

# Variability of Morphological Markers of Cone and Seeds in Natural Populations and Artificial Plantations of the Scots Pine (*Pinus sylvestris* L.)

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## Abstract

The variability of morphological markers of the reproductive organs in seven natural populations and nine artificial plantations of the Scots pine of Ukrainian Polissya (Volyn, Rivne and Kyiv regions) was studied. The colour of cones, seeds, winged seeds, and the apophysis of the cones of the trees were used as morphological markers. The quantity and percentage of different morphological forms of the cone and seeds of the trees of investigated natural populations and artificial plantations were defined. As shown in the results of investigations, natural populations of the Scots pine of Ukrainian Polissya are characterized by a larger variability of morphological forms in comparison artificial plantations. Cluster analysis of a complex of morphological markers was conducted. It showed significant differences in the structure of artificial plantations from natural populations.

**Keywords:** Variability; Artificial Plantations; Natural Populations; Scots Pine (*PinussylvestrisL.*); Morphological Markers of Cone and Seeds; Colour of Cones; Seeds; Winged Seeds; Apophysis of Cone; Percentage of Morphs; Genetical Diversity

## Introduction

Due to global climate change and the human impact on the environment, the number of changes in the structure of the gene pool of major forest-forming species increases every year. While resilience can be attributed to many levels of organization of biodiversity, the genetic composition of species is the most fundamental [1]. Molecular genetic diversity within a species, species diversity within a forest community, and community or ecosystem diversity across a landscape and bioregion represent expressions of biological diversity at different scales. The basis of all expressions of biological diversity is the genotypic variation found in population. In this regard, the study, conservation and reproduction of genetic polymorphism of natural population of forest species are one of the main tasks of modern genetics and breeding. A survey of literature suggests that a very small amount of data on the research of populations of Scots pine in Ukraine, especially in the area of Ukrainian Polissya [2,3]. The morphological markers of the cone and seeds are used for the evaluation of an interspecies variation of Scots pine in natural populations of the Scots pine of Ukrainian [4-6]. Now in Ukraine, the seeds for the forest planting of the Scots pine are collected in the cutting area and the Clonal and Seedling seed orchards. The forest plantations created such seeds are artificial plantations. The aim of research was evaluation of the variability of morphological markers of the cone and seeds in artificial plantations and natural populations of the Scots pine of Ukrainian Polissya (Volyn, Rivne and Kyiv regions) and definition of differentiation of these populations on the basis of a suite of metrics.

## Materials and Methods

The object in this study was cones and seeds of Scots pine trees from nine artificial plantations and seven natural populations of Ukrainian Polissya. Test portions of cones and seeds of the so-called man-made artificial plantations were taken from 100 trees in variety progeny test. These test cultures on which progeny of total seed Clonal and Seedling seed orchards (Lutsk-2, Lutsk-3; Kostopol; Kyiv-3, Kyiv-4, Kyiv-5) and ordinary trees of the region are represented (Volyn, control; Rivne, control; Kyiv, control).

Test portions of cones and seeds of the natural populations were taken from 22 to 62 trees from typical forest growth conditions in accordance with edaphic scale by Alekseev-Pogrebnyak, in particular: C<sub>2</sub> and B<sub>4</sub> in the Volyn region; A<sub>2</sub>, B<sub>4</sub>, and B<sub>3</sub> in the Rivne region and A<sub>2</sub> in the Kyiv region of Ukraine [7]. For population analysis we used standard methods of observation variability [8,9]. We determined the following morphological traits: apophysis of cones, colour of cones, seeds, and winged seeds. We emphasized three kinds of cones of the dominant colour – grey, brown, beige; five kinds of seeds – black, brown, beige, variegated, and grey; three kinds of winged seeds: light brown, brown and dark brown.

## Results and Discussion

To study the varieties of apophysis of cones the classification of L. F. Pravdin was used. Pravdin identified 3 main varieties of this characteristic: 1) a – with a smooth surface of theapophysis (f. Plana C.), 2)  $\delta$  – with a surface of the apophysis in the form of a pyramid (f. Gibba C.), 3) b– with the surface of the apophysis in the form of a hook, bent to the base of the cone (f. reflexa H.). In addition to the main varieties of apophysis, Pravdin described another 8 more detailed groups of theapophysis of cones [8].

Our study found that the apophysis of cones of trees of natural populations of Scots pine of Ukrainian Polissya different in their form from those described by Pravdin, Mazhula [6,8]. Investigation of the variability of apophysis of cones in natural populations of the Scots pine in Ukrainian Polissyashowed a large variety of morphological markers. Altogether, 17 new forms of apophysis of the cone in four regions were described [8]. We described four new forms of apophysis of cone ( $\delta_3, B_4, B_5, B_6$ ) in the trees of natural Scots pine populations from the Volyn region [4]. The trees with hooked (f. reflexa) apophysis of the cone (turning upwards) were discovered in the Rivne region. Altogether, 9 new forms of apophysis of the cone in this region were described ( $B_7-B_{15}$ ) [5]. Three different hooked apophysis of the cone (turning upwards) were discovered in the Zhytomyr region too ( $B_{16} - B_{18}$ ) and one ( $B_{19}$ ) from the Kyiv region [8]. The researchers suggest that natural populations turned out to be much more variable of apophysis of cone than artificial plantations (Table 1). 21 different forms of apophysis of cones are noted by us in natural population and only 5 - in artificial plantations of the Ukrainian Polissya region. New forms of apophysis of cones were described only in natural populations. The most common forms of apophysis of cones of natural Scots pine populations of the Volyn, Rivne and Kyiv regions were  $B_4, \delta$  and  $\delta_2$ . Only these three forms appeared in all seven investigated natural populations and  $\delta_2$  – in seven artificial plantations out of nine too. Over 30% of explored trees in five investigated natural populations had apophysis  $B_4$ . The form of apophysis  $\delta_3$  was discovered in six natural populations out of seven. The most common forms of apophysis of cones in artificial plantations of investigated regions were a and  $B_2$ . These two forms appeared in all nine artificial plantations. Over 20% of explored trees in six investigated artificial plantations had form of apophysis  $B_2$ . Forms of apophysis  $\delta_1$  appeared in five natural populations out of seven and in seven artificial plantations out of nine. Other forms of apophysis occur more rarely than indicated above. Thus, in artificial plantations of Scots pine of the Ukrainian Polissya region, we significantly reduced of various forms of apophysis of cones. In addition, we change the structure of plantations in comparison with natural populations and did not reproduce the structure of any of them.

The percentages of different morphological forms by colour of cones of the trees in the investigated populations and plantations of Scots pine of the Ukrainian Polissya are set out in Table 2. The most common colour of cones is brown. It prevails in three natural populations (42.6-73.5%) and six artificial plantations (48-66%). Brown cones prevail particular in four out of five in Volyn region (one natural population: Syomaky and three artificial plantations: Volyn, control; Lutsk-2; Lutsk-3). About the same percentage of brown and grey cones appeared in two natural populations (Sarny; Klesiv) and one artificial plantation in the Rivne region (Rivne, control). About the same percentage of grey and beige cones appeared in two natural populations (Rivne, Yasnohirka; Kyiv, Teteriv) and two artificial plantations in the Kyiv region (Kyiv-3; Kyiv-4). Consequently, investigated natural populations and artificial plantations of Scots pine of the Ukrainian Polissya had a similar ratio of trees with different colour of cones. The researches of different morphological forms of seeds of the trees suggest that natural populations turned out to be much more variable of colour of seeds than artificial plantations (Table 2). 4 different colours of seeds are noted by us in five natural populations and 5 - in two natural populations. 4 different colours of seeds are noted only one artificial plantation.

The most common colour of seeds in natural populations of the Scots pine in Ukrainian Polissya is black. This colour prevails in six natural populations out of seven (40.6-76.6%). The same percentage (46.9%) of black and brown seeds appeared in one natural population in the Volyn region, in particular in the Karasyn. The most common colour of seeds in artificial plantations is brown (51-91%). It prevails in five artificial plantations out of nine. The trees with beige seeds prevail in two artificial plantations (50, 97%), with black seeds – in two plantations (82, 90%) too.

The percentage of trees with brown seeds in all investigated natural populations ranged from 12.8 to 46.9%, beige seeds- from 4.1 to 9.1% and variegated seeds - from 2.1% to 21.6%. The trees with grey seeds appeared only in two natural populations: one in Rivne (Klesiv- 2.2%), and one in Kyiv (Teteriv- 5.4%) regions. In the case of artificial plantations the trees with variegated seeds appeared only in five out of nine investigated plantations (3 - 15%), with grey seeds – in two Volyn (Lutsk-3 – 9%) and Kyiv (Kyiv-4 – 8%) regions.

Thus, artificial plantations differ significantly from natural populations of the Scots pine in Ukrainian Polissya in the percentage of trees with different colour of seeds.

The researches into natural populations suggest that the most common colour of winged seeds was dark brown (40.8-51.0%) (Table 2). This colour predominates in trees of six natural populations out of seven. The most common colour of winged seeds was brown in the artificial plantations (58-88%). This colour prevails in five artificial plantations out of nine. Light brown winged seeds prevail in investigated trees of three artificial plantations out of nine, dark brown – only one plantation. The percentage of morphological forms enables the application of cluster analysis for a complex of morphological markers. The results of cluster analysis are set out in Figure 1,2 and 3 for three regions of Ukrainian Polissya (Volyn, Rivne, Kyiv).

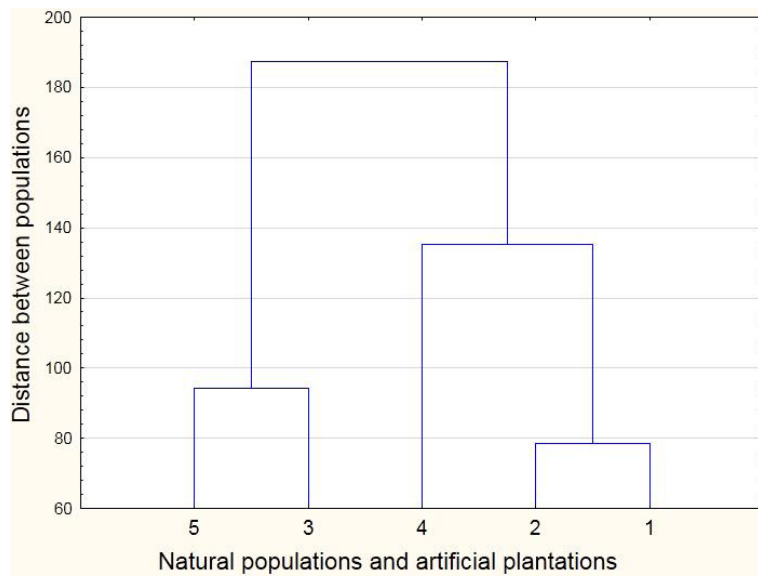
Forms of apophysis of cones	Quantity of trees with different forms of apophysis of cones in different region, %															
	Volyn					Rivne						Kyiv				
	natural populations		artificial plantations			natural populations			artificial plantations			natural populations	artificial plantations			
	Syomaky	Karasyn	Volyn, control	Lutsk-2	Lutsk-3	Sarny	Klesiv	Yasnohirka	Sek-hiv	Rivne, control	Kostopol	Teterviv	Kyiv, control	Kyiv-5	Kyiv-4	Kyiv-3
a	14.3	8.2	12	14	56		2.1		2	35	14		24	59	20	34
$\delta$	4.1	6.1	10			4.5	10.4	4.4	3.9			2.9				
$\delta_1$		10.2	58	12	18		8.3	2.9	5.9	47	24	2.9			52	22
$\delta_2$	22.4	8.2	10	14	2	13.7	10.4	5.9	9.7	4	12	17.1	74			12
$\delta_3$		20.4				4.5	22.9	19.3	43.1			22.8				
B		2							2.9							
B <sub>1</sub>		2									18					
B <sub>2</sub>	8.2	4.1	10	60	24	9.1		2.9	2	14	32		2	41	28	32
B <sub>3</sub>																
B <sub>4</sub>	44.9	36.8				50	6.3	31	13.7			37.1				
B <sub>5</sub>	6.1							2.9								
B <sub>6</sub>		2				9.1		1.5								
B <sub>7</sub>						9.1		2.9	5.9			8.6				
B <sub>8</sub>							8.3	4.4								
B <sub>9</sub>							14.6	4.4	5.9							
B <sub>10</sub>								1.5								
B <sub>11</sub>								2.9								
B <sub>12</sub>							2.1	2.9								
B <sub>13</sub>							6.3	4.4	3.9							
B <sub>14</sub>								2.9	2							
B <sub>15</sub>							8.3		2							
B <sub>19</sub>												8.6				

**Table 1:** Percentage of trees with different forms of the apophysis of cones in natural populations and artificial plantations of the Scots pine in three regions of Ukrainian Polissya

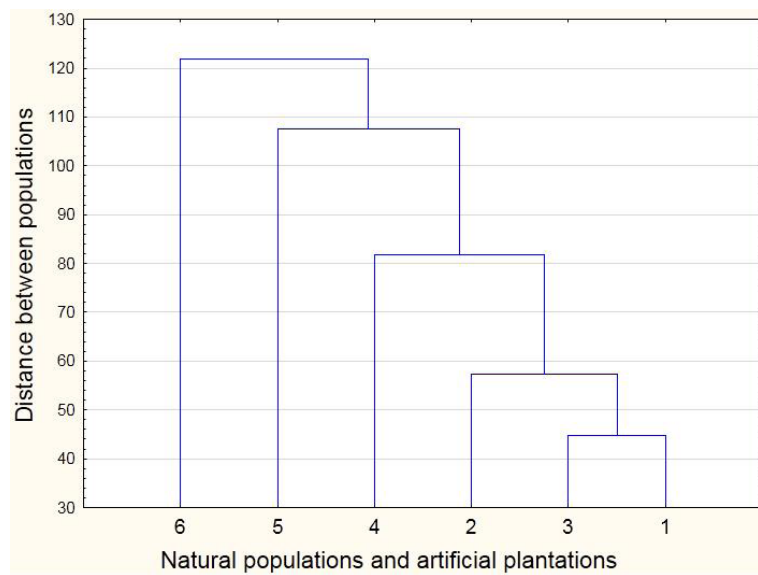
Region, population	Quantity of trees with the dominant colour, %																					
	cones						seeds						winged seeds									
	natural populations			artificial plantations			natural populations				artificial plantations				natural populations			artificial plantations				
	grey	brown	beige	grey	brown	beige	black	brown	beige	variegated	grey	black	brown	beige	variegated	grey	light brown	brown	dark brown	light brown	brown	dark brown
Volyn, Syomaky	20.4	73.5	6.1				57.1	20.4	4.1	18.4							30.6	28.6	40.8			
Volyn, Karasyn	40.8	22.4	36.8				46.9	46.9	4.1	2.1							24.5	24.5	51			
Volyn, control				16	58	26						36	51		13					41	59	
Volyn, Lutsk-2				18	66	16						82		18						79	21	
Volyn, Lutsk-3				6	64	30							91		9					12	88	
Rivne, Sarny	45.5	45.5	9				54.5	27.3	9.1	9.1							22.7	36.4	40.9			
Rivne, Klesiv	52.1	45.8	2.1				58.7	28.3	4.3	6.5	2.2						15.2	37	47.8			

Rivne, Yasnohirka	27.9	42.6	29.5				59.7	28.3	4.5	7.5						11.9	50.8	37.3				
Rivne, Sekhiv	27.5	17.6	54.9				76.6	12.8	4.3	6.3						21.3	34	44.7				
Rivne, control				38	35	27							90	9	1					46	25	29
Rivne, Kostopol				4	54	42							25	60	15					4	63	33
Kyiv, Teteriv	28.6	45.7	25.7				40.6	27	5.4	21.6	5.4					13.5	37.8	48.7				
Kyiv, control				78	22	0								37	50	14				46	32	21
Kyiv-5				53	21	26									97	3				14	86	0
Kyiv-4				20	56	24							6	80		6	8			9	41	50
Kyiv-3				22	48	30							35	65						0	58	42

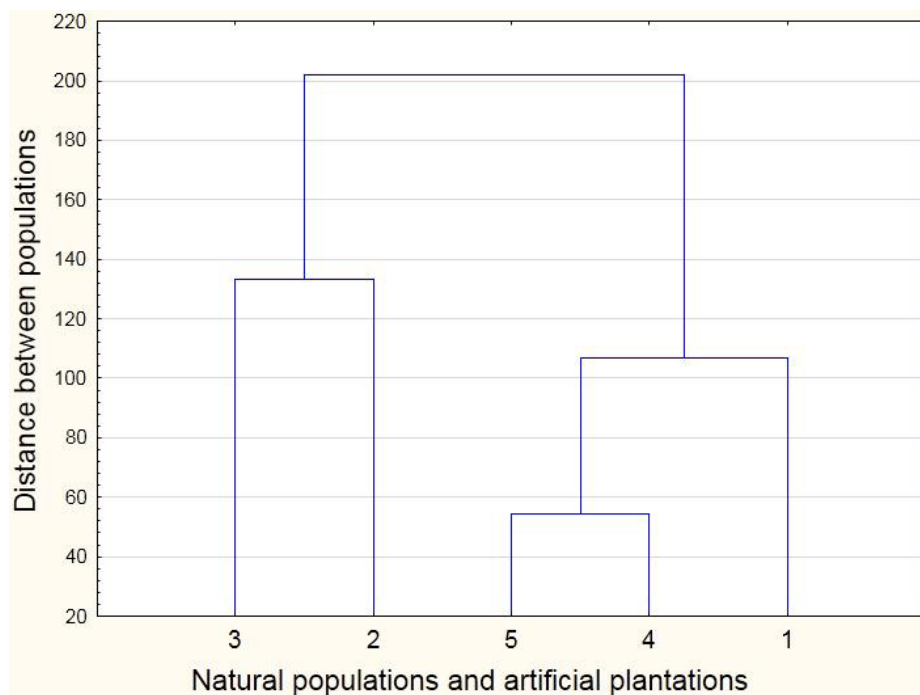
**Table 2:** Percentage of trees with different colours of cones, seeds and winged seeds in natural populations and artificial plantations of the Scots pine in Ukrainian Polissya in the percentage of trees with different colour of seeds.



**Figure 1:** Results of the cluster analysis of examined natural populations: 1 – Syomaky, 2 – Karasyn and artificial plantations: 3 – Volyn, control; 4 – Lutsk-2, 5 – Lutsk-3, for a complex of morphological markers of Volyn region of Ukrainian Polissya.



**Figure 2:** Results of the cluster analysis of examined natural populations: 1 – Sarny; 2 – Klesiv; 3 – Yasnohirka; 4 – Sekhiv; and artificial plantations: 5 – Rivne, control; 6 – Kostopol for a complex of morphological markers of Rivne region of Ukrainian Polissya



**Figure 3:** Results of the cluster analysis of examined natural population: 1 – Teteriv and artificial plantations: 2 – Kyiv, control; 3 – Kyiv-5; 4 – Kyiv-4; 5 – Kyiv-3 for a complex of morphological markers of Kyiv region of Ukrainian Polissya

The results show that investigated natural populations differ considerably from artificial plantations. The Euclidean distance between natural populations (Syomaky, Karasyn) and artificial plantations (Volyn, control; Lutsk-2, Lutsk-3) reaches the high data (105-164) in Volyn region. Natural populations significantly different from the artificial plantations in Rivne and Kiev region (Euclidean distance accordingly: 86-117 and 86-157) too.

The investigated natural populations are more similar in the markers researches both in Volyn and in the Rivne regions (Euclidean distance accordingly: 78 and 44.8-83.8).

## Conclusion

The researches of different morphological forms of cones and seeds of the trees seven natural populations and nine artificial plantations of the Scots pine of the Ukrainian Polissya suggest that natural populations turned out to be much more variable of morphs than artificial plantations especially it concerns forms of apophysis of cones and colour of seeds. We significantly reduced of various forms cones and seeds of trees in the artificial plantations created of investigated region.

The cluster analysis of a complex of morphological markers of the reproductive organs in natural populations and artificial plantations of the Scots pine showed a major difference between investigated natural populations and artificial plantations in Ukrainian Polissya.

Increase in the number of clones of seed orchards and the creation of seed orchards and seed use according to forest types will contribute to the conservation of biodiversity in artificial plantations. There is a strong tendency for natural populations to vary in a complex of morphological markers according to forest types [5]

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