DE GRUYTER
OPEN

DOI: 10.1515/frp-2015-0002
Available online: www.lesne-prace-badawcze.pl

Leśne Prace Badawcze / *Forest Research Papers*
March 2015, Vol. 76 (1): 18–36

ORIGINAL RESEARCH ARTICLE

e-ISSN 2082-8926

The 'Tisovik' reserve of Silver fir in the Belarusian national park 'Belavezhskaya Pushcha'

Adolf F. Korczyk

Bialystok University of Technology, Faculty of Forestry in Hajnówka, ul. Piłsudzkiego 8, 17–200 Hajnówka, Poland.

Tel. +48 694 056 850, e-mail: adolfkorczyk@gmail.com

Abstract. Silver firs (*Abies alba* Mill.) of natural origin occurring in the Belorussian part of the Białowieża Primeval Forest constitute an enclave situated 120 km to the north-east of a dense fir stand in the Polish part of the forest. In order to protect this population a reserve called 'Tisovik' was established. In this study, plant communities occurring in the 'Tisovik' reserve were described and its fir population (20 trees) was characterised in terms of its genetic structure.

Keywords: *Abies alba* Mill., forest communities, nature protection, 'Belavezhskaya Pushcha', Belarus

1. Introduction

The presence of Silver fir (*Abies alba* Mill.) in Białowieża Primeval Forest was noted for the first time by Górski in 1829. Up to this moment, many publications had appeared describing the presence of fir in an area of virgin forest. Information about presence of Silver fir in Białowieża Primeval Forest listed chronologically are as following:

1823 Fir in Białowieża Primeval Forest was discovered by Górski 1829. In compartment no. 562 in forest part 'Cisówka' in a small mineral forest enclave placed among extensive swamps of 'Dziki Nikor'. The thickest trunk had a diameter up to 3 feet in butt end (ar. 90 cm). Górski, recognised this position of fir as natural.

1830 Jundził in description of Lithuania plants mentioned fir's position in Białowieża Primeval Forest. Eichwald wrote about native fir's position in Białowieża Primeval Forest. Neither author gave sources of these information.

1863 Semenov posted information of fir's presence in Białowieża Primeval Forest in the dictionary of Russian empire (Slovar' Rossijskoi Imperii).

1884 Bretschneider stated the presence of small number of firs in forest part 'Cisówka' (after Szafer 1920a).

1887-88 Błoński, Drymmer and Ejsmond found in forest part 'Cisówka' few hundred firs, 'which on man height, had 5 to 6 inches thickness'. The area of 'Cisówka' forest part had then ar. 22 ha and the fir occupied an area of 7–9 ha (Błoński, Drymmer 1889).

1889 Kóppen accredited Eichwald for discovering fir in Białowieża Primeval Forest.

1891 Entry 'Białowieża Primeval Forest' in 'Encyclopedic dictionary' (Brokhaus, Efron 1891) consists information that fir grows among swamps of 'Dziki Nikor'.

1897 Archipov (1897) mentioned fir among tree species occurring in Białowieża Primeval Forest.

1902 Genko (1902, 1903), announced that in 'Cisówka' forest part with area 15.08 ha grow numerous natural seeding and trees of diameter breast height (dbh) from 17 cm to 27 cm. The dbh of the thickest fir is 57.8 cm. He considered this position as natural.

1918 Graebner (1918) announced, that on 'Cisówka' grew around 200 firs with height slightly above 2 m and some trees with dbh from 12 cm to 15 cm and average age ar. 40 years. The forest stand was artificially planted.

Received: 5.03.2014, reviewed: 19.08.2014, accepted: 29.09.2014.

1920 Szafer found in 'Cisówka' forest part around 100 firs with dbh from 12 to 34 cm and one old tree with dbh 120 cm and height 33.5 cm, the age of which on the basis of incomplete drill was defined as 190–200 years. Noted was also the presence of 2–5 years old fir natural seeding. The lack of fir underwood, he attributed, on the other hand, to the excessive number of deer that bite higher seedlings. Moreover, Szafer described two freshly cut trees with dbh of 18 and 30 cm, the age of which was defined at 1m height from root collar as 57 and 47 years. According to Szafer, 'fir concentration in 'Cisówka' has every feature of primary concentration, settled there for hundreds of years and 'This isolation of fir position was definitely a favorable circumstance for preserving this tree species'. Szafer believed that in contemporary climate, the range of fir regresses in southwest direction. That is why the enclave of fir from Białowieża, 120 km away to northeast from dense range, he considered as relict of the southwest type, which in the phase of so-called climate optimum after regress of diluvial ice sheet reached temporarily far to the northwest direction in Europe. State Council for Nature Conservation called for creating in 'Cisówka' forest part a reserve for fir protection (Szafer 1920b).

1921 At the request of State Council for Nature Conservation, the population of Silver fir growing in comp. 562 was provided with legal protection – as 'Cisówka' reserve (Karpiński 1929).

1922 Kłoska (1922) inventoried in forest part 'Hubar' in comp. 738 one fir with dbh 37.5 cm of height 22 m of age ar. 70 years and 3 trees of age 5, 7 and 10 years and several dozens of 1 and 2 years old natural seeding. This position 18 km away from fir reserve in 'Cisówka' he considered as natural.

1922 In July, a storm knocked down the oldest fir in 'Cisówka' reserve. Measurements made on fallen tree showed that it had 36 m height and 320 cm circuit on 1.3 m height. Near fallen tree grew 72 younger firs (Romanów 1922).

1924 Wiśniewski (1924) confirmed the presence of fir in 'Hubar' forest part. He found one 70 years old fir, two aged 8 and 10 years and numerous 1 and 3 years old natural seeding. He announced (unproven) information about finding fir in Lacka virgin forest (northeast part of Białowieża Primeval Forest).

1925/26 Mattfeld (1925, 1926) based on Polish, Russian and German naturalists' publications, recognised fir in 'Cisówka' as natural enclave.

1928 Paczoski (1928, 1930) wrote that in 'Hubar' forest part, the biggest fir was cut and there remained only some very small trees. On the other hand, in 'Cisówka' reserve grew at that time 255 firs with dbh from 7 to 38 cm. Paczoski stressed at the same time that oak-hornbeam forest with fir share is the model of primeval forest and belongs to relict forest stands, which used to be more widespread in Białowieża Primeval Forests.

1928 Paszewski collected materials for pollen analysis. Only on sphagnum bog in comp. 88 located in the west from 'Cisówka' within 4 km, in two drills was found fir pollen (1%) at a depth of 50 cm corresponding more or less to Atlantic period (Paszewski, Poznański 1935).

1933 Karpiński (1933) expressed his view that the lack of firs in 'Cisówka' such bark beetles like: Pityokteines curvidens Germ., P. spinidens Reit, P. vorontzovi Jacobs. and Pissodes piceae Ill. proves its artificial origin. At the same time, 200-year-old fir found by Szafer in 1920 was considered by him as a planted tree and all other remaining firs as a progeny of this tree.

1935 Paszewski (1937) made some drills in 'Dziki Nikor' in the closest neighborhood of 'Cisówka' reserve. At a depth of 75 and 125 cm, he found fir pollen (0.5%). He stated that even if fir's position was a relict one, pollen analysis results indicated vividly that fir did not occur profusely in Białowieża Primeval Forest in any period'. In reserve 'Cisówka' he found around 100 living mature (arborescent) firs and 'younger firs, unevenly aged'.

1939 On December 31st, forest part 'Cisówka' received the name 'Tisovik' and was recognised as nature reserve by authorities of Belarusian Republic.

1951 Dąbrowski (1959), on the basis of palynological studies conducted on two bogs in Białowieski National Park (comp. 317 and 373), stated inter alia the presence of fir pollen in amount from 0.5%–2.0%: in profile I at depth 0, 11 cm and 245 cm and in profile II at depth 4, 155 cm, 210–255 cm and 510 cm. Based on this, he stated that in the period of early Holocene 'presumably through areas of Lubelszczyzna and Łukowski Płaskowyż travels fir to the area of Białowieża Primeval Forest'. However, in different part of this elaboration, the author negates relict character of fir position in Białowieża Primeval Forest suggesting that fir pollens blew in from Łukowski Płaskowyż.

1956 Irrigation works of 'Dziki Nikor' bog were finished (Šutko, Martynovič 1967). On those areas, intensive pasturage of cattle and sheep was run that caused heavy loss in fir forest stand (Budničenko et al. 1987).

1957/58 In 'Tisovik' forest part, on area of around 2 ha, Zefirov found 36 firs of dbh from 22–75 cm, few underwood growing to height of 2.4 m and fir natural seeding in number from 14–82 per 100 m^2. He noted also that in 1957, fir cropped well. The level of ground water in fir forest stand in 1958 amounted slightly below 1 m from the ground surface. In 'Hubar' (comp. 738), Zefirov (1958) found 6 firs of height 53–180 cm.

1966 Gunia and Kowalski (1968) found in comp. 453 Aa of Białowieża Forest District artificial fir forest stand of unknown origin (ar. 200 trees on area of 0.20 ha) with an average age of 38 years. Fir position in 'Tisovik', on the other hand, they recognised with the help of literature as natural.

1967 Šutko and Martynovič (1967) in 'Tisovik' reserve inventoried 35 firs with dbh 25–77 cm and height 33 m and one tree of dbh 12 cm and height 8 m. Also, numerous natural seeding and underwood aged 2–20 years occurred there. Some of them grew to a height of 2.5 m. Terminal shoots of fir underwood were strongly bitten by deer. One fir of dbh 25 cm and height 19 m was cut for research purposes. Analysis of annual increments showed that age of this fir was 110 years and increments to thickness underwent fluctuation. On this basis, authors estimated the age of thickest fir for 250 years. Fir's position in 'Tisovik' was recognised as natural. They stated, however, that due to deterioration in environmental conditions in the near future, the fir will become extinct. They stated also, that in Oszczepski forest district (Belarusian part of Białowieża Primeval Forest) on area of ha found can be 30 years old artificial fir-spruce forest stand.

1972 Gunia et al. (1972) while elaborately reviewing the northern boundary of natural fir occurrence omitted the position in Białowieża Primeval Forest. As a result of this, it was also not included in the monograph of forests of Central Europe (Dengler 1992).

1981 Silver fir from 'Tisovik' reserve was inscribed to Belarusian 'Red Book' of species threatened with extinction.

1983-85 In 1983, in 'Tisovik', 12 firs were uprooted by a spring hurricane. On an area of around 1.3 ha remained 23 living firs with dbh 39–83 cm, height 27.0–33.3 m and age 120–150 years with numerous cones, and 1–3 years old natural seeding in number of 15–80 per 100 m^2. Fir underwood did not appear. Fir cropped well and average mass of 100 seeds amounted to 65.2 g. Due to drying of 'Dziki Nikor', the level of ground water decreased below 2 m from ground surface. Dendrometric research performed on 5 firs and 3 spruces knocked down by hurricane showed that from 50s–70s, vividly noticeable was more dominant height growth. On the other hand, from the 70s, rapidly increased increment to thickness and vividly inhibited fir increment to height. The main cause of those changes was continuous lowering of ground water due to melioration of 'Dziki Nikor' (Budničenko et al. 1987).

1992-97 Full inventory and measurements of firs growing in this reserve, phytosociological study (Korczyk et al. 1997).

2000 A summary of long-term research over natural fir renewal in 'Tisovik' reserve (Korczyk 2000).

2002 Wind knocked down a fir marked as no. 3. The age was defined on the base of block acquired from butt end and amounted to 136 years. The block is now situated in Nonresident Forest Faculty of Białystok Technical Univeristy in Hajnówka.

2003 The research in 'Tisovik' reserve was finished.

2. Methodology

Phytosociological study

Flora in reserve 'Tisovik' was examined from 1992 to 1995 with two methods. In lobe, in which from close neighborhood were made three phytosociological pictures of old firs. Three following pictures were made from a distance of 90–250 m from fir grouping (Fig. 1, 2). Moreover, analysed was forest stand species composition and soil cover flora from three lots in northern parts of the reserve in order to establish the degree of naturalness of this forest's fragment, which was created probably spontaneously after periodic agricultural use.

Plant species naming was adopted according to Flora Europaea 1964–1980. Phytosociological pictures were made and elaborated with Braun–Blanquet (1964) and Ellenberg (1956) method.

On area of 50 × 50 m in the lobe with old firs, examined was structure of forest stands trees' thickness. Measured the dbh of all trees with height above 1.3 m and counting of shrubs and underwood aged above 3 years and height above 30 cm was done.

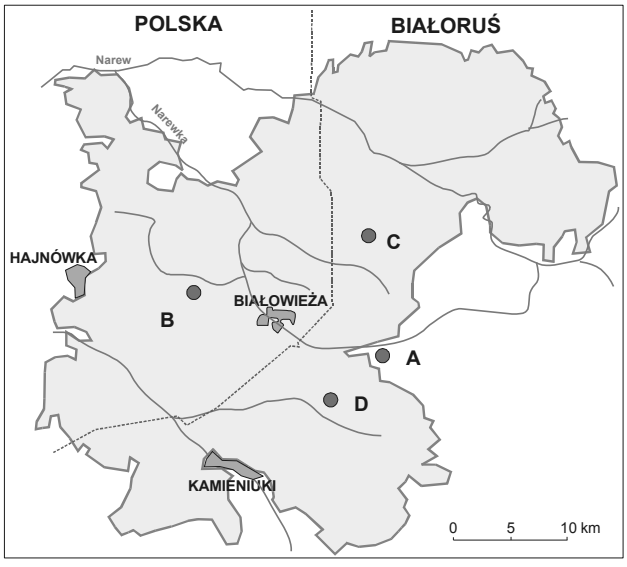

Figure 1. Locality of investigated objects in Białowieża Primeval Forest. A – silver fir reserve 'Tisovik' (comp. 563); conservative cultures of silver fir: B – compartment 416Ag /416Cf; C – compartment 235A; D – compartment 717C.

Fir measurements

Firs in reserve were permanently numbered in 1956 (Fig. 2, Zefirov 1958). Each tree was measured in 1992. Beside growth characteristics, measured was the distance from trunk base to first living branch (for calculation of crown length) and to first dry branch (for calculating the height of shaft's clearance). Bark's thickness was measured with the use of bark gauge at 1.30 m height from sides N and S and wood density on the same height from N side with the use of pilodine type 6J Forest. Density, according to scale posted on pilodine corresponds to depth of spire penetration in wood (Giefing 1985).

Diameter breast height age was established on the basis of drills obtained with the use of increment borer on height of 1.30 m from the north side of the shaft. The hole after the drill was filled with oak peg saturated with fungicidal preparation. Actual age of firs was established by adding 18 years to age dbh.

This correction was defined experimentally in Łuków Forest District, where the age of young firs of height 1.30 m was examined. Firs originated from natural renewal.

Firs state of health was defined with UNEP method on a 4-stage scale of damage: 0-undamaged population; I-slightly damaged; II-average damaged and III-strongly damaged (Draft 1985; Korczyk 1995a).

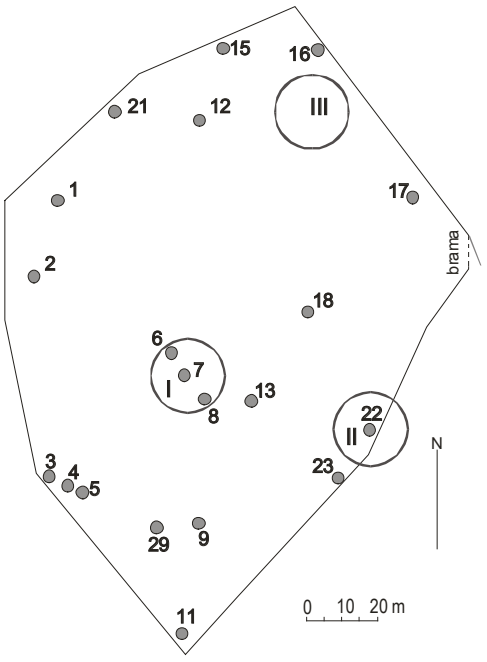

Figure 2. The scheme of plot with silver fir in the reserve 'Tisovik'. 1–29 – growing firs with their number; I–III – circular plots to count the young generation of fir

Natural renewal

Firs natural renewal in 'Tisovik' was examined in years: 1992–2003 on 3 permanent circular plots, each of radius 10 m (314 m^2) (Fig. 3, Table 1). Plot no. I was established under dense canopy of three firs (trees no. 6, 7 and 8) (Fig. 4) on soil covered only by moss. Plot no. II under canopy of one fir (no. 22) and one spruce on soil with poor turfing and plot no. III with one hornbeam (no. 3) in the middle was established on open area overgrew with thick carpet of herbaceous plants. Each plot was divided into 4 parts. In each quarter, was defined: the number of 1- and 2-year-old seedlings and the number of older ones of height over 20 cm (Fig. 3 and Table 1).

In the years 2000–2003, counted was all natural seeding and measured were underwood on whole fenced area with fir with the exception of circular plots, and counted were fir seedlings between fence surrounding reserve and inner fence surrounding the forest stand with fir.

Cropping and quality of seeds

Those observations were conducted in years 1992–2003. A 3-stage scale was adopted: 0-lack of cones, 1-small crop (up to 10 cones), 2-good crop (11–30 cones), 3-very good crop (more than 30 cones).

Cones from standing trees were collected twice: in October 1992 from 11 firs and in October 1995 from 20 trees.

Conducted were also research over quality of seeds collected in years 1992 and 1995. Radiological method was used defying the state of endosperm and embryo development on the basis of X-ray picture of seeds. Two classes of endosperm development were distinguished: A-endosperm fully developed, B-endosperm undeveloped. In the case of embryos, distinguished were 4 types (Ehrenberg et al. 1955):

I – seed has endosperm and embryonic canal, but it lacks embryo,

II – embryo is vividly underdeveloped with length smaller than one-half the length of embryonic canal,

III – embryo is developed, and its length ranges between one-half and three-fourth of embryonic canal length,

IV – embryo is fully developed and fills completely or almost completely embryonic canal.

Examined were 100 seeds from each tree that were X-rayed in X-ray camera, type Elektron 25 of Russian production from 1993.

In 1995, for comparison, collected were fir cones from natural forest stands in three reserves: 'Jata' in Łuków Forest District, 'Kamienna Góra' in Roztoczański National Park and 'Łabowiec' in Nawojowa Forest District (in each reserve, cones were collected from 50 trees selected randomly along the line transect) and from forest stands established in the beginning of 20th century in Białowieża Forest District – 28 firs growing in two forest stands (Korczyk 1995b).

Table 1. The natural regeneration of the silver fir inside the circular plots in the reserve 'Tisovik' on the years 1992–2003

	Control date	1992.08.18		1994.06.24		1995.05.19		1997.05.25		1998.05.27		1999.05.18-20		2000.05.23-24		2001.10.03		2002.09.18		2003.08.06	
	Seed yield	2		0		2		1		1		0		1		0		0		2	
		Plot I (under fir trees no 6, 7 and 8)																			
Number of seedlings	a	75	49	18	69	35	4	36	31	14	6	15	1	0	0	0	8	48	9	28	42
	b	57	34	8	64	23	46	122	31	98	36	91	40	66	40	53	66	64	84	42	96
	c	0	0	0	0	0	0	0	0	1z	2z	0	0	0	3	127	2	7	8	24	10
	a	87	8	30	22	2	4	19	27	6	5	9	8	0	0	0	0	45	24	77	34
	b	18	21	9	16	75	48	87	36	82	34	50	20	68	34	64	31	81	38	109	347
	c	0	0	0	0	0	0	0	0	0	2+1z	0	0	0	3	149	52	12	9	48	59
		Plot II (under fir tree no 22)																			
	a	9	1	0	21	0	4	2	4	1	1	2	5	0	0	1	3	0	0	1	4
	b	12	14	0	7	2	4	2	3	0	4	1	7	1	3	6	7	0	1	9	24
	c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0
	a	0	2	3	17	1	3	2	5	1	1	0	0	0	0	1	0	0	1	0	20
	b	21	21	6	8	2	9	3+15z	8	2	7	1	4	1	0	3	8	6	14	0	10
	c	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Plot III (under common hornbeam tree no 3)																			
	a	0	3	3	8	1	0	5	10	2	0	0	3	0	0	14	6	0	3	21	32
	b	38	44	5	8	4	16	8	14	16	9	10	31	5	23	18	42	107	46	15	0
	c	0	0	0	0	0	0	0	0	1+2z	2z	3	1	3	9	4	2	5	13	43	50
	a	0	1	4	5	0	0	8	17	1	1	5	0	0	1	8	5	2	42	22	10
	b	9	30	5	6	11	10	16	8	9	16	27	15	32	16	38	25	35	36	23	6
	c	0	0	0	0	0	0	0	0	1z	0	2	0	7	4	7	11	14	10	17	5

Seed yield: 2 – good ; 1 – weak; 0 – lack of cones; a, b, c, z – as in Figure 3

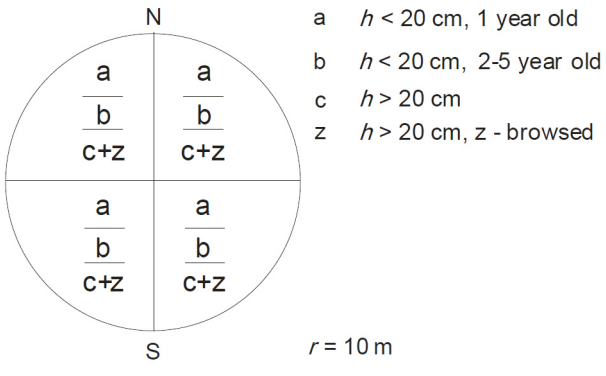

Figure 3. Scheme of description of the young generation of fir on the circular plot (r = 10 m)

Figure 4. The silver fir no 6 in the reserve 'Tisovik' (June 2013)

Table 2. Phytosociological characteristic of the forest communities in the *Tilio–Carpinetum typicum* subassociation in the reserve 'Tisovik'

Number of relevé		10902	10927	10926	10903	10928	10925
Tree layer cover	a	90	90	80	40	80	85
	a1	40	70	70	10	40	30
	a2	70	40	20	30	40	40
	a3					10	20
Shrub layer cover	b	2	+	10	5	8	20
Herb layer cover	c	65	40	70	80	70	70
Moss layer cover	d				+	+	+
Surface of relevé [m^2]		390	250	200	300	250	250
Number of species		29	25	24	24	30	28
Trees							
Abies alba	a1	3.3					
	b				+		
	c	2.1	+		+	+	
Carpinus betulus *	a1		3.3	4.4			
	a2	4.4	3.3	2.2	3.3	2.2	
	a3					1.1	
	b	+.2	+		1.1	+.2	+
	c	+	1.2	1.2	+	+	+
Picea abies	a1	(,+)	3.2	1.1	(2.1)	1.2	1.1
	a2			+		+	
	b				+		+
	c				+		+
Quercus robur	a1	1.1	1.1	2.1			
	a2	1.1				1.1	2.2
	a3					1.1	2.2
	b	+			1.1		1.2
	c	1.1					
Acer platanoides ***	a1		1.1				
	a2	1.1	+			1.1	
	a3						+
	b	+	1.2	1.1	1.1	+	2.2
	c	+	+	1.2	+		1.1
Sorbus aucuparia	a3						+
	b	+	+	+	+	+	+
	c	+					+
Populus tremula	a1					3.3	2.2
	a3						1.1
	b		+	+		+	+
	c		+	+		+	1.1
Fraxinus excelsior ***	a2	+					
	b			+		+	
Tilia cordata *	a2	1.2		+			
	b		+.2	+			
Ulmus glabra **	a2	+					
	b	+	+				
Betula pubescens	a2						2.2
	c		+				

Betula pendula	a1					+	1.2
	a2					+	
Carpinion betuli:							
*Stellaria holostea**		1.2	2.2	2.2	+	2.2	2.3
*Galium schultesii**							+.2
*Milium effusum***		3.3	2.3	2.3	3.3	2.3	2.3
*Lamiastrum galeobdolon***		1.2	1.2	+2	+2	+2	
*Polygonatum multiflorum***		+.2	+.2		+	+.2	+
*Galium odoratum***		+		+.2		1.2	+.2
*Dryopteris filix-mas***		+.2		+.2	+.2		
*Carex remota***					+.2		
*Eurynchium angustirete***					+.3		
*Paris quadrifolia***						+.2	
*Atrichum undulatum***							+.3
Querco – Fagetea:							
*Corylus avellana****	b	+.2	+.2		+.2	+.2	+.2
	c	+	+		+	+	
*Anemone nemorosa****		+.2	3.4	2.3		2.3	2.3
*Carex digitata****		+.2					
*Euonymus europaeus****	c	+					
*Lathrea squamaria****				+3			
Accompanying:							
Frangula alnus	b	+	+.2	+.2	+		1.2
	c			+	+	+	+
Majanthemum bifolium		1.1	2.2	2.2	+.2	2.2	2.2
Dryopteris carthusiana		+.2	1.2	1.2	+.2	+.2	1.2
Equisetum sylvaticum		(,+)	+	+	+	+	+
Oxalis acetosella		2.2	+.2	+.2	2.2	+.2	
Athyrium filix-femina		+.2	+.2	+.2	1.2	+.2	
Gymnocarpium dryopteris		+	1.2	1.2	+	+.3	
Rubus idaeus		1.2	+	+		1.2	+
Rubus saxatilis				+.2		+	
Rubus nessensis					+.3		+
Urtica dioica						+	+
Brachythecium salebrosum						+.3	+.3
Stellaria nemorum		+					
Calamagrostis arundinacea		+.2					
Dryopteris assimilis			+.2				
Deschampsia caespitosa					+.2		
Epilobium angustifolium					+		
Moehringia trinervia						+.2	
Plagiomnium elatum						+.3	
Lysimachia vulgaris							+
Polytrichum formosum							+.3
Plagiomnium cuspidatum							+.3
Brachythecium rutabulum							+.3

* species specific for *Carpinion betuli:*
* species specific for *Fagetalia sylvaticae*
* species specific for *Querco–Fagetea*

3. Results

Characteristic of 'Tisovik' reserve

Phytosociological research proved that plant communities in the whole area of the reserve are not much diverse and represent typical oak-hornbeam sub-community *Tilio-Carpinetum typicum* Tracz. (Matuszkiewicz 1984). It is proved by high share of species of alliance: *Carpinion betuli*, order *Fagetalia sylvaticae* and class *Querco-Fagetea*, and lack of species characteristic for other contemporaneous groups (Table 2). Only in narrow forest zone of several meters on the edges of reserve appear fragments of wet site, on which developed communities similar to alder swamp forest or broods.

Forest stand of typical oak-hornbeam, covering practically the whole reserve is characterised by high share of European hornbeam, English oak and Norway spruce.

Admixture constitutes Silver fir, small-leaved lime, Norway maple, Wych elm and European ash. Moderately developed layer of bushes is created mainly by European hornbeam;

Table 3. Diameter structure of the stand (50 × 50 m) in the reserve 'Tisovik'. Date of 19.05.1995

Diameter class [cm]	The number of trees of species:													
	Abies alba	*Picea abies*	*Ulmus glabra*	*Quercus robur*	*Carpinus betulus*	*Acer platanoides*	*Tilia cordata*	*Betula pubescens*	*Populus tremula*	*Sorbus aucuparia*	*Corylus avellana*	*Frangula alnus*	*Evonymus verrucosa*	*Evonymus europaea*
0–1				1			1			2				
1.1–3					9		15			10				
3.1–5			1		7		2			1				
5.1–7					5		2							
7.1–9					1									
9.1–11			2		8		1							
11.1–13					5									
13.1–15					5									
15.1–17				3	9									
17.1–19					2		1							
19.1–21				1	3									
21.1–23				1		1	1							
23.1–25														
25.1–27				1	1		1							
27.1–29					1		1							
29.1–31		1			1		1							
31.1–33				1	2		2							
33.1–35					1		1							
35.1–37					1									
37.1–39					1									
39.1–41				1	3		2							
41.1–43														
43.1–45														
45.1–47														
47.1–49														
49.1–51				1										
53.1–55	1													
75.1–77	2													
79.1–81														
89.1–91	1													
Shrubs	79	1	17	49	88	42	101	1	3	31	58	11	8	3

Norway maple, Mountain ash and hazel and in some places; also by English oak, small-leaved lime and Silver fir (Table 3). In physiognomy of herbs, layer plays the main part: *Milium effusum, Stellaria holostea, Lamiastrum galeobdolon, Anemone nemorosa, Majanthemum bifolium, Oxalis acetosella, Gymnocarpium dryopteris* and *Dryopteris carthusiana*. The layer of mosses, poorly developed and consisted of a few species. Diversity of plant species composition in examined lobs was small. Only lobs on edges of the reserve being at certain point under bigger anthropopressure are characterised by a significant share of common aspen and Silver birch in forest stand (Korczyk et al. 1997).

On the basis of phytosociological pictures made in years 1992–95, floristic notes and studies over structure of forest stand, a florist list was made of species occurring in reserve. It includes 56 species–13 species of trees, 4 species of bushes, 31 species of herbaceous vascular plants and 8 species of mosses (Table 4).

In Table 3, also included are herbaceous and spore species, confirmed on examined area in years 1920–1978 (Szafer 1920; Paczoski1928, 1930; Zefirov 1958; Budničenko et al. 1987). Total number of species in Table 3 is 83. Those species were listed according to their ecological behavior (Ellenberg et al. 1992). Additions to this list are two slimes – *Stereum*

Table 4. The list of herbaceous and cryptogamous plants which occur in the reserve 'Tisovik' according to various authors (1920 – Szafer 1920; 1926 – Paczoski 1928 i 1930; 1957 – Zefirov 1958; 1969 i 1978 – Budnichenko et al. 1985; 1992–95 – our data)

Species	Observation year					
	1920	1926	1957	1969	1978	1992–95
Mezoxerophytes						
Brachythecium rutabulum (Hedw.) B.,S.	-	-	-	-	-	+
Brachythecium salebrosum (Web.& Mohr) B., S.	-	-	-	-	-	+
Convallaria majalis L.	+	-	+	-	+	-
Eurhynchium angustirete (Broth.) Kop.	-	-	-	-	-	+
Galium schultesii Vest.	+	+	+	-	-	+
Hepatica nobilis Mill.	+	+	+	+	+	-
Melampyrum nemorosum L.	+	-	-	-	-	-
Melica nutans L.	-	-	-	+	-	-
Viola canina L.	-	-	+	+	-	-
Viola riviniana Reichenb.	-	-	+	-	-	-
Total	4	2	5	3	2	4
Mezophytes						
Actaea spicata L.	+	+	+	+	-	-
Adoxa moschatellina L	-	-	+	-	-	-
Aegopodium podagraria L.	+	+	+	+	+	-
Agrostis tenuis Sibth.	-	-	-	-	-	+
Ajuga reptans L.	-	+	+	+	-	-
Anemome nemorosa L.	-	+	+	+	+	+
Anthriscus sylvestris (L.) Hofft.	+	-	-	-	-	-
Asarum europeum L.	+	+	+	+	+	-
Atrichum undulatum (Hedw.) P. Beauv.	-	-	-	-	-	+
Brachypodium sylvaticum Hudson Beauv.	+	-	-	-	-	-
Calamagrostis arundinacea (L.) Roth.	-	-	+	-	-	+
Campanula trachelium L.	+	+	-	-	-	-
Carex digitata L.	-	-	+	-	-	+
Carex pilosa Scop.	-	+	+	+	-	-
Cimicifuga europaea N. Schipcz.	+	-	-	-	-	-
Circaea lutetiana L.	+	+	-	-	-	-
Dentaria bulbifera L.	+	-	+	-	+	-
Dryopteris assimilis S. Walker	-	-	-	-	-	+
Dryopteris carthusiana (Vill.) H.P. Fuchs	-	-	+	-	+	+
Dryopteris filix-mas (L.) Schott.	-	+	+	+	-	+

Species	Observation year					
	1920	1926	1957	1969	1978	1992–95
Epilobium montanum L.	-	+	-	-	-	-
Fragaria vesca L.	+	-	+	-	-	-
Galium odoratum (L.) Scop.	+	+	+	+	+	+
Geranium robertianum L.	+	+	+	+	-	-
Geum aleppicum Jacq.	+	-	+	-	-	-
Geum urbanum L.	+	+	-	-	+	-
Glechoma hederacea L.	-	+	-	-	-	-
Gymnocarpium dryopteris (L.) Newm.	+	+	-	+	-	+
Lamiastrum galeobdolon (L.) Ehrend.et Polatsche	-	+	-	+	-	+
Lathraea squamaria L.	-	-	-	-	+	+
Lathyrus vernus (L.) Bernh.	+	+	+	+	-	-
Luzula pilosa (L.) Willd.	-	-	+	-	-	-
Lysimachia nummularia L.	-	-	+	-	-	-
Maianthemum bifolium (L.F.W.) Schmidt.	+	+	+	+	+	+
Milium effusum L.	+	+	+	+	+	+
Moehringia trinervia (L.) Clairv.	-	-	-	+	-	+
Mycelis muralis (L.) Dumort	-	+	-	+	-	-
Neottia nidus-avis (L.) L.C.M. Richard	-	-	+	-	-	-
Oxalis acetosella L.	+	+	+	+	+	+
Paris quadrifolia L.	+	+	+	+	+	+
Pleurozium schreberi (Brid.) Mitt.	-	-	-	-	-	+
Poa nemoralis L.	+	-	-	-	-	-
Polygonatum multiflorum (L.) All.	+	+	+	+	+	+
Polytrichum formosum Hedw.	-	-	-	-	-	+
Pulmonaria obscura Dumort	+	+	+	+	+	-
Ranunculus lanuginosus L.	+	+	+	-	-	-
Rubus ideus L.	-	-	-	-	-	+
Rubus nessensis W. Hall	-	-	-	-	-	+
Rubus saxatilis L.	+	+	+	+	+	+
Scrophularia nodosa L.	-	+	-	-	-	-
Stellaria holostea L.	+	+	+	+	+	+
Trientalis europaea L.	-	-	-	-	-	+
Urtica dioica L.	+	+	+	+	-	+
Viola mirabilis L.	+	-	-	-	-	-
Viola reichenbachiana Jordan ex Boreau	-	-	-	-	+	-
Total	28	29	30	23	17	26
	Mezohygrophytes					
Arctium nemorosum Lej. et Court.	-	+	-	-	-	-
Athyrium filix-femina (L.) Roth.	+	+	+	+	+	+
Chaerophyllum aromaticum L.	-	+	+	-	-	-
Cystopteris fragilis (L.) Bernh.	-	-	+	-	-	-
Deschampsia caespitosa (L.) Beauv.	-	-	+	-	-	+
Epilobium angustifolium L.	-	-	-	-	-	+
Equisetum sylvaticum L.	+	+	+	+	+	+
Impatiens noli-tangere L.	+	-	+	-	-	-
Naumburgia thyrsiflora (L.) Reichenb.	-	-	+	-	-	-
Plagiomnium elatum (B.& S.) T. Kop.	-	-	-	-	-	+
Plagiomnium cuspidatum (Hedw.) T.Kop.	-	-	-	-	-	+
Stachys sylvatica L.	+	+	+	+	+	-

Species	Observation year					
	1920	1926	1957	1969	1978	1992–95
Stellaria media (L.) Vill.	-	-	+	-	-	-
Stellaria nemorum L.	-	-	+	-	-	+
Total	4	5	10	3	3	7
	Hygrophytes					
Angelica sylvestris L.	+	-	-	-	-	-
Carex remota L.	-	+	-	-	-	+
Lysimachia vulgaris L.	-	-	-	-	-	+
Poa palustris L.	-	-	+	-	-	-
Total	1	1	1	-	-	2
TOTAL	37	37	46	29	22	39

sanguinolentum (Alb.et Scw.) Fr. and *Corticium* sp. and 17 species of fungi: *Clavicorona pyxidata* (Pers. : Fr.) Doty., *Tyromyces kravtzevianus* Bond. et Parm., *Fomitopsis annosus* (Fr.) Karst., *Fomitopsis pinicola* (Sw. ex Fr.) Karst., *Anisomyces odoratus* (Wulf. ex Fr.) Karst., *Hypholoma fasciculare* (Huds. : Fr.) Kummer, *Crepidotus* sp., *Armillariella mellea* (Vahl. : Fr.) Karst., *Mycena* sp. l, *Mycena* sp. 2, *Xeromphalina campanella* (Batsch. : Fr.) Maire, *Pleurotus ostreatus* (Jacq. : Fr.) Kummer, *Auricularia auricularia-judae* (Buli.) Wettst, *Porothelium fimbriatum* (Pres.) Fr., *Reticularia lycoperdon* Buli., *Stemonitis fusca* Rott. i *Phellinus nigrolimitatus* (Rom.) Bourd. et Galz. found on dead firs (old hollow trunks, deadwood, roots and branches) (Budničenko et al. 1987).

Characteristics of Silver fir population in 'Tisovik' reserve

This population was never numerous. It is limited not only by small area of forest enclave, but also by biting by deer, bison, roe deer, hares and cows and trees being cut by people from villages nearby: Babiniec and Roubik. From 1823 until the outbreak of World War II, the number of trees ranged from 100–300. The biggest drop in the number of trees was noted after the end of World War II (Šutko, Martynovič 1967; Budničenko et al. 1987).

In 1992, the population of Silver fir occupied the highest central part of forest enclave of area ar. 1.2 ha. In this area, was found turf-podzolic soil, created out of clay-poor soil, laid on fine-grained silty sands transforming to the loose sands and underlaid with poor-clay sands.

The analysis of forest stand thickness on area of 50 × 50 m, located within forest part on which old firs grew, showed the lack of continuity in renewal of fir, spruce, maple and oak (Table 3). In bushes layer, occur individual fir, maple, oak and numerous hornbeam and lime (Table 3). That is why, in 1958, the reserve was fenced with a net 1.5 m high. This fence was not sufficient for protection against game because it was too short, and moreover, in many places, it was damaged (on purpose).

In 1992, in an area of 1.2 ha, grew 20 mature firs (Fig. 2, Table 5). Beside this group grew two more firs: one is currently localised within 30 m to east from group, while the second one was not found. Forest stand with firs has a broken crown closure and has large gaps. For this reason, despite significant difference in firs height (28.0 m–42.0 m), only one tree was included in the group of intermediate trees while the remaining trees were included in co-dominant and dominant trees (Table 5). Those trees showed vivid inhibition in growth to height.

In 1992, firs dbh ranged from 43.5 to 87.0 cm. Particular trees differed vividly in dynamic of growth to thickness, as evidenced by values of wood density (Table 5). The comparison of dbh measurements performed in 1985 and 1992 indicates that during 7 years, increment to tree thickness ranged from 1.5 cm to 6.5 cm (Table 5).

Firs were characterised with relatively long crown, which often constituted two-third of the shaft's length (Table 5) and 'stork nests'.

Crowns, similar in shape to a cut cone, were dense and built out of numerous thin branches. Fir shafts were full and relatively straight without any damage trail, poorly self-cleaned. No-knot zone began on average at a height of 4 m from trunk base (min. 2 m, max. 9 m).

Evaluation of health state of crown performed in 1992 and 1995 showed that they were damaged in weak degree (I degree). With some trees, noticed decrease in crowns health state (Table 5).

In 1992, firs actual age ranged from 106 to 154 years (due to safety considerations, the measurement was taken only on 11 trees). These data deviate significantly from evaluation from 1985 (Table 5). This is because in 1985, actual age was defined only for 6 trees, which were knocked down by wind in 1983, and on the basis of this, by interpolation, the age of the standing trees was defined. Those trees began their growth in the 19th century, and majority of them before 1850, when the game in Białowieża Primeval Forest was nearly exhausted (Samojlik 2005).

Table 5. Characteristics of *Abies alba* Mill. trees growing in the reserve 'Tisovik'. Data of 1985 according to Budničenko et al. 1987.

No.	Tree No.	Kraft's class	Age [years]		Tree height [m]		dbh [cm]		Crown lenght [m]	Timber density* [mm]	Bark thickness* [mm]		Defoliation [%]	
			1985	1992	1985	1992	1985	1992		N	N	S	1992	1995
1	1	I	140	-	30.7	35.5	66.0	70.5	27	21	26	23	30	35
2	2	II	140	-	30.7	36.0	65.0	68.5	26	20	18	19	20	35
3	3	II	140	-	30.7	38.0	68.0	74.0	26	24	21	19	25	25
4	4	III	120	-	27.0	33.0	48.0	51.0	20	19	15	13	20	25
5	5	II	150	138	33.3	42.0	81.0	87.0	28	26	25	23	30	30
6	6	I	150	154	33.3	36.0	80.0	82.0	28	13	19	22	35	35
7	7	I	140	144	30.7	32.5	71.0	72.5	23	20	19	17	25	25
8	8	II	140	112	30.7	33.5	63.0	69.5	26	17	19	19	20	35
9	9	II	120	138	27.0	32.0	49.0	49.5	21	17	15	14	15	25
10	11	I	150	109	33.3	38.0	82.0	84.0	23	23	21	24	35	35
11	12	II	140	136	30.7	34.0	61.0	64.5	26	16	19	15	25	30
12	13	I	150	-	33.3	33.5	82.0	85.0	21	13	20	19	20	25
13	15	II	120	123	28.6	29.5	51.0	54.5	17	16	17	15	20	20
14	16	II	130	136	28.6	34.0	58.0	60.0	19	16	21	19	15	25
15	17	I	150	123	33.3	36.5	83.0	86.5	25	16	22	18	30	30
16	18	I	140	-	30.7	34.5	65.0	68.5	20	20	17	14	30	35
17	21	II	120	106	27.0	28.0	39.0	43.5	17	18	18	16	20	20
18	22	II	140	-	30.7	36.0	69.0	71.0	27	19	21	26	30	30
19	23	II	140	-	30.7	33.0	71.0	61.5	21	16	19	17	25	30
20	29	II	120	-	28.6	33.5	53.0	58.0	24	17	18	18	30	35
21	dead fir	I	rot		-	37.0	-	95.3	-	-	-	-	-	-

In 2002, the wind knocked down fir no. 3 of height 37.5 m that had a crown length of 29.5 m and width 11.6 m. Block obtained from trunk base was 252 cm in circuit (diameter 80.3 cm) and had 137 annual rings.

Fir's natural regeneration in 'Tisovik' reserve

Until 1939, in reserve 'Tisovik' occurred underwood and numerous 2–5 years old fir natural seeding (Genko 1902, 1903; Szafer 1920; Paszewski1937). Zefirov (1958) stated the presence of few fir underwood. The presence of fir underwood reaching the height of 2.5 m and numerous natural seeding was noted also in 1967 (Šutko, Martynovič 1967). But in 1985, stated was only the presence of 1–3 years old natural seeding 80 in number per 100 m^2.

Detailed studies over cropping and natural renewal of fir in reserve 'Tisovik' were conducted in years 1992–2003. Stated was, that fir crops with various intensity every 2–3 years (Table 1).

In 1992, permanent circular plots were counted. The research showed that the highest number of seeds occurred always under dense fir canopy layers – plot I; around 10 times less on plots under fir–spruce canopy with gaps – plot II; and on open area – plot III (Table 1, 6 and 7).

The number of seedlings underwent fluctuation in following years. Until 1997, on circular plots, no many-years seedlings were noted of height above 20 cm. However, beside circular plots, found were few seedling of height 20 cm, which had their terminal and epicormic shoots bitten. In order to prevent damages by deer, the area with fir was in 1995 fenced with 1.5 m height net. It did not, however, limit deer penetration on fir area. Only the increase in fence height to 2 m made in 2000 in radical way prevented the deer penetration to the surface. On circular plots, started to appear seedlings of height above 20 cm without any traces of biting.

In years 2000–2003, annually counted were all seedlings growing outside circular plots and measured were heights of older firs (Table 7). The dynamic of seedling growth was very high. The average annual height increment amounted to around 10 cm, but found were also specimen of 50 cm increment. Most of the young firs had height in the range of 30–70 cm (Table 7).

In 2003, in reserve 'Tisovik', found were jointly 11.062 seedlings, including 3487 of 1-year-old seedling, 4389 of 2–5 years old seedling and 31.887 firs of height above 20 cm (Table 7).

Table 6. The silver fir natural regeneration on the circular plots in the reserve 'Tisovik'

Years	Code	Plot		
		I	II	III
1992	2	219	12	4
		130	68	121
		0	0	0
1994	0	139	41	20
		97	21	24
		0	0	0
1995	2	45	8	1
		192	17	41
		0	0	0
1997	1	113	13	40
		276	31	46
		0	0	0
1998	1	31	4	4
		250	13	50
		2+4z	0	1+5z
1999	0	33	7	8
		201	13	83
		0	0	6
2000	1	0	0	1
		208	5	76
		6	1	23
2001	0	8	5	33
		214	24	123
		330	0	24
2002	0	126	1	47
		267	21	224
		36	1	42
2003	2	181	25	85
		594	43	44
		141	3	115

In period 1992–2003, noted was no case of fir seedling damaged by spring frost.

In November 2012, it was stated that large part of samplings was bitten by deer at height above 30–40 cm. During winter 2012–2013, almost all (several thousand) firs of height 30–180 cm were mutilated

Crop and quality of Silver fir seeds from 'Tisovik' reserve

In the examined period, stated was good fir crop in years 1992, 1995 and 2003, poor crop in years 1997, 1998 and 2000 and total lack of crop in years 1994, 1999, 2001 and 2002 (Table 1).

Table 7. Height and root collar diameter of the silver fir seedlings in reserve 'Tisovik' in 2003

Measured objects	Seedlings of h>20 cm			Number of seedlings:	
	Features	Height [cm]	Diameter [mm]	2-5 year old	1 year old
	'Tisovik', circular plots				
I+II+III	n	259	17	681	291
	min	5	9	-	-
	max	119	61	-	-
	$\bar{x}$	27.5	15.1	-	-
I	n	141	-	552	153
	min	19	-	-	-
	max	47	-	-	-
	$\bar{x}$	24.5	-	-	-
II	n	3		43	25
	min	23	-	-	-
	max	30	-	-	-
	$\bar{x}$	25.7	-	-	-
III	n	115	17	44	85
	min	5	9	-	-
	max	119	61	-	-
	$\bar{x}$	31.1	15.1	-	-
	'Tisovik', transekts				
	n	2784	441	3291	3167
	min	16	6	-	-
	max	191	27	-	-
	$\bar{x}$	38.1	12.9	-	-
	Outside the fence				
	n	145	6	417	29
	min	20	9	-	-
	max	127	20	-	-
	$\bar{x}$	29.1	14.0		
	Total				
	n	3188	464	4389	3487
	min	5	6	-	-
	max	191	61	-	-
	$\bar{x}$	36.8	13.0	-	-

In 1995 the number of cones on particular firs ranged from 57 to 356 (Table 8). In 1992, the average mass of 1000 seeds amounted to 53.35 g (40.46–74.15 g in dependence on tree) and in 1995 – 51.59 g (39.69–72.69 g) (Table 8). The mass of 1000 seeds of the same tree was different in following years of cones collection and irrespective of share of empty seeds. For example, the mass of 1000 seeds from fir no. 17 in 1992 with share of empty seeds – 40%, amounted to 74.15 g and in 1995, with no empty seeds 51.00 g (Fig. 2, Table 8).

The seeds obtained in 1992 and 1996 were used for establishing ancestral preservative cultivation in polish part of Białowieża Forest District.

The seeds obtained in 1992 and1996 used were for establishing ancestral preservative cultivation in polish part of Białowieża Primeval Forest.

Average mass of seeds from 'Tisovik'reserve was more similar to mass of seeds from fir's natural eastern range ('Jata' reserve in Łuków Forest Inspectorate, reserve 'Kamienna Góra' on Roztocze and reserve 'Łabowiec' in Beskid Sądecki) than to mass of seeds from fir forest stands growing in Białowieża Primeval Forest Inspectorate (Table 8).

X-ray studies of seeds collected in 1992 showed that the share of full seeds amounted on an average to 92.86. Among full seeds, up to 76.92% were parasitised by insect larvae, and only 23.08% was healthy. Among healthy seeds 64.96% had embryos fully developed (type IV), and 34.73% was without any embryos (type I). Seeds with embryos of type III and IV were collected from fir no. 4 (Table 8). Average potential germination capacity of seeds obtained in 1992 amounted to 17.51%, and in case of seeds from particular trees, ranged from 2.67% (fir no. 3) to 67.90% (fir no. 4) (Table 7).

In seeds, found were larvae of two insect species: *Megastigmus suspectus* Borr. from Hymenoptera order, and *Resseliella piceae* Seitn. from Diptera order. Larvae of those insects mutilated embryos and partially also primary endosperm. Some of seeds, and first of all cones, were damaged by *Barbara herrichiana* Obr. from Lepidoptera order. Such high degree of seeds parasitisation in 'Tisovik' was most likely a result of very small number of fir population in 'Tisovik'.

X-ray studies of seeds collected in 1995 showed that the percentage of full fir seeds from 'Tisovik' amounting on an average to 97.99% was similar to the case of three natural comparative populations. Vivid differences were visible in percentage of healthy seeds and parasitized ones. In 1995, the share of healthy seeds from 'Tisovik' amounted on an average 37.67% and was significantly smaller than from 3 natural fir populations (Table 8). In seeds from 'Tisovik' reserve and reserves 'Jata', 'Kamienna Góra' and 'Łabowiec', stated was the presence of larvae of the same insect species as in 1992. Development of embryos was different in consecutive years of fir crop. The percentage of seeds with normal embryos (type IV) in 1992 was 64.96% and in 1995 only 29.09%, however, the number of seeds without embryos (type I) increased twice in comparison to 1992. In 1995, noted was the increase of seed number with underdeveloped embryo (type II and III) to 13.54% (Table 8). In different years, observed were also disorders in primary endosperm development in seeds of particular trees.

In 1992, in seeds undamaged by insects, the percentage of seeds with underdeveloped primary endosperm (B) amounted on an average to 5.44%, and in 1995, to 21.61% (Table 8). Irrespective of seeds origin and the year of crop, the percentage of full seeds was always very high – above 90%.

4. Summary and discussion

In broad literature concerning Silver fir in forest part 'Cisówka', found were only thesis of two authors, who negated its natural origin. First of them was Trauwatter, who in 1850 expressed such view without any justification (after Szafer 1920). Second author was Karpiński (1933), who found this population artificial on the basis of absence on firs of four monophagous species of bark beetles (*Pityokteines curvidens, P. spinidens* i *P. vorontzovi*) and fir weevil (*Pissodes piceae*). Karpiński (1933) constructed a thesis, that all generations of fir in 'Tisovik' reserve come from one tree, which was planted there in the 18th century (Karpiński 1933).

Significant number of authors claims that the position of Silver firs in 'Tisovik' reserve has a natural character (Górski 1829; Jundziłł 1830; Eichwald 1830; Błoński, Drymmer, Ejsmond 1888; Błoński, Drymmer 1889; Genko 1902,1903; Szafer 1920a,b, 1926; Kloska 1922; Wiśniewski 1923, J 924; Mattfeld 1925, 1926; Paczoski 1928, 1930; Paszewski, Poznański 1935; Paszewski 1937; Zefirov 1958; Dąbrowski 1959; Środoń 1959, 1983; Tutin 1964; Hegi 1965; Gunia, Kowalski 1966; Šutko, Martynovič 1957; Falińskin 1968,1986; Nikolaeva, Zefirov 1971; Budničenko in. 1987; Korczyk, Chilimoniuk 1993; Korczyk l995b; Sokołowski 1995).

For the natural origin of fir in Białowieża Primeval Forest, speaks also facts discussed in following subsections.

Palaeobotanical materials

The oldest fir remains, dated for interglacials of Middle Pleistocene, come from Grodno region (ar. 120 km to north from Białowieża) (Szafer 1926; Jaroń 1933; Środoń 1983). In Białowieża Primeval Forest, the oldest traces of Silver fir found in the form of pollen was from early Holocene (Dąbrowski 1959) and from Atlantic period – 5400–3000 years BC, Paszewski and Poznański (1935) and Paszewski (1937). Quoted authors found fir pollens only in 6 profiles representing 3 midforest moors (in Białowieża Primeval Forest comp. 317 and 373, and comp. 588 in Belarusian part of virgin forest). The share of fir pollens amounted from 0.5 to 2% pollens of arborescent species. They considered those facts as a confirmation of Szafer's (1920a) hypothesis of natural origin of fir in 'Tisovik'. Nevertheless, they suggested that firs pollen may have been blown to virgin forest from south of Poland with beech pollens. If the thesis about transport of fir pollens' origin from far was accepted, pollen should be found not only in six out of 18 analysed profiles because examined moors are not far from each other (Fig. 1) and the pollen cloud brought

Table 8. Silver fir seed yield and its quality in the reserve „Tisovik" in comparison with others populations

No.	Tree No.	Number of cones		Weight of harvested seeds	Weight of 1000 seeds	Seeds		Full seeds		Percentage of seeds with embryo type:				Endosperm		Potential seed germinationeger-minatione
		on tree	harvested			empty	full	sponged	sound	I	II	III	IV	A	B	
				g	g	%		%		%				%		%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cones bearing 1992																
Reserve „Tisovik"																
1	1	b.d	101	655	49.68	4.55	95.45	84.13	15.87	40.00	0.00	0.00	60.00	93.65	6.35	9.52
2	2	b.d	103	1 625	65.94	2.94	97.06	83.33	16.67	18.18	0.00	0.00	81.82	96.97	3.03	13.64
3	3	b.d	55	245	50.02	6.25	93.75	92.00	8.00	66.67	0.00	0.00	33.33	94.67	5.33	2.67
4	4	b.d	8	125	43.30	10.00	90.00	28.40	71.60	3.45	1.72	1.72	93.10	97.53	2.47	67.90
5	5	b.d	55	580	52.38	2.56	97.44	75.00	25.00	21.05	0.00	0.00	78.95	94.74	5.26	19.74
6	11	b.d	45	625	56.40	4.41	95.59	76.92	23.08	53.33	0.00	0.00	46.67	87.69	12.31	10.77
7	12	b.d	147	1 500	54.75	5.97	94.03	84.13	15.87	10.00	0.00	0.00	90.00	98.41	1.59	14.29
8	15	b.d	159	1 465	51.45	4.35	95.65	72.73	27.27	38.89	0.00	0.00	61.11	89.39	10.61	16.67
9	16	b.d	32	210	48.35	0.00	100.00	92.42	7.58	60.00	0.00	0.00	40.00	95.45	4.55	3.03
10	17	b.d	117	2 070	74.15	40.00	60.00	74.07	25.93	57.14	0.00	0.00	42.86	85.19	14.81	11.11
11	21	b.d	71	335	40.46	7.83	92.17	85.85	14.15	13.33	0.00	0.00	86.67	98.11	1.89	12.26
Average					**53.35**	**7.14**	**92.86**	**76.92**	**23.08**	**34.73**	**0.155**	**0.55**	**64.96**	**94.56**	**5.44**	**17.51**
Forst District Białowieża - 62 year old artificial stand																
Average					**57.39**	**4.00**	**96.00**	**0.00**	**100.00**	**74.74**	**0,52**	**0.00**	**24.74**	**25.26**	**74.74**	**24.74**
Cones bearing 1995																
Reserve „Tisovik"																
1	1	258	60	665	50.77	1.47	98.53	67.16	32.84	50.00	0.00	4.55	45.45	83.58	16.42	16.42
2	2	142	20	170	55.80	7.35	92.65	52.38	47.62	60.00	3.33	6.67	30.00	71.43	28.57	17.46
3	3	170	35	299	43.58	0.00	100.00	52.94	47.06	50.00	12.50	0.00	37.50	76.47	23.53	17.65
4	4	253	40	380	44.13	4.55	95.45	52.38	47.62	43.33	3.33	20.00	33.33	79.37	20.63	25.40

5	5	149	15	134	59.21	1.49	98.51	37.88	62.12	60.98	7.32	4.88	26.83	62.12	37.88	19.70
6	6	57	10	47	57.27	2.94	97.06	46.97	53.03	54.29	14.29	11.43	20.00	71.21	28.79	16.67
7	7	255	50	792	61.98	7.35	92.65	55.56	44.44	25.00	0.00	17.86	57.14	88.89	11.11	33.33
8	8	195	20	253	72.69	1.47	98.53	38.81	61.19	46.34	0.00	4.88	48.78	71.64	28.36	32.84
9	9	220	60	374	41.85	1.47	98.53	91.04	8.96	33.33	0.00	16.67	50.00	97.01	2.99	5.97
10	11	230	60	621	64.40	2.94	97.06	42.42	57.58	81.58	7.89	5.26	5.26	53.03	46.97	6.06
11	12	175	50	733	61.62	0.00	100.00	89.71	10.29	71.43	0.00	0.00	28.57	92.65	7.35	2.94
12	13	115	15	86	52.62	2.94	97.06	62.12	37.88	64.00	0.00	0.00	36.00	75.76	24.24	13.64
13	15	197	70	693	44.60	3.23	96.77	53.33	46.67	46.43	7.14	7.14	39.29	78.33	21.67	21.67
14	16	185	50	507	48.90	0.00	100.00	74.14	25.86	86.67	0.00	0.00	13.33	77.59	22.41	3.45
15	17	356	100	1454	51.00	0.00	100.00	86.76	13.24	44.44	0.00	55.56	0.00	94.12	5.88	7.35
16	18	210	30	323	52.82	1.47	98.53	77.61	22.39	40.00	0.00	13.33	46.67	91.04	8.96	13.43
17	21	94	15	65	40.27	1.47	98.53	64.18	35.82	45.83	0.00	25.00	29.17	83.58	16.42	19.40
18	22	90	30	211	39.95	0.00	100.00	80.88	19.12	76.92	0.00	7.69	15.38	85.29	14.71	4.41
19	23	116	35	156	39.69	0.00	100.00	73.53	26.47	83.33	5.56	5.56	5.56	77.94	22.06	2.94
20	29	230	50	302	48.62	0.00	100.00	44.12	55.88	78.95	10.53	2.63	7.89	55.88	44.12	5.88
Average					51.59	2.01	97.99	62.33	37.67	57.37	4.85	8.69	29.09	78.39	21.61	14.23
Forst District Białowieża - ca 80 years old artificial stand																
Average					**61.78**	**20.67**	**79.33**	0.10	99.90	48.33	3.33	0.87	47.46	51.71	48.29	48.29
Reserve „Jata”																
Average					49.72	9.67	90.33	27.40	72.60	25.79	1.63	1.41	71.17	81.28	18.72	52.70
Reserve „Kamienna Góra”																
Average					45.08	1.75	98.25	51.97	48.03	9.10	0.91	6.12	83.87	95.63	4.37	43.23
Reserve „Łabowiec”																
Average					54.28	3.43	96.57	17.90	82.10	10.25	1.19	2.02	86.54	91.59	8.41	72.71

lack of data

by wind could not have selectively fallen only on some of them. Fir pollens should not only be present in profiles made on barrow situated on area of Białowieża Primeval Forest in comp. 256, but also in surface layer of this barrow (Borowik-Dąbrowska 1976). In accordance with this conception, pollens from firs growing presently within limits of dense range should also now reach Białowieża Primeval Forest and this fact was not stated (Bremówna, Sobolewska 1939). That is why more probable is Szafer's hypothesis of natural origin of fir in virgin forest and its relict character. For this thesis, speaks also the fact that relatively large weight of firs pollen grain (ar. 10 times bigger than pine's pollen) and high speed of their drop (ar. three times faster than pine's pollen) limits their transport by wind to greater distance (Hibino 1969).

The occurrence of fir in forest part 'Hubar' (comp. 738) – some specimen found by Kłoska (1922) – indicates that, although in small numbers, but it also occurs in virgin forest not only in 'Tisovik'. Fir in Białowieża Primeval Forest, as in 'Jata' reserve on Wysoczyzna Siedlecka, is found on light mineral soils, but always on watersheds near moors and watercourse.

Such neighborhood provides high air humidity and frequent horizontal precipitation. These are the main factors that decide the survival of firs at such distances from dense range enclaves, which 'Tisovik' and 'Jata' reserves are.

Fir's monophagous entomofauna

Megastigmus suspectus Borr., *Resseliella piceae* Seitn. and *Barbara herrichiana* Obr. are monophagous species, which in Poland occur only on Silver fir. Their intensified presence was stated in material collected in 1995 from reserves 'Łabowiec', 'Kamienna Góra', 'Jata', and 'Tisovik', and they were not found in cones collected from two fir forest stands established in the beginning of the 20th century in Białowieża Forest District (Table 8). These two forests stands are situated ar. 7 km to southern-west from 'Tisovik' and firs growing there crop at least from 1984. Is this distance, therefore, a sufficient barrier, which mentioned insects could not overcome? If it is true, then in what way they managed to reach 'Tisovik', which is 120 km away from the closest natural fir position in 'Jata'? The only logical explanation is adopting hypothesis that monophagous insects moved together with fir migration (change of fir range) – their food base. It means that they reached Białowieża Primeval Forest together with fir in Holocene climate optimum period, and after climate cooling, they remained with fir as the relict of those times. They survived also because the local fir had quite regular crop.

Genetic structure of population

Mejnartowicz (1996) showed that fir population from 'Tisovik' is characterised by very small average number of alleles per locus and a very small share of polymorphic loci.

Heterozygosity observed (Ho) of examined populations except 'Tisovik' did not differ significantly from heterozygosity expected (He). He considered that the surplus of heterozygosity in such small population like 'Tisovik' is a result of selection ongoing from the last glaciations, focused on adjusting fir to fast-changing environmental factors of Białowieża Primeval Forest. Those researches excluded affinity between 'Tisovik' population and artificial fir forest stands in Białowieża Primeval Forest.On the other hand, showed vivid separateness of fir of unknown origin from Białowieża Primeval Forest from remaining populations.

Research of genetic structure of 20 firs growing in 'Tisovik' (Gončarenko, Savickij 2000) showed genetic variability only in 8 loci (Idh, Lap-1, Lap-2, Mdh-2, 6-Pgd-1, Pgm-1, Pgm-2, i Me), whereas the remaining loci turned out to be monomorphic. They stated a low level of inbreeding. 17 out of 20 examined firs were characterised with specific individual genotypes, and 3 firs had the same genotype, differing, however, vividly from the remaining trees. Based on the obtained results, Gončarenko and Savickij recognised fir from 'Tisovik' as natural and native population of Białowieża Primeval Forest.

For characterising the genetic structure of fir population from its eastern range Gončarenko and Savickij (2000) analysed the same isoenzymes, besides fir from 'Tisovik' reserve, 7 more populations from Poland and Ukraine. Dendrogram showed close affinity of fir from 'Tisovik' with natural fir population from eastern limit of range (from reserves: 'Jata', 'Kamienna Góra' and 'Łabowiec' and from Forest Districts: Drohobycz, Dielatin and Worohta) and vivid fir separateness of unknown origin from Białowieża Primeval Forest.

Fir in 'Tisovik' reserve has grown continuously, at least for 300 years. Hypothesis that it was introduced there artificially in the 18th century as Trauwetter (after Szafer 1920) and Karpiński (1933) suggest is unlikely. Especially, when considered is hindered access to this forest part because of surrounding swamps. Moreover, its capacity for intensive cropping every 3–5 years, its good growth and development not deviating from fir from dense range proves its good breeding conditions.

5. Conclusions

Analysis of published materials and the author's own fieldwork indicates that:

– Silver fir in Białowieża Primeval Forest is a native species and relict from Holocene climatic optimum period;

– in the past, fir, as a rare admixed tree species occurred also in different part of Białowieża Primeval Forest;

– fir still finds favorable growth conditions in virgin forest. It is visible in its health and breeding condition and ability for renewal by natural seeding;

– 'Tisovik' reserve is the last natural refuge of fir in Biało-

wieża Primeval Forest, which survived here due to favorable conditions and hindered access. It should be considered as fir's *locus classicus* and treated with special protection and care.

For those reasons, a special research program was prepared, in which following goals were assumed:

– preserving gene resources of Białowieża Silver fir population by establishing in Polish part of Białowieża Primeval Forest preserve cultivations;

– estimating fir's biogenetic diversity and its breeding quality on the basis of DNA research and family testing.

Conflict of interest

None declared.

Acknowledgement and financial support

The author would like to thank the Directorate of State National Park 'Białowieża Primeval Forest' for enabling the conduct of research in 'Tisovik' reserve. Many thanks to Mrs. Jevgenevnej Dvorak for sharing floristic notes from 'Tisovik' reserve. Special cordial gratitude for employees of Center of Natural Forest of Forest Research Institute in Białowieża, Mr. Mirosław Bugwin and Mr. Kazimierz Borowski for technical help.

References

Arhipov C. 1897. Istorićeskoe prośloe Belovežskoj Pušči. *Lesnoj Žurnal*, 3: 391–399.

Błoński F., Drymmer K., Ejsmond A. 1888. Sprawozdanie z wycieczki botanicznej, odbytej do Puszczy Białowieskiej w lecie 1887 roku. *Pamiętnik Fizjograficzny*, 8: 59–74.

Błoński F., Drymmer K. 1889. Sprawozdanie z wycieczki botanicznej, odbytej do Puszczy Białowieskiej, Ladzkiej i Świsłockiej w 1888 roku. *Pamiętnik Fizjograficzny*, 9: 55–62.

Borowik-Dąbrowska M. 1976. Opracowanie palinologiczne kurhanu w Białowieskim Parku Narodowym. *Archeologia Polski*, 21(1): 135–210.

Braun-Blanquet J. 1964. Pflanzensoziologie, Wien-New York, Springer-Verlag: 1–865.

Bremowna M., Sobolewska M. 1939. Studia nad opadem pyłku drzew leśnych w Puszczy Białowieskiej [The studdus of tree pollen rain in Białowieża Primeval]. *Sylwan, A*, 56, 3–4: 1–19.

Brokhaus F. A., Efron I. A. 1891. Belovežskaja Puščsca. in: Encyklopedičeskij Slovar', S. Petersburg: 208–211.

Budničenko N. I., Strelkov A. Z., Saevič F. F., Michalevič P. K. 1987. Pichta belaja v Belovežskoj Pušče. *Zapovedniki Belorusi*, 11: 13–24.

Dąbrowski M. J. 1959. Późnoglacjalna i holoceńska historia lasów Puszczy Białowieskiej. Cz. I. Białowieski Park Narodowy [Late Glacial and Holocene vegetation history of Białowieża Primeval Forest. Part I]. Acta Societatis Botanicorum Poloniae, 28, 2: 197–248.

Dengler A. 1992. Waldbau. Band I. Berlin, Paul Parey Verlag: 222–226.

Draft manual on methodologies and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. 1985. Programme Coordinating Centres with the assistance of the UNEP and Secretariat of UN–ECE: 1–96.

Ehrenberg C., Gustafsson A., Plym Forshell C., Simak M. 1955. Seed quality and the principles of Forest Genetics. *Heredity*, 41: 291–366.

Eichwald E. 1830. Naturhistorische Skizze von Lithauen, Volhynien und Podolien. Wilno, J. Zawadzki: 241–253.

Ellenberg H, Webere W., Dullr R., Wirht V., Werner W., Pauliben D. 1992. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica. Lehrstuhl fur Geobotanik der Universität Göttingen, Göttingen: 1–258.

Faliński J. B. 1968. Park Narodowy w Puszczy Białowieskiej. Warszawa, PWRiL: 1–504

Faliński J. B. 1986. Vegetation dynamics in temperate lowland primeval forests. Ecological studies in Białowieża Primeval Forest. Dordrecht Boston Lancaster, W. Junk Publishers: 1–537.

Flora Europea (eds. Tutin T. G., Heywood V. H., Burges N. A., Yalentine D. H., Walters S. M., Webb D. A.) 1964. Vol. 1. The University Press, Cambridge: 1–464.

Genko N. 1902. Charakteristika Belovežskoj Pušči i istoričeskoe o nej svedenija. *Lesnoj Žurnal*, 32, 5: 1009–1056, 6: 1269–1302.

Genko N. 1903. Charakteristika Belovežskoj Pušči i istoričeskoe o nej svedenija. *Lesnoj Žurnal*, 33, I: 22–5.

Giefing D. F. 1985. Budowa i zastosowanie urządzenia pilodyn. *Sylwan*, 129, 7: 63–77.

Gončarenko G.G., Savickij B.P. 2000. Populacjonno-genetičeskie resurcy pichty beloj v Belarusi. Nationalnaja Akademia Nauk Belarusi. Instytut Lesa. p. 121.

Górski S. 1829. O roślinach żubrom upodobanych, jako też innych w puszczy Białowiezkiey. *Dziennik Wileński*, 9: 207–217.

Graebner P. 1918. Diepflanzengeographischen Verhaltnisse von Bialovies. *Bialowies in deutscher Verwaltung*,4: 219–250.

Gunia S., Due J. E., Kramer W. 1972. Die Weißtanne (*Abies alba* Mill.) im Nordosten ihres natürlichen Verbreitungsgebietes. Forstarchiv, 43: 84–91

Gunia S., Kowalski M. 1968. Jodła pospolita (*Abies alba* Mill.) w Puszczy Białowieskiej [Silver fir (*Abies alba* Mill.) in Białowieża Primeval Forest]. Sylwan, 112: 59–66.

Hegi G. 1965. *Abies alba* Mill. in: Illustrierte Flora von Mittel-Europa mit besonderer Berücksichtigung von Deutschland, Oesterreich und der Schweiz zum Gebrauche in den Schulen und zum Selbstunterricht. Ed. G. Hegi. München, C. Hanser Verlag: 120–122

Hibino K. 1969. Relation between air-born pollen and the living vegetation in Mt. Hakkoda. *Ecological Revue*, 17,3: 189–195.

Jaroń B. 1933. Analiza pyłkowa interglacjału z Żydowszczyzny koło Grodna. *Roczniki Polskiego Towarzystwa Geologicznego*, 9: 147–183.

Jundziłł J. 1830. Opisanie roślin w Litwie, na Wołyniu, Podolu i Ukrainie dziko rosnących, jako i oswojonych, Wilno, Józef Zawadzki: 1–583.

Karpiński J. 1933. Fauna korników Puszczy Białowieskiej na tle występujących w puszczy typów drzewostanów. Warszawa, Zakład Doświadczalny Lasów Państwowych: 1–68.

Karpiński J. J. 1929. Rezerwaty Puszczy Białowieskiej. *Echa Leśne*, 6, 11: 2–4.

Kloska J. 1922. Nowe stanowisko jodły w Puszczy Białowieskiej. *Las Polski*, 10: 383–385.

Korczyk A., Chilimoniuk M. 1993. Jodła w Puszczy Białowieskiej. *Las Polski.*, 10: 14–16.

Korczyk A. F. 1995a. Restytucja jodły pospolitej w puszczy gospodarczej. Raport GEF 3. 4. Maszynopis w Zakł. Lasów Naturalnych IBL, 1–12.

Korczyk A. F. 1995b. Risk assessment of pollution load on reproductive systems in forest tree. in: Protecion of forest ecosystems biodiversity of Białowieża Primeval Forest (eds. P. Paschalis, K. Rykowski, S. Zajączkowski), Warsaw, Fundacja SGGW: 33–52.

Korczyk A. F. 1999. Ocena wartości genetycznej i hodowlanej naturalnych populacji jodły pospolitej (*Abies alba* Mill.) ze wschodniego zasięgu w Polsce. *Zeszyty Naukowe Akademii Rolniczej w Krakowie*, 339: 155–170.

Korczyk A. F. 2000. Reliktowe stanowisko jodły pospolitej w białoruskiej części Puszczy Białowieskiej. *Prace Instytutu Badawczego Leśnictwa*, 2: 90–93.

Korczyk A. F, Kawecka A., Martysevič V. V, Strelkov A. Z. 1997. Naturalne stanowisko jodły pospolitej (*Abies alba* Mill.) w Puszczy Białowieskiej. *Prace Instytutu Badawczego Leśnictwa, A*, 837: 29–61.

Mattfeld J. 1925. Die in Europa und dem Mittelmeergebiet wildwachsenden Tannen. *Mitteilungen der Deutschen Dendrologischen Gesellschaft*, 35: 1–37.

Mattfeld J. 1926. Das Areal der Weißtanne. *Mitteilungen der Deutschen Dendrologischen Gesellschaft*, 37: 16–35.

Matuszkiewicz W. 1984. Przewodnik do oznaczania zbiorowisk roślinnych Polski, Warszawa, PWN: 1–298.

Mejnartowicz L. 1996. Origin of Silver-fir stands in Białowieża Primeval Forest. in: Biodiversity Protection of Białowieża Primeval Forest (eds. P. Paschaslis, S. Zajączkowski), Warsaw: 35–50.

Nikolaeva V. M., Zefitrov B. M. 1971. Flora Belovežskoj Pušči, Minsk: 1–182.

Paczoski J. 1928. Roślinność Puszczy Białowieskiej (La végétation de la forêt de Białowieża). Ministere de 1'Agriculture, Varsovie,1–87.

Paczoski J. 1930. Lasy Białowieży. Poznań, Państwowa Rada Ochrony Przyrody: 1–575.

Paszewski A., Poznański F. 1935. Materiały do historii lasów Puszczy Białowieskiej [Contribution to the history of the Białowieża Primeval Forests I]. *Roczniki Nauk Rolniczych i Leśnych*, 36: 59–67.

Paszewski A. 1937. Dalsze badania nad historią lasów Puszczy Białowieskiej na podstawie analizy pyłkowej torfowisk [Contribution to the history of the Białowieża Primeval Forests II]. Roczniki Nauk Rolniczych. i Leśnych, 41: 1–5.

Romanów M. 1922: Zgon najstarszej jodły w Puszczy Białowieskiej. *Las Polski*, 10: 381–383.

Samojlik T. 2005. Ochrona i łowy. Puszcza Białowieska w czasach królewskich. Białowieża, ZBS PAN, p. 90. ISBN 83-907521-5-8.

Semenov P. 1863. Beloyežskaja Pušča. in: Slovar' Rossijskoj Imperii. Sankt Petersburg: 359–360.

Šutko N. V., Martynovič B. S. 1967. Pichta belaja v Belarusi. in: Dendrologia i lesovedene. Nauka i Technika, Min´sk: 77–81.

Sokołowski A. W. 1995. Flora roślin naczyniowych Puszczy Białowieskiej, Białowieża, Białowieski Park Narodowy: 1–273.

Szafer W. 1920a. Jodła w Puszczy Białowieskiej. *Sylwan*, 38, lipiec-wrzesień: 65–74.

Szafer W. 1920b. Plan utworzenia rezerwatu leśnego w Puszczy Białowieskiej. *Sylwan*, 38, październik-grudzień: 97–117.

Szafer W. 1926. O florze i klimacie okresu międzylodowcowego pod Grodnem. *Sprawozdania Komisji Fizjograficznej PAU*, 60: 1–40.

Środoń A. 1959. Zarys historycznego rozwoju szaty roślinnej Polski w późnym glacjalc i postglacjale. in: Szata roślinna Polski (ed. W. Szafer). Warszawa, PWN: 511–543.

Środoń A. 1983. Jodła pospolita w historii naszych lasów. in: Jodla pospolita *Abies alba* Mili. (red. S. Białobok). PWN, Warszawa-Poznań: 9–39.

Utenkova A. P., Romanovskij V. P., Kočanovskij S. B., Smirnov H. S. 1972: Vlijanie osušenija lesnych bolot na gidrologičeskij režim okružajuščich suchodolov. *Belovežskaja Pušča. Issledovanja*, 6: 11–36.

Wiśniewski T. 1923. Przyczynek do znajomości Puszczy Białowieskiej. Białowieża, 2: 33–61.

Wiśniewski T. 1924. Kilka szczegółów o jodle w Puszczy Białowieskiej. *Ochrona Przyrody*, 4: 100–103.

Zefirov B. M. 1958. Zamietki o flore gosudarstvennogo zapovednika Belovežskaja Pušča. *Trudy Zapovedno-Ochtnič'ego Chozjajstva Belovežskaja Pušča*, 1: 68–80.

Translated by: Anna Wyszyńska