

# Differentiation of natural populations of the Scots pine (*Pinus sylvestris* L.) in Ukrainian Polissya based on the findings of research into the morphological markers of cones and seeds

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Research into variability of morphological markers of the reproductive organs in nine natural populations of the Scots pine of Ukrainian Polissya (Volyn, Rivne, Zhytomyr, and Kyiv regions) was carried out during which the colour of cones, seeds, winged seeds, and the apophysis of the cones of the trees of native populations of the Scots pine were examined.

The quantity and percentage of different morphological forms of the cone and seeds of the trees of investigated populations were defined. Trees with hooked (f. reflexa) apophysis of the cone (turning upwards) were discovered. As shown in the results of investigations, natural populations of the Scots pine of Ukrainian Polissya are characterized by a large variability of morphological forms. Altogether, 17 new forms of apophysis were described.

Cluster analysis of a complex of morphological markers was conducted. It showed differentiation of some populations from the Rivne region.

**Keywords:** variability, natural populations, Scots pine (*Pinus sylvestris* L.), morphological markers of cone and seeds, apophysis of cone, percentage of morphs, genetical diversity

## INTRODUCTION

Groups of scientists have been doing research into the variability of populations of the Scots pine in different regions of the former Soviet Union (Mamaev, 1973; Pravdin, 1973; Sannikov et al.,

2003; Novikova, 2007; Petrova et al., 2013, and others).

A survey of literature showed a small number of researches into Ukrainian populations (Yatsyk, 1977; Sannikov et al., 1991; Korshikov et al., 2009). Up until now, natural populations of the Scots pine in Ukraine have been under-investigated, particularly as regards the natural population of pine of Ukrainian Polissya.

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The morphological markers of the cone and seeds are the original genotype of the species of trees in the genus *Pinus*. These significant markers are used for the evaluation of an inter-species variation of pines in a natural area.

The aim of research was evaluation of the variability of morphological markers of the cone and seeds of natural populations of the Scots pine in Ukrainian Polissya (Volyn, Rivne, Zhytomyr, and Kyiv regions), definition of differentiation of study population 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 natural populations of Ukrainian Polissya from typical forest growth conditions in accordance with edaphic scale by Alekseev-Pogrebnyak, in particular:  $C_2$  and  $B_4$  in the Volyn region;  $A_2$ ,  $B_4$ , and  $B_3$  in the Rivne region;  $C_2$  and  $B_2$  in the Zhytomyr region, and  $A_2$  in the Kyiv region of Ukraine (Pogrebnyak, 1955).

Test portions of cones and seeds were taken from 22 to 62 trees of the Scots pine, proportionally to cone crop in different natural populations. For population analysis we used standard methods of observation variability (Pravdin, 1973, Iroshnikov, 1973). We determined the following morphological traits: apophysis of cones, colour of cones, seeds, and winged seeds.

L. F. Pravdin characterized eight forms of apophysis of cones (Pravdin, 1973). Our study found that the apophysis of cones of trees of natural populations of Ukrainian Polissya different in their form from those described by Pravdin (a – f. plana,  $\delta$  – f. gibba, B – f. reflexa).

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

Investigation of the variability of apophysis of cones in natural populations of the Scots pine

in Ukrainian Polissya showed a large variety of morphological markers. Altogether, 17 new forms of apophysis of the cone in four regions were described. 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 (Mazhula, 2013), nine ( $B_7-B_{15}$ ) from the Rivne region (Mazhula, 2015), three ( $B_{16}-B_{18}$ ) from the Zhitomyr region, and one ( $B_{19}$ ) from the Kyiv region.

The trees with hooked apophysis of the cone which turn up were discovered in the Rivne region (Mazhula, 2015). Different hooked apophysis of the cone which turns up was characterized in the Zhytomyr region too:

$B_{16}$  – on the sunlit surface of the cone at the upside and centre located a hooked apophysis turning up, underside – a hooked apophysis of the cone turning down; on shaded parts of the cone at the upside – a hooked apophysis turning upwards, underside pyramid-shaped.

$B_{17}$  – on the sunlit surface of the cone at the upside and centre located hooked apophysis turning upwards, underside – a hooked apophysis of the cone turning down; on shaded parts of the cone at the upside – a pyramid-shaped, underside flat.

$B_{18}$  – on the sunlit surface of the cone a hooked apophysis turning upwards; on shaded parts of the cone all apophyses are flat.

One new form of apophysis of the cone was described in the Kyiv region:

$B_{19}$  – on the sunlit surface of cone apophysis located at the upside is pyramid-shaped, at the centre – flat, underside – a hooked apophysis of the cone which turns downwards; the apophysis located on the shaded parts of the cone is the same as on the sunlit surface of the cone.

The most common forms of apophysis of cones in all investigated stands of the Ukrainian Polissya region were  $B_4$  and  $\delta_2$  (Table 1). Only these two forms appeared in all nine investigated populations. Over 30% of explored trees in seven natural populations had apophysis  $B_4$ . The form of apophysis  $\delta_3$  was discovered in eight natural populations out of nine. Over 20% of explored trees in five investigated

Table 1. Percentage of trees with different forms of the apophysis of cones in natural populations of the Scots pine in Ukrainian Polissya

Forms of apophysis of cones	Quantity of trees with different forms of apophysis of cones in region, forest district, %								
	Volyn, Syomaky	Volyn, Karasyn	Rivne, Sarny	Rivne, Klesiv	Rivne, Yasnohirka	Rivne, Sekhiv	Zhytomyr, Slobidka	Zhytomyr, Irsha	Kyiv, Teteriv
a	14.3	8.2		2.1		2.0	9.7		
$\delta$	4.1	6.1	4.5	10.4	4.4	3.9			2.9
$\delta_1$		10.2		8.3	2.9	5.9	3.2	6.5	2.9
$\delta_2$	22.4	8.2	13.7	10.4	5.9	9.7	3.2	9.7	17.1
$\delta_3$		20.4	4.5	22.9	19.3	43.1	6.5	38.7	22.8
B		2			2.9				
B <sub>1</sub>		2							
B <sub>2</sub>	8.2	4.1	9.1		2.9	2.0		3.2	
B <sub>3</sub>									
B <sub>4</sub>	44.9	36.8	50.0	6.3	31.0	13.7	45.1	32.2	37.1
B <sub>5</sub>	6.1				2.9		3.2		
B <sub>6</sub>		2	9.1		1.5		6.5		
B <sub>7</sub>			9.1		2.9	5.9	3.2	6.5	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	2.0	9.7		
B <sub>15</sub>				8.3		2.0			
B <sub>16</sub>							6.5		
B <sub>17</sub>							3.2		
B <sub>18</sub>								3.2	
B <sub>19</sub>									8.6

populations had this form of apophysis. Forms of apophysis  $\delta$  and  $\delta_1$  appeared in seven natural populations out of nine. Other forms of apophysis occur more rarely than indicated above.

The researches of natural populations of Ukrainian Polissya suggest that the largest morphological variety of forms of apophysis was observed in the populations of the Rivne region, particularly in Yasnohirka. There are 17 forms of apophysis of cones in the trees of this investigated population.

As shown in the results of investigations, natural populations of the Scots pine in Ukrainian Polissya are characterized by typical colours of their cones (Table 2). The most common colour of the cone is brown. It prevails in two populations of the forest type C<sub>2</sub> – Volyn, Syomaky (73.5%), Zhytomyr, Slobidka (77.4%), one of B<sub>2</sub> – Zhytomyr, Irsha (61.3%), and one of A<sub>2</sub> – Kyiv, Teteriv (45.7%).

Grey cones prevail in one population of the forest type B<sub>3</sub> – Rivne, Klesiv (52.1%) and one of B<sub>4</sub> – Volyn, Karasyn (40.8%). The same

Table 2. Percentage of trees with different colours of cones in natural populations of the Scots pine in Ukrainian Polissya

Region, forest district	Forest types	Quantity of trees with the dominant colour of cones, %		
		grey	brown	beige
Volyn, Syomaky	C <sub>2</sub>	20.4	73.5	6.1
Volyn, Karasyn	B <sub>4</sub>	40.8	22.4	36.8
Rivne, Sarny	B <sub>4</sub>	45.5	45.5	9.0
Rivne, Klesiv	B <sub>3</sub>	52.1	45.8	2.1
Rivne, Yasnohirka	B <sub>4</sub>	27.9	42.6	29.5
Rivne, Sekhiv	A <sub>2</sub>	27.5	17.6	54.9
Zhytomyr, Slobidka	C <sub>2</sub>	0	77.4	22.6
Zhytomyr, Irsha	B <sub>2</sub>	22.6	61.3	16.1
Kyiv, Teteriv	A <sub>2</sub>	28.6	45.7	25.7

percentage (45.5%) of brown and grey cones appeared in one population in the Rivne region, in particular in Sarny. Beige cones prevail in one out of nine of investigated populations of the forest type A<sub>2</sub> (Sekhiv, Rivne).

The percentages of different morphological forms of seeds of the trees of the investigated population are set out in Table 3. The most common colour of seed is black. This colour prevails in eight natural populations out of nine. Over 50% of the explored in seven investigated populations trees had black seeds. The same percentage (46.9%) of black and brown seeds appeared in one population in the Volyn region, in particular in the Karasyn.

The percentage of trees with brown seeds in different populations ranged from 6.5% to 46.9%, variegated seeds from 2.1% to 22.6%, and beige seeds from 0 to 9.6%. The trees with grey seeds appeared in two populations: one in Rivne region, in particular in the Klesiv, and one in Kyiv region, in particular in the Teteriv forest enterprise.

The researches into natural populations suggest that the most common colour of winged seeds was dark brown (Table 4). This colour predominates in trees of six natural populations out of nine. Brown winged seeds prevail in investigated trees of three populations.

Table 3. Percentage of trees with different colours of seeds in natural populations of the Scots pine in Ukrainian Polissya

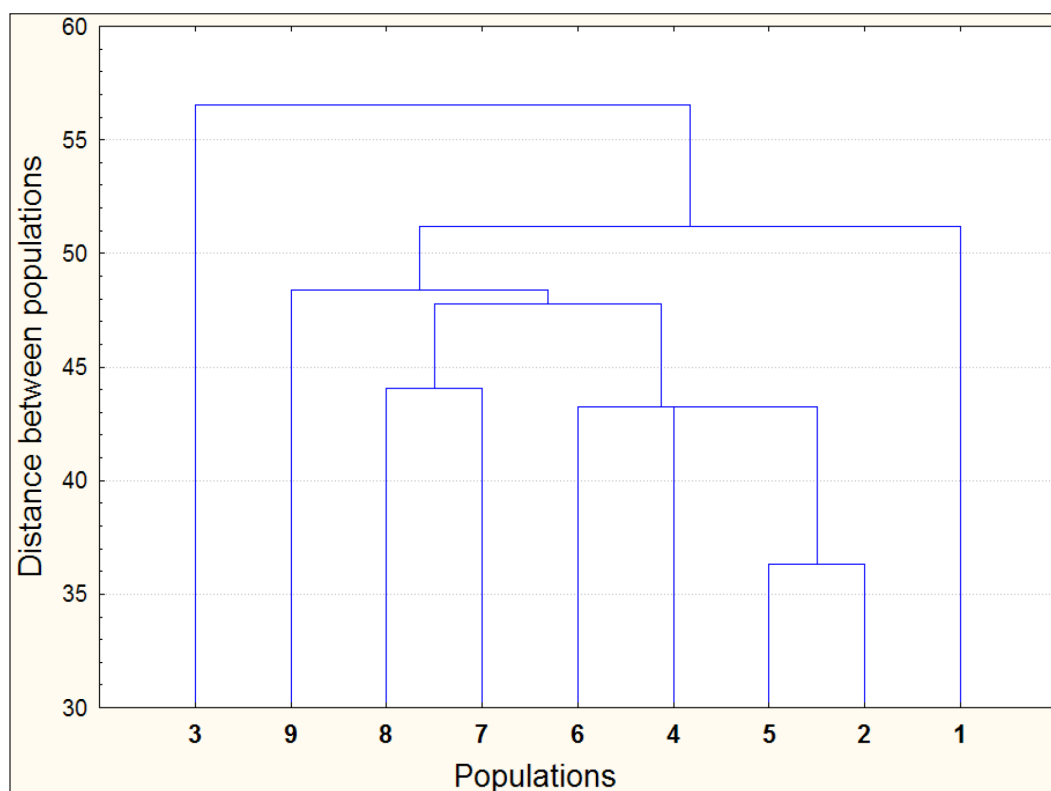
Region, forest district	Forest types	Quantity of trees with dominant colour of seeds, %				
		black	brown	beige	variegated	grey
Volyn, Syomaky	C <sub>2</sub>	57.1	20.4	4.1	18.4	0
Volyn, Karasyn	B <sub>4</sub>	46.9	46.9	4.1	2.1	0
Rivne, Sarny	B <sub>4</sub>	54.5	27.3	9.1	9.1	0
Rivne, Klesiv	B <sub>3</sub>	58.7	28.3	4.3	6.5	2.2
Rivne, Yasnohirka	B <sub>4</sub>	59.7	28.3	4.5	7.5	0
Rivne, Sekhiv	A <sub>2</sub>	76.6	12.8	4.3	6.3	0
Zhytomyr, Slobidka	C <sub>2</sub>	64.5	12.9	0	22.6	0
Zhytomyr, Irsha	B <sub>2</sub>	61.3	6.5	9.6	22.6	0
Kyiv, Teteriv	A <sub>2</sub>	40.6	27.0	5.4	21.6	5.4

Table 4. Percentage of trees with different colours of winged seeds in natural populations of the Scots pine in Ukrainian Polissya

Region, forest district	Forest types	Quantity of trees with dominant colour of winged seeds, %		
		light brown	brown	dark brown
Volyn, Syomaky	C <sub>2</sub>	30.6	28.6	40.8
Volyn, Karasyn	B <sub>4</sub>	24.5	24.5	51.0
Rivne, Sarny	B <sub>4</sub>	22.7	36.4	40.9
Rivne, Klesiv	B <sub>3</sub>	15.2	37.0	47.8
Rivne, Yasnohirka	B <sub>4</sub>	11.9	50.8	37.3
Rivne, Sekhiv	A <sub>2</sub>	21.3	34.0	44.7
Zhytomyr, Slobidka	C <sub>2</sub>	22.6	41.9	35.5
Zhytomyr, Irsha	B <sub>2</sub>	19.4	41.9	38.7
Kyiv, Teteriv	A <sub>2</sub>	13.5	37.8	48.7

The percentage of morphological forms enable the application of cluster analysis for a complex of morphological markers. The results of cluster analysis are set out in Figure for all research markers. The matrix of distance between populations is given in Table 5.

The results show that the Sekhiv population (3 – A<sub>2</sub> Rivne, Klesiv) differs considerably from the point of view of the markers examined. It forms the first cluster. The Euclidean distance between the Sekhiv population and six other populations reaches the high data (67.5–98.3),



**Figure.** Results of the cluster analysis of examined populations (forest districts) for a complex of morphological markers: 1 – Klesiv, 2 – Yasnohirka, 3 – Sekhiv, 4 – Sarny, 5 – Teteriv, 6 – Irsha, 7 – Slobidka, 8 – Syomaky, 9 – Karasyn

Table 5. The Euclidean distance between natural populations of the Scots pine in Ukrainian Polissya

Names of populations	1 – Klesiv	2 – Yasnohirka	3 – Sekhiv	4 – Sarny	5 – Teteriv	6 – Irsha	7 – Slobidka	8 – Syomaky	9 – Karasyn
1 – Klesiv	0.0	51.2	74.6	57.1	57.5	60.8	86.9	73.0	63.6
2 – Yasnohirka	51.2	0.0	56.5	44.8	36.3	44.6	58.8	62.1	49.7
3 – Sekhiv	74.6	56.5	0.0	83.8	68.3	67.5	92.9	98.3	62.8
4 – Sarny	57.1	44.8	83.8	0.0	43.2	56.8	66.8	47.8	54.3
5 – Teteriv	57.5	36.3	68.3	43.2	0.0	43.3	62.2	55.9	48.4
6 – Irsha	60.8	44.6	67.5	56.8	43.3	0.0	50.5	55.4	74.8
7 – Slobidka	86.9	58.8	92.9	66.8	62.2	50.5	0.0	44.0	89.1
8 – Syomaky	73.0	62.1	98.3	47.8	55.9	55.4	44.0	0.0	78.8
9 – Karasyn	63.6	49.7	62.8	54.3	48.4	74.8	89.1	78.8	0.0

which shows that this population is specific. The other eight populations form the second cluster, in which the Klesiv population (1 – B<sub>3</sub> Rivne, Klesiv) differs from the remaining seven populations. The other seven populations from the second cluster are more similar in the markers researched.

Among these seven populations, it is possible to single out the most similar markers researched: Slobidka (7 – C<sub>2</sub> Zhytomyr) and Syomaky (8 – C<sub>2</sub> Volyn), Irsha (6 – B<sub>2</sub> Zhytomyr) and Sarny (4 – B<sub>4</sub> Rivne), and Teteriv (5 – A<sub>2</sub> Kyiv) and Yasnohirka (2 – B<sub>4</sub> Rivne). The populations of the first pair share the same moisture conditions and soil fertility, those in the second pair have identical soil fertility in common, and the populations of the third pair differ in forest types.

## CONCLUSIONS

The cluster analysis of a complex of morphological markers of nine natural populations of the Scots pine showed a major difference between investigated stands (populations) in Ukrainian Polissya. Our research shows that the populations from the Rivne region are the most specific of the examined populations, which renders them promising for further more detailed research.

There is a strong tendency for natural populations to vary in a complex of morphological

markers according to forest types. It is most pronounced in a specific region, in particular in the Rivne region (Mazhula, 2015). The differences between the populations were the more obvious when their moisture conditions and soil fertility varied. The populations with different moisture conditions differed less.

The results of our research into nine natural populations of the Scots pine from three regions of Ukrainian Polissya confirmed this hypothesis to a considerable degree.

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**PAPRASTOSIOS PUŠIES (*PINUS SYLVESTRIS* L.) NATŪRALIŲ POPULIACIJŲ DIFERENCIJAVIMAS UKRAINOS POLESĖJE, PAREMTAS KANKORĖŽIŲ IR SĖKLŲ MORFOLOGINIŲ ŽYMENŲ TYRIMO IŠVADOMIS**

*Santrauka*

Įvairios mokslininkų grupės atliko paprastosios pušies populiacijų kintamumo tyrimus skirtinguose buvusios Sovietų Sąjungos regionuose, tačiau Ukrainoje paprastosios pušies natūralios populiacijos nėra pakankamai ištirtos. Šio tyrimo metu buvo tiriamas devynių paprastosios pušies natūralių populiacijų Ukrainos Polesėje (Volynskos, Rivnenskos, Zhytomyrskos ir Kyjvskos regionuose) reprodukcinių organų morfologinių žymenų kintamumas. Buvo vertinama paprastosios pušies natūralios populiacijos kankorėžių spalva, sėklos ir jų sparneliai, kankorėžių apofizė. Nustatyti kankorėžių ir sėklų skirtingų morfologinių formų kiekybė ir procentai tirtose populiacijose. Atrasta medžių, kurių kankorėžių apofizės žvyneliai riečiasi į viršų. Tyrimo rezultatai rodo, kad paprastosios pušies natūralios populiacijos Ukrainos Polesėje pasižymi dideliu morfologinių formų kintamumu. Iš viso buvo aprašyta 17 naujų kankorėžių apofizės formų. Morfologinių žymenų komplekso klasterinė analizė atskleidė kai kurių Rivnenskos regiono populiacijų diferenciaciją.

**Raktažodžiai:** kintamumas, natūralios populiacijos, paprastoji pušis, *Pinus sylvestris*, genetinė įvairovė