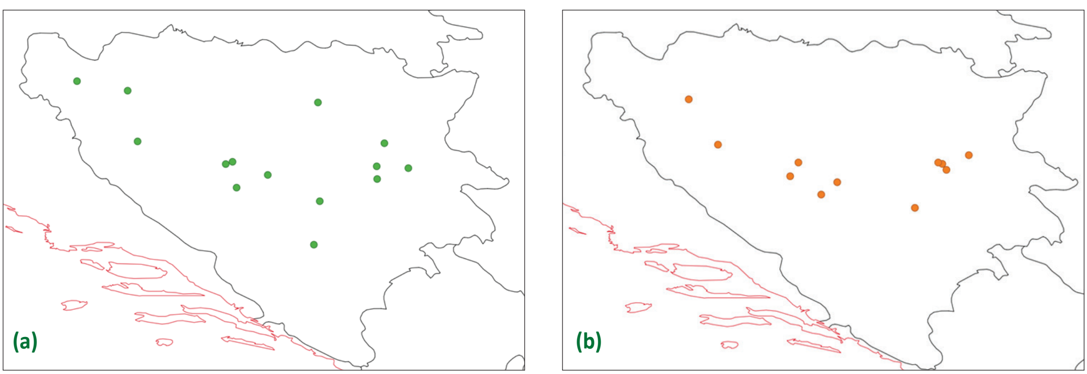


Figure 1. Spatial distribution of: **(a)** silver fir seed stands, and **(b)** Norway spruce seed stands.

Table 1. Spatial arrangement of silver fir and Norway spruce seed stands (source: http://portal.eufgis.org/ and authors' data - highlighted in gray).

Species	Location of seed stand	Latitude	Longitude	Minimum altitude (m a.s.l.)	Maximum altitude (m a.s.l.)	Label of the ecological-vegetation region/area/ district
Abies alba	Sanski Most Korčanica	44°39'39"	16°27'46"	950	1100	3.2.1.
	Bihać Risovac	44°45'30"	16°5'32"	950	1020	3.2.1.
	Ilijaš Gornja Ljubinja	44°1'51"	18°30'23"	980	1050	3.4.
	Kladanj Piskavica	44°17'20"	18°37'3"	1000	1050	3.4.
	Kupres Blagajska privija	44°03'45"	17°12'58"	1347	1373	3.3.2.
	Donji Vakuf Velika Vrljevača	44°02'57"	17°19'35"	1036	1054	3.3.2.
	Gornji Vakuf Suhodol	43°59'38"	17°37'28"	900	1160	3.3.2.
	Bugojno Donji Mračaj	43°59'2"	17°22'28"	1100	1300	3.2.4.
	Konjic Grabovica	43°32'0"	18°2'11"	1080	1140	4.1.
	Olovo Gajine	44°3'2"	18°34'0"	900	987	3.5.1.
	Olovo Klis	44°7'9"	18°44'30"	1000	1100	3.5.2.
	Hadžići Suhodol	43°48'28"	18°06'03"	815	815	3.3.3.
	Tešanj Mekiš	44°34'35"	17°59'40"	295	320	1.1.
	Glamoč Klekovača	44°20'8"	16°38'8"	1150	1250	3.2.3.
Picea abies	Bosanski Petrovac Tavani	44°36'33"	16°29'23"	1050	1060	3.2.1.
	Glamoč Klekovača	44°17'18"	16°41'34"	1257	1307	3.2.1.
	Kupres Blagajska Privija	44°4'7"	17°12'54"	1330	1380	3.2.4.
	Kladanj Paljike	44°11'24"	18°39'39"	850	890	3.5.2.
	Donji Vakuf Mala Vrljevača	44°02'57"	17°19'35"	1036	1054	3.3.2.
	Bugojno Čador	43°54'15"	17°26'58"	1228	1322	3.3.2.
	Gornji Vakuf Vrela	43°57'32"	17°42'7"	1450	1850	3.3.2.
	Ilijaš Čauševo brdo	44°2'54"	18°32'5"	930	1050	3.4.
	Olovo Grab	44°5'19"	18°34'5"	850	865	3.4.
	Ilijaš Bijambare	44°5'39"	18°30'6"	950	955	3.4.
	Hadžići Veliko polje	43°44'37"	18°16'24"	1180	1200	3.3.3.

1.1. – Pripanonian region, Northern Bosnia area
3.2.1. - Inner Dinarides region, West Bosnian limestone - dolomite area, Ključ-Petrovac district
3.2.3. - Inner Dinarides region, West Bosnian limestone - dolomite area, Glamoč-Kupres district
3.2.4. - Inner Dinarides region, West Bosnian limestone - dolomite area, Koprivnica district
3.3.2. - Inner Dinarides region, Central Bosnia area, Vranica district
3.3.3. - Inner Dinarides region, Central Bosnia area, Sarajevo-Zenica district
3.4. - Inner Dinarides region, Zavidovići-Teslić area
3.5.1. - Inner Dinarides region, the area of the East-Bosnian Plateau, Ozren-Okruglica district
3.5.2. - Inner Dinarides region, the area of the East-Bosnian Plateau, Romanija district
4.1. - Mediterranean-Dinaric region, sub-Mediterranean mountain area

Table 2. Summary overview of Norway spruce and silver fir seed stands (source: Ministry of Agriculture, Water Management and Forestry of the Federation of Bosnia and Herzegovina 2024)

Species	Number of seed objects	Surface (ha)	Reduced surface (ha)
Picea abies	11	297.63	208.82
Abies alba	14	336.01	249.41

Table 3. Measured and evaluated properties during the evaluation of seed stands.

No	Property	No	Property
1.	The age of the tree	13.	Branch thickness
2.	Social position	14.	Number of branches in a whorl
3.	Breast height diameter	15.	Distance between whorls
4.	Height	16.	Trunk purity from branches
5.	Gender	17.	Mechanical damage (on the trunk or crown)
6.	Crown shape	18.	Presence of disease on the tree
7.	Crown length	19.	Twistedness
8.	Branch insertion angle	20.	The structure of the bark
9.	Branch type	21.	Bark color
10.	Trunk fullness	22.	The place where the roughness of the bark stops
11.	Trunk straightness	23.	Fruiting properties
12.	Forkness	-	-

RESULTS

The average values of age, height and diameter at breast height (DBH) by seed stands are given in Table 4 for Norway spruce and in Table 5 for silver fir.

Age

The age of the tree is crucial when choosing a seed object. There should not be too many physiologically immature trees that produce stunted seeds (Ballian 2013), as well as too old trees that have a greater share of mutations in the seeds, because after sprouting the seedlings dry quickly. At most, old and too young trees can be allowed in the stand up to 30%. Age information is taken from the forest management plan, or determined using standard dendrometric methods. Thus, our Norway spruce seed stands have trees aged from 20 to 280 years, while the average is 98 years. For silver fir the age ranges from 20 to 220 years, and the average is about 75 years.

Social Position

The social position of the tree in the stand is determined according to Kraft's classification. When grading, only trees from class II - dominant trees, and class III - co-dominant trees are taken. The evaluator must have a lot of experience, because in the territory of the Federation of Bosnia and Herzegovina, seed stands are separated in forests of various ages, and it is difficult to determine these two classes.

Diameter at Breast Height

The arithmetic mean of the two measurements is the diameter at breast height. The average diameter values for seed stands are shown in Table 5. The diameters of Norway spruce ranged from 19 to 75 cm, and the average for all stands was 43 cm. In silver fir, diameters in seed stands ranged from 5 to 98 cm, while the average diameter for all stands was 38 cm.

Table 4. Data on age, height and breast height diameter of trees in Norway spruce seed stands.

Seed stand	Age from-to (years)	Average age (years)	DBH from-to (cm)	Average DBH (cm)	Height from-to (m)	Average height (m)
Bos. Petrovac Tavani	35-110	65	19-52	31	14-31	25
Glamoč Klekovača	20-280	75	22-75	56	17-49	37
Kupres Blagajska Privija	20-130	90	25-61	42	19-32	26
Kladanj Paljike	75-156	110	28-70	44	19-34	27
D. Vakuf Mala Vrljevača	50-160	70	28-74	44	19-42	29
Bugojno Čador	90-150	130	35-74	56	22-41	33
Gornji Vakuf Vrela	60-100	120	27-55	40	16-32	25
Ilijaš Čauševo brdo	60-120	100	28-64	45	21-36	30
Olovo Grab	40-170	100	21-59	30	20-32	27
Hadžići Veliko polje	80-190	110	33-51	39	24-31	26
Ilijaš Bijambare	80-160	110	32-66	46	24-43	34
Average	-	98	-	43	-	30

Table 5. Data on age, height and breast height diameter of trees in silver fir seed stands.

Seed stand	Age from-to (years)	Average age (years)	DBH from-to (cm)	Average DBH (cm)	Height from-to (m)	Average height (m)
Sanski Most Korčanica	35-180	90	23-98	55	14-37	29
Bihać Risovac	45-100	60	17-53	26	13-32	23
Ilijaš Gornja Ljubinja	45-150	110	31-66	42	23-38	28
Glamoč Klekovača	20-220	55	23-80	40	15-42	28
Kupres Blagajska Privija	20-110	90	28-51	36	17-28	23
Kladanj Piskavica	35-120	60	25-63	41	20-32	28
Donji Vakuf Velika Vrljevača	50-160	70	32-72	52	19-38	25
Gornji Vakuf Suhodol	30-160	70	21-55	36	16-37	24
Bugojno Donji Mračaj	50-130	100	27-55	39	17-29	22
Konjic Grabovica	20-60	30	21-45	28	15-26	19
Olovo Gajine	70-140	120	32-66	43	21-36	30
Olovo Klis	35-160	110	28-70	45	25-42	31
Hadžići Suhodol (artificial plantation)	38	38	5-37	16	6-24	19
Tešanj Mekiš	25-45	40	11-34	25	12-23	18
Average	-	75	-	38	-	25

Tree Heights

Tree heights are measured with an accuracy of ±0.5 m. Tree height is also taken as a basis for determining the relative length and width of the crown, the length of the trunk to the crown, the technical cleanliness of the trunk, etc., which is expressed in relation to the total height of the tree. Heights for Norway spruce ranged from 14 to 49 m, and the average for all seed stands was 30 m. For silver fir, heights ranged from 6 to 42 m, and the average for all stands was 25 m.

Crown Shape

The shape of the crown is evaluated based on the ratio of its width and length. The frequencies of different crown shapes in Norway spruce and silver fir seed stands are shown in Figure 2. In the case of trees in the spruce seed stands, the conical shape dominates. The nested shape is related to the Paljika seed stand, which indicates its greater age. A higher proportion of the neiloid crown shape was found in Norway spruce in the frost ecotype on Igman, which is probably a consequence of the interaction with environmental factors. In silver fir trees, the conical shape dominates, while the neiloid and nested shapes were found in older specimens.

Crown Length

The property of crown length is a very important element for evaluating the quality of a tree. The length of the crown also affects the production of cones, especially in spruce where cones occur throughout the crown, while

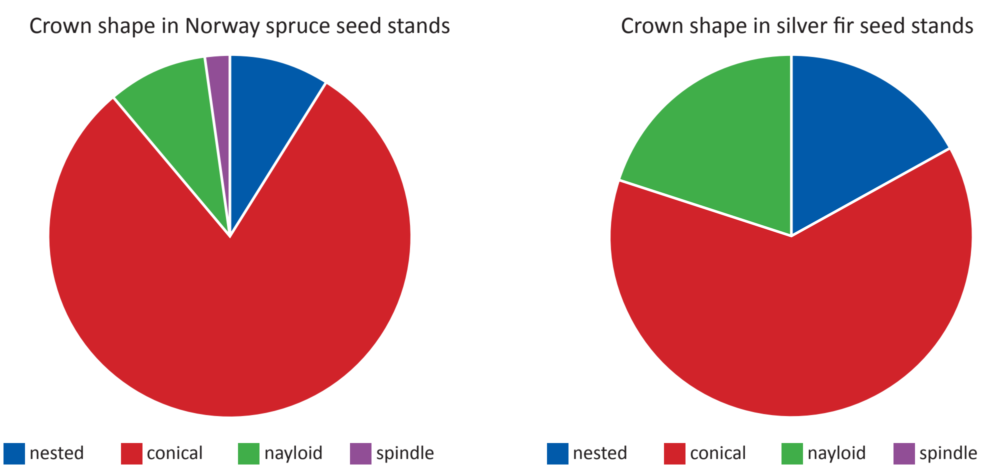


Figure 2. Crown shape in Norway spruce and silver fir seed stands in Federation of BiH.

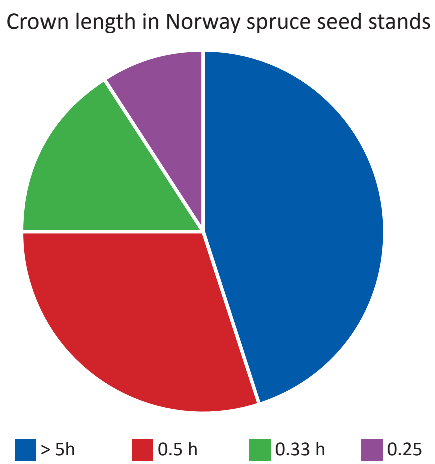
in fir the production takes place at the top of the crown. For production forestry, it is considered that the length of the crown, in conifers, is optimal if it ranges from 1/3 to 1/4 of the total height, and normal if it is no longer than 1/2 of the total height of the tree. A longer crown length is better for seed production. For spruce and fir, the usual classification of crown length into four classes is accepted. Due to the diversity of our forests, there is a great variety of crown lengths in seed stands (Figure 3). Both spruce and fir are dominated by long and medium-long crowns.

Branch Insertion Angle

The branch insertion angle represents the upper angle between the axis of the trunk and the branch and is crucial for better cleaning of the trunk from the branches. It is known that trees with a sharper insertion angle in combination with a higher forest density have better cleaning from branches. When evaluating this property by visual assessment, it was determined that Norway spruce and silver fir do not have a sharp insertion angle, but are approximately horizontal and higher than 90° (Figure 4). This, along with the age diversity of forest stands, is unfavorable for cleaning trunks, and therefore forest density is crucial for the cleaning of trees from branches. The only advantage of higher angle of insertion is that there are fewer branch breaks from snow.

Branch Type

In conifers, branches can be distinguished in the form of brushes, combs, flattened, and indifferent types of branches. According to this property, silver fir is monomorphic and only has flattened branches. Spruce has branches in all four categories (Figure 5) (Vidaković and Franjić 2004), but comb-like branches are the most represented in this research. The branches of this type are thinner and retain less snow, while



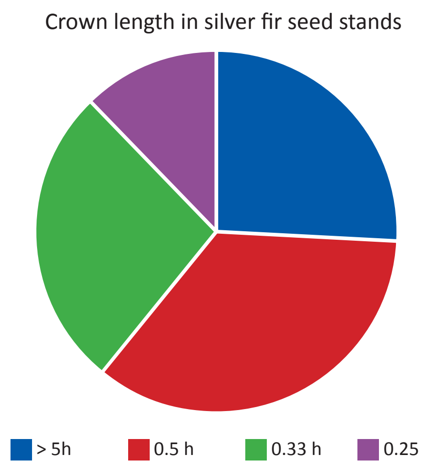
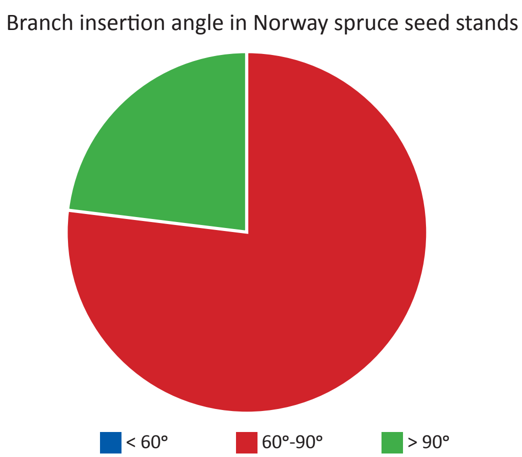


Figure 3. Crown length in Norway spruce and silver fir seed stands.



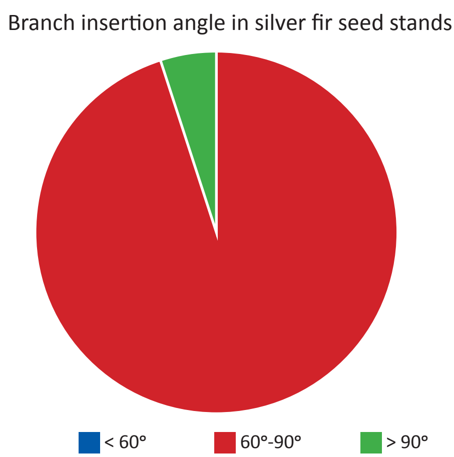


Figure 4. Branch insertion angle in Norway spruce and silver fir seed stands.

the other types of branches are not so well adapted for snow, because the branches are thicker and retain snow.

Trunk Fullness (Change in Tree Diameter with Height)

The fullness of the trunk is a very important property from the point of view of the technical use of wood. Although this property is related to the composition of the stand, it is also under the control of a larger number of genes, which is defined by quantitative inheritance. Fullness is estimated based on the decrease in diameter with increasing trunk height, and for the estimation four classes are used: poor, good, very good, and excellent. In the seed stands of Norway spruce (Figure 6, Table 6) and silver fir (Figure 6, Table 7) the largest number of trees had excellent and very good trunk fullness.

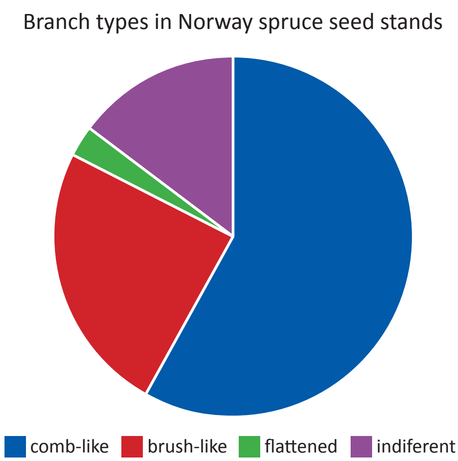


Figure 5. Branch types in Norway spruce seed stands.

Trunk Straightness

Trunk straightness is also a property that can be regulated by the density of trees in the stand. A tree is considered straight if its axis, viewed from two directions, is without deviation, otherwise it is considered curved. Curvature is assessed according to the direction and intensity. Four classes are used for this phenotypic trait: poor, good, very good and excellent. In the Norway spruce seed stands, excellent straightness dominated (Figure 7), and in the seed stand near Bosanski Petrovac, all trees showed excellent straightness (Table 6). Trees with excellent straightness also dominated in seed stands of silver fir (Figure 7), especially in the Sanski Most Korčanica seed stand (Table 7).

Forkness

The property of forkness can indicate the plant's sensitivity to early frosts when the apical meristems freeze. In addition, it can also indicate certain mechanical damage in youth. Forkness occurs when two parallel buds or branches take on an orthotropic growth direction after the decay of the apex bud or the top of the tree and develop into two approximately equal branches. From the side buds of the top whorl, a fork develops, as well as from the side branches. The appearance of forkness should always be evaluated as a negative phenotypic trait. The criteria for evaluating the height of forkness are: low forkness - up to 1/3 of the tree's height; medium-high forkness - from 1/3 to 2/3 of the tree's height; high forkness - over 2/3 of the tree's height, and no forkness. The analyzed seed stands show a small incidence of forkness, which indicates a good resistance to frost (Figure 8).

Branch Thickness

The thickness of the branches is important for the technical properties of the wood and is evaluated in the lower half of the crown. It is determined by the ratio of the diameter of the branches and the thickness of the trunk at a

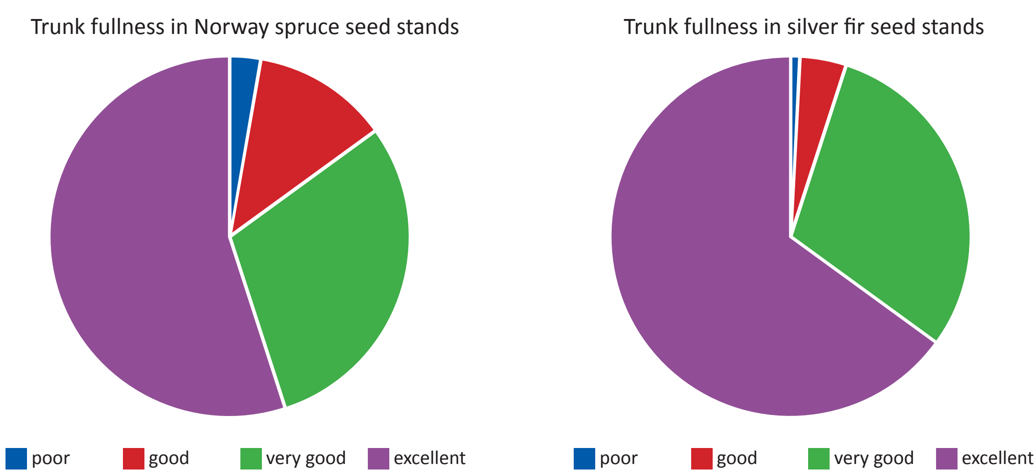


Figure 6. Trunk fullness in Norway spruce and silver fir seed stands.

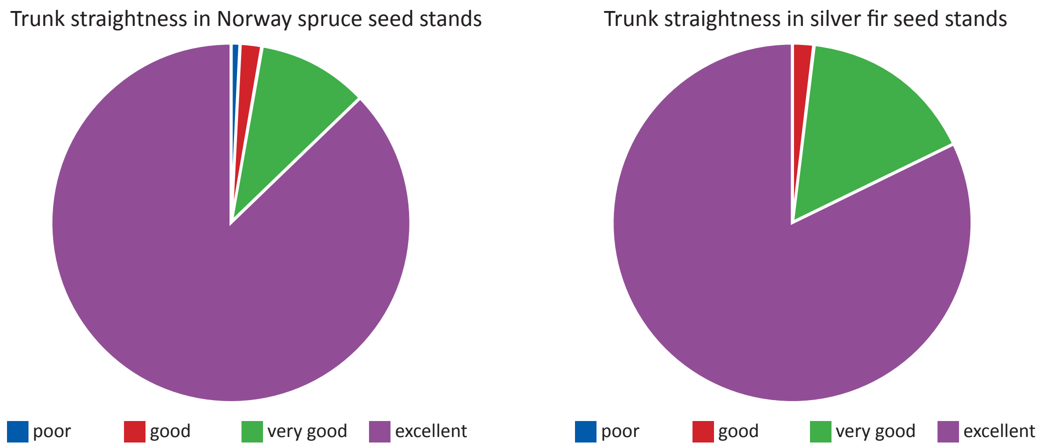


Figure 7. Trunk straightness in Norway spruce and silver fir seed stands.

Table 6. Data on trunk fullness and trunk straightness of trees in Norway spruce seed stands.

Seed stand	Trunk fullness				Trunk straightness			
	poor	good	very good	excellent	poor	good	very good	excellent
Bos. Petrovac Tavani	0	5	54	41				100
Glamoč Klekovača	0	7	50	43			10	90
Kupres Blagajska Privija	2	4	35	61		2	22	76
Kladanj Paljike	0	1	29	70			9	91
Donji Vakuf Mala Vrljevača	3	5	26	69	1	2	13	84
Bugojno Čador	2	3	36	61	1	5	7	87
Gornji Vakuf Vrela	11	3	16	81		1	17	82
Ilijaš Čauševo brdo	0	1	6	93		1	1	98
Olovo Grab	1	7	24	69			2	98
Hadžići Veliko polje	3	73	27	0		1	14	85
Ilijaš Bijambare	10	22	38	40	4	7	17	72

Table 7. Data on trunk fullness and trunk straightness of trees in silver fir seed stands.

Seed stand	Trunk fullness				Trunk straightness			
	poor	good	very good	excellent	poor	good	very good	excellent
Sanski Most Korčanica				100			3	97
Bihać Risovac		4	49	47		2	35	63
Ilijaš Gornja Ljubinja	6	11	59	24	2	5	31	62
Glamoč Klekovača		10	42	48			8	92
Kupres Blagajska Privija			26	74			18	32
Kladanj Piskavica		2	9	89		2	3	95
D. Vakuf Velika Vrljevača		8	49	43		2	27	71
Gornji Vakuf Suhodol		1	20	79		8	12	80
Bugojno Donji Mračaj	2	11	31	56		5	7	88
Konjic Grabovica		4	46	50			26	74
Olovo Gajine			21	79			4	94
Olovo Klis		6	40	54		2	19	79
Hadžići Suhodol			8	92			6	94
Tešanj Mekiš			20	80			10	90

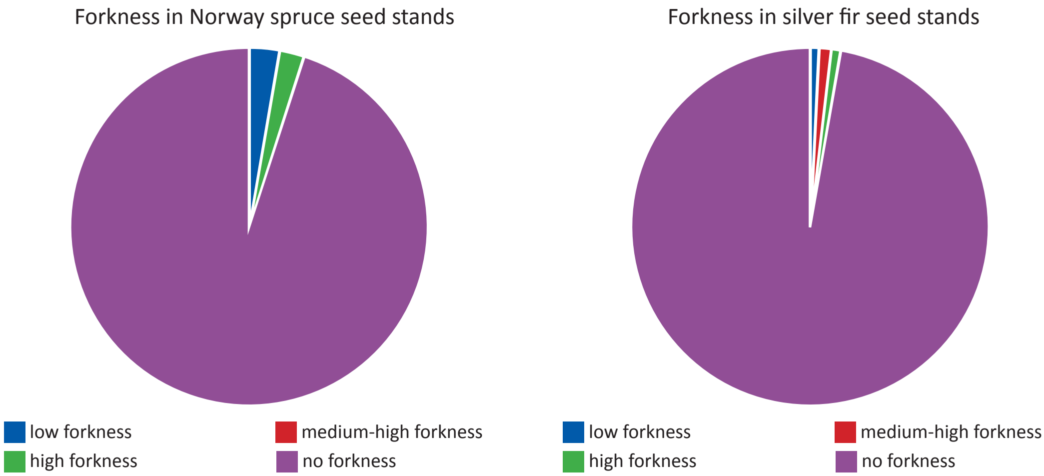


Figure 8. Forkness in Norway spruce and silver fir seed stands.

distance of 15-20 cm from the base of the branch. Depending on the length of the crown, its construction, and the density of trees in the stand, which affects the possibility of visibility, the minimum number of whorls for which the thickness of the branches in conifers will be evaluated, should be from 5 to 7 whorls in the middle part of the lower third of the crown. The thickness of the branches is estimated visually, and experience is required. This property is evaluated in four categories: thin branches, medium thick branches, thick branches, very thick branches. In the analyzed Norway spruce and silver fir seed stands, the thickness of the branches is favorable, with a large proportion of thin and medium-thick branches (Figure 9). For silver fir, the best ratio of branch thickness was observed in the Piskavica seed stand near Kladanj, and for Norway spruce in the Čauševo brdo stand near Ilijaš.

The Number of Branches in a Whorl

The number of branches in a whorl is determined by counting all living and dry branches. The average number of branches in a whorl represents the arithmetic mean of the number of branches in several whorls. Depending on the stand conditions, the number of whorls on which the branches will be counted should be previously determined for each species. The number of branches in a whorl is presented in three categories: up to 4, 4 - 6, and over 6. This trait is crucial for biomass growth, because trees with

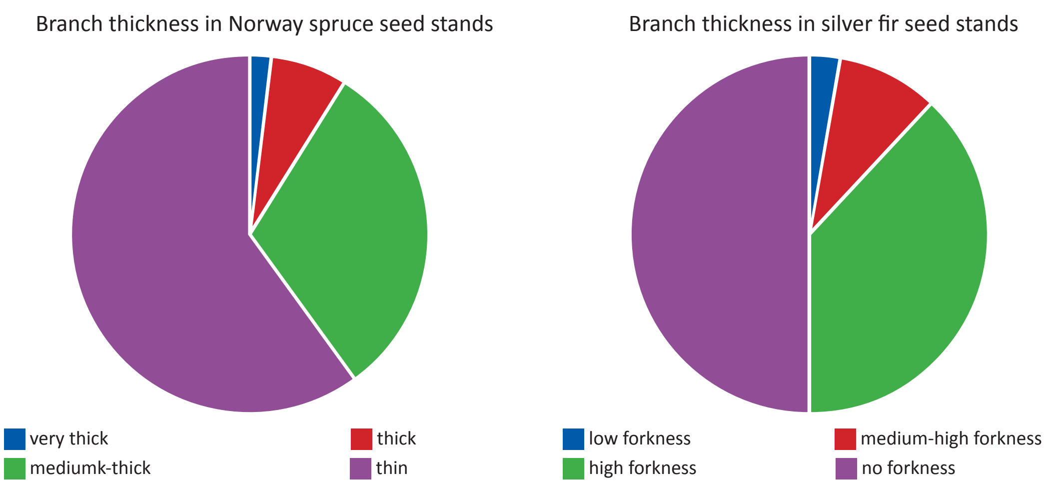


Figure 9. Branch thickness in Norway spruce and silver fir seed stands.

more branches have better growth, while those with fewer branches in a whorl have better technical quality. The number of branches in a whorl was high in both analyzed species. Only a small number of trees had up to 4 branches in a whorl (Figure 10). For this reason, when arranging seed stands, the selection should be directed towards trees with a smaller number of branches in a whorl to improve the quality of the stand.

The Distance Between the Whorls

The distance between the whorls along the tree is a phenotypic property important for the evaluation of the quality of the trunk and for the organization of the collection of seeds or fruits. This property also indicates the growth potential of the tree. It is expressed in four distance categories, 0.2 m, 0.4 m, 0.6 m, and 0.8 m. It is recommended to measure the distance between several whorls in the lower part of the crown and divide the measured length by the number of included whorls. In the case of spruce seed stands, there is a greater share of trees with a higher distance between the whorls (Figure 11). Unfortunately, in the seed stands of both species, there are many trees with small growth (small distance between the whorls), so in the coming period, efforts should be made to improve the height of the seed stands.

Trunk Purity from Branches

The purity of the trunk is evaluated visually and represents the percentage ratio between the length of the trunk to the first live branch and the part where there are

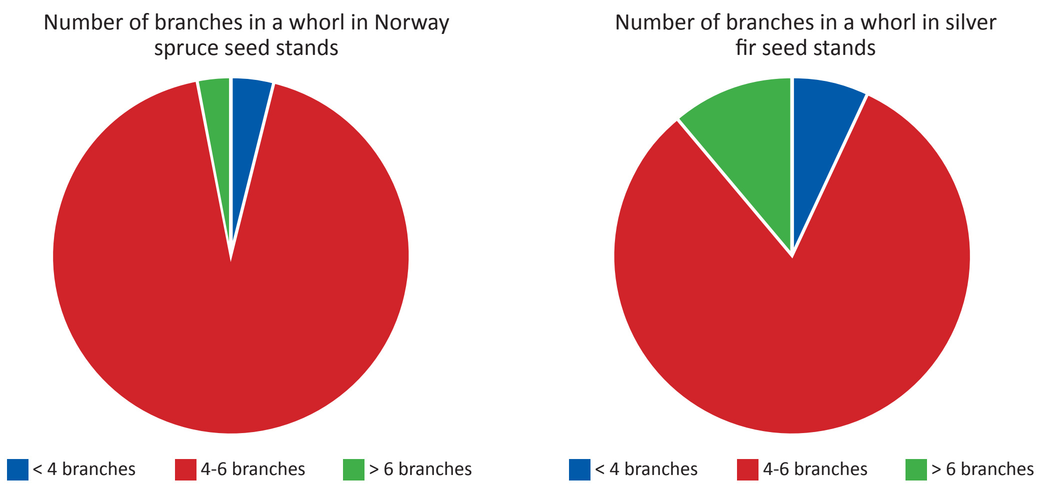


Figure 10. Number of branches in a whorl in Norway spruce and silver fir seed stands.

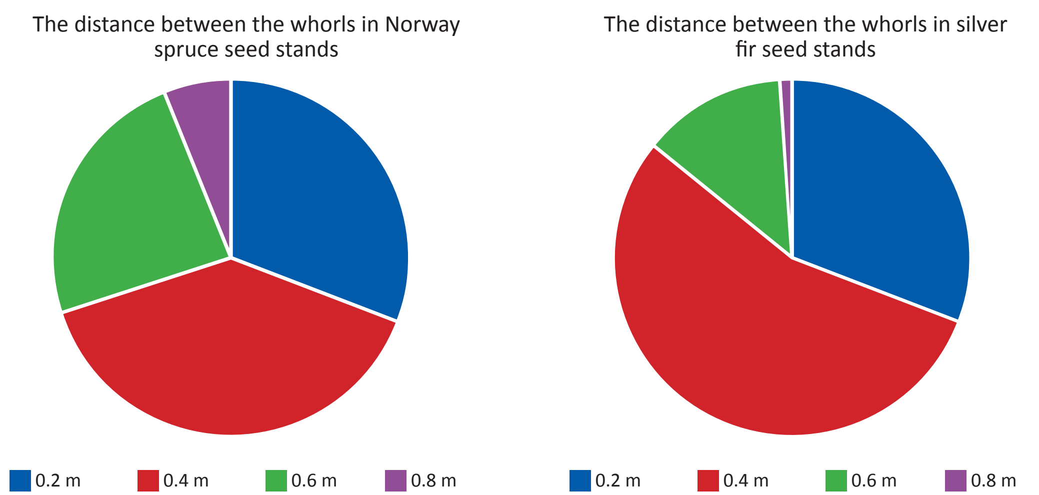


Figure 11. The distance between the whorls in Norway spruce and silver fir seed stands.

dry branches. It is divided into four categories: poor, good, very good, and excellent. This property is related to the structure of the stand, and the density of trees in the stand. In the analyzed seed stands of Norway spruce and silver fir, a high share of trees with poor clearing of the trunk from dead branches was obtained (Figure 12). The reason for this could be in the structure of analyzed forests, which are of various ages. However, some stands had a good structure, such as Piskavica (Kladanj) for silver fir.

Mechanical Damage (on the Trunk or Crown)

Mechanical damage is evaluated separately for the tree and the crown. Mechanical damage represents those places on the tree and crown where, under the influence of some external factor, there has been decay of dead and living bark, wood, broken branches, and vegetative organs. The cause of mechanical damage can be abiotic or biotic. Abiotic causes are: wind, snow, ice, hail, thunder, and fire, and biotic causes are diseases, insects, rodents, birds, and game. Mechanical damage can often be caused by humans. The criterion for assessing mechanical damage is as follows: no damage, moderate damage, medium damage, and severe damage. Moderate damage can be tolerated on the trunk if the wound is healthy and the healing is intensive. Mechanical damage caused by abiotic influences cannot be tolerated, except moderate damage caused by hail. All trees with mechanical damage that exceed the tolerance limits must be evaluated as a minus variant. There was a large number of undamaged trees in the analyzed seed stands (Figure 13), but there should not be any damaged trees in the seed stands.

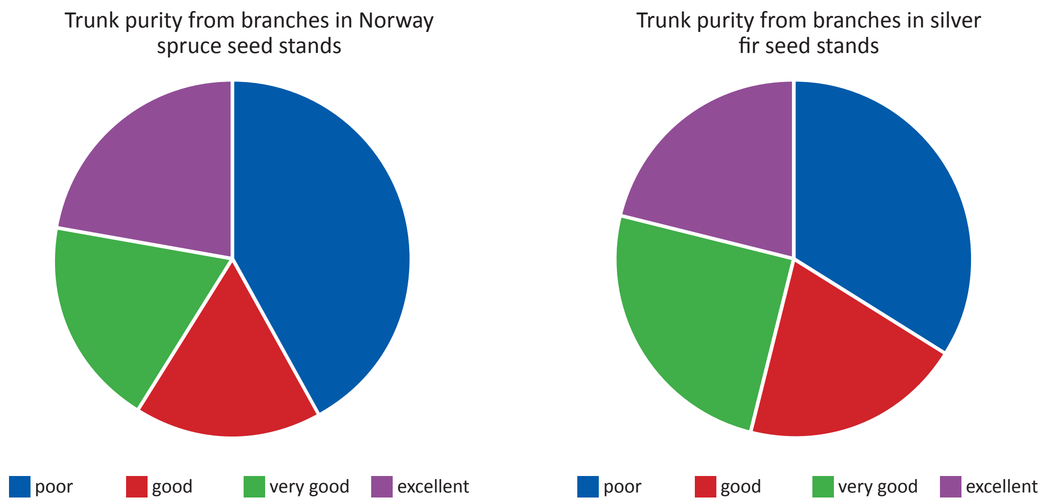


Figure 12. Trunk purity from branches in Norway spruce and silver fir seed stands.

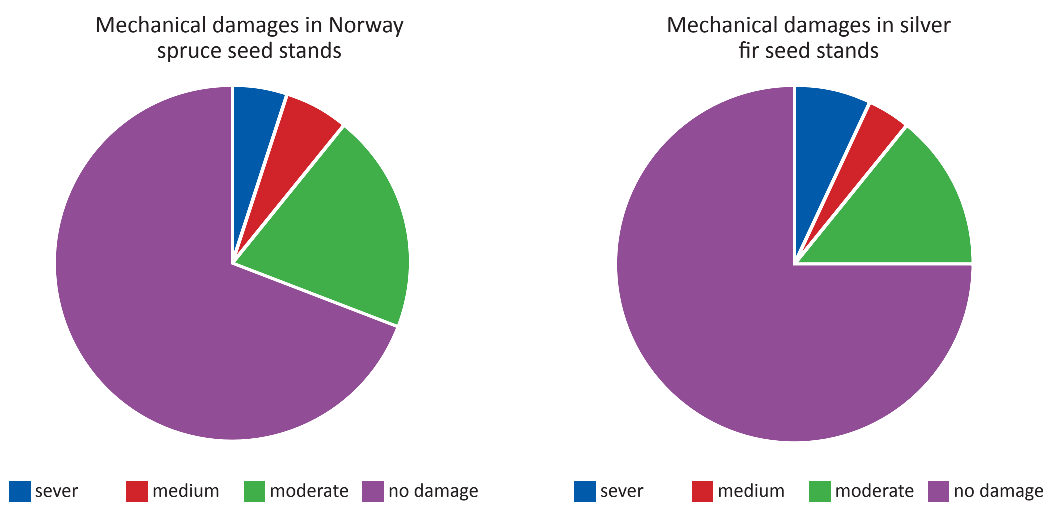


Figure 13. Mechanical damages in Norway spruce and silver fir seed stands.

Presence of Disease on the Tree

The presence of disease on a tree is an eliminative property for seed stands, but an individual diseased tree can be tolerated. The visible signs of disease, insect damage, or weakening of tree vitality without visible external signs of disease or insect attack are determined visually and evaluated as strong, medium, moderate, and non-existent. The evaluator only registers the appearance of the disease, and the type of pathogen or pest should be determined in cooperation with phytopathologists and entomologists. No diseases were registered in Norway spruce seed stands, and in silver fir seed stands there was a small number of trees with the presence of the disease (Figure 14).

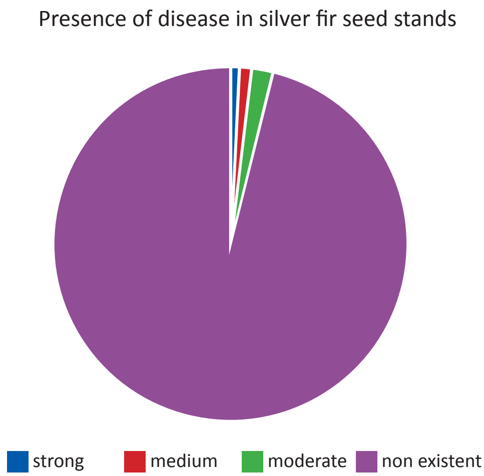


Figure 14. Presence of disease in silver fir seed stands.

Twistedness

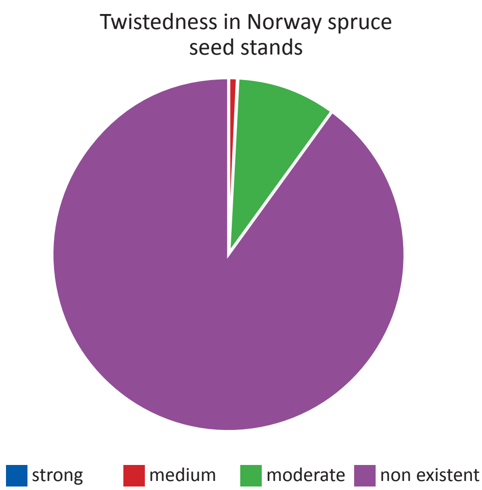
Twisting is when the wire of the wood intersects the plane of the radial section of the tree at a certain angle. This trait is under high genetic control. It is evaluated using four degrees: strong, medium, weak, and non-existent - less than 5%. The appearance of wood twisting is the most common hereditary characteristic and is not tolerated when selecting plus trees. Therefore, trees with twisting are evaluated as phenotypically minus variants. In Norway spruce and silver fir seed stands, there was a certain number of trees with moderate twisting (Figure 15). When arranging seed stands, it is necessary to remove such trees.

Properties of Bark

The following bark properties were described: bark structure, bark color, and the place on the trunk where the roughness of the bark stops. The structure of the bark can be defined as very cracked, slightly cracked, scaly, and smooth. Bark color was divided into: red-brown, light gray, and dark gray. The roughness of bark stops was determined as: high, medium high, and low. The bark indicates the maturity of the tree for technical processing, but in some cases, it also shows resistance to low temperatures, because trees with smooth bark can die from frosts. The bark color of all silver fir trees was dark gray, while 21% of Norway spruce trees had red-brown and 79% of trees had dark gray bark.

Fruiting Properties

The fruiting property is evaluated in four categories: poor, good, very good, and excellent, using the modified Kaper crop prediction scale. When extracting the seed object, the fruiting can be assessed based on the remains of the cones under the tree that is being assessed. The percentage of fruiting in seed stands of Norway spruce and silver fir is shown in Figure 16.



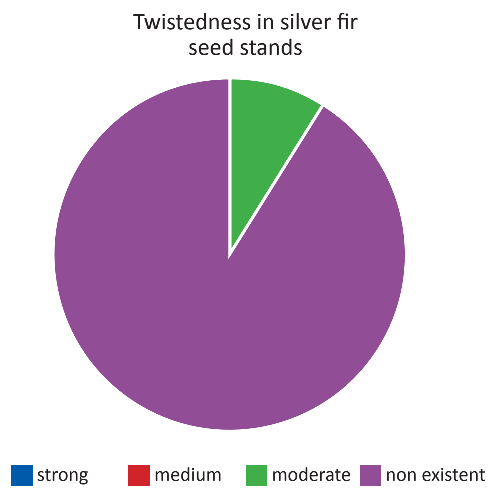


Figure 15. Twistedness in Norway spruce and silver fir seed stands.

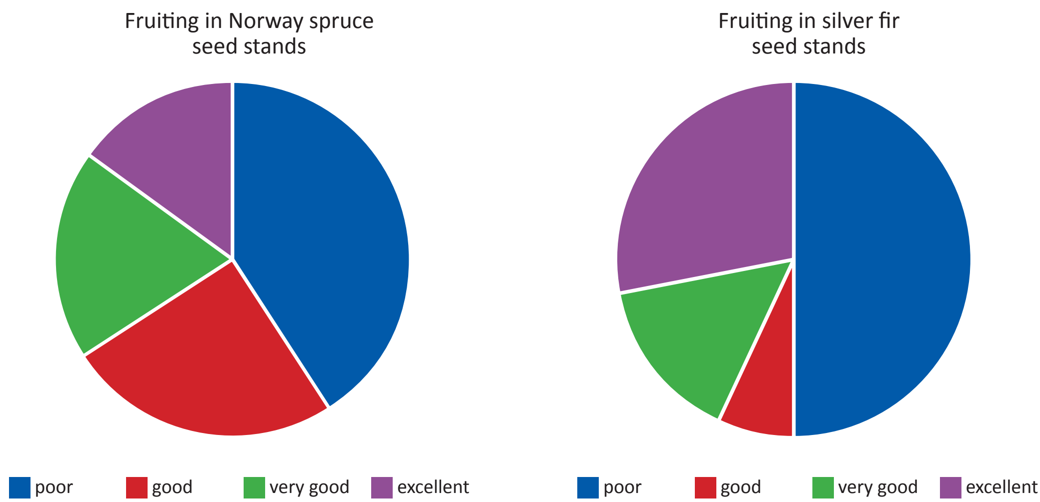


Figure 16. Fruiting in Norway spruce and silver fir seed stands.

DISCUSSION

Bosnia and Herzegovina has great geological, pedological, climatic, and biological diversity in a small geographical area (Stefanović et al. 1983). This diversity is also reflected in tree species such as Norway spruce and silver fir (Ballian and Halilović 2016, Ballian and Božič 2018). It should be emphasized that Norway spruce differentiates more easily than silver fir, and in Bosnia and Herzegovina there are several races of Norway spruce (Ballian et al. 2006, 2007). The differentiation of silver fir was also determined by molecular genetic research (Ballian et al. 2012). This has been confirmed several times through numerous studies that indicate the close existence of glacial refuges of silver fir, which is the basis for great genetic diversity (Gömöry et al. 2004). Already in the mid-1980s, some results on genetic diversity were obtained through provenance tests with silver fir (Ballian 2000, 2005). Based on this, it was analyzed how to use the seeds, and it was planned to use the results of the ecological vegetation regionalization (Dizadarević et al. 1987), with additional experimental regionalization of the main conifer species. Unfortunately, experimental regionalization has never been completed, and most of the experimental plots were destroyed during the war. In the last 25 years, numerous morphological, phenological, and molecular research in Bosnia and Herzegovina have shown that there is a great genetic wealth in Bosnian and Herzegovinian forests, with great genetic differences between relatively close populations of the same species (Ballian et al. 2007). In addition, it is necessary to carry out altitudinal regionalization and separate the races of forest tree species, as suggested by Barner and Willan (1995), Ballian et al. (2007), Ballian and Halilović (2016), and Ballian and Božič (2018). The conducted research indicated that detailed genetic regionalization for Norway spruce and silver fir and genetic demarcations between provenances and areas of seed use should be done. These findings require the users of forest reproductive material to use only locally sourced seeds. To succeed in this, it is necessary to create a dense network of Norway spruce and silver fir seed objects, which requires high financial resources. Currently, in the Federation of Bosnia and Herzegovina, there have been 11 separated and registered Norway spruce and 14 silver fir seed objects, using only part of the produced seed, which is insufficient. In addition to registered seed objects, we use seeds that come from cuts (Law on seeds and seedlings of forest and horticultural trees and shrubs, 2005), which is still not sufficient to successfully use the genetic potential of these two species. By not respecting the genetic structure of the species, the structures of local populations are significantly damaged, and natural potentials are not used to preserve the genetic structure, both in terms of quality and quantity.

CONCLUSIONS

The number of separated seed stands of Norway spruce and silver fir is small and can not ensure the preservation of the autochthonous genetic diversity of these important species of forest trees in the Federation of Bosnia and Herzegovina. The arrangement of seed objects is such that it only partially covers the genetic structure of the species, and the coverage is good only in the central part of the researched area. Additional selection of Norway spruce and silver fir seed stands is necessary, and the focus should be on small and isolated stands that grow in extreme conditions. When selecting new stands, special attention should also be paid to specific races of these species in the sub-Mediterranean area of the country because they tolerate xerothermic conditions very well and can be used in the reforestation of zones that are highly exposed to climate change. Also, considering the good qualities of some of the seed stands, individual selection and separation of plus trees is recommended. After the testing of plus trees, the planting of seed plantations is recommended.

Author Contributions

DB and MMH conceived and designed the research, DB carried out the field measurements, DB and MMH processed the data and performed the statistical analysis, DB and MMH wrote the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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