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AVIFAUNA OF 'BULGARKA' NATURE PARK (BULGARIA) WITH DISTRIBUTION, POPULATION SIZE AND BREEDING DENSITY DATA FOR THE SPECIES OF CONSERVATION IMPORTANCE

Peter Shurulinkov[1*], Girgina Daskalova[1, 2], Doncho Kirov[3], Borislav Borisov[5], Lachezar Spasov[1], Andrey Ralev[4], Ilian Stoev[3], and Alexandar Mechev[3]

[1]National Museum of Natural History, Sofia, Bulgarian Academy of Sciences, 1000 Sofia, 1 Tsar Osvoboditel Str., Bulgaria. [*]E-mail: p.shurulinkov@gmail.com
[2]Bulgarian Society for the Protection of Birds, 8800 Sliven, 37 Georgi Ikonomov Str., Bulgaria. E-mail: girginand@gmail.com
[3]Green Balkans Federation, 4000 Plovdiv, 1 Skopie Str., Bulgaria. E-mail: office@greenbalkans.org
[4]Balkani Wildlife Society, 1142 Sofia, 93 Evlogi i Hristo Georgievi Str., Bulgaria. E-mail: alibotush@gmail.com
[5]6300 Haskovo, 15 Knyaz Dondukov Str., Bulgaria. E-mail: barsirbis@gmail.com

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Abstract

Study was completed in 2012 and 2013. A total of 163 bird species were registered during the field studies and on the basis of literature sources. 121 species are breeding and 42 are transitory migrants, wintering or wandering in the area. High number and population densities were registered for some endangered species as White-backed woodpecker – 35–40 breeding pairs, overall density – 0.24 pairs/100 ha, Red-breasted flycatcher – 80–110 pairs, density 1.1–5.5 pairs/100 ha and Semi-collared flycatcher – 150–300 pairs, density – 7.5–24.3 pairs/100 ha. Also significant populations of Corncrake, Grey-headed woodpecker and Black woodpecker were found. Breeding of Goosander and Woodcock is probable. In the old beech forests two dominant species were Robin and Common chaffinch, and subdominant were found to be Blackcap, Common chiffchaff, Song thrush and Semi-collared flycatcher.

Key words: breeding populations, Central Stara Planina Mts., forest birds, protected territory.

Introduction

Avifauna of 'Bulgarka' Nature Park (NP) in Central Stara Planina Mts., Central Bulgaria, has not been a subject of specific research until now and that mountain area remains poorly studied. That protected territory was created in 2002 to preserve the old beech-wood habitats on the northern slopes of Stara Planina Mts. above the towns of Gabrovo, Tryavna and Plachkovtsi. From the published sources there are data about the presence of 119 bird species on that territory and in its vicinity (the whole Shipchenska Mt. and Trevnenska Mt. – parts of Stara Planina Mts.)

but in almost all of the cases without given exact localities and without data about their general status, distribution, number, densities and preferred habitats. The only ornithological study that covers the current territory of 'Bulgarka' NP as well as much larger territories of Stara Planina Mts. was published 43 years ago (Donchev 1974). That study presented concrete observations of 21 bird species. Some older observations were cited even from the end of XIX century (Reiser 1894), giving concrete findings of five species. The studies of Dr. Stefan Donchev have been localized mainly in two parts of Shipchenska Mt. – at Yantra hut and at 'Buzludzha' hut.

The richest information about the birdlife of that region can be obtained from the national mapping of the breeding birds in Bulgaria (Iankov 2007). In that study are included data about the presence of 116 bird species breeding in the NP and its surroundings for the period 1990–2007. That information is presented on the basis of mapping of all 10×10 km UTM squares situated on the territory of the NP. Unfortunately these data are not confined to particular localities, dates, years, altitude or habitat. In the text of that atlas there are no any concrete data on the number, localization or breeding densities of the species mapped on that mountain territory. From these 116 species found, seven are included with possible breeding, 21 with probable breeding and 88 – with confirmed breeding status.

Undoubtedly there is lack of concrete data on bird status, distribution, number, habitats, etc. on the territory of 'Bulgarka' NP. The species checklist is also far from complete. Thus we conducted the presented here research in the frames of the works for establishment of Management Plan for 'Bulgarka' NP in 2012–2013. We hope that the information presented will be used for the proper management of the protected territory.

Study Area

The research covered the whole territory of 'Bulgarka' NP – 21,772 ha. Geographical coordinates of its central area above Potoka village – 42°45'33.9" N and 25°21'52.2" E. The area is covered predominantly by mature Beech (*Fagus moesiaca* Czeczott) and Common hornbeam (*Carpinus betulus* L.) forests, about half of them over 80 years old. Locally there are coniferous plantations, mainly of Spruce (*Picea abies* L.), Scots pine (*Pinus sylvestris* L.) and Fir (*Abies* ssp.). Forests cover more than 80 % of the territory. Mountain meadows cover the highest parts of the mountain but also some mesophilic meadows are situated in the foothills, often along the rivers and streams. The altitudinal belt of the studied territory was between 500 and 1510 m a.s.l. There is one artificial lake in the western part – 'Smirnenski' Dam situated at 530 m a.s.l., with a total water surface of 105.4 ha. It has predominantly steep shores thus it does not supply attractive habitats for feeding of waterfowl.

Material and Methods

Study on the avifauna of 'Bulgarka' NP was completed in 2012 and 2013 but some observations were added also from the periods 2009–2011 and 2014–2017. A total of 370 days were spent on field research. Thus all the territory was covered in all four seasons of the year.

For studying the populations' densities of passerine birds and woodpeckers and their species composition in the most typical beech forest habitat we used two line transects, with length of 3.14 km and 1.94 km, completed in the middle of every month. These transects were situated in the eastern parts of the NP, close to the road Plachkovtsi – Krustets, in mature (80–90 years old) beech forests with a presence of dispersed solitary Scots pine trees. The birds were counted visually or acoustically in two spatial belts – 0–25 m and over 25 m. For the breeding birds’ composition and densities we used the data from May, June and July, 2012.

Additionally, we completed line transects in a considerable number of other NP territories mainly during the breeding period. All the main river valleys were included in the research. Transects for woodpeckers were made in the period March–May. They had length of 5–10 km and the birds were provoked to vocalize or attracted using mp3 players for imitations of their voice. Part of these transects were completed by car with regular stops for imitations at each 500–700 m.

The distribution of the diurnal birds of prey was studied from stationary points with good visibility. At least two hours in good weather conditions were spent on each observation point. The separate points were at a distance over 2 km from each other (Watson et al. 1989, Bibby et al. 1992). The observations were made in the period March–July using binoculars with magnification 10×50 or 8×30 and spotting scopes with magnification 30–60x. The species and number of all birds of prey were noted as well as age, sex, flight height and direction of each observed individual (if possible). Part of the stationary points were visited 2–4 times per year for collecting data from both breeding and migration periods.

For specific search for Corncrake (*Crex crex* L., 1758) we used acoustic provocation (imitation) of its mating calls in transects chosen in appropriate to its habitat – wet meadows in foothills, mostly along the river (stream) courses. Transects and the points for imitation were visited in the evening, during the night and in the morning, approximately between 19:00 and 8:00 when the highest vocal activity was expected. The search for that species was completed in the period 15 May – 30 June, in 2012 and 2013. Most transects were made by car and the imitation points were set at a distance of not less than 100 m between them. These transects were made in different locations, not repeated at a same location.

The taxonomy used for results presentation follows that accepted in the list of the birds recorded in Bulgaria (BUNARCO 2009).

Results

Totally 163 bird species were registered both in the field studies and literature sources. From these 121 species are breeding (possible, probable and confirmed breeders) (Table 1), and 42 transitory migrants, wintering or wandering in the area (Table 2). Confirmed breeding can be accepted for 105 species. The other 16 species are possible or probable breeders or they nest in neighboring territories to the NP and visit it during their regular search for food.

We present data about the status, distribution and ecological information for the rare and endangered (on national or international level) breeding or possibly breeding bird species.

Table 1. List of birds recorded during the breeding period.

English name	Latin name	Status
Black stork	*Ciconia nigra* L., 1758	B,M
White stork	*Ciconia ciconia* L., 1758	B*,M
Mallard	*Anas plathyrhynchos* L., 1758	B,S
Goosander	*Mergus merganser* L., 1758	(B),S
Honey buzzard	*Pernis apivorus* L., 1758	B,M
Northern goshawk	*Accipiter gentilis* L., 1758	B,S
Eurasian sparrowhawk	*Accipiter nisus* L., 1758	B,S
Common buzzard	*Buteo buteo* L., 1758	B,S
Long-legged buzzard	*Buteo rufinus* Cretzschmar, 1827	B*,S
Lesser spotted eagle	*Aquila pomarina* Brehm, 1831	(B),M
Golden eagle	*Aquila chrysaetos* L., 1758	B,S
Kestrel	*Falco tinnunculus* L., 1758	B,S
Hobby	*Falco subbuteo* L., 1758	B,M
Peregrine falcon	*Falco peregrinus* Tunstall, 1771	B*,S
Rock partridge	*Alectoris graeca* Meisner, 1804	(B),S
Grey partridge	*Perdix perdix* L., 1758	B,S
Quail	*Coturnix coturnix* L., 1758	B,M
Common pheasant	*Phasianus colchicus* L., 1758	B*,S
Corncrake	*Crex crex* L., 1758	B,M
Little ringed plover	*Charadrius dubius* Scopoli, 1786	B,M
Common sandpiper	*Actitis hypoleucos* L., 1758	B,M
Eurasian woodcock	*Scolopax rusticola* L., 1758	B,S
Feral pigeon	*Columba livia* f. *domestica* Gmelin, 1789	B*,S
Stock dove	*Columba oenas* L., 1758	(B),S
Wood pigeon	*Columba palumbus* L., 1758	B,S
Collared dove	*Streptopelia decaocto* Frivaldszky, 1838	B,S
Turtle dove	*Streptopelia turtur* L., 1758	B,M
Cuckoo	*Cuculus canorus* L., 1758	B,M
Scops owl	*Otus scops* L., 1758	B,M
Little owl	*Athene noctua* Scopoli, 1769	(B),S
Tawny owl	*Strix aluco* L., 1758	B,S
Long-eared owl	*Asio otus* L., 1758	B,S
Nightjar	*Caprimulgus europaeus* L., 1758	B,M
Common swift	*Apus apus* L., 1758	B,M
Pallid swift	*Apus pallidus* Shelley, 1870	B,M
Common kingfisher	*Alcedo atthis* L., 1758	B,S
Hoopoe	*Upupa epops* L., 1758	B,M
Wryneck	*Jynx torquilla* L., 1758	B,M
Grey-headed woodpecker	*Picus canus* Gmelin,1788	B,S
Green woodpecker	*Picus viridis* L., 1758	B,S
Black woodpecker	*Dryocopus martius* L., 1758	B,S
Great spotted woodpecker	*Dendrocopos major* L., 1758	B,S

English name	Latin name	Status
Syrian woodpecker	*Dendrocopos syriacus* Hemprich & Eherberg, 1833	B,S
Middle spotted woodpecker	*Dendrocopos medius* L., 1758	B,S
White-backed woodpecker	*Dendrocopos leucotos lilfordi* Sharpe et Desser 1871 **	B,S
Lesser spotted woodpecker	*Dendrocopos minor* L., 1758	B,S
Crested lark	*Galerida cristata* L., 1758	B,S
Woodlark	*Lullula arborea* L., 1758	B,M
Skylark	*Alauda arvensis* L., 1758	B,M
Rock martin	*Ptyonoprogne rupestris* Scopoli, 1769	B,M
Barn swallow	*Hirundo rustica* L., 1758	B,M
Red-rumped swallow	*Cecropis daurica* L., 1758	B,M
House martin	*Delichon urbicum* L., 1758	B,M
Tree pipit	*Anthus trivialis* L., 1758	B,M
Water pipit	*Anthus spinoletta* L., 1758	B,S
Yellow wagtail	*Motacilla flava* L., 1758	B,M
White wagtail	*Motacilla alba* L., 1758	B,M
Grey wagtail	*Motacilla cinerea* Tunstall, 1771	B,S
Dipper	*Cinclus cinclus* L., 1758	B,S
Eurasian wren	*Troglodytes troglodytes* L., 1758	B,S
Dunnock	*Prunella modularis* L., 1758	(B),S
Robin	*Erithacus rubecula* L., 1758	B,S
Nightingale	*Luscinia megarhynchos* Brehm, 1831	B,M
Common redstart	*Phoenicurus phoenicurus* L., 1758	B,M
Black redstart	*Phoenicurus ochrurus* Gmelin, 1789	B,M
Whinchat	*Saxicola rubetra* L., 1758	B,M
Stonechat	*Saxicola rubicola* L., 1766	B,M
Common wheatear	*Oenanthe oenanthe* L., 1758	B,M
Blackbird	*Turdus merula* L., 1758	B,S
Song thrush	*Turdus philomelos* Brehm,1831	B,M
Mistle thrush	*Turdus viscivorus* L., 1758	B,S
Ring ouzel	*Turdus torquatus* L., 1758	B,M
Marsh warbler	*Acrocephalus palustris* Bechstein, 1798	B*,M
Great reed warbler	*Acrocephalus arundinaceus* L., 1758	B*,M
Barred warbler	*Sylvia nisoria* Bechstein, 1792	B,M
Lesser whitethroat	*Sylvia curruca* L., 1758	B,M
Common whitethroat	*Sylvia communis* Latham, 1787	B,M
Blackcap	*Sylvia atricapilla* L., 1758	B,M
Garden warbler	*Sylvia borin* Boddaert, 1783	(B),M
Chiffchaff	*Phylloscopus collybita* Vieillot, 1817	B,M
Wood warbler	*Phylloscopus sibilatrix* Bechstein, 1793	B,M
Goldcrest	*Regulus regulus* L., 1758	B,S
Firecrest	*Regulus ignicapillus* Temminck, 1820	B,S
Semi-collared flycatcher	*Ficedula semitorquata* Homeyer, 1885	B,M
Red-breasted flycatcher	*Ficedula parva* Bechstein,1794	B,M

English name	Latin name	Status
Long-tailed tit	*Aegithalos caudatus* L., 1758	B,S
Marsh tit	*Poecile palustris* L., 1758	B,S
Willow tit	*Poecile montana* Baldenstein, 1827	B,S
Sombre tit	*Poecile lugubris* Temminck, 1820	B,S
Coal tit	*Periparus ater* L., 1758	B,S
Blue tit	*Cyanistes caeruleus* L., 1758	B,S
Great tit	*Parus major* L., 1758	B,S
Nuthatch	*Sitta europaea* L., 1758	B,S
Short-toed treecreeper	*Certhia brachydactyla* Brehm, 1831	B,S
Eurasian treecreeper	*Certhia familiaris* L., 1758	B,S
Golden oriole	*Oriolus oriolus* L., 1758	B,M
Red-backed shrike	*Lanius collurio* L., 1758	B,M
Lesser grey shrike	*Lanius minor* Gmelin, 1788	B,M
Jay	*Garrulus glandarius* L., 1758	B,S
Magpie	*Pica pica* L., 1758	B,S
Western jackdaw	*Corvus monedula* L., 1758	B*,S
Hooded crow	*Corvus cornix* L., 1758	B,S
Raven	*Corvus corax* L., 1758	B,S
Common starling	*Sturnus vulgaris* L., 1758	B,M
House sparrow	*Passer domesticus* L., 1758	B,S
Tree sparrow	*Passer montanus* L., 1758	B,S
Common chaffinch	*Fringilla coelebs* L.1758	B,S
European serin	*Serinus serinus* L., 1758	(B),S
Greenfinch	*Carduelis chloris* L., 1758	B,S
Goldfinch	*Carduelis carduelis* L., 1758	B,S
Linnet	*Carduelis cannabina* L., 1758	B,S
Bulfinch	*Pyrrhula pyrrhula* L., 1758	B,S
Hawfinch	*Coccothraustes coccothraustes* L., 1758	B,S
Common crossbill	*Loxia curvirostra* L., 1758	B,S
Siskin	*Carduelis spinus* L., 1758	(B),S
Yellowhammer	*Emberiza citrinella* L., 1758	B,S
Cirl bunting	*Emberiza cirlus* L., 1758	B,S
Rock bunting	*Emberiza cia* L., 1758	B,S
Ortolan bunting	*Emberiza hortulana* L., 1758	B,M
Black headed bunting	*Emberiza melanocephala* Scopoli, 1769	B,M
Corn bunting	*Emberiza calandra* L., 1758	B,M
In total: 121 species		

Legend: B – breeding species; (B) – probably breeding species; B* – species breeding in the vicinity of the Nature Park; M – migratory species; S – sedentary species.
Note: ** That subspecies is mentioned as it is well differentiated and can be easily detected during field study without need of capturing the birds.

Goosander (*Mergus merganser*)

A pair was observed on 7.04.2012 in ‘Smirnenski’ Dam. On 17.05.2012, only the female was spotted in the lake. It is typical for the species that the pairs separate after the hatching of the chicks. But probably the nesting here has not been successful as chicks were not observed at all in our next visits during the summer of 2012.

Table 2. List of birds recorded during migration and wintering; extinct species.

Species	Latin name	Status
Great cormorant	*Phalacrocorax carbo* L., 1758	M,W
Night heron	*Nycticorax nycticorax* L., 1758	M
Grey heron	*Ardea cinerea* L., 1758	M,W
Whooper swan	*Cygnus cygnus* L., 1758	M
Osprey	*Pandion haliaetos* L., 1758	M
Black kite	*Milvus migrans* Bodaert, 1783	M
Short-toed eagle	*Circaetus gallicus* Gmelin, 1788	M
Marsh harrier	*Circus aeruginosus* L., 1758	M
Hen harrier	*Circus cyaneus* L., 1758	M,W
Pallid harrier	*Circus macrourus* Gmelin, 1770	M
Montagu’s harrier	*Circus pygargus* L., 1758	M
Levant sparrowhawk	*Accipiter brevipes* Severtzov, 1850	M
Griffon vulture	*Gyps fulvus* Hablizl, 1783	Wa
Spotted eagle	*Aquila clanga* Pallas, 1811	M
Booted eagle	*Hieraaetus pennatus* Gmelin, 1788	M
Chukar partridge	*Alectoris chukar* Gray, 1830	E
Hazel grouse	*Tetrastes bonasia* L., 1758	Wa
Capercaillie	*Tetrao urogallus* L., 1758	E
Moorhen	*Gallinula chloropus* L., 1758	M
Common crane	*Grus grus* L., 1758	M
Michahelli’s gull	*Larus michahellis* Naumann, 1840	M,Wa
Eagle owl	*Bubo bubo* L., 1758	E
Alpine swift	*Tachymarptis melba* L., 1758	M
European bee-eater	*Merops apiaster* L., 1758	M
Roller	*Coracias garrulus* L., 1758	M
Balkan horned lark	*Eremophila alpestris balcanica* Reichenow, 1859**	Wa
Alpine accentor	*Prunella collaris* Scopoli, 1769	W,Wa
Meadow pipit	*Anthus pratensis* L., 1758	M
Fieldfare	*Turdus pilaris* L., 1758	M,W
Redwing	*Turdus iliacus* L., 1758	M,W
Thrush nightingale	*Luscinia luscinia* L., 1758	M
Willow warbler	*Phylloscopus trochilus* L., 1758	M
Waxwing	*Bombycilla garrulus* L., 1758	W
Grey flycatcher	*Muscicapa striata* Pallas, 1764	M
Collared flycatcher	*Ficedula albicollis* Temminck, 1815	M
Pied flycatcher	*Ficedula hypoleuca* Pallas, 1764	M

Species	Latin name	Status
Crested tit	*Lophophanes cristatus* L., 1758	E
Great grey shrike	*Lanius excubitor* L., 1758	W
Nutcracker	*Nucifraga caryocatactes* L., 1758	Wa
Alpine chough	*Pyrrhocorax graculus* L., 1758	E
Spanish sparrow	*Passer hispaniolensis* Temminck, 1820	M
Brambling	*Fringilla montifringilla* L., 1758	M,W
In total: 42 species		

Legend: M – transitory migrant; W – wintering species; Wa – wandering species, occurring sporadically; E – extinct species.
Note: ** That subspecies is mentioned as it is well differentiated and can be easily detected during field study without need of capturing the birds.

Black stork (*Ciconia nigra*)

One pair supposedly nests in the area near the mouth of Panicharka River in 'Smirnenski' damlake. The Black storks probably nest on the rocks in Topleshki dol or on a tree in the surrounding forests. The species is observed also in the eastern parts of the NP, to the northeast of Krustets village, but we consider the probability of nesting there as small. The species is more common as a breeder along Yantra River below the town of Gabrovo (unpublished data).

Honey buzzard (*Pernis apivorus*)

A total of eight localities of separate pairs were found. In the western parts of the studied territory pairs were registered during the breeding period around 'Malusha' peak and the upper course of Levicharka River – close to its springs. Another pair was found in the forests to the south of rivers Levicharka and Panicharka confluence. Probably a bird from the same locality was seen on 23.05.2013 along Panicharka River. It was observed also between 'Partizanska pesen' hut and Osenikova polyana, on 21.05.2013. In the eastern parts of the NP pairs were seen above Gaydari village (18.06.2012), in 'Studen Kladenets' protected area and between 'Babata' peak and 'Gorelska chuka' peak (19.05.2013).

Northern goshawk (*Accipiter gentilis*)

Very rare as a breeding species. One pair was observed on 1.04.2013 close to Konarskoto village. An adult specimen was observed at 0.5 km to the west of 'Partizanska pesen' hut, on 02.05.2017.

Eurasian sparrowhawk (*Accipiter nisus*)

Not numerous breeding species. At least eight localities of the species were found during the breeding period. Possibly about 8–10 pairs nest is the deciduous and mixed forests. Observed on 14.05.2013 at Buzludzha, on 15.05.2013 hunting close to peak 'Golyam Bedek' and on 22.05.2013 between 'Uzana' hut and peak 'Ispolin'.

Golden eagle (*Aquila chrysaetos*)

Two pairs of the species were recorded in their hunting territories. The first area is in the upper course of Yantra River, 'Muhnatite skali' and 'Kurvina mogila'. That pair was observed flying with a juvenile eagle both in 2012 and 2013 years. The second territory lies in Kozya River valley – Golden eagles were observed there on 18.05.2013. One adult bird seen in flight over Sokolski Monastery on 30.06.2012 probably originated from the same pair (Rosen Tzonev – pers. communication). Occupied nests of the species were not found. Possibly the Golden eagles nest at the southern rocky slopes of Shipchenska Mt. or on a tree in the old beech forests.

In the neighbouring to ‘Bulgarka’ NP forest enterprise ‘Mazalat’ one subadult Golden eagle was observed on 2.05.2017, at 1.4 km to the west of NP borders.

In the past the species was observed at Shipka pass during the breeding period (Baumgart 1971).

Peregrine falcon (*Falco peregrinus*)

The species was observed on 31.03.2013 in the central parts of NP. During April, 2012 the species has been recorded on a rocky slope in close vicinity to the place of our observation (Georgi Stoyanov – pers. communication).

Hobby (*Falco subbuteo*)

One pair was recorded in May, 2013 to the south of Brezhnitsite village close to the road for Krustets. The birds occupied a nest on an electric pylon, most probably built by a pair of Ravens breeding at a neighbouring one. The breeding was unsuccessful, without detected reason for its failure.

Hazel grouse (*Tetrastes bonasia*)

The species was not observed during the present study. In April, 2012 some feathers and excrements were found in a young beech forest to the north of ‘Muhnatite skali’ area. One individual was seen by Yulian Marinov in September, 2012 to the north-east of ‘Golemia Vis’ peak (1117 m a.s.l.) in a beech forest (pers. communication). In the same area tracks of a Hazel grouse were found on snow on 05.12.2012 and 03.02.2013. These facts proved that single specimens of the species enter the territory of the NP very rarely, mostly in its southern parts and supposedly more often out of the breeding period.

Corncrake (*Crex crex*)

Breeding species in wet and mesophilic meadows. Most of the localities are situated in the low parts of the studied territory (Fig. 1). The total number of the registered singing males was 20, grouped at 11 localities. In the western parts of the NP 9 males were recorded at 4 places – at Zeleno Durvo village, at ‘Uzana’ hut, in the lower course of Panicharka River and at meadows above Radetski village. In the central parts the species was encountered only at one locality with two singing males – to the north of Ezeroto village. In the eastern parts of the park nine males were recorded at six localities – at the villages Dragnevtsi, Prestoy, Radevtsi and Mruzetsite, to the south of Velchovtsi village and between Prestoy and Stanchov Khan villages.

Eurasian woodcock (*Scolopax rusticola*)

The species was found at three localities in beech and mixed forests bordering to mesophilic meadows. In each locality only single mating male was observed during the late evening hours – at peak ‘Golemia Vis’, on 31.03.2013, in a mixed beech-scots pine forest; at peak ‘Chereshata’, in the easternmost part of the studied ter-

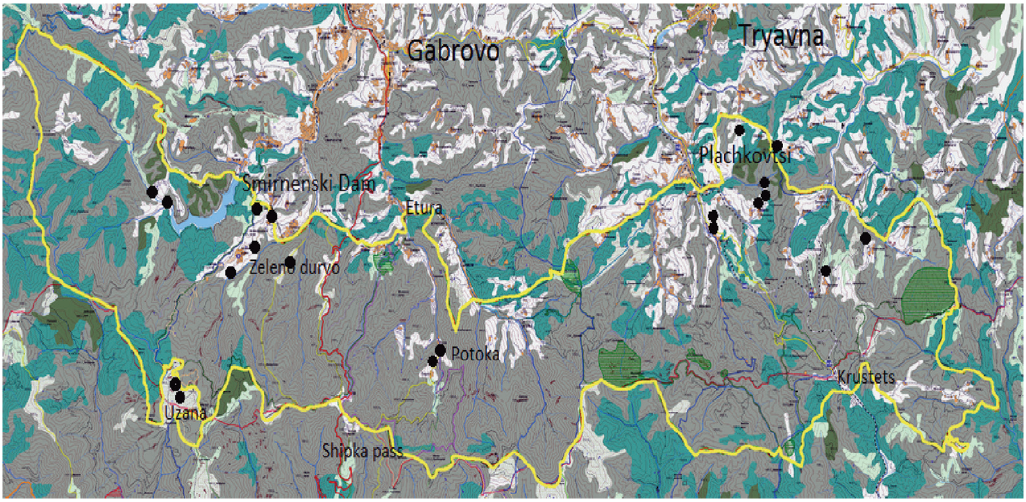

Fig. 1. Map of Corncrake (*Crex crex*) breeding localities (black spots).

ritory, on 01.04.2013 – over a beech forest mixed with some pine plantations and at 'Bulgarka' hut – flying over old beech forest. Out of the breeding season Woodcocks were seen in the basins of Sivyak and Byala rivers, in the area between 'Golemia Vis' and 'Bulgarka' hut, at 'Shipka' pass and in an area to the northwest of Radevtsi village.

Stock dove (*Columba oenas*)

The species was observed only once during the field studies – on 18.06.2012 in the area 'Moravata', in the basin of Kozya River. Several times the species was seen also during the autumn period – from September to November, probably autumn migrants. The species is on the edge of extinction as a breeder in 'Bulgarka' NP as well as many other parts of Bulgaria.

White-backed woodpecker (Lilford's) (*Dendrocopos leucotos lilfordi*)

Widely distributed species but only in old forest stands (Fig. 2). It prefers old beech forests, in deep river (stream) basins. A total of 34 pairs were found. The highest number was registered in the basins of Plachkovska and Panicharka rivers. In the western parts of the NP 14 territories were found, in central – 4 and in the eastern parts – 16 territories. Probably the total number is 35–40 pairs. At every 420 ha forest territory lives one pair White-backed woodpecker and the total density is 0.24 pairs/100 ha. Taking into account that the average size of the territory of White-backed woodpecker pair is 100–150 ha (Spiridonov and Virrkala 1997) it means that about 1/3 of the potential habitat in NP is occupied by the species. The altitude of the localities varied between 560 and 1232 m a.s.l., on average – 881 m a.s.l. (n=34). They were situated mostly on northern, northeastern and northwestern slopes where the oldest forest in the studied area grows (see Table 3).

Middle spotted woodpecker (*Dendrocopos medius*)

Rare breeding species, found in low number. It was recorded in low altitude forests

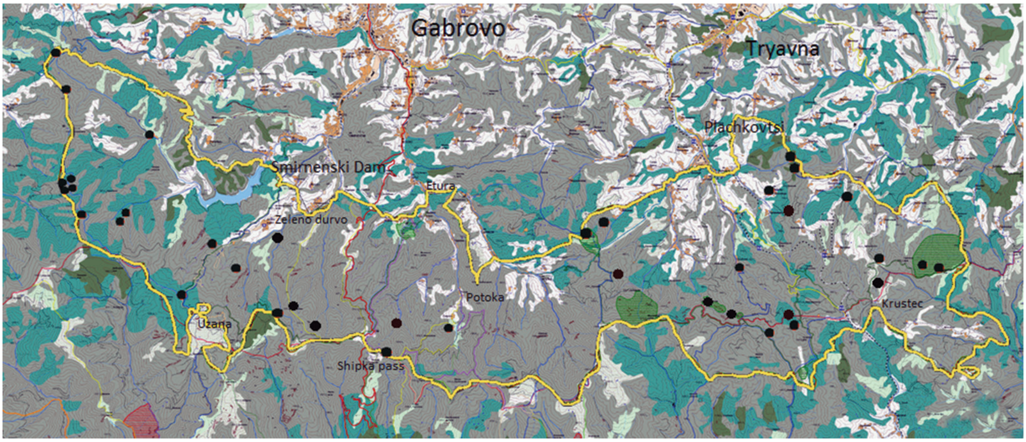

Fig. 2. Map of the recorded breeding localities (black spots) of White-backed woodpecker (*Dendrocopos leucotos lilfordi*).

Table 3. Slope exposure of White-backed woodpecker (*Dendrocopos leucotos lilfordi*) localities.

Exposure	Number of cases	Share, %
Northeastern	9	33,3
Northern	5	18,5
Northwestern	4	14,8
Eastern	4	14,8
Southern	1	3,7
Southwestern	1	3,7
Southeastern	1	3,7
Flat area	2	7,4
Total	27	100

with significant presence of oak, hornbeam and wild cherry. During the breeding period only seven localities were found – in Panicharka River basin, in an area to the east of ‘Bulgarka’ hut, between ‘Hlebna’ hut and ‘Uzana’ hut (22.05.2013), at Radevtsi village, between Potoka village and peak ‘Buzludhza’, in ‘Studen kladenets’ protected area and close to ‘Smirnenski’ damlake. In autumn (15.11.2012) the species was registered also above Gaydari village. The number of the Middle spotted woodpecker’s pairs in the NP probably is not more than 10–15 pairs.

Grey-headed woodpecker (*Picus canus*)

Widely distributed and well-presented species. A total of 23 pairs were located. According to river basins they were found as follows: Plachkovska River – 6 pairs, Panicharka and Borushtitsa Rivers – 4, Levicharka River – 3, Stanchovhanska River – 2, Borushtenska River – 2, Zelenishka River – 2, Yantra River – 1, Kozya River – 1, Gabrishtitsa River – 1, others – 1. The total number of the species should be estimated at 30–35 breeding pairs.

Black woodpecker (*Dryocopus martius*)

The species is distributed everywhere on the studied territory except in the youngest forest stands (<50 years of age). Practically all territories offering appropriate habitat are occupied by the species. The number can be estimated at around 50 pairs, on average one pair at each 340 ha forest habitat. It lives in all forest habitats, mostly in beech and mixed forests, but in all cases it needs a presence of old, thick trees in the stand.

Red-breasted flycatcher (*Ficedula parva*)

Rare species, distributed sparsely and unevenly in the oldest (over 80 years) beech and beech-hornbeam forests (Fig. 3). The total number of the registered occupied territories was 24. The overall number of the species in the studied area can be determined at 80–110 pairs taking in account that in large areas of beech habitat the species does not nest at all. The population density is about four times lower compared to the Semi-collared flycatcher and varies between the different parts of the NP from 1.1 to 5.5 pairs/100 ha, on average – 3.2 pairs/100 ha. The highest density of the species was recorded in the valleys of the rivers Panicharka, Zelenishka and Belilshka. The localities lied at altitudinal belt 604 – 1208 m a.s.l., on average 879 m a.s.l. (*n*=21).

Semi-collared flycatcher (*Ficedula semitorquata*)

The species is widely distributed and locally abundant in beech and beech-hornbeam forests over 65–75 years. It was recorded in all parts of the NP where such habitats exist. In total 85 occupied territories were mapped (Fig. 4) and the expected number for the whole studied territory can be estimated at 150–300 pairs. The biggest part of the localities were situated in the basins of rivers Kozya, Plachkovska, Stanchovhanska, Panicharka and Levicharka. In these five basins were situated about 66 % of all found localities of the species. The breeding density varied between 7.5 and 24.3 pairs/100 ha of optimal habitat, on average 13.5 pairs/100 ha (Fig. 5). Highest density was calculated for 'Studen Kladenets' protected area were logging is prohibited and in the basins of Panicharka and Kozya river. High density of the species was found also in the beech forests to the west of 'Bulgarka' hut. The altitudes of the localities varied between 549 and 1260 m a.s.l., on average 991 m a.s.l. (*n*=80). The forest stand age varied between 65 and 130 years, on average 92.7 years (*n*=24). The percent of the standing dead trees in the stands around the localities varied between 1 and 17.5 %, on average 7.5 % (*n*=20).

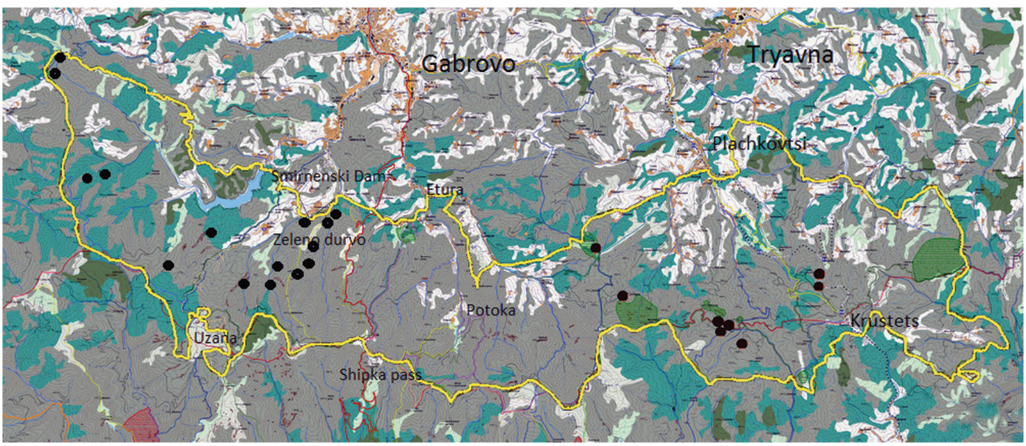

Fig. 3. Map of Red-breasted flycatcher (*Ficedula parva*) breeding localities (black spots).

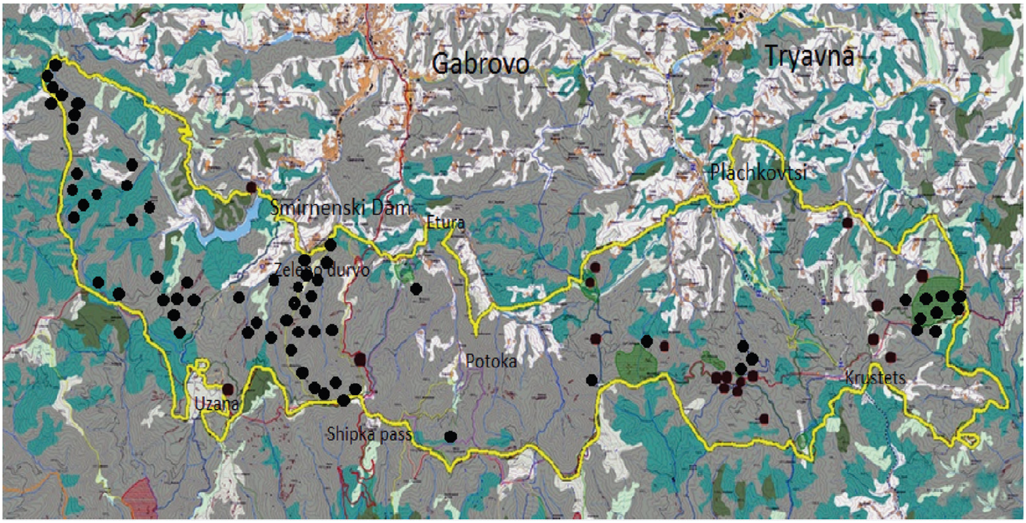

Fig. 4. Map of Semi-collared flycatcher (*Ficedula semitorquata*) breeding localities (black spots).

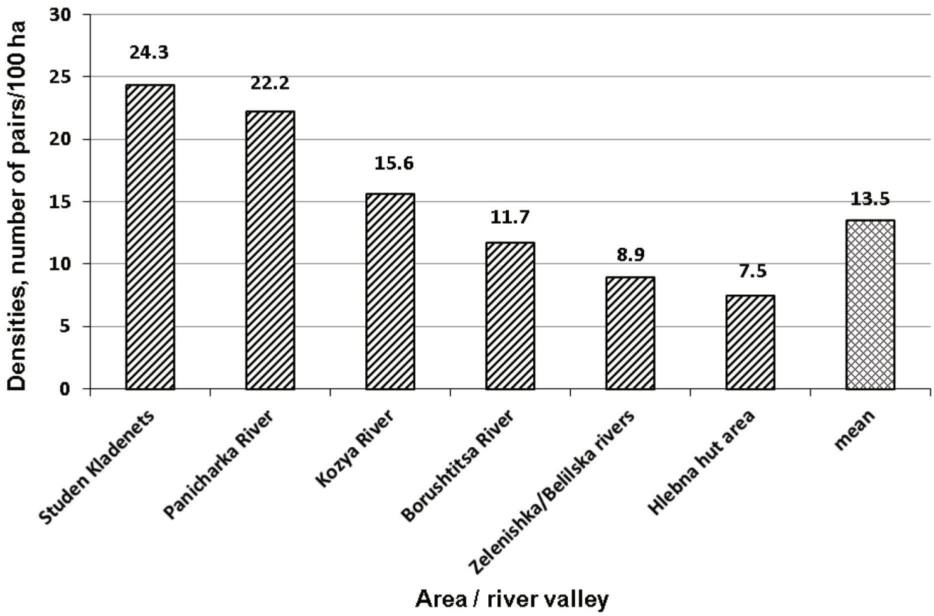

Fig. 5. Breeding densities of Semi-collared flycatcher (*Ficedula semitorquata*) in different parts of NP ‘Bulgarka’ (number of pairs/100 ha).

Breeding densities of common bird species

Overall densities of the breeding birds calculated along two transects in mature beech forests with presence of Scots pine trees are presented in Figure 6. Two dominant species with highest values of their population density were Robin and Common chaffinch. As subdominants can be considered Blackcap, Common chiffchaff, Song thrush and Semi-collared flycatcher. Some species characteristic for coniferous forests were also recorded – Goldcrest, Coal tit and Firecrest.

Conservation status of the recorded bird species

Avifauna of 'Bulgarka' NP includes high number of species of conservation concern. From a total of 164 bird species 146 (89 %) are protected by law on national level, 46 species (28 %) are included in Red Data Book Bulgaria (Golemansky et al. 2015), 44 species (26.8 %) are listed in Annex I of the European Bird Directive, 153 species (93.3 %) are included in Bern Convention, 46 species (28 %) are included in Bonn Convention for the protection of migratory species of animals, 30 species (18.3 %) are listed in CITES Convention regulating the trade with endangered species of flora and fauna and three species (1.8 %) are globally threatened, listed in categories above 'Least Concern' of IUCN Red Data List (Pallid harrier, Spotted eagle, Rock partridge).

Discussion

Among the faunistic findings we can mention the record of a pair of Goosanders possibly breeding in 'Smirnenski' damlake. Its shores offer good habitat for breeding of the species – old forests and some small rocks. The only known breeding locality of that species in Bulgaria until now is in 'Kurdzhali' damlake, Eastern Rhodopes where they were found with nestlings annually since 2011 (Borislav Borisov and Ivailo Angelov – pers. com-

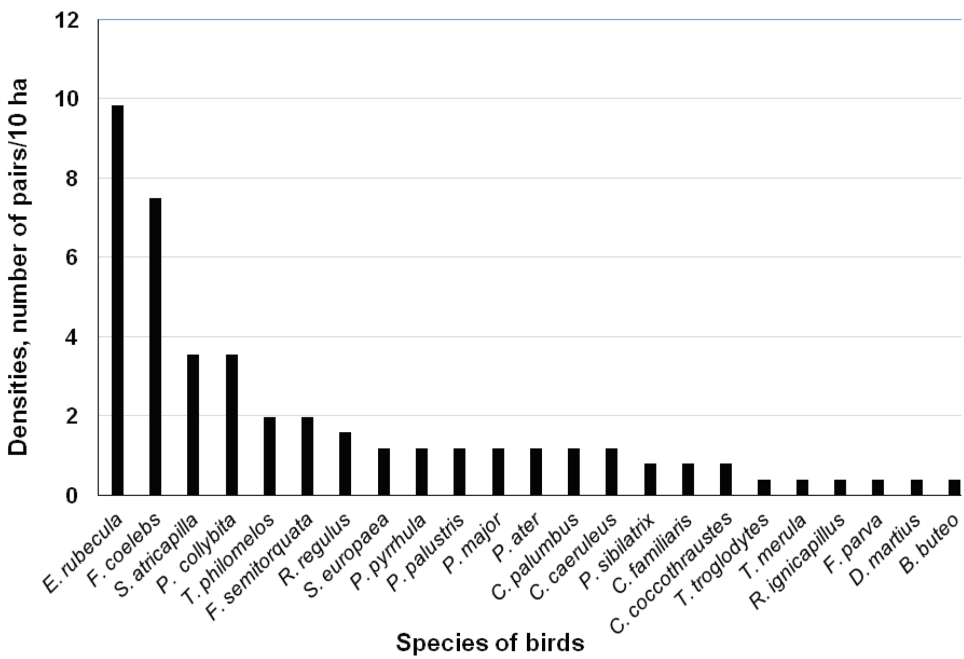

Fig. 6. Densities of breeding birds in mature beech forest with some Scots pine trees in the eastern part of 'Bulgarka' Nature Park (number of pairs/10 ha).

munication). During the last decades the species showed significant progress of its breeding population on the Balkans and in Southeastern Europe, especially on the territory of Serbia, Greece and FYR of Macedonia (Marinkovic et al. 2008, Catsadorakis et al. 2016). In FYR of Macedonia and Greece Goosanders breed in Prespa and Ohrid lakes where the population of 18–29 pairs was found and it showed a positive trend in number (Catsadorakis et al. 2016). In Serbia it was found to nest in a number of large artificial lakes and big rivers (Marinkovic et al. 2008; Drazenko Rajkovic, Milan Ruzic and Dimitrije Radisic, Bird Protection and Study Society of Serbia – pers. communication), mostly in the western parts of the country. It can be supposed that soon Goosanders will colonize other places on Bulgarian territory especially the large artificial lakes in the Rhodopes as 'Dospat, 'Krichim', 'Vucha', 'Batak', 'Golyam Beglik', 'Shiroka Polyana', 'Borovitsa', 'Studen Kladenets' and 'Ivailovgrad'.

In the past Hazel grouse has been widely distributed and quite often observed in Central Stara Planina Mts. It was seen in the mountain forests along the upper Yantra River basin (Reiser 1894). In the second half of 20th century it was appointed as quite rare sedentary bird in Central and Eastern Stara Planina Mts. and it was recorded in an old beech forest above Enina village, Kazanluk municipality – to the south of the present borders of 'Bulgarka' NP (Donchev 1974). Nowadays the presence of the species is confirmed in 'Tsarichina' nature reserve (situated in 'Central Balkan' National Park) and some neighbouring forests close to it (Stoyan Hristov and Rosen Tzonev – pers. communication). In the Atlas of the breeding birds of Bulgaria it is stated that Hazel grouse still lives in Stara Planina Mts. from 'Chuprene' nature reserve to the west to Kotlenska Mt. to the east, including one 10×10 km UTM square in 'Bulgarka' NP with probable breeding (Gerasimov et al. 2007). Probably the rare records in 'Bulgarka' NP represent birds from the population of 'Central Balkan' National Park. During their seasonal movements they most probably leave their breeding territories and reach lower parts of the mountains in eastwards direction. In our opinion there is no vital, self-sustainable population of Hazel grouse in 'Bulgarka' NP.

Woodcock is already extinct from the most of the territory of Bulgaria and its national population was recently estimated at not more than 30–100 or 200–400 breeding 'pairs'/territorial males (Nikolov et al. 2007, Shurulinkov et al. 2015b). In Central Stara Planina Mts. it was observed on 11.06.1963 in an oak-hornbeam forest over the town of Klisura (Donchev 1974). Female Woodcocks with well-developed eggs in ovarium were shot at Kesarevo village, Veliko Turnovo district in spring 1937 – at 40 km northeast from the present borders of 'Bulgarka' NP (Dumanov 1937). The localities found during the present work showed that despite Woodcock is rare, it still nests in these parts of Stara Planina Mts. Because of the early dates of these observations we cannot fully exclude the possibility that part of these displaying males or all of them were spring migrants. Usually the Woodcock starts its display flights in most of its Southern European breeding localities during the last decade of March and the first half of April (Cramp 1983). Thus we consider the breeding of the species in the studied territory as very probable.

In the middle of 20th century Stock dove has been comparatively common in the old oak and beech forest in the whole Central Stara Planina Mts. (Donchev

1974). But as regards the data gathered in the present study it has decreased drastically. This trend is valid for almost all the territory of Bulgaria (Spiridonov 2015).

White-backed woodpecker showed quite a high number and density in the studied territory. That population is naturally tied and it is a part of the well-known core population of the species in 'Central Balkan' National Park. In that core area about 100–150 breeding pairs were found in 28,808 ha of old beech forests (Anonymous 2018), which corresponds to an average density of 3.47–5.2 pairs/1000 ha. In 'Bulgarka' NP the density calculated for the White-backed woodpecker was lower – 2.38 pairs/1000 ha, which can be explained with the lower average age of the forests and much more active forestry activities. Further to the east, in different parts of Eastern Stara Planina Mts., the species is even scarcer and with much lower density despite the presence of optimal habitats (Girgina Daskalova and Peter Shurulinkov – unpublished data). Higher population densities of the White-backed woodpecker were calculated in mixed forests in the Carpathians – 30 pairs/1000 ha (Balaz and Balazova 2012), in Lithuania – 12 pairs/1000 ha (Brazaitis and Pėtelis 2010), in Strandzha Mt., SE-Bulgaria – 7.92 pairs/1000 ha (Shurulinkov et al. 2015a), in Poland, Białowieża forest – 5 pairs/1000 ha (Pugacewicz 2011), in Western Pyrenees – 3.8 pairs/1000 ha (Fernandez and Azkona 1996).

In the past White-backed woodpeckers have been registered at Shipka pass (Jordans 1940), on the nowadays territory of 'Bulgarka' NP.

The breeding density and number of the Semi-collared flycatcher in 'Bulgarka' NP is comparatively high – on average 13.5 pairs/100 ha, similar to the reported for the easternmost parts of Stara Planina Mts. – Eminska Mt. – 12 pairs/100 ha (Georgiev and Iankov 2009). Higher densities were recorded in the Bulgarian part of Belasitsa Mt. – 48.6 pairs/100 ha and in Kozyak Mt. in Southern Serbia – 37.5 pairs/100 ha (Nikolov et al. 2011, Ružić et al. 2011), but these two results were based on much smaller studied territories consisting mainly core zones with optimal habitat for the species.

Breeding density of Red-breasted flycatcher in 'Bulgarka' NP (on average 3.2 pairs/100 ha) also can be evaluated as moderate to high. In Germany its average population density was calculated to be 2.8 pairs/100 ha (Flade 1997) and in Russia it varied between 0.8 and 2.5 pairs/100 ha (Taylor 2006). In Poland, Białowieża primaveral forest, the species average population density is much higher – 12 pairs/100 ha (Tomiałojć et al. 1984).

From the species list of the birds formerly recorded in the studied area, six species were not registered during the present study and in our opinion can be accepted as extinct as breeders or as species with regular occurrence there. These are Griffon vulture, Capercaillie, Eagle owl, Crested tit, Chukar partridge and Alpine chough. Griffon vulture was successfully reintroduced during the last ten years in Vrachanska Mt. (part of Western Stara planiana Mts.) and in Kotlenska Mt. (in Eastern Stara Planina Mts.). It is very likely that birds from these newly established colonies pass over 'Bulgarka' NP during their wanderings between the different feeding places for vultures in Stara Planina Mts. Eagle owl was not recorded during the present study but due to its secretive activity and habitat it cannot be excluded that the species still lives in that area. Furthermore Eagle owl showed stable or increasing numbers in many parts of Bulgaria during the last 20 years (Peter Shurulinkov and Girgina Daskalova – unpublished data).

The closest to our study territory breeding localities of Alpine chough are in the high altitude rocky areas of ‘Central Balkan’ National Park (Stoyanov 2015). It is quite possible that separate birds or small flocks of that species can fly to the mountain meadows of ‘Bulgarka’ NP for feeding, especially out of their nesting period.

The three species showing highest population density in the present study were Robin, Common chaffinch and Blackcap. Similarly these three species were the most numerous dominants in beech-spruce and beech natural forests at Šutovska dolina, Mala Fatra Mts., Slovakia and Babia gora Mt. (Carpathians) in Poland but in much different ratios and densities (Kies 1991, Kornan and Adamik 2014). The Common chaffinch density in Slovak and Polish study is the highest – on average 13.9 pairs/10 ha and 22.1 pairs/10 ha respectively, which is much higher than in the present study (7.5 pairs/10 ha). Robin showed population density of 5.1 pairs/10 ha in Mala Fatra Mts. and 13.3 pairs/10 ha in Babia gora Mts. In ‘Bulgarka’ NP beech forests Robin was the most numerous species with a density of 9.8 pairs/10 ha. In all three compared forest bird communities Blackcap was on third place by population density showing very similar values of about 4 pairs/10 ha. Densities of two most common flycatchers in ‘Bulgarka’ NP and Mala Fatra Mts. were also quite similar – 2.0 pairs/10 ha for Semi-collared flycatcher in Bulgaria and 2.62 pairs/10 ha for the Collared flycatcher (*Ficedula albicollis*) in Slovakia.

Conclusions

‘Bulgarka’ NP has diverse avifauna including many species of high conservation importance. The high bird diversity (163 species) and conservation value of ‘Bulgarka’ NP can be highlighted when we compare the number of recorded bird species with other similar by territory and habitats protected territories or mountain areas in Bulgaria and SE-Europe – ‘Mt. Tara’ National Park, Western Serbia – 135 species (Jankovic et al. 2014), ‘Mt. Shar’ National Park, FYR of Macedonia – 130 species (Melovski et al. 2010), ‘Rila Monastery’ Nature Park, SW-Bulgaria – 122 species (Anonym. 2004), Bulgarian part of Osogovo Mt. – 111 species (Iankov et al. 2007), Vasilyovska Mt. – 108 species (Nikolov 2007).

Significant populations of Corncrake, Black woodpecker, Grey-headed woodpecker, White-backed woodpecker, Red-breasted flycatcher and Semi-collared flycatcher occur in the nature park. The most important habitat for most of these birds are the old beech forests. Their preservation and sustainable management is very important for ensuring a long-term stability in their population numbers and conservation status.

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RESPONSE OF SCOTS PINE (*PINUS SYLVESTRIS* L.), SUKACHYOV'S LARCH (*LARIX SUKACZEWII* DYLIS), AND SILVER BIRCH (*BETULA PENDULA* ROTH) TO MAGNESITE DUST IN SATKINSKY INDUSTRIAL HUB

Konstantin Zavyalov[1], Sergey Menshikov[1], Pavel Mohnachev[1], Nadezda Kuzmina[1], Anton Potapenko[2], and Sezgin Ayan[3*]

[1]Botanical Garden Ural Branch of Russian Academy of Sciences, Yekaterinburg, Russia.
[2]Institute of Forest of the National Academy of Sciences of Belarus, Gomel, Republic of Belarus.
[3]Kastamonu University, Faculty of Forestry, Silviculture Department, Kastamonu, Turkey.
[*]E-mail: sezginayan@gmail.com

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Abstract

Deforestation due to air pollution is a serious problem in industrial sites. Aim of this study was to evaluate the impact of magnesite dust on growth of Scots pine (*Pinus sylvestris* L.), Sukachyov's larch (*Larix sukaczewii* Dylis; Syn. *Larix sibirica* Ledeb.) and Silver birch (*Betula pendula* Roth) planted in soil plots between 1980 and 1983 in Satkinsky District, Chelyabinsk. The trees in zones of moderate and low pollution survived, while those in strongly polluted zones died with the exception of Silver birch in soils ameliorated with 12 cm thick peat layer. However, in the zone of strong pollution, coniferous species treated with only 2 cm thick peat layer and weak sulphuric acid solution, grew better than the Silver birch. Twelve centimetres of peat layers could mitigate dust impact on Silver birch, while their 2 cm thickness was not adequate. The dust pollution hit the plants at strongly polluted sites more severely than those at sites with moderate and low pollution. Silver birch and Scots pine trees were more severely impacted by dust pollution compared to Sukachyov's larch trees. Soil remediation is needed in strongly affected areas. While soil remediation is not needed at moderately and low affected sites, these sites should be monitored to avoid their degradation.

Key words: conifers, reforestation, survive, technogenic pollution.

Introduction

Technogenic load is currently considered to be one of the most powerful factors (Ozel et al. 2015) destabilizing forest ecosystems (Isaev and Korovin 1998) and the plantation in urban areas, especially in temperate and boreal zones. The impact of chronic technogenic air pollution near large industrial centres severely affects the plants in these areas; thus, plants cannot fulfil their aesthetic and air-cleaning role. Decreased productivity of pine plantations on anthropogenically damaged forests has been reported in the Republic of Belarus. In that forest, Scots pine (46 %) and Silver birch (30 %) are the prevailing species as a part of natural regeneration, the presence of other species is insignificant (Potapenko 2014).

Plants in industrial centres clean the air, improve the microclimate and keep and inactivate toxic emissions (Grigoriev and Yurgenson 1982). However, long-term air pollution prevents reforestation (Guderian 1979, Smith 1985). It is emphasized that the main problem of applied ecology is to develop a system of parameters to reliably diagnose the initial stages of anthropogenic transformation of ecosystems and critical conditions of their dynamics. It is closely connected with questions of setting ecological standards for anthropogenic loads. Many studies have been carried out on technogenic pollutions (Guderian 1979, Smith 1985, Burton 1986). The Satkinsky District, Chelyabinsk is such a highly polluted area.

The main air pollutant in this area is the magnesite dust, which is highly alkaline (approximate pH 10) and mostly comprises magnesium oxide that breaks down to form $Mg(OH)_2$. The pollution in this area is thus alkaline. Previous studies have been conducted on magnesite pollution (Zavyalov and Menshikov 2009), elevated phytomass (Zavyalov and Menshikov 2010), the morphological and chemical composition of leaves of pilot plantations (*Betula pendula* Roth) (Zavyalov 2013), reproduction (Mohnachev et al. 2013, Mohnachev 2014), quality of seeds and seed posterities (Makhniova et al. 2013, Makhniova and Mohnachev 2014) of pilot plantations (*Pinus silvestris* L). These studies suggested the need for reforestation by cultivating pollution-resistant species.

The aims of this research were i) to evaluate the response of Scots pine (*Pinus sylvestris* L.), Sukachyov's larch (*Larix sukaczewii* Dylis; Synonym of *Larix sibirica* Ledeb.), and Silver birch (*Betula pendula* Roth) woody plants, exposed to different levels of magnesite dust and ii) evaluate the effect of peat thickness in mitigating impact of magnesite dust on the Scots pine, Sukachyov's larch, and Silver birch.

Material and Methods

The research area is near the town of Satka, Chelyabinsk Region, Russia (55°04'N, 59°03'E) (figs 1 and 2). The area of Satka is located in the central sub-belt of the southern boreal forests of South Ural (Kolesnikov 1969). The study area comprises experimental sites (ES) comprising polluted zones at different degree; one highly polluted zone (ES No 2), two moderately polluted zones (ES No 5–6), one low polluted zone (ES No 3) and one slightly polluted zone (ES No 4, conditionally controlled site) (Menshikov 1985).

All experimental sites have similar plant species and vegetation conditions, except the sites ES 3 and ES 6 where soil fertility is better than the others.

Two and 12 cm thick peat layers were mixed with nitrogen–phosphorus–potassium (NPK) fertilizers and diluted sulphuric acid solution to decrease pH of ES2. Ploughed soil of ES 2–4 and 5–6 were milled and mixed (Menshikov 1985). All surveyed sites are situated northeast of the source of emissions and along the main path of the dust.

The breast diameters of trees (DBH) on experimental site were measured with an accuracy of 0.1 cm. The height of the trees was measured with a Haglof altimeter with an accuracy of 0.20. The comparisons were made by F-test for the height and the breast diameter obtained from the treatments. The visual assessment of the extent of air pollution was carried out according by technique (Anonymous 1994). In each tree, the defoliation of the crown and its current state were recorded and damage of the forest stand was charac-

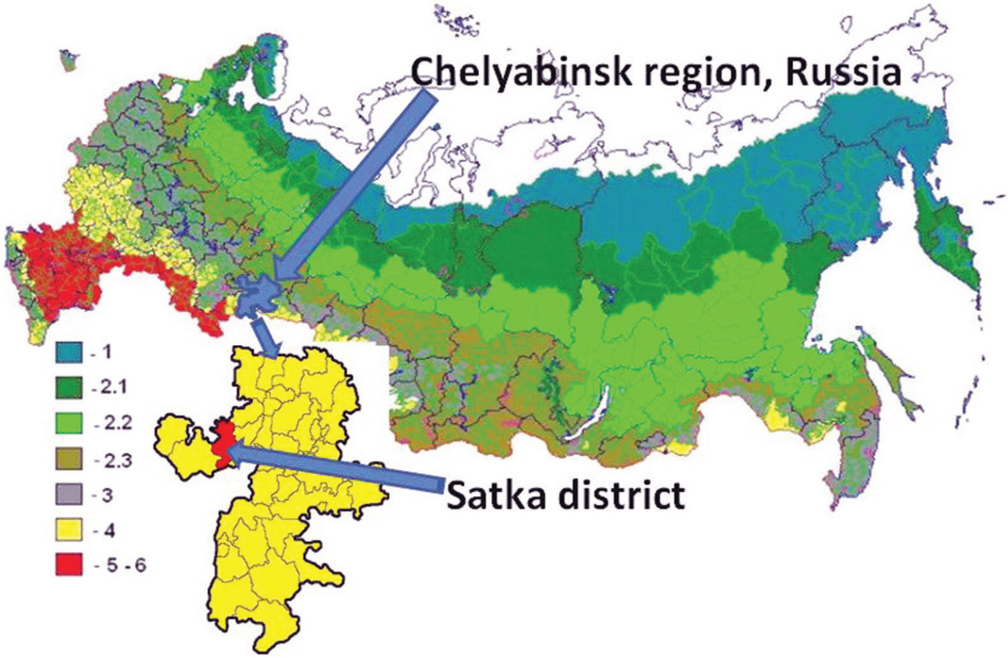

Fig. 1. Location of the study area.

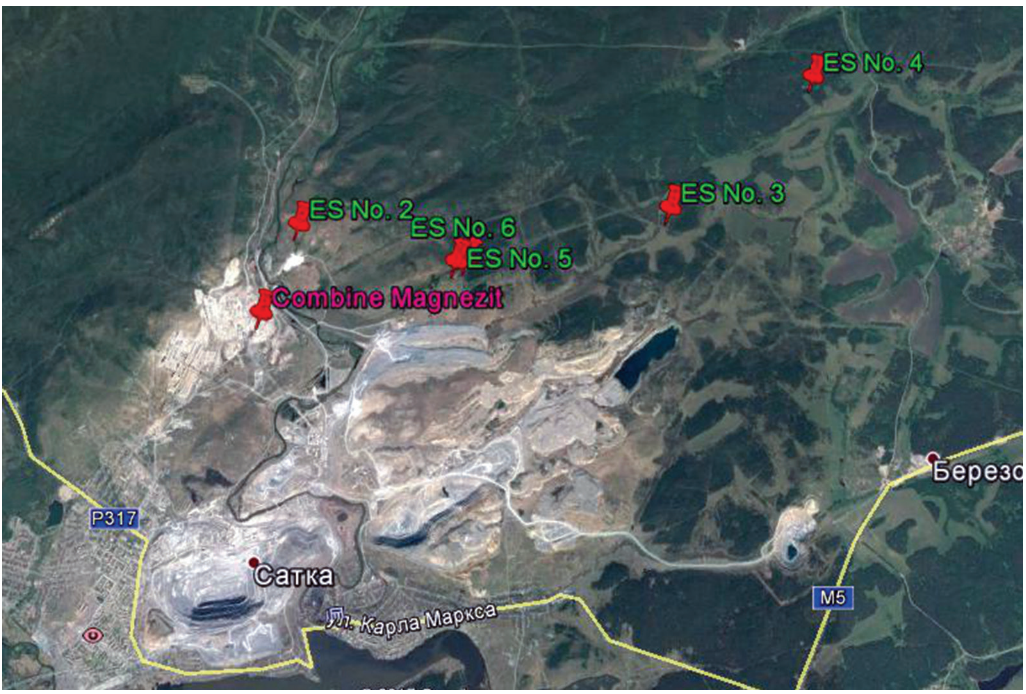

Fig. 2. Location of experimental sites and Combine Magnezit.

terized after Menshikov (2001) (Table 1).

Table 1. Scale used in determination of tree defoliation in different damage groups (Menshikov 2001).

Damage	Mean defoliation, %
Background	0–20
Low	21–40
Average	41–60
Heavy	61–99

Integral classes based on the account of morphological bio-indication signs of tree damage were used to assess the vital state of the stand. As a result of forest pathological research, a system of correct and objective criteria was developed, such as the status category, damage classes, life scores (Menschikov 2001).

The status of trees can be defined in six classes:

1. Background (without signs of damage). Degree of defoliation is 0–20 %.

2. Low. The degree of defoliation is 21–40 %. The life span of pine needles is reduced by 20–30 %.

3. Average. The degree of defoliation is 41–60 %. The life span of pine needles is reduced by 31–50 %.

4. Heavy. Degree of defoliation is 61–99 %. The life span of pine needles is reduced by 50–75 %.

The index of damage to the stand on the site was calculated as the average of the categories (classes, points) of the state of 100 to 120 main-tree trees counted on the experimental site.

Equation (1) was used in the calculation:

$$Ip = \frac{n_1K_1 + n_2K_2 + ... + n_6K_6}{N} \quad (1),$$

where:

n_{1-6} is number of trees I, I–IV category (damage classes);

K_{1-6} – the points of the living condition of the categories of trees corresponding to the category number (damage class);

N – the total number of recorded trees on the sample area.

In mixed stands, the damage index was determined separately for each breed. Then a general index was calculated, the average for each of them.

The life expectancy of the pine needles was made by a visual estimate of the shoots, based on the number of interned internodes. Escape from the fully preserved needles is taken equal to unity, with a partially preserved one – to the tenth parts of the unit. The age limit was determined by summing all the values. Observations were made on 15–20 tree shoots in the upper third of the crown (Gruber 1988).

Results

The trees in moderately and low polluted zones had survived for 30 years, whereas those in strongly polluted zones died, with the exception of Silver birch in soils with 12 cm thick peat layers (Fig. 3).

Peat layers of 12 cm thickness, fertilizer NPK, a low acid solution (H_2SO_4) were added to the soils prior to planting of Silver birch, Scots pine, and Sukachyov's larch in the strongly and low polluted zones (Fig. 4). For Silver birch was another variant with a peat layer 12 cm. This is done primarily to acidify the soil.

The tree growth suggests that the mean diameter of the Silver birch in soils with the 12 cm thick peat layers is not significantly different compared to the diameter of the larch in soils treated with acid and that of the Scots pine in soils with 2 cm thick peat layers, while the mean height of the Silver birch trees is 43 % and

Fig. 3. Silver birch in strongly polluted soils treated with 12 cm thick peat layers.

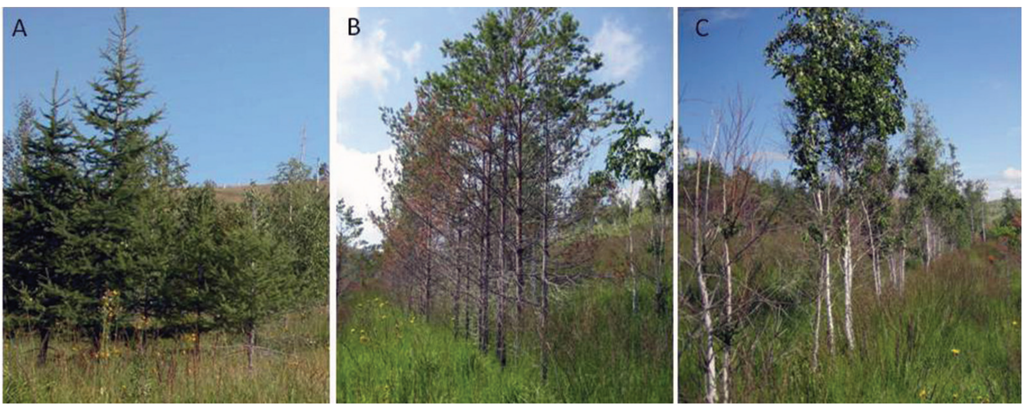

Fig. 4. The experimental plots in the strongly polluted zone: A) Sukachyov's larch in soils treated with diluted H_2SO_4 solution; B) Scots pine in soils treated with 2 cm thick peat layer; C) Silver birch in soils treated with 2 cm thick peat layer.

29 % higher than those of Scots pine and Sukachyov's larch, respectively (F = 3.99 and F = 3.67 with p < 0.001) (figs 5 and 6).

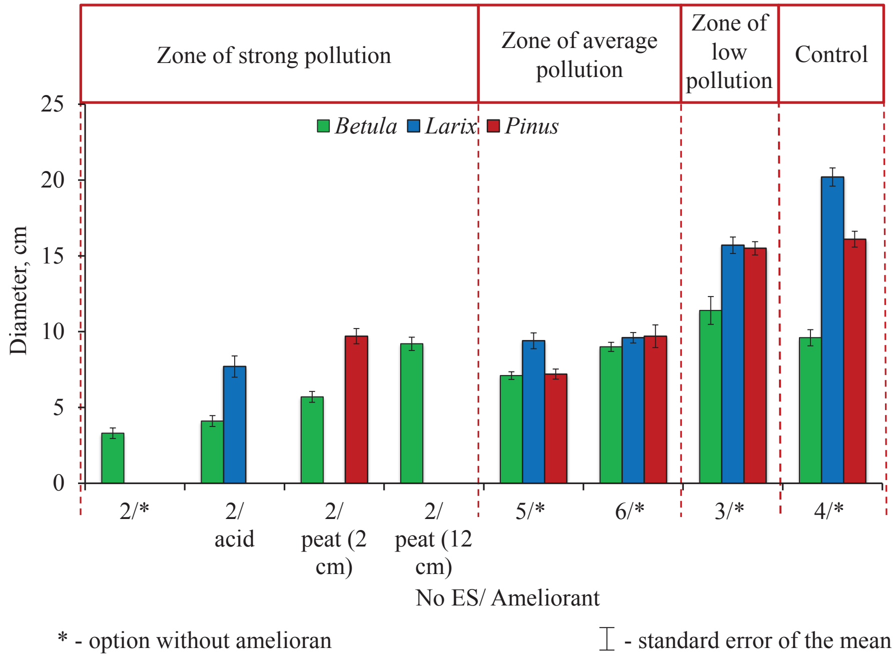

Fig. 5. Mean breast diameter of trees at the different experimental sites.

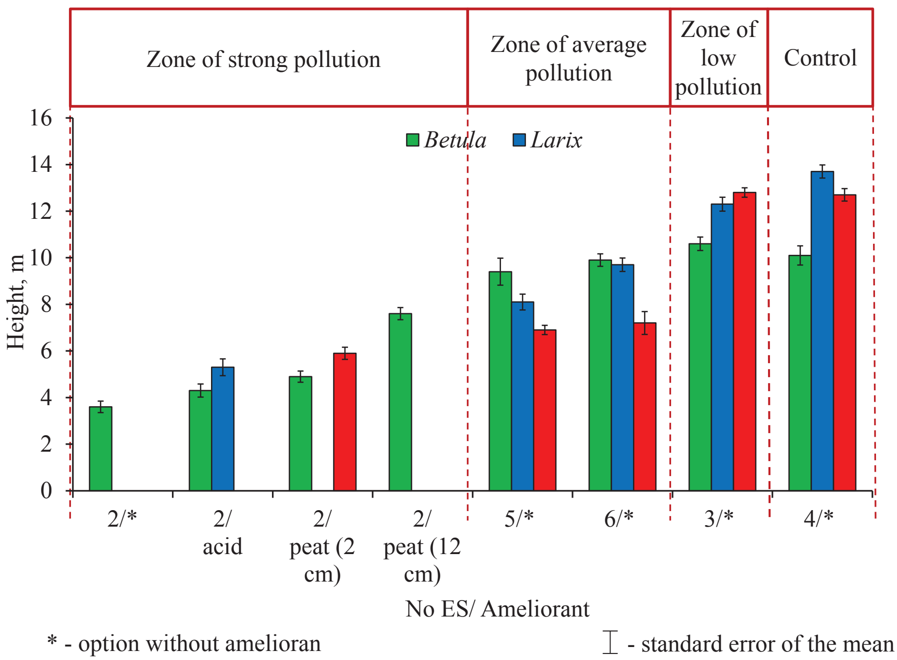

Fig. 6. Mean tree height at the different experimental sites average pollution.

Silver birch individuals survived only in soils with the 12 cm thick peat layers. The breast diameter of the stem increased 2.8 times (F = 9.23, p < 0.001) and the tree height increased 2.1 times (F = 10.2, p < 0.001). Silver birch and Scots pine data in soils with 2 cm thick peat layers suggest that the height and diameter of the pine individuals was 20 % (F = 2.46, p = 0.02) and 70 % higher (F = 6.34, p < 0.001) than those in the Silver birch individuals. The larch individuals in soil treated with the acid solution show increased growth compared with birch; the breast diameter is 88 % (F = 4.75, p < 0.001) and the height is 23 % higher (F = 1.89, p = 0.06). However, the larch individuals had smaller (26 %) diameter than the Scots pine (F = 2.40, p = 0.02). In the zone of strong pollution, the coniferous species grew better than the birch.

In the moderately polluted zone (ES 5), larch individuals showed the largest increase in the breast diameter; that is 32 % and 31 % higher than that of the birch and pine (F = 4.23, F = 3.48, p < 0.001), respectively. However, the differences in height among the different tree species are not significant in this zone.

In the zone of low pollution, the growth rate of larch individuals was higher than the Silver birch. The breast diameter of the former was 38 % higher than that of the later (F = 3.81, p < 0.001) and the height of the larch individuals was 16 % (F = 4.01, p < 0.001). In this zone, larch and Scots pine trees do not differ significantly in growth rate. At the control site, larch individuals grew most rapidly. Their diameter is 2.1 times thicker than that of the Silver birch (F = 13.14, p < 0.001) and 25 % thicker than that of Scots pine (F = 5.06, p < 0.001). The height of the Sukachyov's larch trees is 36 % higher than that of the Silver birch (F = 7.10, p < 0.001) but it is not different from that of the Scots pine individuals. Apparently, magnesite dust pollution did not hinder the growth of larch, but Silver birch and Scots pine trees.

The data suggest that air pollution resulted in all tree growth indicators to decrease in the ESs. In strongly polluted zone, the mean height of the Silver birch trees growth in the soil with 12 cm thick peat layer is 25 % lower (F = 4.71, p < 0.001) than that of the Silver birch trees at the control site, while their diameters were highly similar. However, mean diameter and height of the birch trees growth in soils with 2 cm thick peat layers were smaller than those in the same species at the control site (41 % and 51 %, respectively) (F = 4.68 and F = 8.21, p < 0.001) in the strongly polluted zone. For the Scots pine, in the same zone and soils, the diameter and height were 40 % and 54 % (F = 5.77 and F = 11.84, p < 0.001) smaller than those at the control site, respectively The diameter and height of the Silver birch trees in soils treated with acid solution in the strongly polluted zone are 20 % lower than the same species at the control site (F = 1.67, p = 0.10 and F = 1.88, p = 0.06), and smaller than the Sukachyov's larch trees (87 % and 23 %, respectively) (F = 4.75, p < 0.001 and F = 1.89, p = 0.06) in the strongly polluted zone. Clearly, tree growth is negatively affected by magnesite dust. Furthermore, the use of 12 cm thick peat layers in the soils mitigates the pollution impact on woody plant growth more than use of 2 cm thick peat layers.

Air pollution resulted in increased defoliation and decreased tree growth. Trees, closer to the source of emissions, are damaged most severely. In the zone of strong pollution, the pollution impacted Silver birch trees in soils without ameliorants 2.9 times and Scots pines in soils with 2 cm peat layers 3.2 times of those at control site. Sukachyov's larch trees are impacted in relatively lesser degree, 90 % more than those at the control site (Fig. 7).

In the strongly polluted zone, the pollution increased defoliation of pine trees by sevenfold and that of the birch trees fivefold, compared to those of same species at the control site (Fig. 8). Larch trees are observed to be the least and Scots pine trees the most damaged. The addition of peat to the soil mitigated the impact on the Silver birch. For example, the defoliation of birch in soils with 12-cm peat layers was 20 % less than that in soils without peat.

The amount of defoliation allows grouping the experimental plantations in Fig. 8. In the zone of strong pollution, Scots pine is heavily impacted, whereas birch trees are impacted moderately. In the zone of moderate pollution, Scots pine trees are into the moderately impacted group, whereas Silver birch trees are in the weakly impacted group. In the low pollution and control zones, these pine and birch species are into the background impacted group.

With increasing pollution, the lifespan of Scots pine needles is reduced by 40 % in comparison with the same species at the control site (Fig. 9).

Discussion and Conclusions

Relationship between soil and plants, under the influence of the accumulated aerial technogenic impact of emissions in areas of pollution, has been studied comprehensively for a long time. Snow water

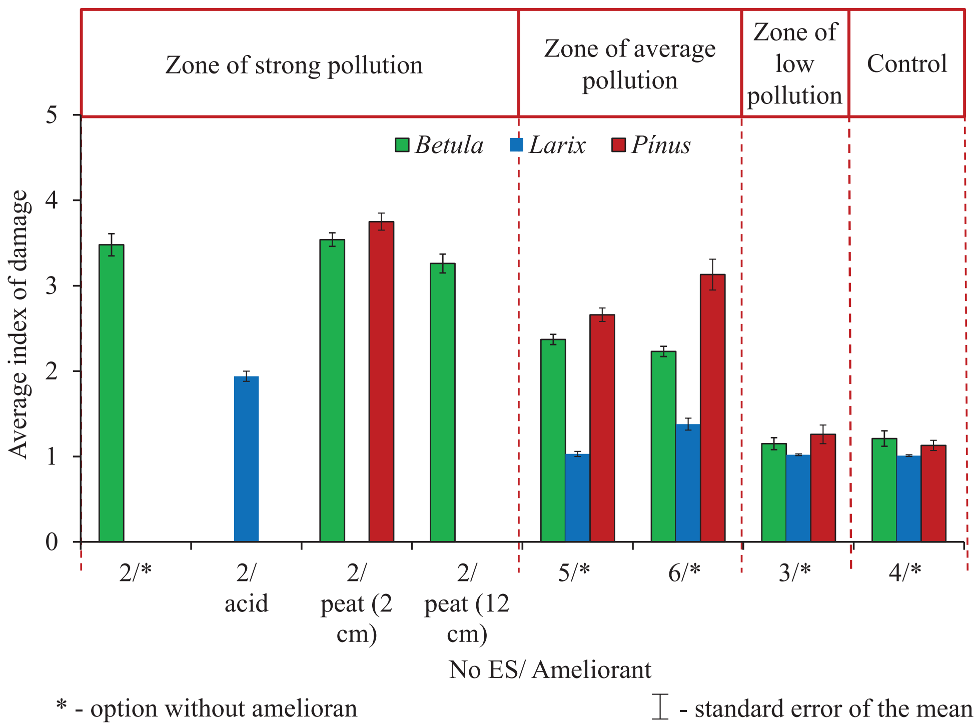

Fig. 7. Mean tree damage at different pollution zones.

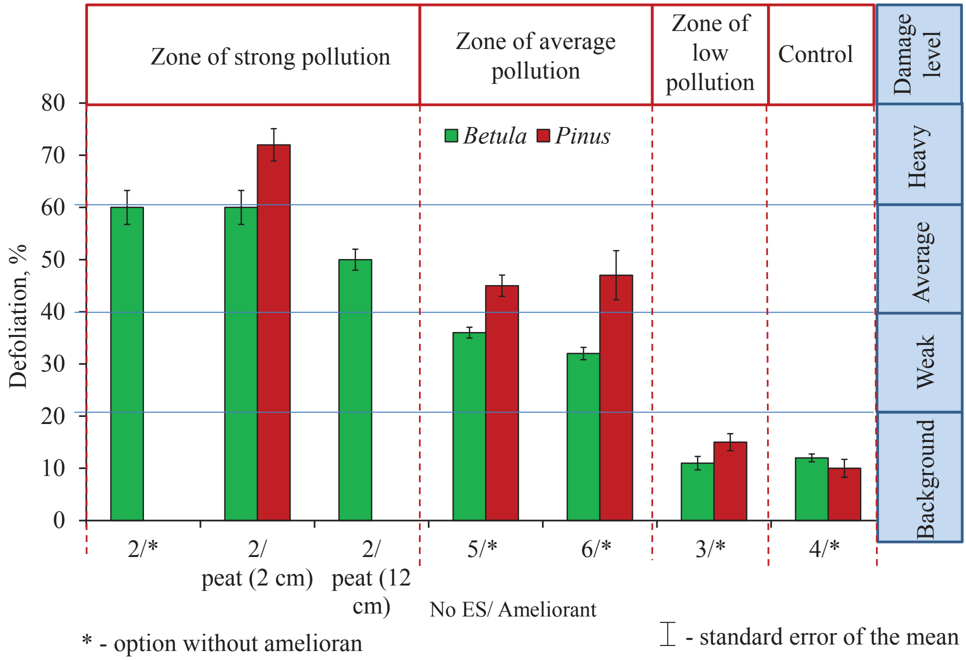

Fig. 8. Average defoliation in the different zones of pollution.

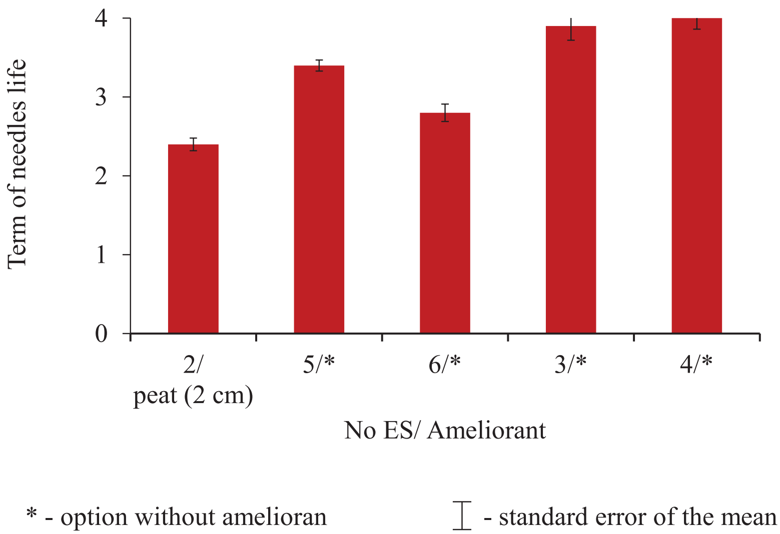

Fig. 9. Lifespan of the Scots pine needles as affected by rate of ameliorant.

is often used as an indicator of pollution at sites where snow cover stays for long winter period (6–8 months). Our study shows that snow water in the strongly (1 km from the source of exposure) impacted forest areas had suspended solids almost 15 times higher than those in low (10 from the source of exposure) impacted ones for 2012–2014 (Fig. 10).

The content of pollutants reaching up to 30 g/m^2 in the solid fraction (suspended solids) which caused strong destruction of the forest was due to the maximum pollution of air with particulate matter and mineralization of the snow cover.

The snow water was strongly alkaline due to strongly alkaline dust (pH > 10.0) deposited in the snow. The mean values of pH were between 9 and 9.5 in strongly polluted zones in 2012–2013 and was 8.9 in the low affected zones in 2014 (Fig. 11).

During the examination of the soil in areas of the Combine Magnezit (Table 2), a decrease of 0.2–0.6 was found in the pH level of the soil in the upper horizons of moderate and low impacted zones, while almost no pH decrease was observed on strongly polluted soils. Restoration of the polluted soils in this zone is extremely slow, even with a decrease or complete cessation of emissions due to low mobility of most metals in alkaline medium (Kuzmina and Menshikov 2015). Recovery of soils in areas of moderate and low contamination may occur more rapidly if the Combine Magnesite will reduce the volume of gaseous emissions (vapors of alkalis, sulphur dioxide and fluoride).

Our research showed that natural ratio among the elements in the soil adsorbents was disrupted in 1983, indicating that the magnesium was the principal exchangeable element at the soil adsorbents in strongly polluted soils (Fig. 12), and calcium in slightly polluted ones. However, the ratio of exchangeable cations changed in favor of calcium in strongly polluted soils in 2013.

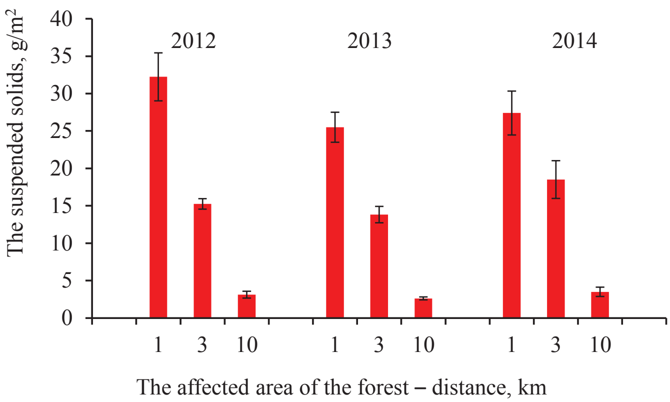

Fig. 10. Dynamics of suspended solids in snow water.

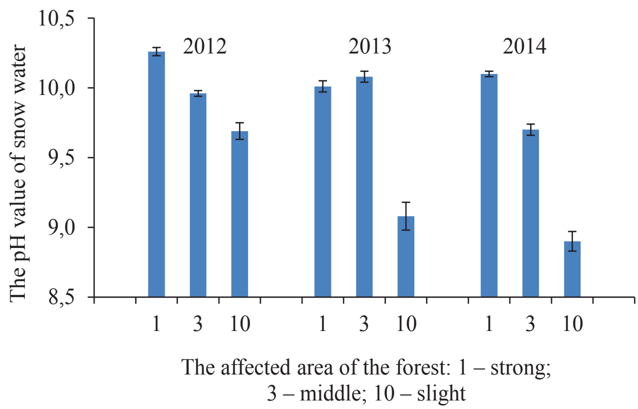

Fig. 11. pH of the snow water filtrates at strongly (1), moderately (3), and slight (10) affected sites in 2012–2014.

Table 2. Soil pH in different zones of magnesite contamination in the upper (0–10 cm) soil layer in different years.

Severity of pollution	Distance from the emission source, km	Soil type	pH (H_2O) soil by years				
			1983*	1990	2005	2008	2010
Strong (ES No 2)	1	Gray soils, light loamy	9.1	8.2	8.9	8.7	8.9
Moderate (ES No 5)	3	Gray soils, medium loamy	8.9	8.0	8.5	8.0	8.3
Moderate (ES No 6)	3.5	Dark gray soils, medium loamy	8.2		no data		7.8
Low (ES No 3)	5	Dark gray soils, light loamy	7.9	7.3	7.4	7.5	7.6
Slight (ES No 4, conditionally controlled site)	10	Gray soils, light loamy	7.7	7.0	7.6	7.2	7.3

Note: *Data are from Menshikov et al. (1987).

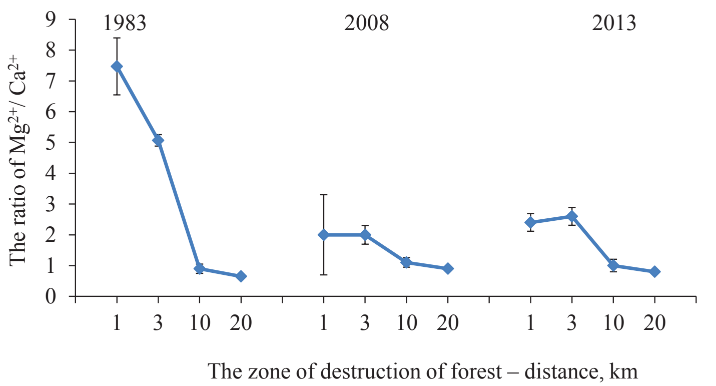

Fig. 12. Ratios of exchangeable Mg^{2+} to Ca^{2+} in soil of strongly (1), moderately (3), slightly (10) polluted and control (20) sites in 1983*, 2008 and 2013.

Note: *Data are from Menshikov et al. (1987).

We observed that reduction of solid emissions of the Combine Magnezit resulted in a partial recovery of soils in 30-year period as Mg and Ca ratio in the emissions decreased, resulting in reduced amounts of Mg accumulations in soils.

Scots pine, a widely distributed pioneer and important forest-forming tree, is characterized by high sensitivity to technogenic polluting agents (Mikhailova 2000). High correlation has been found between levels of SO_2, HF, and aerosols with heavy metals in polluted atmospheric air and accumulation of related elements such as sulphur, fluorine, lead, cadmium, mercury, etc. in pine needles (Mikhailova et al. 2003). Sazonova and Olchev (2010) emphasized that comparisons of the responses of *Picea obovata* Ledeb. and *Pinus sylvestris* L. trees to industrial pollution showed that a relationship between tree vitality statuses shown by visual traits and by physiological criteria was more evident for *P. obovata* than *P. sylvestris* trees. It can be expected that at the same pollution level, the life span of pollution exposed Siberian spruce would be shorter than that of the Scots pine trees at the same pollution level. Thus, spruce may be less resistant to pollution than pine trees. Decreased pH generally results in increased migration of pollutants from the soils. In parallel, revealed an increase of sulphur, fluoride, heavy metals in the tissues of woody plants (twigs, leaves) (Mikhailova et al. 2015).

Sulphur and lead make complexes with exchangeable calcium, magnesium, potassium, and sodium in soils, therefore, is reducing their availability for root uptake by plants (Mikhailova et al. 2007, 2015). Biogeochemical disturbances in forest ecosystems ultimately lead to changes in the nutrient status of major producers (woody plants) and reductions in their morphostructural parameters and overall growth characteristics (Mikhailova and Shergina 2011, Trowbridge and Bassuk 2004).

There are two points of view on the response of plants to elevated levels of magnesium in soils. Ions of magnesium carbonate have the same impact on the growth and development of plants as ions of soluble salts (Gedroits 1935). Altered nutrient flow affects magnesium ratio in plant cells, as well as the lack of a vegetative organism some other items. The result is a poorly developed root system in such soils. A reduction of bio-ecological quality of trees growing on soils containing more cations of magnesium was found – one grade lower (Rzhannikova 1972).

Excess calcium and magnesium and the ratio between them have little effect on the growth of pine trees, but have an indirect impact, shifting the pH to the alkaline side. At pH above 8 iron compounds are in the form of insoluble hydroxides and plants can’t use them (Wozbudskya 1964). Plant availability of P, Mn, Zn, Fe, Cu, B, and N is decreased as pH increases (Pokhlebkina and Ignatov 1983). The content of exchangeable magnesium in 36 % dramatically enhances the toxic effect in the soil, providing strong soil salinity caused by sodium (Orlovsky 1979). In this regard, the soil takes on the properties of alkalinity, becomes viscous, structureless. It is known that the exchange of magnesium is one of the main cations, and its availability depends on the cation-exchange capacity of the soil and the influence of competing cations Ca^{2+}, K^+, NH_4^+, Fe^{2+}, Al^{3+}. In addition, increased Mg concentration in the nutrient medium reduces the plant uptake of competing cations, primarily potassium and calcium.

Magnesite dust pollution impacted birch and Scots pine more than larch. The addition of 12 cm thick peat layers to the soil mitigated the effect of high air pollution and fosters tree growth. In moderately and low polluted sites, tree growth is affected less and soil does not require treatment.

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IDENTIFICATION OF VARIETIES AND GENETIC DIVERSITY OF DOUGLAS-FIR STANDS IN THE REGION OF OSOGOVO, SOUTH WEST BULGARIA

Asya Milenkova[1*], Monika Konnert[2], Barbara Fussi[2], and Krasimira Petkova[1]

[1]Department of Silviculture, Faculty of Forestry. University of Forestry. 10 Kliment Ohridski blvd., 1797 Sofia, Bulgaria. E-mails: media_media@abv.bg[*]; kpet@abv.bg
[2]Bavarian Office for Forest Seeding and Planting, Forstamtplatz 1, 83317 Teisendorf, Germany. E-mails: Monika.Konnert@asp.bayern.de; barbara.fussi@asp.bayern.de

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Abstract

Douglas-fir is one of the most frequently planted non-native coniferous tree species in the recent past in Bulgaria. Based on phenotypic and morphological characteristics, the Douglas-fir plantations in Bulgaria are attributed to the coastal variety (*Pseudotsuga menziesii* var. *menziesii*). Genetic studies on variety identification are missing. The aim of the present study was to assess the variety of four Douglas-fir stands in the region of Osogovo based on genetic markers (isozymes and nuclear microsatellites) and to determine their genetic diversity and differentiation. Both markers types clearly indicated that the investigated stands were of coastal variety. Genetic diversity values were similar or even higher compared to coastal Douglas-fir natural stands, indicating that the genetic variation in the artificial stands in Bulgaria is not significantly reduced. The high level of genetic diversity is a prerequisite for good adaptation and vitality of the studied plantations.

Key words: coastal variety, isozymes, nuclear microsatellites, *Pseudotsuga menziesii*.

Introduction

Douglas-fir is a coniferous tree species native to western North America – from British Columbia in the North, through California and the southern parts of Northern Mexico to the south. The British botanist Murray was the first that recognized in 1869 two geographically distinct groups of Douglas-fir, known as the coastal variety (*Pseudotsuga menziesii* var. *menziesii*) and the interior variety (*Pseudotsuga menziesii* var. *glauca* Beissn. (Franco) (Little 1979). In Bulgaria the coastal Douglas-fir is known as 'green', the interior – as 'blue' Douglas-fir. Literature particularly from Europe (e.g. Göhre 1958, Klumpp 1999, Fitschen 1987, Vidakovic 1991) sometimes mentions another interior variety *Pseudotsuga menziesii* var. *caesia* (Schwerin) Franco situated in the transition zone between coastal and interior variety especially in British Columbia. The coastal variety occurs from central British Columbia southward primarily along the Pacific Coast for about 2200 km, while the continental interior variety – along the Rocky Mountains into the mountains of southern Mexico over a distance of more than 4500 km (Eckenwalder 2009, Farjon 2010, Müller et al. 2012, Lavender and Hermann 2014). Both varieties, coastal and interior, differ morphologically and ecologically. Var. *menziesii* grows faster and is considerably larger in size than var. *glauca*, which is more shade tolerant, more cold-hardy, and more drought resistant (Eckenwalder 2009). Interior varieties (*glauca* and *caesia*) have high susceptibility to fungal diseases caused by the ascomycete fungi *Phaeocryptopus gaeumannii* (Rohde) Petrak and *Rhabdocline pseudotsugae* (Syd.) (Rohde) Petrak (Hood et al. 1990, Stimm and Dong 2001, Lavender and Hermann 2014).

Douglas-fir is one of the most frequently used non-native coniferous species in the recent past in Bulgaria. It was introduced in Bulgaria about a century ago, but it became widespread only in the late 1950s and during the 1960s (Petkova 2011). The French forester Félix Vogeli established in Bulgaria the first Douglas-fir plantation in 1906 with seeds of unknown origin at 700 m elevation in the Stara Planina mountain range.

At the same time single trees and groups of 'blue' Douglas-fir were introduced near Koprivshtitsa (Central Bulgaria), in the park Borisova Gradina (Sofia) and near Dolni Lozen (Sofia) (Ganchev and Prokopiev 1959, Vakarelov 1970). Vakarelov (1970) studied this variety mainly for the Sofia region (Borisova garden and Dolni Lozen) in relation to its use in parks and gardens. He recommended using it on the northern slopes in the oak altitudinal zone, on slanting seats with fresh and light soil. The same author (Vakarelov 1970) reported high level of phytoncide activity, with values from 12.5 to 93.7 formaldehyde units which prevents the growth of attacking organism or surrounding plant for 'blue' Douglas-fir, and therefore recommended to be used for landscaping on the grounds around hospitals.

Interior variety was introduced in Bulgaria also in provenance tests (Petkova et al. 2014, Popov 2014, Petkova et al. 2015). Damages caused by the ascomycete fungi *Phaeocryptopus gaeumannii* and *Rhabdocline pseudotsugae* were recorded in parts of these test plots (Petkova et al. 2014, Popov 2014).

The main part of the established Douglas-fir plantations in Bulgaria belongs to the coastal variety (*Pseudotsuga menziesii* var. *menziesii*), identified by phenotypic and morphological characters. Genetic similarities and differences between some provenances in provenance test and some of the older Douglas-fir plantations were determined using RAPD analyses of DNA (Chyzhyk et al. 2011), but detailed genetic studies for variety identification have not yet been performed in Bulgaria.

A clear differentiation of the coastal and interior varieties is possible with isozymes, nuclear, mitochondrial, and chloroplast DNA gene markers (e.g. Neal and Adamas 1985, Li and Adams 1989; Aagaard et al. 1995, Aagaard 1997, Aagaard et al. 1998, Klumpp 1999).

Isozymes (Lewontin and Hubby 1966) have been used in forestry to study the genetic variation within and between populations, population structure, phylogeny and mating systems in natural as well as artificial populations of different species (e.g. Mitton 1983, Hamrick and Godt 1989, El-Kassaby and Ritland 1996, Yeh 1979, Namkoong and Koshy 2001). The first range-wide investigation of the genetic structure of Douglas-fir was done by Li and Adams (1989) based on isozymes. Differentiation of coastal (var. *menziesii*) and interior (var. *glauca*) varieties of Douglas-fir was based mainly on the isozyme gene loci 6PGDH-A and PGM-A (Yeh and O'Malley 1980; El-Kassaby et al. 1982a, 1982b; Merkle and Adams 1987; Merkle et al. 1987; Klumpp 1999; Fussi et al. 2013). In Europe this method was applied to check similarities between Douglas-fir plantations and natural stands in North America (Stauffer and Adams 1993, Fontes et al. 2003), but also for variety identification of planted stands (Fussi et al. 2013). The development of nuclear microsatellite markers for Douglas-fir (Slavov et al. 2004, Krutovsky et al. 2009) offered new possibilities for a more precise classification of varieties (Fussi et al. 2013). Two of the microsatellite markers – PmOSU_3B2, PmOSU_4A7 are most efficient in distinguishing between the two varieties. If the allele 96 at locus PmOSU_3B2 and the allele 242 at locus PmOSU_4A7 have high frequencies, the variety is attributed to interior Douglas-fir, whereas in coastal Douglas-fir the frequencies of these two alleles are very low or equal to zero (allele is absent) (Fussi et al. 2013, van Loo et al. 2015). Thus, the combination of isoenzymes and nuclear microsatellites offers a more precise way for identification of variety.

Beside variety identification, the assessment of the genetic diversity within and among populations is an important issue especially for the artificially established Douglas-fir stands outside of the natural range of the species. Genetic diversity is the basis of adaptation. Thus maintenance of genetic diversity is important in tree breeding and improvement program to develop well-adapted tree populations and strengthen their useful traits and to ensure vitality of forests to resist to diverse biotic and abiotic stressors under changing and unpredictable environmental conditions (Porth and El-Kassaby 2014).

The aim of the present study was to identify the variety of planted Douglas-fir populations from Bulgaria based on isoenzymes and nuclear microsatellite markers and to assess their genetic diversity and differentiation.

Material and Methods

Plant material

Four plantations of Douglas-fir from the Osogovo subregion (Southwestern Bulgaria), were studied. The plantations are situated in the Forest Enterprises Rila monastery (R), Nevestino (N), Dupnitsa (Da) and Osogovo (Og) (Fig. 1). The four studied stands were planted in the middle of the 20th century with seeds of unknown origin. In total, samples from 192 individuals (Douglas-fir branches) were collected at the beginning of March 2016 (Table 1). In the stand R, the natural regeneration was also included in the study. Altogether 170 adults (stands R, N, Da, Og) and 22 young trees from natural regeneration (stand R) were analyzed (Table 1).

Laboratory analyses

The number of analyzed individuals per population is given in Table 1 for both isoenzymes and nuclear microsatellites. Isoenzyme analysis was performed using starch gel electrophoresis following the procedures described by Konnert (2004). The following 11 isoenzyme loci, representing 7 enzyme systems, were used (see Table 2): GOT-A, GOT-B, GOT-C, FEST-B, IDH-A, MDH-A, MDH-B, MDH-C, PGI-B, PGM-A, 6PGDH-A. The distinction of varieties was based on allele frequencies at the loci 6PGDH-A and PGM-A.

For nuclear microsatellite analysis DNA was extracted from all 192 samples, using the CTAB method (Wagner et al.

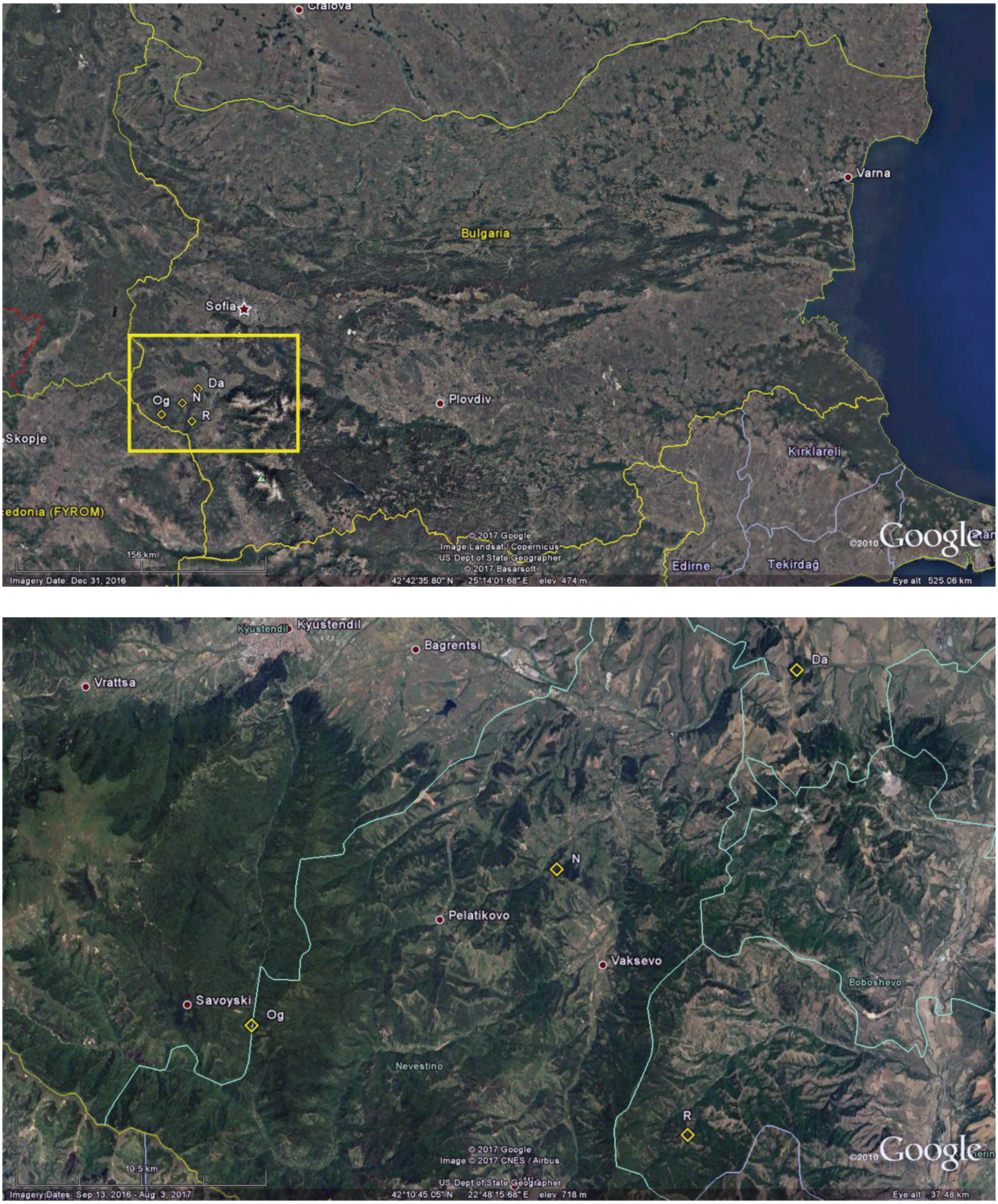

Fig. 1. Location of the studied Douglas-fir stands.

Table 1. Description of plant material for the investigated Douglas-fir stands in Southwestern Bulgaria.

Population abbr.	Location	Latitude	Longitude	Altitude, m, a.s.l	Age, years	Exposure	Soil		Collective	Material	No of indiv.
							depth	moisture			
R	Rila monastery	42°5'34.29" N	22°54'4.95" E	900	35	East	Moderately deep	Mesic	Adult trees Natural regeneration	Needles/buds Needles/buds	20 22
N	Nevestino	42°11'39.84" N	22°50'01.68" E	650	40	South - East	Moderately deep	Mesic	Adult tree	Needles/buds	50
Da	Dupnica	42°16'15.73" N	22°57'29.9" E	600	35	North - East	Moderately deep	Mesic	Adult tree	Needles/buds	50
Og	Osogovo	42°8'5.85" N	22°40'40.98" E	1300	40	East	Moderately deep	Mesic	Adult tree	Needles/buds	50
Total											192

1987). Ten to twelve needles of each individual were cut in half and put in two DNA-pellets. The samples were further dissolved in 10 µl 1xTE Buffer and the pellets were stored overnight in a fridge. DNA extracts were quantified (Gene Quant Pro, Amersham Bioscience) and adjusted to 20 ng·µl^{-1}. All 192 individuals were genotyped at nine highly polymorphic nuclear microsatellite loci, namely: PmOSU_3F1, PmOSU_2G12, PmOSU_3B2, PmOSU_3G9, PmOSU_4A7, PmOSU_1F9, PmOSU_2D4, PmOSU_1C3, PmOSU_2D6 (Slavov et al. 2004, Krutovsky et al. 2009).

A Multiplex PCR with two versions of PCR–program was applied – 'Kombi A' and 'Kombi B'. Multiplex PCR reaction was performed using fluorescent labelled primers in a mixture of 10 µl total volume containing 1 X reaction buffer (Qiagen), 0.2 µM of each primer and about 20 ng template DNA. The program for amplification was optimized using gradient PCR-conditions. The final PCR program started with initial denaturation at 95 °C for 15 min, followed by 30 cycles of 94 °C for 30 sec, 54 °C for 1.30 min for 'Kombi A' and 60 °C for 1.30 min for 'Kombi B', 72 °C for 30 sec and a final elongation step at 60 °C for 30 min. The length of the PCR fragments was determined by using an automated sequencer (CEQ 8000 Beckman Coulter) and analyzed by using an internal size standard. Fragment length determination and allele assignment were carried out using the fragment analysis tool of CEQ 8000 (Beckman Coulter).

Data analysis

For isoenzymes SAS 9.4 Software (SAS/STAT Software) and for nuclear microsatellites GenAlEx 6.41 (Peakall and Smouse 2006) were used to calculate relative allele frequencies per each population, the mean number of alleles (N_A), gene diversity (N_E), effective number of alleles (Brown and Weir 1983), observed heterozygosity (*H*o, Hartl and Clark 1997), expected heterozygosity (H_E, Hartl and Clark 1997) and inbreeding coefficient (F_{IS}, Hartl and Clark 1997). By using the FSTAT software (Goudet 1995), inbreeding coefficients (F_{IS}) for each locus and population was calculated. For nuclear microsatellites possible scoring errors and occurrence of null (non-amplifiable) alleles were checked by using the software Microchecker (Van Oosterhout et al. 2004). Based on this software, scoring errors, like large allele drop-off (poor amplification of large-sized alleles) and error due to stuttering, both leading to homozygote excess, were proved. In order to detect deviations from Hardy-Weinberg-equilibrium due to null alleles, the software conducts simulations within each population. The adjusted frequencies accounting for null alleles were then used for further statistical analysis. The pairwise genetic distance, a measure of differentiation between populations, was calculated for isozyme data according to Gregorius (1974), with the SAS 9.4 Software. For nuclear microsatellites the software GenAlEx 6.41 (Peakall and Smouse 2006) was used to estimate genetic distance between populations following Nei (1972).

Results and Discussion

Variety identification

Allele frequencies for the four Douglas-fir populations and the 11 investigated isoenzyme gene loci are listed in Table 2. No variation was detected at the loci FEST-B and GOT-A. All other gene loci were polymorphic. Differences between populations in the allele frequencies were low. An exception was the allele GOT-C_1, with 6.2 % in the populations Da and N. In the other two populations – Og and R – the frequency of GOT-C_1 was substantially higher with 14.6 % and 14.5 %, respectively. A similar situation was observed at the locus 6-PGDH. The frequencies of allele 6-PGDH-A_6 was in two populations – Da and N – around 6.0 %, while in the other two populations it was significantly lower: for Og – 1.2 %, for R – 1.1 %. (see Table 2).

Allele frequencies for all nine investigated nuclear microsatellite loci are available from authors upon request. All observed gene loci were polymorphic in at least one of the studied populations. Similar to the results obtained with isozymes, differences in allele frequencies between populations were low with a few exceptions: thus, for example, the allele 215 at the gene locus PmOSU_3F1 ranged between 4.9 % in population R and 16.3 % in population Og. The frequency of allele 231 at the same locus varied between 3.1 % in population Og and 12.2 % in populations R. There was also a difference in allele frequencies at the gene locus PmOSU_2G12 with the allele 274 varying between 1.0 % for the Og stand and 14 % for the Da stand.

Here we will focus only on the microsatellite loci PmOSU_3B2 and PmOSU_4A7, which together with the two isozyme 6-PGDHA and PGM-A loci were reported to be the most efficient for variety identification (Fussi et al. 2013). For these four loci the following variety-specific alleles were identified: 6-PGDH-$A_{6,}$ PGM-$A_{4,}$ allele 96 at the locus PmOSU_3B2 and allele 242 at the locus PmOSU_4A7. Fussi et al. (2013) reported that in populations with known

Table 2. Allele frequencies at isozyme loci for the investigated Douglas-fir populations.

Locus	Allele	Population			
		Da	N	Og	R
FEST-B	B_2	1.000	1.000	1.000	1.000
GOT-A	A_2	1.000	1.000	1.000	1.000
GOT-B	B_0	0.020	0.000	0.010	0.000
	B_1	0.102	0.030	0.051	0.071
	B_2	0.020	0.010	0.030	0.036
	B_3	0.806	0.900	0.879	0.869
	B_5	0.051	0.060	0.030	0.024
GOT-C	C_0	0.031	0.031	0.042	0.012
	C_1	0.062	0.062	0.146	0.145
	C_2	0.887	0.907	0.812	0.795
	C_3	0.020	0.000	0.000	0.048
IDH-A	A_0	0.000	0.000	0.010	0.000
	A_2	0.090	0.120	0.131	0.119
	A_3	0.010	0.010	0.020	0.024
	A_4	0.890	0.870	0.808	0.845
	A_5	0.000	0.000	0.020	0.000
	A6	0.010	0.000	0.010	0.012
MDH-A	A_2	0.040	0.010	0.000	0.024
	A_3	0.880	0.900	0.850	0.905
	A_4	0.070	0.090	0.130	0.060
	A_5	0.010	0.000	0.020	0.012
MDH-B	B_2	0.920	0.990	0.970	0.941
	B_3	0.080	0.010	0.030	0.060
MDH-C	C_1	0.020	0.000	0.000	0.000
	C_2	0.800	0.810	0.790	0.810
	C_3	0.180	0.190	0.210	0.191
PGI-B	B_0	0.000	0.000	0.010	0.000
	B_1	0.080	0.070	0.010	0.036
	B_2	0.910	0.920	0.950	0.929
	B_3	0.010	0.010	0.030	0.024
	B_4	0.000	0.000	0.000	0.012
PGM-A	A_2	0.110	0.170	0.090	0.155
	A_4	0.830	0.770	0.790	0.738
	A_6	0.060	0.060	0.120	0.107
6-PGDH-A	A_0	0.000	0.000	0.010	0.000
	A_1	0.000	0.020	0.010	0.000
	A_3	0.960	0.960	0.919	0.976
	A_6	0.040	0.020	0.061	0.024

origin representing the coastal Douglas-fir variety the frequencies of 6-PGDH-A_6 are higher than 90 %, compared to populations of interior Douglas-fir with frequencies around 50–60 %. A similar tendency was observed for the allele PGM_A_4 with frequencies generally higher than 80 % in coastal populations and only 50–60 % in interior Douglas-fir. In addition, in the coastal variety the allele 96 at the locus PmOSU_3B2 and the allele 242 at the locus PmOSU_4A7 are absent or present only in very low proportions, whereas in the interior populations frequencies of the mentioned alleles were higher than 20 % (allele 96 at locus PmOSU_3B2) respectively around 15 % (allele 242 at locus PmOSU_4A7).

Similar results were obtained by Konnert and Ruetz (2006) who investigated older Bavarian Douglas-fir stands with isozyme markers. It was already known that the stands belong to the coastal Douglas-fir variety. In these stands, frequencies for 6-PGDH-A_3 varied between 90.7–96.2 % and for PGM-A_4 between 81.9–88.5 %.

For the investigated stands from Bulgaria the values for the mentioned variety-specific alleles are introduced in Table 3. Comparing the values in the table with the mentioned findings we concluded that all four investigated stands represent the coastal variety. Both marker systems give rise to a similar conclusion.

Table 3. Allele frequencies at two isoenzyme (6-PGDH, PGM) and two nuclear microsatellite loci PmOSU_3B2 and PmOSU_4A7 for the four investigated Douglas-fir populations.

Locus	Population			
	Da	N	Og	R
6-PGDH - A_6	0.960	0.960	0.919	0.976
PGM-A_4	0.830	0.770	0.790	0.738
PmOSU_3B2 Allel 96	0.050	0.073	0.071	0.038
PmOSU_4A7 Allel 242	0.010	0.000	0.010	0.024

Genetic diversity of the investigated Douglas-fir plantations

The mean number of alleles (N_A), analyzed with isoenzymes varied between 2.55 and 3.09, the effective number of alleles (N_E) between 1.18 and 1.24 (Table 4). The observed (H_O) and expected (H_E) heterozygosity ranged from 0.153 to 0.196 and from 0.154 to 0.193, respectively, resulting in inbreeding coefficients (F_{IS}) varying from -0.0482 to 0.0300, which were close to zero (Table 4). Positive F_{IS} values as in populations Da and N show that individuals in the populations are more related than expected. The opposite holds for populations Og and *R* with negative F_{IS} values. Given the significantly higher polymorphism at microsatellite gene loci all diversity values were also higher for all four analyzed populations. The mean number of alleles (N_A), based on nuclear microsatellites was clearly higher compared to values based on isozymes and varied between 24.6 and 26.9, the effective number of alleles (N_E) lies between 15.3 and 16.6 (Table 4). The observed (H_O) and expected (H_E) heterozygosity ranged from 0.617 to 0.961 and from 0.926 to 0.933, respectively, resulting in significantly high inbreeding coefficients (F_{IS}) varying from 0.256 to 0.337 for each population over all loci (Table 4). The observed (H_O) and expected (H_E) heterozygosity have almost the same values – 0.961 (H_O) and 0.927 (H_E). The values of F_{IS} are high and are not significant for the four investigated populations, so for each locus separately within populations were calculated F_{IS} values (Table 5).

Table 4. Mean diversity values based on isozyme gene markers (ISO) and nuclear microsatellites markers (nSSR) over all loci for the four investigated Douglas-fir populations.

Population	N_A		N_E		H_O		H_E		F_{IS}	
	ISO	SSR	ISO	SSR	ISO	SSR	ISO	SSR	ISO	SSR
Da	2.909	26.1	1 219	15.4	0.1691	0.663	0.1796	0.926	0.0300	0.284n.s
N	2.546	26.9	1 182	16.6	0.1527	0.647	0.1542	0.933	0.0058	0.307n.s.
Og	3.091	24.6	1 239	15.3	0.1964	0.617	0.1928	0.927	- 0.0209	0.337n.s.
R	2.818	24.6	1 229	15.6	0.1948	0.961	0.1866	0.927	- 0.0482	0.256n.s.

Note: N_A – mean number of alleles; N_E – effective number of alleles; H_O – observed heterozygosity; H_E – expected heterozygosity; F_{IS} – inbreeding coefficient; Significance of F_{IS} values: non-significant (n.s.), *$p < 0.01$, **$p < 0.001$.

Table 5. Diversity statistics for the nine analyzed nuclear microsatellite loci.

Population	Locus	N	N_A	N_E	A	H_O	H_E	F_{IS}	
D	PmOSU_3F1	48	22.000	14.817	20.316	0.750	0.933	0.196	***
	PmOSU_2G12	50	19.000	8.104	17.185	0.680	0.877	0.224	***
	PmOSU_3B2	50	30.000	18.657	26.689	0.880	0.946	0.070	ns
	PmOSU_3G9	43	19.000	8.348	17.771	0.488	0.880	0.445	***
	PmOSU_4A7	49	27.000	11.916	23.598	0.918	0.916	-0.003	ns
	PmOSU_1F9	50	37.000	25.907	32.403	0.860	0.961	0.105	ns
	PmOSU_2D4	46	23.000	14.797	21.669	0.348	0.932	0.627	***
	PmOSU_1C3	40	26.000	17.204	25.201	0.450	0.942	0.522	***
	PmOSU_2D6	47	32.000	19.126	28.704	0.596	0.948	0.371	***
	Mean	47	26.1	15.4	23.7	0.7	0.9	0.284	
N	PmOSU_3F1	49	25.000	15.391	22.692	0.735	0.935	0.214	***
	PmOSU_2G12	49	21.000	9.681	19.174	0.878	0.897	0.021	ns
	PmOSU_3B2	48	33.000	22.154	29.647	0.750	0.955	0.215	ns
	PmOSU_3G9	48	18.000	9.481	16.700	0.500	0.895	0.441	***
	PmOSU_4A7	49	28.000	15.901	25.129	0.837	0.937	0.107	***
	PmOSU_1F9	48	34.000	26.331	31.374	0.792	0.962	0.177	*
	PmOSU_2D4	43	25.000	15.473	23.909	0.349	0.935	0.627	***
	PmOSU_1C3	39	27.000	16.355	26.009	0.385	0.939	0.590	***
	PmOSU_2D6	45	31.000	18.837	28.344	0.600	0.947	0.366	***
	Mean	46.4	26.9	16.6	24.8	0.6	0.9	0.307	
O	PmOSU_3F1	49	21.000	12.313	19.271	0.612	0.919	0.334	***
	PmOSU_2G12	49	19.000	10.671	17.605	0.776	0.906	0.144	***
	PmOSU_3B2	49	28.000	18.685	25.675	0.857	0.946	0.094	***
	PmOSU_3G9	48	17.000	7.706	15.928	0.417	0.870	0.521	***
	PmOSU_4A7	49	30.000	18.053	26.302	0.796	0.945	0.157	*
	PmOSU_1F9	47	32.000	20.938	29.048	0.809	0.952	0.151	***
	PmOSU_2D4	43	20.000	11.206	18.718	0.302	0.911	0.668	***

Population	Locus	N	N_A	N_E	A	H_O	H_E	F_{IS}	
	PmOSU_1C3	40	22.000	14.545	21.396	0.350	0.931	0.624	***
	PmOSU_2D6	46	32.000	23.910	30.252	0.630	0.958	0.342	***
	Mean	46.7	24.6	15.3	22.7	0.6	0.9	0.337	
R	PmOSU_3F1	41	19.000	13.394	18.515	0.829	0.925	0.104	ns
	PmOSU_2G12	42	20.000	10.376	18.866	0.881	0.904	0.025	ns
	PmOSU_3B2	40	26.000	15.385	24.921	0.700	0.935	0.251	***
	PmOSU_3G9	35	14.000	7.164	14.000	0.429	0.860	0.502	***
	PmOSU_4A7	42	26.000	13.213	24.305	0.905	0.924	0.021	*
	PmOSU_1F9	41	34.000	25.470	32.055	0.805	0.961	0.162	***
	PmOSU_2D4	39	24.000	16.095	23.149	0.462	0.938	0.508	***
	PmOSU_1C3	36	30.000	19.786	29.636	0.583	0.949	0.386	***
	PmOSU_2D6	40	28.000	19.277	26.684	0.625	0.948	0.341	***
	Mean	39.6	24.6	15.6	23.6	0.7	0.9	0.256	

Note: N – number of analyzed individuals; N_A – actual number of alleles; N_E – effective number of allele; A – allelic richness; H_O – observed heterozygosity; H_E – expected heterozygosity; fixation index (F_{IS}:* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

For the locus PmOSU_4A7 results are significant in three populations – N, Og and R (values between 0.021 and 0.157). For the locus PmOSU_3G9 all populations showed significant deviation from HWE (range 0.441 to 0.502). All nine analyzed loci are significant for Og plantation. Compared to other studies based on the same nSSR loci genetic diversity values in Bulgarian populations are at the upper limit. Thus for example Fussi et al. (2013) reported the following values: N_A = 19.3 – 30.5; H_O = 0.734 – 0.826; H_E = 0.897 – 0.919 whereas Krutovski et al. (2009) found heterozygosity values between 0.639–0.783 (H_O) and 0.935–0.936 (H_E). For isozyme gene loci the investigated Bulgarian Douglas-fir stands have similar levels of genetic diversity with observations reported for native populations of coastal Douglas-fir (Moran and Adams 1989, Li and Adams 1989, El Kassaby and Ritland 1996, Krutovsky et al. 2009). Thus for example El Kassaby and Ritland (1996) have studied 49 coastal low-elevation Douglas-fir populations in SW British Columbia and NW Washington State at 20 isozyme loci. The determined a mean number of alleles (N_A) per locus of 2.14 (1.75 to 2.35), mean values of expected (H_E) heterozygosity of 0.163 (0.122 to 0.198). Fussi et al. (2013) applied for six planted stands in Bavaria the same isozyme loci and calculated a mean number of alleles (N_A) of 3.0 (2.9–3.2) and mean values of expected (H_E) heterozygosity of 0.159 (0.132–0.183). One more study (Krutovsky et al. 2009) at 18 isozyme loci in 20 costal Douglas-fir populations at north- and south-facing slopes in SW Oregon shows the similar results. The mean number of alleles (N_A) is 2.32 (2.11–2.55), the mean values of expected (H_E) heterozygosity is 0.160 (0.128–0.189). In naturally regenerated stands at 1,048 locations from western Oregon and Washington the mean number of alleles (N_A) was 3.02 and the heterozygosity values 0.203 (H_O), respectively 0.206 (H_E).

The extent of genetic variation between populations is measured by the genetic distances between populations. Results for genetic distances between the four Douglas-fir populations investigated based on isozymes and microsatellite markers are given in Table 6. For isozyme markers the Gregorius distance was calculated, because it reflects better the differences in the genetic structure of populations. Gregorius distance shows which amount of alleles has to be replaced to equalize the genetic structures of the compared populations. Gregorius distances, based on isoenzymes, ranged from 0.034 (population Da to population N) to 0.053 (population Da to population Og).

Table 6. Pairwise Population Matrix of Nei Genetic Distance for the investigated Douglas-fir populations, using isoenzyme (ISO) and microsatellite (SSR) markers.

Population	Da		N		Og		R	
	ISO	SSR	ISO	SSR	ISO	SSR	ISO	SSR
Da			0.034	0.218	0.053	0.240	0.041	0.250
N					0.045	0.239	0.037	0.285
Og							0.037	0.338

The highest genetic distances were found between the population pairs Og vs. Da 0.053 and Og vs. N 0.045. This means that the highest genetic distances are between the population with the highest genetic diversity (Og) and the two populations with the lowest genetic diversities (N, Da).

Nei's genetic distances, based on microsatellite markers, between all populations are clearly higher and range between 0.218 and 0.338. The highest genetic distance was found between populations Og and R (0.338). Values over 20 % can be considered extremely high and indicate probably a different origin of the four populations within the distribution range of 'coastal' Douglas-fir.

Conclusions

Provenance trials and comparative field studies in Bulgaria including coastal and interior provenances of Douglas-fir (Popov 2010, Popov 2014, Petkova et.al. 2014, Petkova et.al. 2015) demonstrated the superiority of the coastal variety in growths performance, survival, stability and a lower susceptibility to fungal diseases. Our results demonstrated that the four investigated Douglas-fir plantations are of coastal variety and thus can be recommended as seed sources for future afforestation in Bulgaria.

The comparatively high level of genetic variation within and between investigated stands is a good prerequisite for adaptation. At the same time it shows that during the artificial installation of these stands by planting no genetic bottlenecks appeared. These are good news for artificial regeneration and management of Douglas-fir in Bulgaria, as this species will become of increasing importance for Bulgarian forestry under climate change.

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THE EFFECT OF ALTERNATIVE THINNING REGIMES ON GROWTH AND STABILITY OF SCOTS PINE PLANTATIONS IN SOUTHERN FOREST-STEPPE IN UKRAINE

Oksana Tarnopilska[1,2], Sergiy Musienko[2]*, Oleksandr Lyalin[2], Ludmila Tkach[2], and Vira Babenko[2]

[1]Ukrainian Research Institute of Forestry and Forest Melioration, 86, Pushkinska Street, Kharkiv, 61024, Ukraine.

[2]O. M. Beketov National University of Urban Economy in Kharkiv, Department of Forestry and Horticulture. 17, Marshal Bazhanov Street, Kharkiv, 61002, Ukraine. *E-mail: lspg@ukr.net

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Abstract

The effect of selective and combination (row + selective) thinning of varying intensities on mensuration characteristics, differentiation, and productivity of middle-aged plantations of Scots pine was studied in southern Forest-Steppe in Ukraine. The experiment on thinning by combination method in planted Scots pine (*Pinus sylvestris* L.) stands was established in 1967 in 16-year-old pine plantations. The plantations were created in 1950 by one-year seedlings with 1.5 × 0.7 m spacing. The initial density of the stands was 9.5 thousand stems per ha. The experiment included five variants of different thinning regimes: selective thinning of moderate intensity; combination thinning with removal of every 4th row; combination thinning with removal of every 3rd row; combination thinning with removal of every 2nd row; combination thinning with removal of every 4th row at 16 years followed by combination thinning of middle rows at the age of 23. Thereafter, up to 40 years of age, the plantations were thinned twice using selective thinning from below of low and moderate intensity – 24 % by the growing stock volume. During the thinning, the plantations were kept to a specified density. 64-years-old planted Scots pine stands with a density of about 650 stems·ha^{-1}, in which thinning was carried out by selective method of moderate intensity and by combination (row+ select thinning) method of moderate and high intensities (with complete removal of trees in every 2nd, or 3rd, or 4th row) at the age of 17 and the subsequent selective thinning of moderate intensity, are scarcely different in mensuration characteristics. The best method was the combination thinning with the removal of each 3rd or 4th row; the method can be recommended for practice, given the high mensuration characteristics, productivity, and resistance of the thinned stands against a physical load.

Key words: combination thinning, stand density, production, stand resistance.

Introduction

One of the main instruments by which foresters can affect the production and quality of stands is improvement thinning. This issue is the subject of many scientific papers (Sennov 1984, 2001; Anonimous 1987; Shinkarenko and Izyumskiy 1989; Shinkarenko 1990; Golovashchenko 1993; Manoylo 2006; Tarnopilska and

Ponomarev 2008; Ryabokon 2010). Economic, environmental and social aspects of forest cultivation encourage seeking biologically allowable limits for increasing the intensity of the specific thinning and extension of the thinning period. They stimulate the development of methods and means of trees selection for cutting and the determination of thinning impact on the productivity of plantations, as well as on the environment and the residual trees.

The analysis of the studies devoted to the methods of improvement thinning revealed quite contradictory ideas. As a result of the increased mechanization and a higher workload during the thinning, there is a tendency to increase the intensity of cutting and decrease the number of interventions (Hokajärvi 2007, Nilsson et al. 2010, Tkach et al. 2010). For the same reason, as well as to reduce the labor intensity and cost of work, the technology of improvement thinning, based on row and combination (row + selective) methods of thinning, has spread to many countries in Europe and America (Granskog and Anderson 1980, Mitchell and Gallagher 2007, Ishii et al. 2008, Barlow and Dubois 2011, Tkach et al. 2010). Row and combination thinnings are widely used in overstocked row plantations of pine and other coniferous and hardwood species (spruce, poplar, pure oak, etc.) (Karr et al. 1987, Baldwin et al. 1989, Harrington 2001, Ishii et al. 2008).

During row thinning, trees are removed from the stand in alternate rows, without removal of trees in the residual rows. The combination thinning is a combination of both row thinning and selective thinning: alternate rows are removed and at the same time, individual trees are selectively removed from the residual rows. It is essential to determine in advance the intensity of thinning, which provides the remaining trees with an optimal living space (Izyumskiy 1980, Intermediate Treatments 2015).

The application of a particular regime of combination thinning depends on the distance between rows, the number of stems per hectare (Schönau and Coetzee 1989), the site quality (Stiff and Stansfield 2004), and the stand age and condition. In poor sites, in older stands with wide rows and low plant liveability, and especially if the thinning was not timely, more rows should be left in a strip. A large space between rows contributes to increased machine productivity rate (Granskog and Anderson 1980) and lower fuel consumption per harvested area. Row cutting is cost-effective until a certain time, but it can become unprofitable if the spacing becomes high rectangular, because the unused living space is remained between the rows after cutting. The close within-row spacing required for a wide distance between rows can also complicate the removal within the left rows without damage to residual trees. Wider rows had no significant effect on survival, growth, timber production and stem quality of the stand at a rectangular spacing up to the 1:3 (Sharma et al. 2002, Amateis et al. 2004). However, a more rectangular spacing can promote the development of trees with large branches and wider crowns (Sharma et al. 2002, Amateis et al. 2004).

Usually, row thinning is more often used as the first thinning in the rotation. It is difficult to perform row thinning twice since the distance between the left rows will become too large over time for closing of crowns. Also, as a result of late row thinning in the rotation, too many valuable dominant trees of large diameter can be removed, which would be better left until the end of the rotation. Often, a row thinning is followed by a thinning from below.

In practice, various schemes are used to cut the rows. It has been found that in steppe pine forests growing in the Left Bank zone of Ukraine, in 4–6-year-old sparse plantations with a row spacing of 2 m or less, the most effective method is removing alternating rows, followed by disc ploughing in the formed 3-meter row spacing until canopy closure. Row thinning in 8–15-year-old Scots pine plantations in dry and fresh poor forest site conditions can be used to maximize mechanization of subsequent forestry operations. Therefore, at the age of 10–15 years in stands with a row spacing of 2 m or less, every 7th or 9th row was recommended to be removed, and the remaining 6–8-row strips should be thinned from below. This would allow mechanizing the log skidding and minimizing the manual skidding distance. The intensity of thinning of such strips should be 40–50 % by the number of trees (20–30 % by the growing stock volume), provided that up to 3.5 thousand trees remain on the hectare (Tkach et al. 2010). The strips should be wider in plantations with a larger distance between rows and in worse site conditions, especially in the case of late thinning.

In the Volyn region, Ukraine, row thinning has been used since 1967. During this time more than ten thinning patterns have been investigated. In 13–19-year-old pine plantations with 1.5–2 m spacing between rows, every 4th, or 6th, 7th, 8th or 11th row is harvested. With 1 m spacing between rows, two rows are removed: 10th and 11th or 12th and 13th. According to the first pattern, every 8th row (8th, 16th, 24th, etc.) is cut in the first felling (10–12 years) with simultaneous selective removing in the adjacent rows. During the second felling, every 4th row (4th, 12th, 20th, etc.) is removed and in the third, the remaining even rows (2nd, 6th, 10th, etc.) should be harvested.

In Western Polissya, Ukraine, in planted Scots pine stands with the inter-row spacing of 1.25–1.5 m, every 4th row is cut in the first stage, with simultaneous selective removing with up to 20 % intensity in the left rows; in the second intervention, every 2nd row is harvested. If the distance between the rows is 2 m, each 4th row is cut in the first felling, and only individual trees are selectively removed in left rows during next thinnings (Sviridenko 1974).

For sandy soils of the Voronezh region, removing every 3rd row is advisable and in the northern regions of Kazakhstan, every 5th row is (Atrokhin and Ievin 1985). In the dense 15–20-year-old Scots pine plantations with 1.5 m distance between the rows, it is recommended to leave two-row unfelled strips and in older stands, to create corridors in 2 stages (first, the 6th or 9th row is harvested, then the central rows are cut) (Izyumskiy 1980).

The most common is the harvesting of every 3rd, 4th or 5th row. With the removal of every 3rd, 4th or 5th row of trees, the sum of basal areas is reduced by 33, 25 or 20 %, respectively (Adams et al. 1994).

Row and combination regimes of thinning have an indisputable technological advantage over uniform thinning, as it maximizes mechanization and reduces the cost (Lemmien and Rudolph 1964).

Individual trees accumulate more photosynthates and grow faster after thinning. There was a less growth of smaller-sized trees if row thinning was used in place of selective thinning from below, but the degree of this effect varies depending on the species (Baldwin et al. 1989).

For southern pines, early row thinning can be an effective insect attack mitigating factor for species like southern pine beetle due to reducing the density of a plantation

(Nebeker and Hodges 1983, Burkhart et al. 1986).

Row and combination methods of thinning have some silvicultural limitations, as follows: applicability only in dense plantations, limited selection of trees for growing, turf formation in the wide (3–4-meter) corridors, as well as branch spreading and *Aradus cinnamomeus* and *Melolontha* colonization (Izyumskiy 1980). Row and combination thinnings result in a removal of dominant trees and in a smaller increment as compared to selective thinning. They promote the growth primarily of smaller trees (Intermediate Treatments 2015). Intensive combination thinning of coniferous crops is recommended to be performed only up to 15 years (Varfolomeev 1983, Intermediate Treatments 2015). This is due to the fact that row and combination thinnings are not always beneficial. For example, intensive row thinning with the removal of every 4th, 3rd or 2nd row in overstocked pine forests in Polissya, Ukraine, can cause annosum root rot infection (Kiselevskiy et al. 1983). In the Voronezh region and in Poland, the removal of every 3rd or 4th row increased ice damage to plantations, and the diameter of the trees shifted towards the smaller ones (Fler 1974, Izyumskiy 1978, Galleger 1987).

During row and combination thinning, heavy equipment is used, which is moved through a significant part of the plantation area. For example, if cutting every 3rd row, this area can reach 40 %, making furrows on an area of up to 15 % if the thinning is performed on soft soil in wet weather (Karr et al. 1987).

Despite the deep and comprehensive knowledge of problems of thinning of pine stands planted in forest-steppe, several important issues are not investigated, including the impact of different regimes of intensive thinning on the growth and productivity of the stands.

Solving these problems will help to grow efficiently the high-yielding and resistant pine plantations, which will meet not only national economic requirements but also environmental ones. Scientific substantiation of methods, frequency, and intensity of thinning requires multi-year research, preferably on an experimental basis, the lifetime of which is comparable with the tending period (Fleming 1999, Sennov 2001). Such long-term observations will help to improve existing methods of forest cultivation and developing new ones, as well as modifying the existing regulations on thinning.

Therefore, the accumulation of experimental data on the basis of long-term experiments on thinning in different forest site conditions is necessary for scientific programming and simulation of stands development.

The aim of the study is to analyse and compare the peculiarities of formation of middle-aged artificial pine stands depending on the thinning of varying intensity conducted by row and combination methods.

Materials and Methods

The research area is located in the southern part of the Left-bank Forest-Steppe in Ukraine. According to the physiographic zoning, the research area is within the boundaries of the Kharkiv forest-steppe region of the western slopes of the Central Russian Upland of the Central Russian forest-steppe province of the Forest-Steppe Zone (Marinich et al. 1985).

The climate of the research area is moderately continental (A = (27–32) °C; T = (84–104) °C; W = (2.0–0.6) (Dubinskiy et al. 1971), where: A is an indicator of climate continentality, the algebraic difference between the mean temperature (°C) of the warmest (July) and coldest (January) months of the year; T is the sum of mean monthly positive temperatures (°C); W is the index of humidity, which is calculated according to the formula (1).

$$W = (R/T) - 0.0286 \cdot T \qquad (1),$$

where: R is the total of the monthly precipitations for the months with a mean temperature above 0°C) (Lavrinenko 1972).

According to long-term data (Marinich et al. 1985), the mean air temperature in January is -8 °C, in July is +20 °C; the mean annual air temperature is about +6 °C. The winter period begins in mid-November. The period with a temperature below 0 °C lasts for about 135 days in the north-eastern part of the region. Weather conditions in winter tend to be mainly cloudy. The frost-free period lasts 155–160 days; the period with the mean daily temperature of above 5 °C is 195–200 days, above 10 °C – 155–160 days, above 15 °C – 110–115 days.

The mean annual rainfall is 538 mm, with one maximum in July and one minimum in February. Fluctuations of the annual values are quite significant – 340–880 mm. This is due to the drought typical for the studied region.

The territory of the Kharkiv region includes a number of rugged tablelands and small uplands, separated by deep and wide ravines cut into cretaceous rocks, and sometimes by gullies with slopes facing mainly southwest and southeast (Marinich et al. 1985).

In the region of the study, sod-podzolic soils (Placic Podzols) had been formed under pine forests on sandy terraces. Typically, such soils are formed at medium groundwater depth, and coniferous or mixed forests grow on them.

The forest-steppe was formed as a primary type of landscape with two equivalent types of vegetation, forest and steppe one.

Forest vegetation is represented by deciduous forests, the main areas of which are concentrated on a deeply rugged relief along the valley sides of rivers, and coniferous and mixed forests associated with sandy terraces (Alekseenko 1971).

During the fieldwork, mapping of sample plots and trees allocation, as well as dendrometric measurements (diameter at breast height D, height of a tree H, height to the first live branch, and diameter and projection area of a crown), were conducted using Field-Map technology developed by the specialists of the Institute of Forest Ecosystem Research (IFER, Czech Republic) (Field-Map 2018). Field-Map is a proprietary integrated tool designed for programmatic field data collection and management. It integrates various models of field computers, GPS, electronic compasses, laser rangefinders and inclinometers, electronic calipers and other advanced tools. The software combines a geographic information system (GIS) and a database management system (DBMS). The degree of differentiation of trees in plantations was estimated using the following Kraft's classification (Avery and Burkhart 2002) based on a tree's social position in the stand and its crown development: 1st class – predominant trees; their crowns extend above the general level of the canopy; they have the largest, fullest crowns in the stand and thicker trunks; 2nd – dominant trees; their crowns make up the general level of the canopy; generally, they are shorter than the predominant trees and have straight trunks; 3rd – subdominant trees; they have the same height as the dominant trees but are relatively weakly developed and restricted often with other trees, there are some signs of suppression; 4th – supressed trees, with crowns restricted on all sides or on two sides, or with one sided development; 5th class – dying and dead trees. Stands resistance against damage by the wind, glaze storm and sleet was assessed by the value of the relative height of plantations − the ratio of the mean height (*H*, cm) to the mean diameter (*D*, cm) − *H*/*D* (Medvedev 1910). The limit value of *H*/*D* of mean trees in the stand, indicating the resistance of the stand against the above-noted factors, is from 80 to 110 according to different sources (Franz 1983, Prien et al. 1985, Anonimous 1987, Shinkarenko 1990, Golovashchenko 1993, Manoylo 2006).

The diameters of trees were measured at a breast height (1.3 m) within the accuracy of 0.1 cm. The mean diameter was calculated using the mean cross-sectional area of trunks. The height of trunks in the field conditions was determined for 35 to 50 trees on each of the sample plots. The mean height was estimated according to the height curve, depending on the diameter of the given stand, which corresponds to the mean diameter of the trunks. Total basal area was determined according to the tables (Strochinsky et al. 2007). The total timber volume per hectare was estimated according to Strochinsky's tables (Strochinsky et al. 2007) for mensuration of young and middle-aged stands.

Processing and analysis of the results were carried out according to common methods of variation statistics (Baginskiy and Lapitskaya 2017). To characterize a homogeneous statistical population, the following values were calculated according to standard formulas: the mean statistical parameters for diameters and heights of the trees and for projected areas of their crowns (arithmetic mean (x), median (*Me*), mode (*Mo*)), their variation characteristics (minimal (min) and maximal (max) variants, sample variance (S_x^2), standard deviation (σ), sampling mean error (S_x), variation coefficient (C_v, %)), as well as skewness and steepness indices of the distribution curve (asymmetry (*As*) and excess (*Ex*)).

When comparing the arithmetic means, the null hypothesis testing was made: the arithmetic means of the general populations, from which the data samples were taken, did not differ by the Student's *t*-test (Fay and Gerow 2013).

If $t_{real} \geq t_{table}$, then the null hypothesis is rejected at the accepted significance level p; the difference between sample means is considered statistically significant. At $t_{real} < t_{table}$ the difference between sample means is not proven.

Experiments on improvement thinning in artificial Scots pine (*Pinus sylvestris* L.) stands were launched by Prof. P. Izyumskiy in Pivdenne Forestry (compartment 155) in 1966 and 1967 in 16-year-old pine plantations. The plantations were established in 1950 by one-year plantings after continuous tilling with the spacing of 1.5 × 0.7 m. The initial planting density was 9,523 stems·ha^{-1}. The type of site conditions was a fresh fairly fertile forest. The soil was soddy eluviated one on warp sands (Humic Podzol).

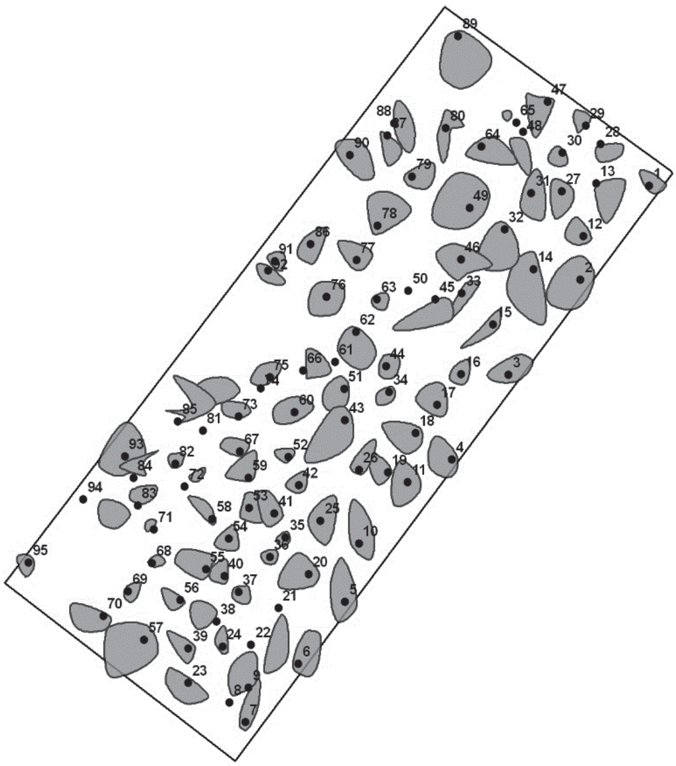
At the time of the experiment beginning, the plantation was a young dense stand having a mean height of 9.2 meters, a diameter of 9.6 cm, and growing stock of 182 m^3·ha^{-1}.

The experiment included six sections with different thinning regimes: Sections B and B-2 represented thinning of moderate intensity (controls); Section III − completely removed trees in every 4th row, and remaining stand was thinned in a moderate intensity; Section II − completely removed trees in every 3rd row, and remaining stand was thinned in a moderate intensity; Section I represented completely removed trees in every 2nd row, and remaining stand was thinned in a moderate intensity; Section IV were completely removed trees in the middle rows of three-row unfelled strips at a half of section III at the age of 23 years (Fig. 1).

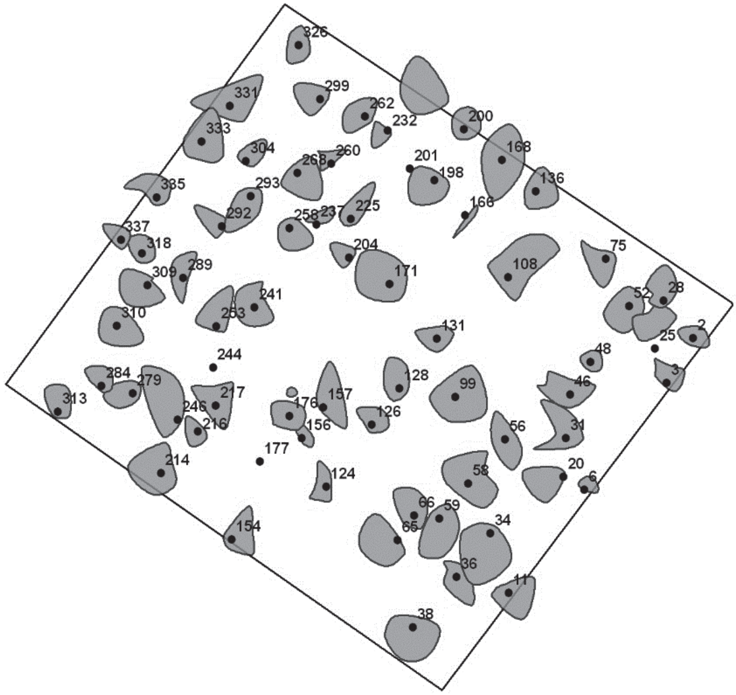
In the stands with row thinning at the Sections III, II, and I, in 1976 there was thinning from below of the low intensity: the removal of 1−7 % by the growing stock volume. In the sections with selective thinning (B and B-2), thinning of moderate intensity (11−24 % by the growing stock volume) was conducted in 1979.

In this experiment, the research was carried out in the stands aged 36, 40 and 56 years (Shinkarenko and Izyumskiy 1989, Shinkarenko and Tarnopilska 1993, Tarnopilska and Ponomarev 2008).

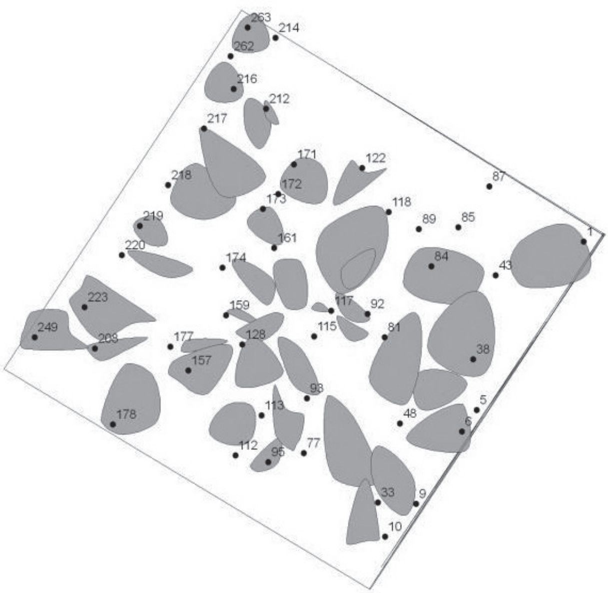
In 1990, 40-year-old stands of all sections were thinned with low and moderate intensity (6−17 % by the growing stock volume) with leaving stands of specified density on the plots, mostly 1,000 stems·ha^{-1} (Table 1).



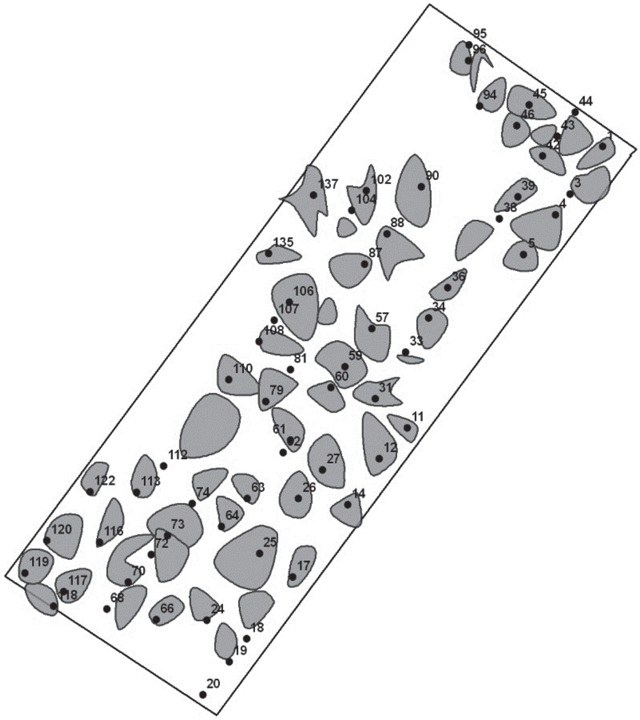
a) Section B-2, *N* = 900 stems·ha^{-1}



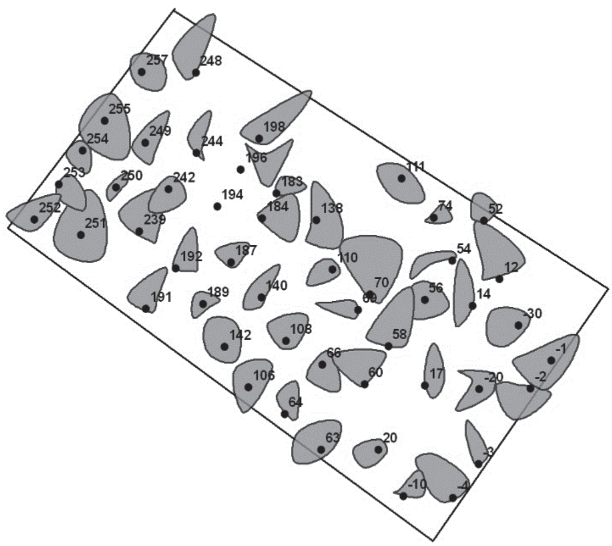
b) Section B, N = 640 stems·ha^{-1}



c) Section III, N = 875 stems·ha^{-1}



d) Section I, N = 656 stems·ha^{-1}



e) Section IV, N = 681 stems·ha^{-1}

Fig. 1. (a–e) Cartograms of the location of trees and projections of their crowns in 64-year-old pine plantations in the experiment on row and combination thinning (Pivdenne Forestry, compartment 155).

Table 1. Mensuration characteristics of 40-year-old pine plantations before and after the thinning (Danylivskyy Experimental Forest Economy, Pivdenne Forestry, compartment 155).

Characteristic	Section					
	B-2	B	III	II	I	IV
Before the thinning in 1990						
Density N, stems·ha^{-1}	2056	1920	2083	1181	1267	1236
Mean diameter D, cm	–	17.1	16.4	20.2	19.9	17.5
Mean height H, m	–	20.0	20.6	21.0	20.7	20.1
Growing stock, m^3·ha^{-1}	–	407	418	355	364	266
Thinned in 1990; age of the plantations is 40 years						
Density N, %	24.9	22.9	33.0	16.2	19.3	32.6
Growing stock, %	12.0	12.3	14.8	5.9	6.6	15.8
Left after the thinning in 1990; age of the plantations is 40 years						
Density N, stems·ha^{-1}	1544	1480	1396	990	1022	833
Mean diameter D, cm	18.6	18.2	18.6	21.1	21.1	19.2
Mean height H, m	20.7	20.5	21.2	21.2	21.2	20.7
Basal area, m^2·ha^{-1}	41	39	37	35	36	24
Growing stock, m^3·ha^{-1}	379	357	351	332	338	224

During the thinning both by selective and combination methods, attention had been given to the cutting the stands to a specified density. In the selection of trees that should be left for further growth, the “thinning by quality” principle had always been followed. Defective or diseased trees or specimens with thick branches were removed around high-quality trees. The preference had been made to the best trees, even if it would break the evenness of tree spacing in the area.

Results

After thinning in 1990, the density of 40-year-old stands in the experimental variants ranged from 833 to 1,544 stems·ha^{-1}. Note that growing stock volumes of the stands, the density of which varied within 990−1,544 stems·ha^{-1}, were similar (M = 332−379 m^3 per ha), and the difference between them was insignificant and did not exceed 12 %. The most thinned stand (N = 833 stems·ha^{-1}) of the variant with the combination thinning of high intensity (Section IV) had a somewhat smaller growing stock (224 m^3 per ha).

64-years-old pine stands had a high productivity (Table 2). In the variants, the stand density ranged from 900 to 640 stems·ha^{-1}, the mean diameter was 23.4−26.3 cm; the mean height was 25.5–26.8 m.

The density of the stand in the variant of moderate intensity thinning at a young age (Section B-2) was the largest; it was the lowest in the variant of thinning of high intensity (Section I). The mean diameter (23.4 cm) of the densest stand with a selective thinning of moderate intensity (Section B-2) was significantly lower compared to the variants of combination thinning of high and very high intensities (Sections I and II) (tables 2 and 3, Fig. 2).

Table 2. Mensuration characteristics of 64-year-old planted stands of Scots pine in the thinning experiment.

Kraft class	Density: stems per ha	Density: %	Mean diameter D, cm	Mean height H, m	Basal area, $m^2 \cdot ha^{-1}$	Growing stock, $m^3 \cdot ha^{-1}$
1st	700	77.8	24.5	26.3	33	371
2nd	178	19.8	19.9	25.9	6	63
3rd	22	2.4	19.9	25.0	1	8
Total	900	100.0	23.4	26.2	40	442
1st	570	89.1	26.0	26.6	30	352
2nd	70	10.9	20.5	25.0	2	26
Total	640	100.0	25.5	26.5	33	378
1st	250	28.6	27.9	26.6	15	174
2nd	438	50.1	25.5	26.0	22	250
3rd	83	9.5	25.0	25.8	4	46
4th	63	7.2	20.2	24.3	2	21
5th	42	4.8	16.0	22.6	1	8
Total	875	100.0	25.5	26.0	44	499
1st	295	43.0	27.0	27.0	17	196
2nd	305	44.5	24.5	27.0	14	166
3rd	76	11.1	22.0	26.9	3	34
4th	10	1.5	24.0	26.5	0	5
Total	686	100.0	25.3	26.8	35	401
1st	533	81.3	27.2	26.4	31	350
2nd	89	13.6	21.4	24.8	3	35
3rd	33	5.0	20.2	24.5	1	11
Total	656	100.0	26.3	26.2	35	396
1st	208	30.5	27.7	26.3	12	141
2nd	181	26.6	27.4	26.2	11	119
3rd	139	20.4	22.9	24.9	6	62
4th	56	8.2	21.1	24.2	2	21
5th	97	14.2	17.1	22.6	2	23
Total	681	100.0	24.8	25.5	33	366

Table 3. The value of the actual Student's *t*-test for mean diameters of 64-year-old Scots pine plantations in different sections of the thinning experiment

Section	B-2	I	II	III	IV
I	3.52	–	–	–	–
II	2.97	0.76	–	–	–
III	0.76	1.00	0.33	–	–
IV	1.56	1.78	1.21	0.69	–
B	3.32	0.29	0.47	1.90	1.56

Note: t_{theor} = 1.96; P = 0.05.

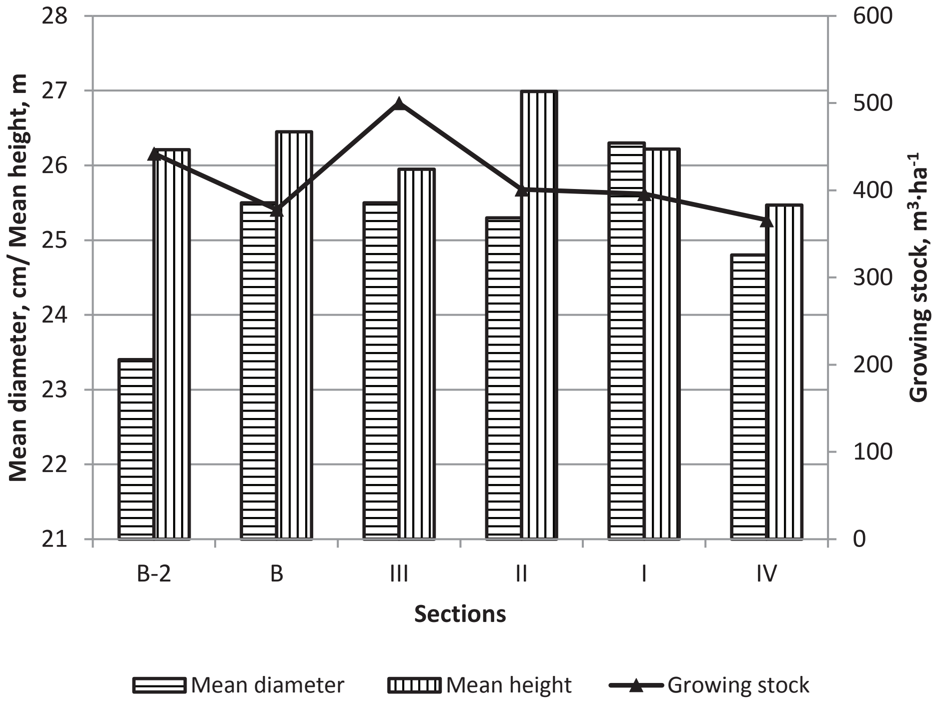


Fig. 2. Distribution of growing stock volume, mean diameter and mean height in 64-year-old planted stand of Scots pine by thinning regimes.

Let us consider the parameters of crowns and canopy of the plantations as an important component of the stand structure. The mean tree crown projections in 64-year-old plantations in different experimental variants ranged from 3.2 to 4.9 m^2 (Table 4). The mean crown projection in variants with selective thinning of moderate intensity (Section B-2) was the smallest (3.2 m^2) (Table 4, Fig. 3). It was significantly lower than crown projections in other variants (Table 4, Fig. 3). At Section B-2, due to the considerable density of the stand (900 stems·ha^{-1}), the crown projection area was smaller compared to the Section B, where the number of trees per hectare was 640. The variants with selective and combination regimes of thinning (Sections B, I, II, III, IV) did not differ in mean crown projections. Here, the mean crown projection area was in the range of 4.1−4.9 m^2 (Table 4, Fig. 3).

Table 4. The value of the actual Student's *t*-test for the mean crown projection areas in 64-year-old Scots pine plantations in the thinning experiment

Section	B	B-2	I	II	III
B-2	2.50	–	–	–	–
I	-1.57	-4.01	–	–	–
II	1.97	-2.36	0.36	–	–
III	-0.94	-2.93	0.31	1.50	–
IV	-1.75	-4.07	-0.25	1.76	0.50

Note: t_{theor} = 1.96; P = 0.05.

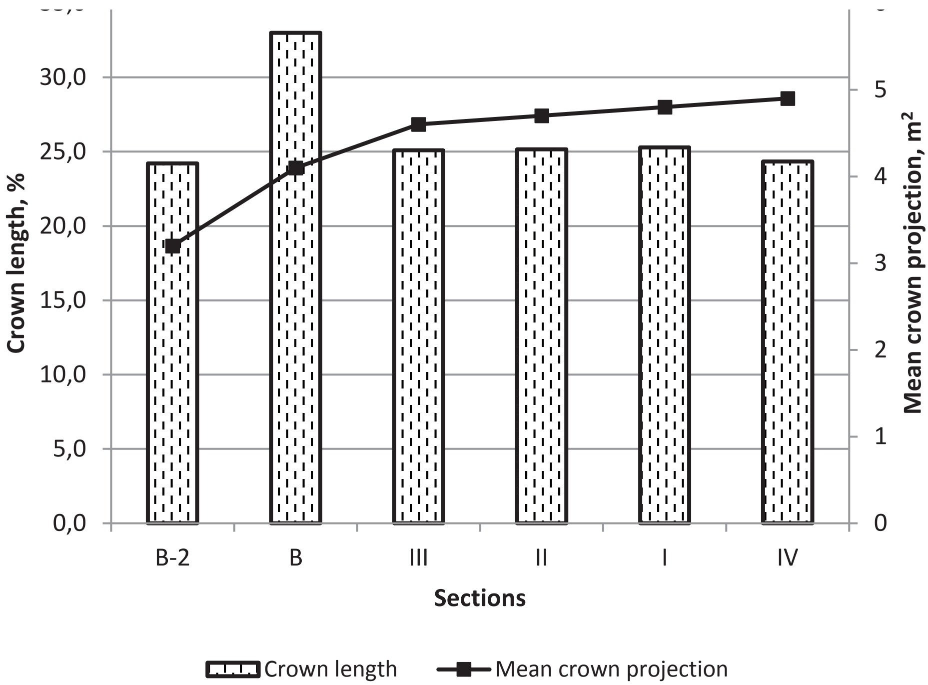


Fig. 3. The length of crowns and the mean crown projection for Scots pine by the thinning regimes.

Discussion

The analysis of the influence of different thinning regimes on the productivity of the plantations indicates that the growing stock depends on the stand density that is in accordance with the results of many researchers (Shinkarenko and Izyumskiy 1989, Sennov 2001, Intermediate Treatments 2015). Stands with highest density (about 900 stems·ha^{-1}) had the highest growing stock and largest total basal area. The best variants were Section III with the removal of every 4th row (the growing stock of the stand was 491 m^3 per ha and the basal area was 43 m^2 per ha) and Section B-2, i. e. the control with selective thinning (442 m^3 per ha and 40 m^2 per ha, respectively) (Table 1, Fig. 2). In this assessment, the combination thinning variant had the advantage in these indicators, although the difference between the best variants did not exceed 10 %. The plantation with the removal of every 4th row followed by thinning of middle rows in unfelled strips at the age of 23 (Section IV) had the lowest stock volume (343 m^3 per ha) and the least basal area (31 m^2 per ha). This variant was considerably exceeded in growing stock and basal area by the control (Section B-2) and the variant with every 4th row removed (Section III) – by almost 22 % and 30 %, respectively. The growing stock volumes and the basal areas of forest stands with a density of about 650 stems·ha^{-1} with combination thinning of every 3rd and 2nd rows (Sections II, I), as well as with selective thinning of moderate intensity (Section B) did not differ markedly. However, as many researchers have pointed out (Izyumskiy 1980, Schönau and Coetzee 1989, Tkach et al. 2010), a high density usually contributes to the greater productivity of plantations but, at the same time, to a decrease in the mean stem diameter and the mean area of crown projection within the stand, as each tree has less access to environmental resources. As a result, this leads to less cost effectiveness of the harvesting (Schönau and Coetzee 1989, Intermediate Treatments 2015). However, in the middle-aged plantations, nearly 50 years after the first thinning, not only the stand density but also the thinning regimes had affected the mean diameter. For example, a dense stand with selective thinning on the control (Section B-2) had a less mean diameter and a smaller crown projection (Table 1, figs 2 and 3). Such plantations need to be grown longer until the harvest is profitable (Intermediate Treatments 2015) due to the influence of the stand density on the diameter. Among combination thinning variants, the stand with the cutting of every 4th row and removal of middle rows in the left three-row strips 6 years after (Section IV) had a much smaller mean diameter (24.8 cm). Combination thinning of every 2nd row had the greatest impact on the mean diameter increase compared to other regimes (Table 2, Fig. 2). On the other hand, the difference between the mean diameters for plantations with every 4th and 3rd rows cut (Sections III, IV) and selective thinning of medium intensity (Section B) was not statistically significant (see Table 3). The plantations with a lower density despite a smaller total growing stock volume will be more cost-effective due to a larger mean diameter that is consistent with other studies (Schönau and Coetzee 1989, Shinkarenko and Izyumskiy 1989, Sennov 2001). These plantations can be thinned earlier because they reach the minimum required diameter more quickly since each tree has access to more site resources (Schönau and Coetzee 1989, Shinkarenko and Izyumskiy 1989, Sennov 2001).

Let's intercompare the variants of plantations with different regimes of initial density or thinning but with close values of the current density. Stands having the density of about 650 stems·ha^{-1} in variants with selective thinning of moderate intensity (Section B) and combination thinning with every 2nd row removal (Section I), every 3rd row removal (Section II) and every 4th row removal followed by cutting middle rows in three-row unfelled strips (Section IV) did not significantly differ in mean diameter, mean height, and growing stock. The difference in mean diameter and growing stock between the variants with selective thinning (Section B-2) and combination thinning with a removal of every 4th row (Section III) having the current density of about 900 stems·ha^{-1} was not significant.

Since at row thinning the trees are removed randomly, based on their spacing in the plantation, as a result, the mean stand diameter does not change (Intermediate Treatments 2015). For example, 33 % of small trees, 33 % of medium and 33 % of large ones are removed during the cutting every 3rd row. Thus, the ratio between the mean diameter of the removed trees and the mean diameter of the stand before cutting will always be equal to 1.00 for any row thinning. The stand density and the basal area will decrease in the same proportion as the number of cut trees will. For example, there were 450 trees per acre (1,111 stems·ha^{-1}) in the stand before thinning and the basal area was 11.15 m² per acre (27.55 m^2 per hectare). After removing every 3rd row in the stand, there will be

300 trees per acre (741 stems·ha^{-1}), and the basal area will amount to 7.43 m² per acre (18.4 m^2 per hectare) (Intermediate Treatments 2015).

Basal area is a common measure of stand density used to prescribe the intensity of thinning in the countries of Europe and the USA (Hokajärvi 2007, Nilsson et al. 2010, Intermediate Treatments 2015). For Loblolly pine (*Pinus taeda* L.) plantations, the stands are commonly thinned when they reach the basal area of 9.3–11.1 m² per acre (23.0–27.4 m^2 per hectare) or more (Intermediate Treatments 2015). Basal area is usually reduced to 6.57.4 m² per acre (up to 16.1–18.3 m^2·ha^{-1}) at each thinning. The targeting basal areas vary depending on the species, region, and objectives (Dickens and Moorhead 2015, Intermediate Treatments 2015).

Taking into account the high values of basal areas of the stands (33–45 m^2·ha^{-1}), as well as the presence of suppressed (4th Kraft class) and dead (5th Kraft class) trees, another improvement selective thinning should be carried out in the experimental sections. The intensity of the thinning should be moderate (up to 11–25 % by growing stock volume) or strong (26–30 % by growing stock volume). Such treatment will promote growth conditions for a high-quality part of the tree stand, as well as fast reaching the economically desirable tree size and income generation.

The stands thinned both by selective and combination methods were not significantly different in the mean height (Table 2, Fig. 2).

The combination method of thinning provides more site resources and living space to the residual trees not only between the rows but also within the rows, contributing to the formation of trees with spreading crowns (Fig. 3). This is consistent with the data of other authors (Izyumskiy 1978, Medhurst and Beadle 2001, Intermediate Treatments 2015). The variant of selective thinning of medium intensity had the largest crown length – 33 % of the bole height. In other variants, this value was about 25 % of the bole height (Fig. 3).

The purpose of thinning is the formation of high-quality and productive stand. The productivity is determined by a selection of the best trees that will be the basis of the stand price at the age of the final felling, which is emphasized by other researchers (Zasady hodowli lasu 2012). There are a number of requirements for the best trees to be selected. The trees must 20–30 % exceed the average tree in height and have straight full-boled stems, developed dense crowns and a good height increment. In addition, the uniform spacing of the best trees in the stand is desirable. The number of best trees to be selected is determined by the age of the stands and the forest site type. Our opinion on this issue is in line with the practice of selecting the best trees in Poland (Zasady hodowli lasu 2012). At the thinning stage, 500–600 best pine trees per hectare should be selected in poor sites and up to 300–400 trees per hectare in the rich ones. The trees can be selected also during the thinning in older stands (over 40 years) but their number should be less than during earlier thinning. For example, their number should be in the range of 350–400 stems·ha^{-1} in pine stands growing in poor forest sites and 250–350 stems·ha^{-1} in the rich sites, as in our case.

The dominant part of the stands of each variant accounts for over 50 % of all trees both by the number and growing stock (see Table 2). As the density of the stand increases, the proportion of trees of 1st and 2nd Kraft classes decreases.

The mean diameter and the mean

height in the dominant part (trees of the 1st and 2nd Kraft classes) of the stands, in which combination thinning had been conducted, were somewhat larger than those of stands with selective thinning (Fig. 4). The trees of 1st and 2nd Kraft classes in the variant with cutting out every 4th row and at the age of 23, with the removal of the middle rows in the three-row strips (Section IV) had a significantly larger mean diameter in comparison with the variant of selective thinning (Section B). The densest stand on the control (Section B-2) had a considerably smaller mean diameter of this part of the plantation as compared to all other variants ($t_{emp0.05}$ = 3.15…5.23, $t_{theor0.05}$ = 1.98). The differences between the diameters of the dominant part of the stands were not statistically significant for all combination thinning variants ($t_{emp0.05}$ = 0.30…1.87, $t_{theor0.05}$ = 1.98) (Table 2, Fig. 4).

The value of the relative height (*H*/*D* < 110) indicates insignificant degree of mutual suppression of trees in all sections.

The value of *H*/*D* mainly did not exceed 105 and indicates the resistance of the stands against the physical load. *H*/*D* value accounted for 113 only in the densest plantation of Section B and is indicative of trees' damage (Fig. 5).

The extreme limit of the *H*/*D* ratio is 126, according to Medvedev (1910). Our data, however, show that it is underestimated and may reach a larger value in planted stands than Medvedev's value indicated for natural forests. The relative height in the dominant part of the stands was much lower than in the dominated one in all variants. This confirms the correctness of Medvedev's statement

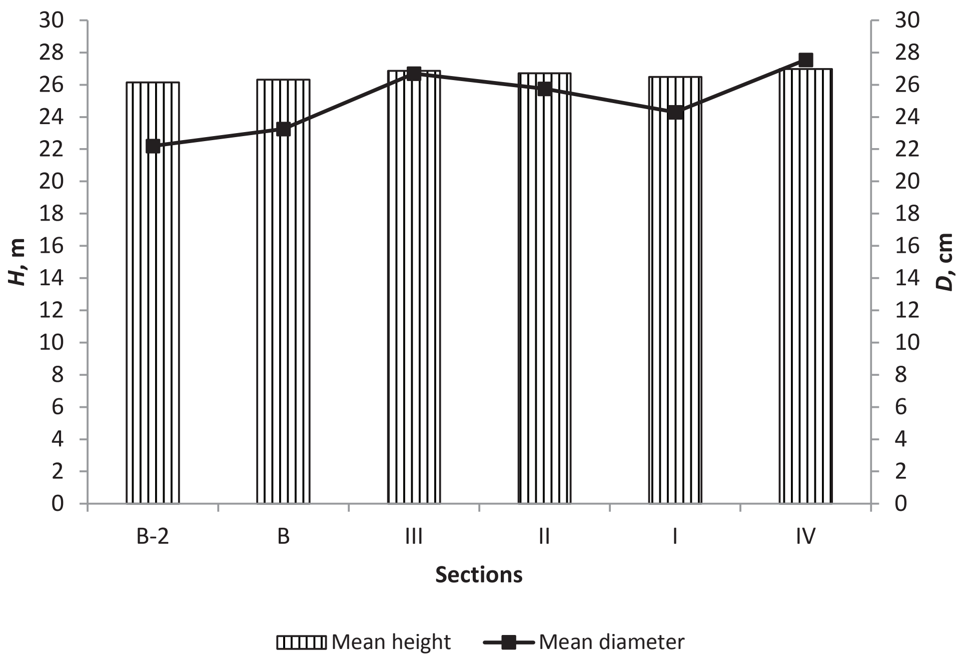


Fig. 4. Mensuration indices of the dominant part of the stands (trees of 1st and 2nd Kraft classes).

that *H*/*D* is a good indicator of tree suppression degree. At the same time, for the dominant part of the plantations with a higher density, especially for the trees of the 2nd Kraft class, the value of relative height has revealed a rather high degree of their suppression (see Fig. 5).

In our case, the storm in 1998 damaged significantly 48-years-old pine plantations of the experiment, causing a wind breakage and windfall. The results of the investigation indicated that the share of broken and blown down trees ranged from 1.4 to 22.2 % in different variants. The majority of the damaged trees in all variants belonged to the dominating 1st and 2nd Kraft classes (*H*/*D* > 110) as they overtopped the main stand canopy level. Their mean diameters varied in the range of 16.0−26.5 cm and the mean height, 23.6−25.6 cm. The amount of wind-damaged trees decreased with the increase of the stand density. This relationship was confirmed by statistically significant high coefficients of correlation r = 0.90 (t = -4.14 at p < 0.05) and determination r^2 = 0.81. However, we should note that windfall broken trees occurred mainly in the variant with the removal of each 2nd row (Section I). On the contrary, trees in the variants with the removal of every 4th row (Section III), every 3rd row (Section II) and every 4th row followed by cutting of middle rows in three-row unfelled strips (Section IV) remained undamaged. In these variants, the stand density ranged from 1,396 to 833 stems·ha^{-1} after thinning in 1990. Therefore, one can assume that the intensity and the nature of the damage depended not only on the strength and direction of the wind but also on the particular location of the sample plots towards the wind and on the structure of the stands. Analysis of the data on heavy

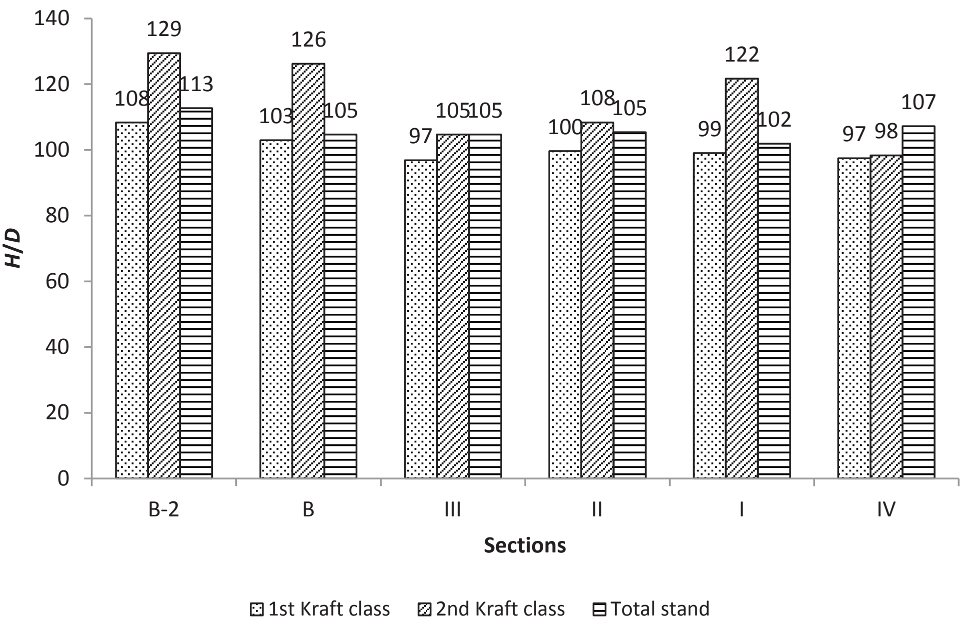


Fig. 5. Relative heights of forest stands and their dominant parts (trees of 1st and 2nd Kraft classes).

wind impact on the investigated stands allows asserting that in fresh fairly fertile forest site, the risk of wind damage to middle-aged pine stands increases with decreasing the stands' density and increasing the intensity of thinning, especially immediately after the thinning. This is due to the increase of crown opening and of wind load on the canopy and decrease of the protective effects of the surrounding trees. The best tall trees, which rise above the main stand canopy, are the most exposed to windfalls. For this reason, combination thinning with the removing every 2nd row in rich forest sites involves a certain risk of a windfall. On the other hand, the thinning may improve the stand stability due to long-term effects on growth and development of trees withstanding high winds.

The results of the experiment on combination thinning showed that the intensive cleaning by combination method with the removing of every 4th, 3rd, and 2nd row in planted pine stands in rich forest sites at the age of 15–18, followed by selective thinning of medium intensity 48 years after cutting, does not lead to a reduction in available growing stock compared to selective methods of thinning.

Thus, high mensuration characteristics and a significant number of dominant trees in the middle-aged artificial Scots pine plantations formed under the influence of thinning by combination method of moderate and high intensity indicate the possibility of use of such regime of improvement thinning in planted Scots pine stands up to 20 years of age, taking into account the simplicity of the technology and its economic benefits.

The results of our experiment also showed that in case of one intensive cleaning the second thinning is not necessary to be carried out in planted stands.

It is proposed to use the relative height (*H*/*D*) in the dominant part of the stand (trees of the 1st and the 2nd Kraft classes) when planning the intensity of late cleaning and thinning. Thinning of high and very high intensity can lead to an irreversible decrease in resistance and productivity of the stands if the relative height is above 110.

Conclusions

64-years-old planted Scots pine stands with the density of 650 stems·ha^{-1}, in which thinning was carried out by selective method of moderate intensity and by combination method of moderate and high intensities (with complete removal of trees in every 2nd, or 3rd, or 4th row), as well as the following selective thinning of moderate intensity, are scarcely different in mensuration characteristics.

The first thinning in planted Scots pine stands growing in the Ukrainian Left-bank Forest-Steppe in rich forest sites can be carried out up to 20 years of age by a combination method of moderate and high intensity with a complete removal of trees in every 3rd or 4th row. The combination thinning with the removal of every 3rd or 4th row is the best method that can be recommended to use in practice, taking into account high mensuration values, productivity, and resistance of the thinned stands to a physical load.

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FEATURES OF THE PHENOLOGICAL TIME SERIES OF COMMON ASH (*FRAXINUS EXCELSIOR* L.) AND ITS ORNAMENTAL FORMS IN THE FOREST-STEPPE ZONE OF RIGHT-BANK UKRAINE

Alexander Bayura*, Vladimir Shlapak, Alexander Ostapchuk, and Galina Ischuk

Department of Forestry, Uman National University of Horticulture, 1 Instytutska str., 20305 Uman, Ukraine. *E-mail: sasha-uman@ukr.net

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Abstract

Growth and development of vegetative and generative organs of Common ash and its ornamental forms – 'Albo-Variegata', 'Aurea', 'Crispa', 'Monophylla Pendula' and 'Pendula' were studied. The dates of swelling and bursting of vegetative and generative buds were established; as well as dates of linear growth and lignification of sprouts, budding, flowering; separation, maturation, colouring change and defoliation; fruit set, development, ripening and fruit abscission. Intensity of growth of Common ash annual sprouts and duration of their growth in all studied plants were determined. The results show that *Fraxinus excelsior* and its ornamental forms belong to plants that later begin the vegetation (the second decade of April to the first decade of May), which is characteristic of many heat-loving woody species. It was found that the rhythmic of ornamental forms vegetation corresponds to climatic rhythm of Forest-Steppes of Ukraine and it is an indicator of high adaptability to the conditions in the region.

Key words: bud, fruit, leaves, linear growth, phenological phases, sprouts.

Introduction

Seasonal growth and development play an important role not only in the fields related to agriculture, but also related to landscape gardening (Balčiūnas et al. 2008, Vilčinskas and Dabkevičienė 2009). Life-sustaining activity of plants occurs under conditions of inconstant, variable and dynamic environment. It is reflected on the stages of seasonal plant development. Knowledge of phenological features of a particular plant species, enables to set the most favourable periods of maturation and seed collection, conducting plant propagation, sowing, planting, etc.

Phenology of species and ornamental forms of *Fraxinus excelsior* L. both in nature and culture, is not enough studied. Hordienko et al. (1996) studied its phenological phases of growth and development in the forest ranges of fresh oak forests. In Donetsk Botanical Garden of NAS of Ukraine, Tereshchenko (2002) studied the growth and development of Common ash and its ornamental form 'Aurea'. The phenological phases of development of vegetative and generative organs were investigated in the British islands (Wardle 1961, Thomas 2016), leaf phenology in the Pyrenees mountains, France (Vitasse et al. 2009a), the timing of bud burst and leaf fall in Sheffield, UK (Chih-Wei at al. 2016), the bud burst date and bud development in Oxfordshire, UK (Ella and Ben 2017).

In National Dendrological Park 'Sofievka' five ornamental forms are growing: *F. excelsior* 'Pendula' Boom, which has been cultivating in the park since 1960; *F. excelsior* 'Aurea' Persoon – is introduced from Poland in 1999; *F. excelsior* 'Albo-Variegata' Hayne, *F. excelsior* 'Crispa' Willdenow and *F. excelsior* 'Monophylla Pendula' Aiton, stalks taken from the Botanical Garden named after Academician O. V. Fomin of Kyiv and replicated by V. F. Sobchenko by different methods of transplantation from 1998 to 2001.

Researches of phenological data of growth and development of vegetative and generative organs of Common ash and its ornamental forms in the parkland of the Right-Bank Forest-Steppe of Ukraine were not carried out, therefore their studying is actual.

Material and Methods

During 2009–2011 were studied phenological rhythms of growth and development of *F. excelsior* and its five ornamental forms at the National Dendrological Park 'Sofievka' NAS of Ukraine and Uman National University of Horticulture by methodology of Botanical Gardens Council of the USSR (Lapin 1975). Vegetative and floral phenological observations were conducted. For this purpose there were selected 7 model exemplars with similar physiological characteristics. Registration of phenological time series was carried out 2–3 times per week during the vegetative season, and during the period of the fastest development (in the spring) – every day.

The swelling of the vegetative buds was recorded before the scales were opened according to the increase of their size and colour change – from black or brown-black to green. The bursting of the buds was recorded when green tips of primordial leaf which had dark brown or black dots appeared in the places of radial cracks. The beginning of twig growth was observed on the shoots that appeared from the apical bud and placed on elongated shoots of the last year. The beginning of phenological time series was recorded in the period when it was possible to touch with fingers the leaves' hidden apex of the shoots which began to grow. The phase of partial lignification of the shoots was recorded by the formation of cortical layer in shoots' basal part. Their complete lignification was observed when they were covered with cork layer throughout the length and changed the colour to mature shoots. The beginning of separation of leaves was determined on the day when among the young green leaves on the branches there have been seen a few small leaves which were not opened yet. The date when they stopped to grow was recorded by the presence in the crown leaves of normal size with straightened laminas and colour, which are characteristic of the researched plants. The change in the colour of the leaves was recorded when the crown completely changed autumn colours. The defoliation was recorded when 50 % of leaves fell off.

The time of swelling of the generative buds was recorded similarly to the vegetative buds. The bursting of the buds was recorded by the appearance of immature inflorescence from the buds of the scales.

The budding was recorded during the separation of flowers in inflorescences. The beginning of flowering was recorded when pollen released from anther after shaking of the branches. Time of infructescence was recorded during intensive growth of ovary in the days prior to wilting and drying of the flower style. The time when immature fruits reached the size of the mature was determined visually by comparing them with mature fruits. The time of fruits ripening was fixed when the colour of the pericarp and the ash-key changed – they became brown and acquired a light brown colour.

During the determination of vegetative season length we choose the beginning of bud burst as start of the vegetation, and the massive leaf fall as its end.

The dynamics of seasonal shoot growth was determined by the method of Molchanov and Smirnov (1967). For this purpose on the model trees were selected 10 branches the length of which was measured with a metal ruler every 7 days from the base (crotch or scar of the last year's bud) to the apex with accuracy of 1 mm. The dynamics of the seasonal growth of *F. excelsior* annual seedlings was measured after 3–4 days. The statistical processing of data was conducted with the use of a computer program in accordance with the method of Dospekhov (1985).

The observations of Common ash trees aged about 50 years and of ornamental forms 8–11 years.

The climate of the studied area is moderately continental with relatively warm winters and frequent thaws. The warmest winter was of 2011 when the average temperature in December amounted +1.9 °C, in January – -3.1 °C, February – -5.2 °C (Table 1).

Table 1. Average temperature (°C) of researches (data by Uman weather-station).

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	-3.4	-0.8	2.2	10.1	14.6	20.2	21.2	19.2	16.1	9.2	4.6	-2.4	9.2
2010	-7.8	-3.0	0.7	9.3	16.4	20.6	23.0	23.6	14.5	5.9	8.8	-3.8	9.0
2011	-3.1	-5.2	1.4	9.5	15.7	19.7	21.7	18.9	15.0	7.0	1.8	1.9	8.7
Average for 3 years	-4.8	-3.0	1.4	9.6	15.6	20.2	22.0	20.6	15.2	7.4	5.1	-1.4	9.0
Long-term average annual	-5.7	-4.2	0.4	8.5	14.6	17.6	19.0	18.2	13.6	7.6	2.1	-2.4	7.4

The coldest winter was of 2010 – December – -3.8 °C, January – -7.8 °C, February – -3.0 °C. For 2009 and 2010 considerably higher temperatures were typical compared to the long-term average annual data. The highest average monthly temperature on the average over three years of researches was +20.2 °C in July.

Annual amount of precipitations ranged from 500 to 700 mm. Not quite favourable in the amount of precipitations for plant growth were 2009 and 2011 (Table 2). In 2009, the amount of precipitations (523.5 mm) was by 109.5 mm lower in comparison with the long-term average annual, which was 633 mm.

Table 2. Average amount of precipitations (mm) of researches (data by Uman weather-station).

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	25.6	73.9	46.8	0.0	38.5	49.0	86.1	4.5	38.8	64.9	14.9	80.5	523.5
2010	108.6	60.2	38.2	43.3	52.6	139.3	59.1	36.4	73.4	29.3	50.0	62.4	752.8
2011	28.8	18.7	3.7	25.2	68.5	129.2	150.7	50.1	12.4	71.6	2.2	32.0	593.1
Average for 3 years	54.3	50.9	29.6	22.8	53.2	105.8	98.6	30.3	41.5	55.3	22.4	58.3	623.1
Long-term average annual	47	44	39	48	55	87	87	59	43	33	43	48	633

Average annual humidity was 75 % (Table 3). Long-term average annual humidity amounts 76 %, the maximum was accounted for November–December (87 %) and minimum – May and June (65 %).

Table 3. Average humidity (%) of researches (data by Uman weather-station).

Years	Months												Average for a year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	88	88	82	54	68	65	72	63	70	81	89	89	76
2010	87	88	79	66	71	71	72	62	71	79	82	89	76
2011	91	77	69	58	66	70	72	70	71	79	79	88	74
Average for 3 years	89	84	77	59	68	69	72	65	71	80	83	89	75
Long-term average annual	86	85	82	68	64	66	67	68	73	80	87	88	76

The dark gray podzolized soils are with humus content from 4.14–4.49 %. By the dry-weight percentage they are heavy loams.

Results and Discussion

Terms of beginning of passing main phenophases of development give an idea of the progress of seasonal development, so special attention was given to the following phenological phases: swelling and bursting of vegetative and generative buds, sprouts growth, separation and defoliation, budding, flowering, fruiting and fruit abscission. Phenospectra of seasonal rhythm of development of *F. excelsior* and its ornamental forms are presented in Fig. 1.

The phases of vegetative organs development

For the vegetative buds in *F. excelsior*, the progression of kidney development is very important for the bud flushing dates (Cun-

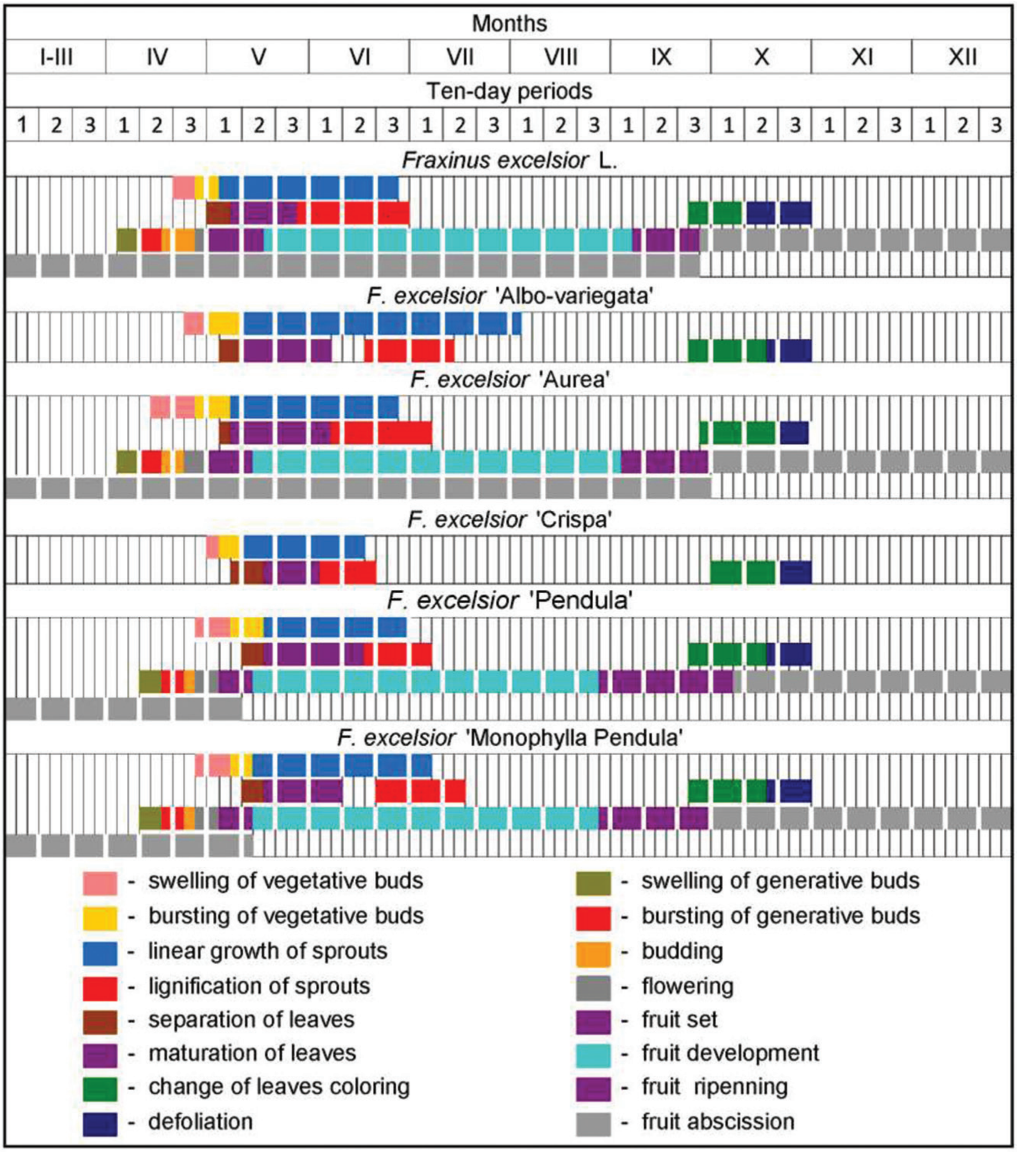

Fig. 1. Phenospectra of seasonal rhythm of development of *Fraxinus excelsior* and its ornamental forms.

dall et al. 2003). The buds' development was observed during the second half of April and sometimes until mid-May in the Vance (Etalle) region of provenance, Belgium (Jouve et al. 2007). The studies of Wardle (1961) showed that vegetative buds begin to swell in early March and open through May, although understorey trees usually begin earlier and can have fully expanded leaves by the beginning of May. The bud burst begins in the first decade of May in Oxfordshire, UK (Ella and

Ben 2017). However, according to data Chih-Wei at al. (2016*)* for riparian and non-riparian ash it ranged from mid-April to the end of May in Sheffield, UK.

Swelling of buds (Fig. 2A) begins at the end of the second decade of April in Common ash and its forms at an average daily temperature of 8.3–9.4 ºC – 'Albo-Variegata' and 'Aurea', and in the third decade – 'Crispa', 'Pendula' and 'Monophylla Pendula' (9.5–9.7 ºC). It is the longest in Common ash – 11–12 days, and the lowest in *F. excelsior* 'Crispa' – 3–5 days.

Bursting of buds (Fig. 2B) during the years of our researches in *F. excelsior* and its forms 'Albo-Variegata' and 'Aurea' started in the third decade of April at a temperature of 8.9–9.4 ºC, and in *F. excelsior* 'Crispa', 'Pendula' and 'Monophylla Pendula' – in the first decade of May (10.8–16.8 ºC). It lasts in Common ash 7–9 days and in its forms – from 5 to 14 days.

Separation of leaves (Fig. 2C) begins at a temperature of 9.2–9.6 ºC in *F. excelsior* and *F. excelsior* 'Aurea' at the end of the third decade of April, and in the rest of the forms – in first and second decade of May (10.6–14.0 ºC). The duration of this phase lasts in 'Crispa' – 8–12 days, least – 3–5 days in 'Aurea' and 'Pendula'. In the rest of ornamental forms it varies 4–8 days. Unlike Uman, according to the data in *F. excelsior* under the conditions of Kyiv the leaves appear in the period from 9 to 18 May. In the conditions of Belarus, leaf formation occurs 10–28 May (Hordienko et al. 1996). According to the observations of Vitasse at al. (2009a) the unfolding tree leaves begins on 6–20 of April at a height 150 m a.s.l. of Pyrenees mountains. According to the results of the Marsham Phenological Record, 1736–1947 (Sparks and Carey 1995) the mean date of the beginning of the unfolding leaves of *F. excelsior* is on the third decade of April in central England.

Linear growth of sprouts (Fig. 2D) begins in early May at an average daily temperature of 11.4–17.0 ºC in *F. excelsior* and its three forms – 'Aurea', 'Albo-Variegata' and 'Crispa', while in other two – in the second decade of May (13.0–16.9 ºC). Completion of this phase begins in the third decade of June in indigenous species, *F. excelsior* 'Aurea' and *F. excelsior* 'Pendu-

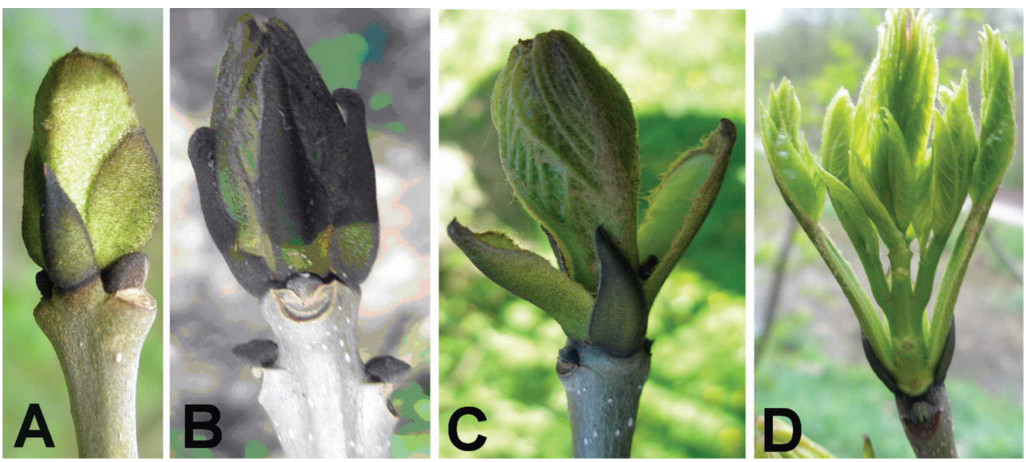

Fig. 2. Phases of vegetative organs development of *Fraxinus excelsior*: A) swelling of buds; B) bursting of buds; C) separation of leaves; D) beginning linear growth of sprouts.

la' (19.8–20.5 ºC), in the first decade of July – *F. excelsior* 'Monophylla Pendula' and 'Albo-Variegata' (16.9–22.3 ºC), the in the second decade of June – *F. excelsior* 'Crispa' (18.5–21.1 ºC).

Sprouts under the conditions of Uman have inconsiderable duration of growth – from 34 to 56 days (Table 4). It was established that the longest growth characterized sprouts 'Albo-Variegata' – 56 days. In 2009 their growth did not significantly differ from indices of the growth of annual sprouts of the indigenous species, ornamental forms 'Aurea' and 'Monophylla Pendula', but significantly differed from the indices of duration of seasonal growth in 'Crispa' and 'Pendula', which respectively amounted 37 and 43 days. The same difference from 'Albo-Variegata' in 'Crispa' and 'Pendula' was observed during the following years of researches. On the average, the difference was 20 and 13 days. The smallest duration of growth was observed in 'Crispa' – 36 days.

Table 4. Duration of growth of *F. excelsior* sprouts and its ornamental forms.

Species and forms	Days			Average for 3 years
	2009	2010	2011	
F. excelsior L.	55	49	51	52
'Albo-Variegata'	56	55	56	56
'Aurea'	55	51	53	53
'Crispa'	37	34	36	36
'Monophylla Pendula'	52	53	54	53
'Pendula'	43	41	45	43
HIP_{05}	*5*	*6*	*4*	–

According to observations of Hordienko et al. (1996) the growth of shoots lasted 54–58 days in Goloseyevsky forestry of Kiev region, and according to our observations in the plantings of the National Dendrological Park 'Sofievka' – 49–55 days.

The analysis of dynamics of annual sprouts seasonal growth of Common ash (Fig. 3) showed that one-vertex curve that corresponds to one wave of growth was formed. The maximum increase was observed in the third decade of May – 11.3 cm or 34.9 % of total increment. In general, the maximum amount of growth of sprouts lasted from 20.05 to 03.06. So, in the beginning of June the sprouts of indigenous species reached 92.3 %, and during the period from 03.06–24.06 only 7.7 % of the total length. In plantings of Uman, maximum amount of growth was observed during the first 22 days and amounts 69.2 % of the total amount of growth.

The studies of Wardle (1961) on the British Isles showed that seedlings growing under a canopy of *F. excelsior* commenced growth at the beginning of May; the growth rate reached a maximum in the latter part of May and declined to zero by the end of June.

Phase of partial fragmentary lignification of sprouts occured at a temperature of 14.4–15.2 ºC in the third decade of May in *F. excelsior*, and in ornamental forms 'Pendula', 'Albo-Variegata', 'Monophylla Pendula' (second and third decades of June) at a temperature of 19.6–20.9 ºC, 'Crispa' and 'Aurea' in the first decade of June (18.4–21.4 ºC). Full lignification of sprouts occured in the typical form on the 7–8th day and for *F. excelsior* 'Crispa' on 5–6th day. In the rest of ornamental forms

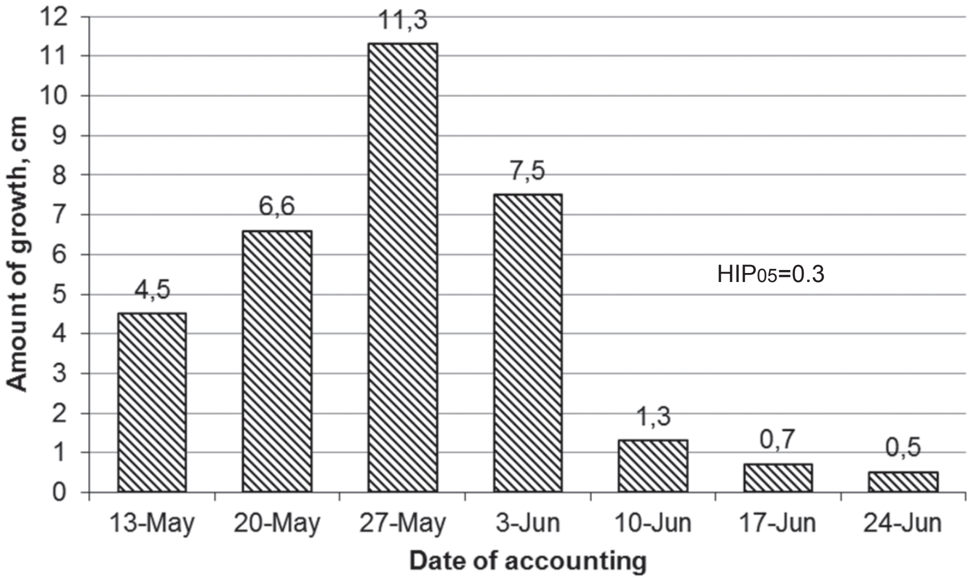

Fig. 3. Dynamics of seasonal growth of annual sprouts of *F. excelsior*.

this phase is observed on the 7–11th day. This phase occurs at an average daily temperature of 20.9–21.6 ºC.

Phase of completion of leaf growth in *F. excelsior* and in ornamental form 'Pendula' occurs, respectively, in the third decade of May (14.4–16.1 ºC) and in the second decade of June (18.9–21.7 ºC). In the rest of forms it occurs in the first decade of June (11.2–16.7 ºC). Duration of leaves formation is different. Thus, in *F. excelsior* 'Aurea', it is the longest – 27–38 days, but in 'Crispa', duration is 15–17 days. This phase in *F. excelsior* is 19–22 days, 3–4 days more in 'Monophylla Pendula', 8–10 in 'Albo-Variegata' and 9–14 in 'Pendula'.

Colour change of leaves could not be observed, because after the first slight frost in late September early October, the green leaves fall off. In indigenous species first simple leaves fall and their stalks – later. Except *F. excelsior*, this phenomenon is observed in 'Albo-Variegata', 'Aurea', 'Pendula' and 'Monophylla Pendula'. Under favourable conditions, change of colour occurs in the third decade of September at an average daily temperature of 14.5–16.7 ºC, and only in 'Crispa' – at the beginning of the first decade of October (7.6–10.3 ºC).

Leaf-fall appears to be a result of declining autumn temperatures, rather than of frost, for the old leaves are quite frost-hardy (Wardle 1961). Leaves are shed during October and the first half of November, though a few persist into December on the British Isles (Wardle 1961, Grime et al. 2007). Leaf fall can be somewhat earlier on polluted sites in or near industrial centers (Thomas 2016).

According to our observations in ornamental forms 'Albo-Variegata', 'Aurea', 'Pendula' and 'Monophylla Pendula' defoliation starts in the second decade of October and lasts until the first decade of November (6.1–10.2 ºC). This phase in 'Crispa' occurs at the beginning of the third decade of October (6.1–10.0 ºC).

Concerning indigenous species, it should be noted that the defoliation in certain trees begins in the third decade of September at a temperature of 14.2–15.8 ºC, but their majority falls in the first and second decades of October with the beginning of slight frost.

Phases of generative organs development

Ash begins to flower in early spring (early–mid March in the UK and Ireland) and ends in mid–end May. Anthesis is not always synchronous in adjacent buds (Douglas 2013). Flowers on male trees open earliest and then hermaphrodite trees followed by female trees last of all (Tal 2011, Albert et al. 2013).

Swelling of the buds (Fig. 4A) begins in the first and second decades of April. The first enters this phase *F. excelsior* (05.04–12.04) and its form 'Aurea' (06.04–14.04) at an average daily temperature of 7.0–9.1 ºC. The longest lasts in *F. excelsior* 6–7 days, and least in *F. excelsior* 'Pendula' – 3–5 days.

Bursting of buds (Fig. 4B) begins in the second decade of April (7.3–9.4 ºC), except 'Pendula' and 'Monophylla Pendula' (beginning of third at a temperature of 7.6–9.7 ºC). In *F. excelsior* it lasts 4–6 days, and in its ornamental forms 3–9 days.

Budding (Fig. 4C) occurs at the end of the second or in third decade of April. Simultaneously bud formation begins in *F. excelsior* and *F. excelsior* 'Aurea' – 16.04–23.04 at an average daily temperature of 7.8–9.3 ºC, ornamental forms 'Pendula' and 'Monophylla Pendula' – 25.04–28.04 (9.1–9.3 ºC).

Beginning of flowering (Fig. 4D) starts in the third decade of April at a temperature of 9.1–10.1 ºC. Its duration is 5–6 days. According to the data in the conditions of Kyiv, *F. excelsior* 'Pendula' blossoms from 3–18 May – 16 days, *F. excelsior* 'Aurea' – 8–18 May for 11 days (Rubtsov 1977). Such difference can be explained by the fact that the indices were taken in different phases, because almost simultaneously there is bud formation and flowering on the same tree. The studies of Latorre and Bianchi (1998) on the flowering season of *Fraxinus excelsior* were 34 days long and its principal phase lasted only 21 days in Argentina.

Fruit set in all plants occurs in the first decade of May (10.7–16.8 ºC). Immature fruits reach mature sizes in the first decade of June (17.8–21.6 ºC), and their ripening – in the last days of the third decade of August and in the beginning of the first decade of September at a temperature of 15.0–23.0 ºC. The duration of fruit ripening in *F. excelsior* is 85–89 days. Among the ornamental forms the longest period of ripening is noted in 'Aurea', which is

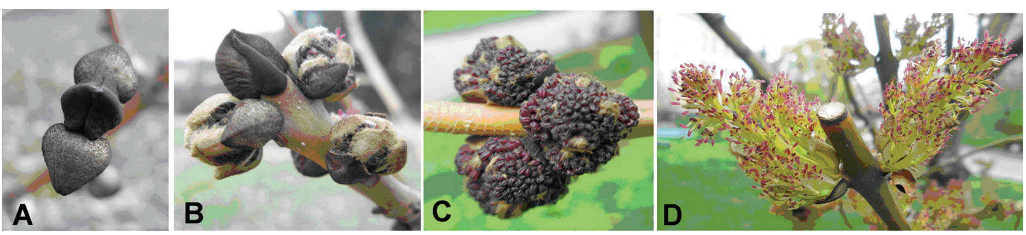

Fig. 4. Phases of generative organs development *Fraxinus excelsior* 'Aurea': A) swelling of buds; B) bursting of buds; C) budding; D) flowering.

88–93 days, and the smallest period in 'Pendula' – 78–81 days. Average indices were recorded in 'Monophylla Pendula' – 84 days.

The samaras are fully grown by the beginning of July, while the enclosed seeds reach their full length by the beginning of August. The embryos grow until August or September (Wardle 1961, Kerr 1995). According to the data in the plantings of Donetsk Botanical Garden of NAS of Ukraine, a fruits ripening of *F. excelsior* begins in the first half of July and lasts for 30 days (Tereshchenko 2002). In the National Dendrological Park 'Sofievka' of NAS of Ukraine in Uman, this phase begins in the third decade of August at an average daily temperature of 18.6–23.5 ºC and lasts about 30–40 days, confirming a significant difference in the duration of the formation of seeds in different regions.

According to our observations, maturation of ash-keys begins in late August. On the same tree, seeds ripen not simultaneously. Maturation elongates on a month and sometimes more. The fruits begin to fall off in early July (unfilled and damaged), and most of them falls off on the snow in winter. It also should be noted that some of ash-keys remain on the tree during summer of the next year, and sometimes even till the end of autumn.

The length of vegetative season in the research years is in a range from 167 to 183 days. For *F. excelsior* and *F. excelsior* 'Pendula' and 'Monophylla Pendula' it is 178 days, *F. excelsior* 'Albo-Variegata' – 167 days, *F. excelsior* 'Aurea' – 183 days, *F. excelsior* 'Crispa' – 171 days. According to Tereshchenko (2002) in the plantings of Donetsk Botanical Garden the length of growing season for *F. excelsior* is 197 days, and for *F. excelsior* 'Aurea' – 199 days. According to observations of Vitasse (2009b) under the conditions of Pyrenees the length of growing season for *F. excelsior* is 189 days.

Conclusions

As a result of the conducted phenological observations the growth and development of vegetative and generative organs of Common ash and its ornamental forms – 'Aurea', 'Albo-variegata', 'Crispa', 'Monophylla Pendula' and 'Pendula' were investigated.

The beginning of vegetation of plants of typical species *F. excelsior* and its ornamental forms except 'Crispa' (first decade of May), begins in the second and third decades of April at an average daily temperature of 8.9–16.8 ºC.

Linear growth of sprouts begins in early May at an average daily temperature of 11.4–17.0 ºC. Completion of this phase begins in the second decade of June – *F. excelsior* 'Crispa' (18.5–21.1 ºC), in the third decade of June in indigenous species, *F. excelsior* 'Aurea' and *F. excelsior* 'Pendula' (19.8–20.5 ºC), in the first decade of July – *F. excelsior* 'Monophylla Pendula' and 'Albo-Variegata' (16.9–22.3 ºC). Duration of growth of annual sprouts *F. excelsior* and its forms are characterized by a short period, duration from 34 (*F. excelsior* 'Crispa') to 56 (*F. excelsior* 'Albo-Variegata') days.

Separation of leaves begins at a temperature of 9.2–9.6 ºC in *F. excelsior* and *F. excelsior* 'Aurea' at the end of the third decade of April, and in the rest of forms – in first and second decades of May (10.6–14.0 ºC). Phase of completion of leaf growth in *F. excelsior* and in ornamental form 'Pendula' occurs, respectively, in the third decade of May (14.4–16.1 ºC) and in the second decade of June (18.9–21.7 ºC). In the rest of forms it occurs in the first decade of June (11.2–16.7 ºC).

The colour change occurs in the third decade of September at an average daily temperature of 14.5–16.7 ºC, and only in 'Crispa' – at the beginning of the first decade of October (7.6–10.3 ºC). The defoliation starts in the second decade of October and lasts until the first decade of November (6.1–10.2 ºC).

Beginning of flowering starts in the third decade of April at a temperature of 9.1–10.1 ºC. Its duration is 5–6 days. All forms bloom and fructify except 'Albo-Variegata' and 'Crispa'. Trees of *F. excelsior* bloom and fructify not every year.

Fruit set in all plants occurs in the first decade of May (10.7–16.8 ºC). Immature fruits reach mature sizes in the first decade of June (17.8–21.6 ºC), and their ripening – in the last days of the third decade of August (18.6–23.5 ºC) and in the beginning of the first decade of September at a temperature of 15.0–23.0 ºC.

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THE COMMUNICATIONAL AND INFORMATIONAL VALUE OF PARK ENVIRONMENT AS AN AESTHETIC OBJECT AND ITS IMPACT ON THE AESTHETIC VIEW FORMATION OF THE SOCIETY

Nadiia Gatalska

National University of Life and Environmental Sciences of Ukraine, Department of Landscape Architecture and Park-Garden Construction, 19 Heneral Rodimtsev Str., Kiev, Ukraine.
E-mail: gatalska@ukr.net

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Abstract

The purpose of the research is to identify the specific features and patterns in the formation of the communicational and informational structure of the park environment as an aesthetic object of anthropogenic origin, which provides a connection in space-time continuum between its formation and perception subjects. As a result of analytical researches of scientific sources of literature, it is revealed that an important general aspect of natural landscape perception, as well as urban and park landscape perception as an aesthetic object, is multisensory (perception is due to all senses), which is fundamentally different from works of art that are calculated on the visual sphere of perception (works of fine art) or hearing (music). Along with the multisensority of the perception, park landscape, as a rule, is impossible to reach immediately, perception occurs as a series of landscapes. It is revealed that the main factors limiting the formation and the perception of the park landscape as a communicative-informational aesthetic object is the time that affects the variability of the material forms of the object on one hand and the aesthetic experience of the person – on the other. Such circumstances determine the logical changes in the information-value function of the landscape in the structure of the object-subjective relations of the park environment-man system. On the basis of the results of the analysis of scientific works aimed at studying the aesthetics of the landscape, a model of subject-object relations of man and a park environment as a unified system was developed.

Key words: communicational and informational value, multisensority of space perception, park environment.

Introduction

The interconnection of nature and art has been observed throughout the history of human development and at different times has acquired peculiar forms and manifestations. In particular, Albrecht Dürer argued that art is hidden in nature, and the ones who find it, would be able to have it. In turn, Leonardo da Vinci, comparing scientific and aesthetic cognition, noticed that painting embodies in the form of proportions the same laws that are hidden in nature, which in the form of a numerical law learns any scientist (Kravetc 1994). Also Stolovich (1972) notes on the aesthetic value of objects in which the natural laws are reflected. In addition, V. Hegel believed that the beauty of art is superior to the beauty of nature. However, the idea of the domination of the beauty of works of art over natural objects radically changed in Europe during the Romantic period, when the landscape was regarded as an object with aesthetic qualities (Lothian 1999, Gross 2002).

Works of scientists of the XX century focus not only on the study of the landscape (both natural and anthropogenic) as an aesthetic object, but cover issues of their interaction within a single system. On constant interaction between urban landscape and man, Ikonnikov (1985) emphasizes the urban environment as a constant interaction of human society and the subject-spatial environment, diverse systems of activity and forms of behaviour with material structures united in space. The presence of the relationship between man and the environment also notes Lynch (1982), who argues that the urban environment is perceived not by itself, but in relation to the environment, the related chain of events, memory of the previous experience of the individual.

The influence of the environment, mainly natural, on the formation of human consciousness and its aesthetic flavours was experimentally proved by Kravetc (1994), on the basis of revealing correlation connections of colour harmony in nature and works of art. The author showed that the fundamental signalling structure of the natural environment was reflected in the structure of the palette of colouring masterpieces of painting of different genres. Investigated by the author, the structure of colour harmony in works of art was identical to the structure of the organization of colour information of the natural environment and objects, including landscapes, flowers, etc. Kravetc (1994) identified the chain of connections in which the reflection in the system of nature-man-art can take place. First, it is a mental form of reflection in the perception of a person of nature (in one direction) and a work of art (in another). Secondly, this is a specially defined type of human activity – aesthetic activity, which is reflected in its specific forms and according to its own purposes. After all, as Kravetc (1994) notes, the artists reflected the patterns of nature describing them in a certain way. In other words, the reflection of the properties of natural environment – the nature inside the human nature and the images created by it in the psyche of this environment, as well as the formed artistic images, due to cultural and social and individual experiences, is a manifestation of the structural and material integrity of the world.

Thus, it has been experimentally proved today that the qualitative characteristics of the components of natural environment, main component of which is the landscape, influenced the formation of the notion of beautiful and aesthetic preferences of man, whose creative expression was the fine art, and his material expression was works of art. At the same time, the attention of scientists focuses mainly on the study of the aesthetics of natural landscapes, which occupy vast spaces, are formed without the participation of man and for a long period of time and aesthetics of the urban environment, as an autonomous structure formed by man according to his needs, technical capabilities, aesthetic looks, etc. The question of aesthetics, namely of park landscapes, can be considered in the context of the natural and urban environment and is determined by the characteristics of the park.

The purpose of the study is to find out

the communicational and informational value of the park environment as an aesthetic object of anthropogenic origin, which provides a connection in the space-time continuum between the subjects of its formation and perception.

Park Landscape as an Aesthetic Object

Despite the great attention of scientists from various fields of scientific knowledge to the question of the nature of aesthetic qualities, there is a discussion of the nature of the aesthetic qualities that act as signs of the object, but on the other hand they are subjective and are assigned by man. An ambiguous issue in the study of the aesthetics of the park environment is also the definition of the aesthetic object and the definition of its place in the context of this general scientific interpretation. Important in this context is the work of Sepännmaa (1993), which formed the classification of aesthetic objects, which includes two types and three kinds. According to her, aesthetic may be an object that has aesthetic qualities, as well as one that acts as an object of aesthetic research. Considering the park environment in the context of the work of Sepännmaa (1993), the park environment combines both natural and artificial type of aesthetic object, which in turn determines the presence of signs of two kinds of aesthetic object – environment and art (Fig. 1). In addition, the park environment can be both natural (natural parks) and ~~a~~ personal (parks of different functional purposes).

The landscape of natural parks, in the formation of which a person did not participate, cannot be defined as a work of art, but can be the subject of aesthetic research. In turn, the park environment created by a person according to a certain goal with taking into account certain aesthetic and ideological considerations can be considered as an art of forming the landscape as an aesthetic object. Accordingly, based on the analysis of the types and kinds of aesthetic objects allocated in the classification of Sepännmaa (1993), the following are found:

1. Park environment is the result of the art of forming the landscape along with the urban environment and inextricably linked with it.
2. Park environment is an object that has aesthetic qualities, and can act as a subject of aesthetic research.

In turn, the dual interpretation of the nature of aesthetic resulted in further development of concrete scientific approaches to the study of the aesthetic qualities of the object in two directions – the analysis of the object of perception (landscape), the definition of qualities that can be characterized as aesthetic and study subject perception – the person, as well as mechanisms of its interaction with the object.

Vygotsky (1987) defines aesthetics as a doctrine of the aesthetic attitude, that is, the general state that embraces a person and is determined by the aesthetic impression. That is, aesthetics is considered as a psychology of aesthetic pleasure and artistic creation of man. The issue of aesthetic pleasure as a motivational aspect of the formation of works of art is set out in Zangwill's (2007) work, where the author states that aesthetic pleasure comes from the idea of an object to the desire for contemplation in the real world. In addition, Zangwill (2007) notes that aesthetic pleasure has a special appearance, but it is still a pleasure, and the desire for pleasure is a reasonable and rational pursuit of time. In his turn, van Etteger et al. (2016) consider the theory of Zangwill (2007) in

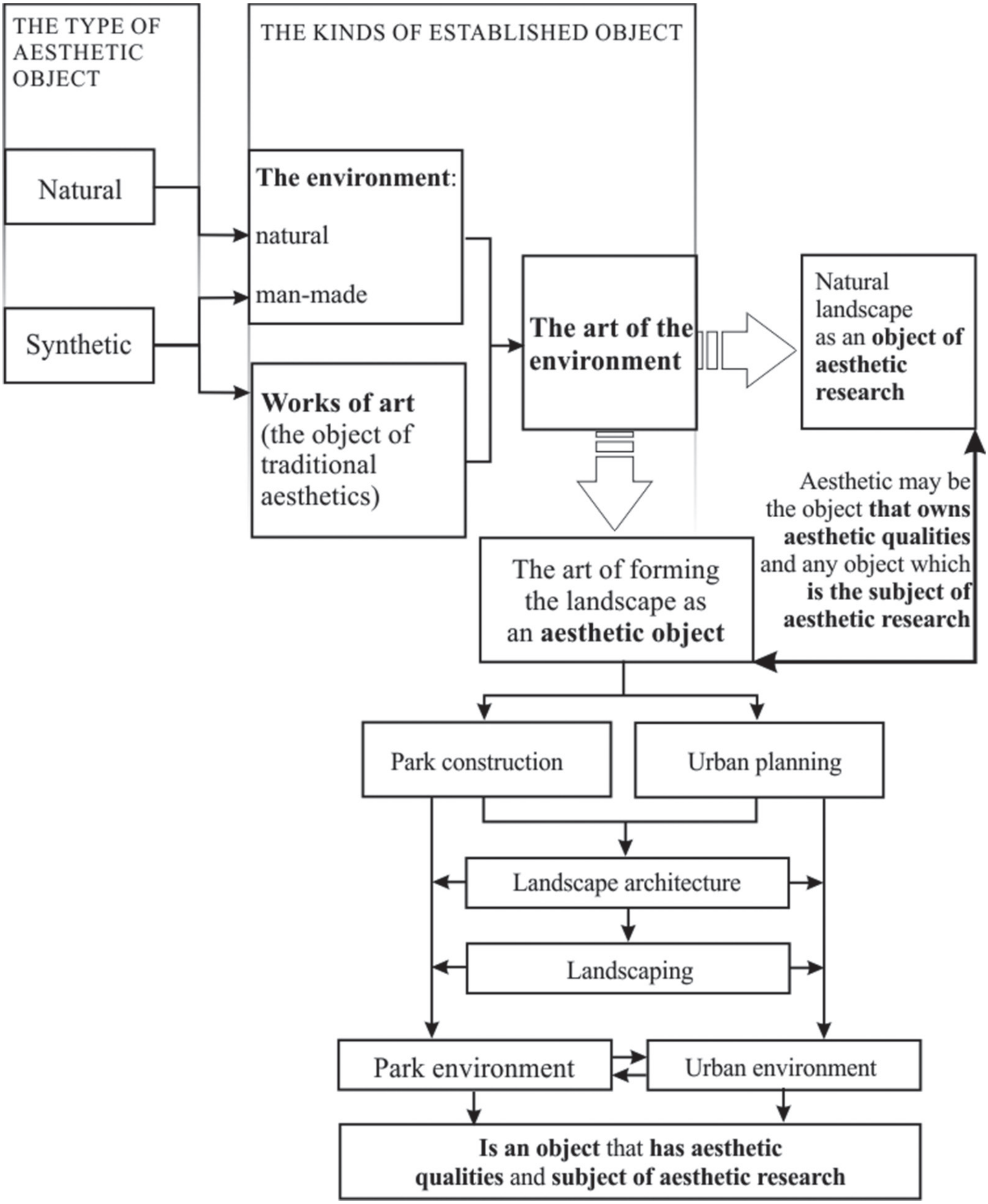

Fig. 1. Park environment as an object of aesthetic research (according to Sepännmaa 1993).

the context of landscape architecture.

Focusing on the person as the subject of perception, we should pay attention to the theory of personality development by Vygotsky (1987), according to which a person is the result of phylogeny (biological evolution), sociogenesis (history of culture) and ontogenesis (individual development). The theory of Vygotsky (1987) formed the basis of the paradigm of research in the field of landscape aesthetics Bourassa (1990), which distinguished three types of aesthetic human experience – biological, cultural and personal. Each type of experience has a number of special qualities that characterize the limitations and possibilities of aesthetic perception. In particular, biological experience identifies a group of factors of similarity of aesthetic preferences, while cultural (or sociocultural) and personal determine the range of differences.

The socio-cultural context of aesthetic perception of landscape was explored by Paul Vidal de La Blache and his students who discovered that there are groups of people characterized by spatial perceptions and landscape-aesthetic preferences and even developed the concept of ′cultural codes′. These ′codes′ define the spiritual and rationalistic landscape and aesthetic sympathies of people (Dirin and Popov 2010).

Brookfield (1969), who was one of the founders of behavioural geography, introduced the concept of ′environment of perception′ – a set of external factors (natural and sociocultural) that form thinking stereotypes in different groups of the population. This contributed to the development of studies devoted to the study of the spiritual and symbolic importance of landscapes, ethno-cultural stereotypes of perception. Therefore, there are the concepts of ′national landscape′, ′native land′ (Brookfield 1969, Haeyrynen 1996). In this context, it is worth paying attention to the work of Gold (1980), who, during the study of human perception of the landscape, identified three elements of this process: the perception of material tangible forms, both natural and man-made; the visible processes of human activity in the landscape, as well as the symbolic meanings given to it by human consciousness. Affecting natural objects in the process of meeting their needs, people reproduce them as ′symbols expressing her feelings′ through which collective beliefs are transmitted, as well as a value system of knowledge. However, there is also the other side, when contemplating the landscape causes a certain sense of the person, that is, the landscape causes certain associations and symbols (Gold 1980). In this way, there is a connection between the subject of shaping the landscape and the subject of its perception through time. Therefore, anthropogenic landscape (including park) serves as the object of the transfer of collective or individual information within the spatial-temporal continuum.

Information Significance of the Park Landscape as an Object of Communication

In recent decades, the question of assessing the aesthetic qualities of natural and anthropogenic landscapes has become increasingly relevant and has been highlighted in a number of scientists: Linton (1968), Kane (1981), van Etteger et al. (2016), Hrozdynskyi and Savytska (2005), Motoshyna and Vdoviuk (2012), Frolova (1994), Kochurova and Buchatckaia (2007), Nikolaev (2005), Hoisl et al. (1985), Dirin and Popov (2010) Hrynasiuk (2014), Osychenko (2011abc, 2012), Stoycheva (2016). Thus, at the present stage, trends in the study of aesthetics of the landscape have been formed, one of which is the focusing of attention on its information function and the object of communication between different societies and generations. First of all, information and cognitive approach within which information is considered as an important component of aesthetic preferences of people and is central in the study to both urban and park environment, but has different meanings. For the urban environment, information is the basis of constructing a cognitive map, which causes the ease of orientation in space, while in the park or natural landscape information, first of all, determines the formation of the image in the imagination to meet the aesthetic needs.

The subject of the information-cognitive approach is the peculiarities of the expression of information in the subject-spatial environment and the significance of the cognitive process of perception, and accessibility, clarity of reading increases the aesthetic evaluation (Fig. 2).

The question of information function of the subject-space environment of scholars in the post-Soviet space is encountered, in the first place, in the theory of architecture (Belyaeva 1977; Ikonnikov 1985, 1986; Barabanov 2002, and others). In particular, Ikonnikov (1985) emphasizes a number of features of architecture, among which – pre-programmed information that is laid down when it is created and has a general cultural and ideological and artistic content, important for the practical orientation of man, the formation of its psychological formation and perception of personality. This medium is both a product and a process of interaction, the object of the formation of information and its reading. Thus, architecture as the basis of the subject-spatial environment of cities has a double value – material-practical and information-aesthetic. System architecture, as its characteristic feature defines the structural basis of the subject-spatial environment, which enters into interaction with the subject (an individual, a group of people, a city community, a nation – it depends on the level at which the environment is considered) and updated its behaviour (Ikonnikov 1986). Along with this, Barabanov (2002) considers the urban environment as a system of replacing emotional and aesthetic signs, symbols and images, visible in architectural forms that determines the emotional and aesthetic, symbolic and figurative perception of a person in the picture of the world. Urban environment as ′hypertext′ is considered by Osychenko (2011ab, 2012), and aesthetic perception is characterized as a communicative act that ′immerses′ man into the sea of sustainable values and integrates it into society.

In turn, the information functions of the landscape were studied by foreign scientists – Kaplan and Kaplan (1978), Antrop (2005) Kaymaz (2012) and others. In particular, Kaplan and Kaplan (1978) define perception as a process of obtaining information through the senses, its organization and interpretation.

Park landscape, as part of the subject-spatial urban environment, inextricably linked with it, its functional and imaginative information system is (along with architecture) the carrier of information that was laid upon its formation, actualized in perception and affects consciousness. This way creates a ′sensible landscape′ (the term introduced by Lynch 1982) – a tangible medium that affects interpersonal communication, focuses on its importance for human comfort and manifests itself in sounds, aromas that can both promote and interfere with communication. The combination of stimuli of all human sensory receptors forms information that Lynch (1982) considers to be one of the most important forms of assessing the urban landscape, which is to analyse the forms of its functioning as an incentive, as well as the environment for learning and self-de-

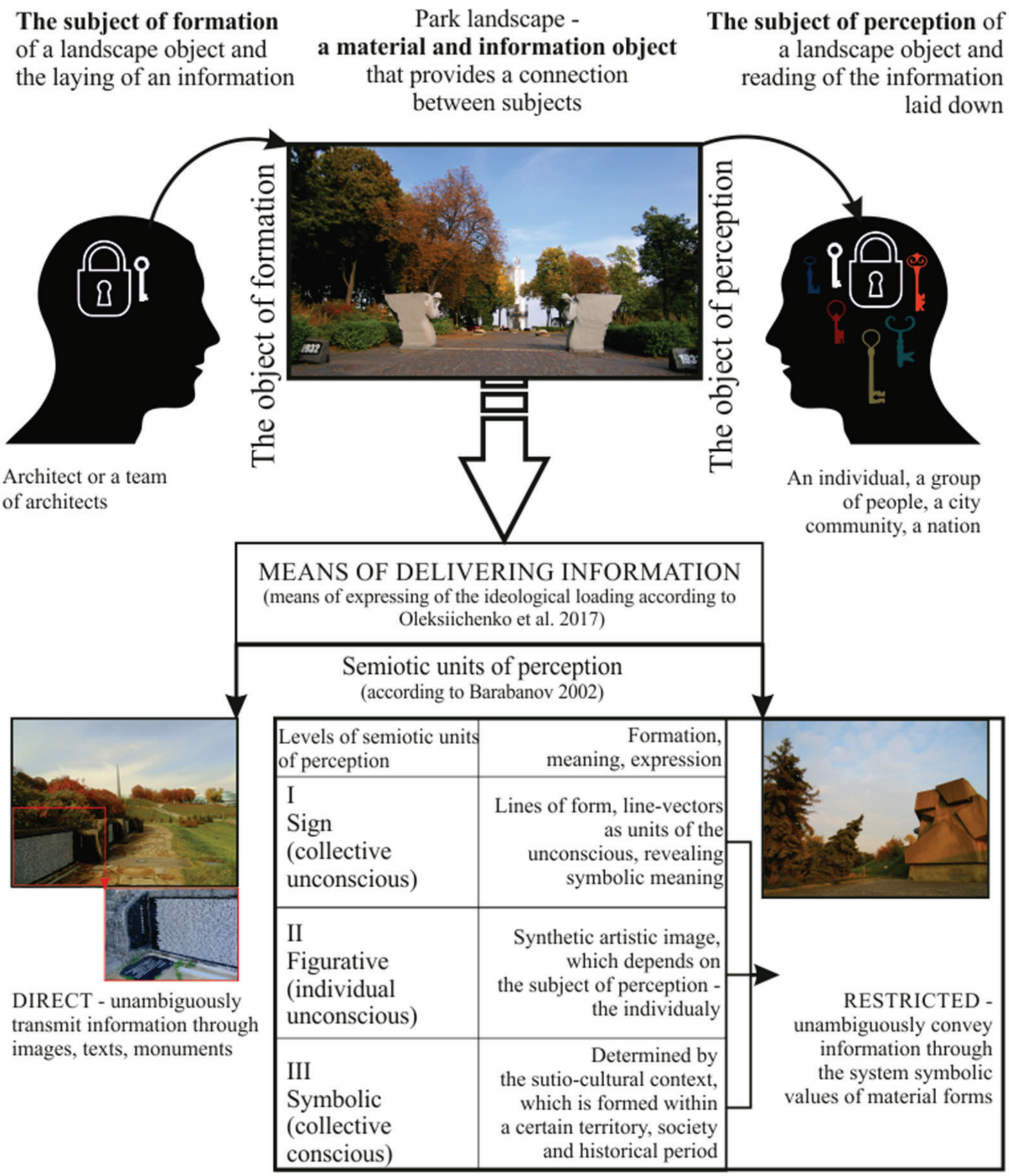

Fig. 2. The conceptual scheme of the process of communication between the actors of creation and perception of the park landscape as a material and information object.

velopment. The thought of Lynch (1982) has developed in subsequent years in the writings of such scholars as Ungar (1999), Antrop (2005), Forster (2010). The latter, in turn, highlighted the peculiarities of the perception of the natural environment:

1. Environmental perception is not immediate and takes time.
2. The scale affects the perception of the environment.

3. The environment is surrounded by people, which causes perception from the inside.

4. Navigational skills are required to perceive the environment.

5. Interaction with the environment, as a rule, is carried out for a certain purpose. As a result, a person chooses spatial information related to its purpose (Ungar 1999, Forster 2010, Kaymaz 2012).

A similar approach can be traced in the studies of Vygotsky (1987), who determines the emotional and aesthetic qualities of the object of observation art as the beginning and the ultimate goal in the chain of the consumer architect. The work of art in terms of psychology is considered by the author as a system of stimuli, which is deliberately organized with the intention of causing a certain aesthetic reaction. Thus, due to the analysis of stimuli, the structure of reactions is reproduced.

Comparing the perception of the architectural environment as the closest feature to the park, one should note the constant development of the latter, which is determined by the spatial-temporal characteristics, which is due to the constant change of landscapes due to seasonal dynamics and life cycle of plants. The compositional structure of the park is constantly changing, which makes it impossible to have a definite result, but is a continuous sequence of states, each of which must be distinguished by aesthetic appeal, readability and informativity. Lynch (1982), an important characteristic of landscape informativity, considers the density of information placement and its comprehensiveness. The clarity of information is determined by orderliness, ease of reading and relevance. According to Lynch (1982), the form and colour correspond to the message, which in turn affects the ease of reading.

An important characteristic of understanding and correct interpretation of information is the simplicity of the means of its communication, in particular at the expense of the simplest elements that organize the architectural form and influence the emotions of a person. It is on the importance of the elementary forming elements of architectural forms and the need to study their influence on the perception of man emphasized Le Corbusier (Barabanov 2002).

Consequently, the notion of informativeness of the urban environment is connected both with direct means of information (Lynch 1982) and with the system of symbols, images, signs (Vygotsky 1987, Barabanov 2002, etc.) that form a certain semiotic structure and most characteristic for the park landscape. At the same time, trees and other vegetation located around monuments can play an important role in increasing their impact. On the other hand, unsuccessful plant composition and invasive vegetation can destabilize the influence of the monuments located nearby (Galev et al. 2016). Particular importance is given to studies in the study of memorial parks, which provide a connection to the past generations at the expense of the symbolic, semantic and sign system, which, first of all, manifests itself in planning structure, monumental decoration and general compositional solution. The most semiotic approach to the formation of the image of the park landscape, as well as the manifestation of 'collective conscious', is observed in memorial parks of military subject, the content component of which is based on the figurative, symbolic and sign level. In particular, Oleksiichenko et al. (2017), in the research of military parks of war themes, direct and indirect means of expressing the ideological load of the park are distinguished, which may contribute to the correct interpretation of the information structure and the semantic values laid down during their formation, and to alleviate them. Such circumstances make it expedient to analyse the research of the semiotic structures of landscape objects in the context of informational-cognitive approach, since semiotic perception can be regarded as the highest level of cognition. Osychenko (2011c) highlights the significance and symbolism of architectural forms, as well as the interpretation of the content of objects as the subject of the study of aesthetic qualities of objects within the framework of the semiotic approach.

The study of ′semiotic units of perception′, is important in the context of formation of the landscape objects semiotic structures which is distinguished by Barabanov (2002), based on three levels of perception: the sign level (collective unconscious); figurative level (individual unconscious); symbolic level (collective conscious). To the sign level, which is actually the original, which is the same for all people, Barabanov (2002) classifies lines of form, line-vectors as integral units of the unconscious and reveals their symbolic meaning. At the figurative level, vectors of the line and holistic visual images form a synthetic artistic image, which depends on the subject of perception – man.

The synthetic image changes in time, because it is related to the individual experience of a person or society as a whole. It is worth noting that over time, not only the subject (man, society, society, humanity) is changing, but also the object of perception – a park landscape whose stability lies only in its variability. Thus, the content of park landscapes as media carriers changes, which respectively affects its interpretation. It becomes obvious that in the conditions of conscious laying of symbolic values through the sign system in the formation of landscape objects should take into account the variability of the components of the park environment.

In turn, when investigating the semiotic structure of a landscape object, which in this case can be considered as the object of mass communication, the particular difficulty lies in the revealed socio-cultural content, which is perceived by man at the third, highest level of visual perception – the symbolic (collective conscious). Collective consciousness is determined mainly by the sociocultural context, which is formed within a certain territory, society and historical period, and the park landscape, in this case, is a material embodiment of the socio-political, ideological and cultural-aesthetic aspirations of this society. The change in the sociocultural context in society leads to a change in the interpretations of the sign and information structure of the landscape object (see Fig. 2) and the incorrect interpretation of the content, the unpredictability of its impact on contemporary cultural and ideological views, and the formation of a worldview of the subject of perception (an individual, a group of people, city community, nation).

Model of Subject-object Relations of Man and the Park Environment

Accordingly, the process of human perception of the park environment can be regarded as a subject-object unity that develops over time and is constantly updated. Attention is focused on the study of mechanisms and conditions for its conservation in the change of the subject-object relations themselves. Accordingly, based on the conducted research, a structural model of the object-object relations of man and park environment was formed

(Fig. 3). An important aspect of this model is the closeness and interdependence of the stages of personality development, the process of perception of the park environment and the formation of its images. Thus, the process of forming landscape images based on Hrozdynskyi and Savytska (2005) is defined by the stages of personality development, identified by Vygotsky (1987), on one hand, and the material and image systems of the park environment on the other. In this case, phylogeny causes the appearance of sensory and operational images, which are

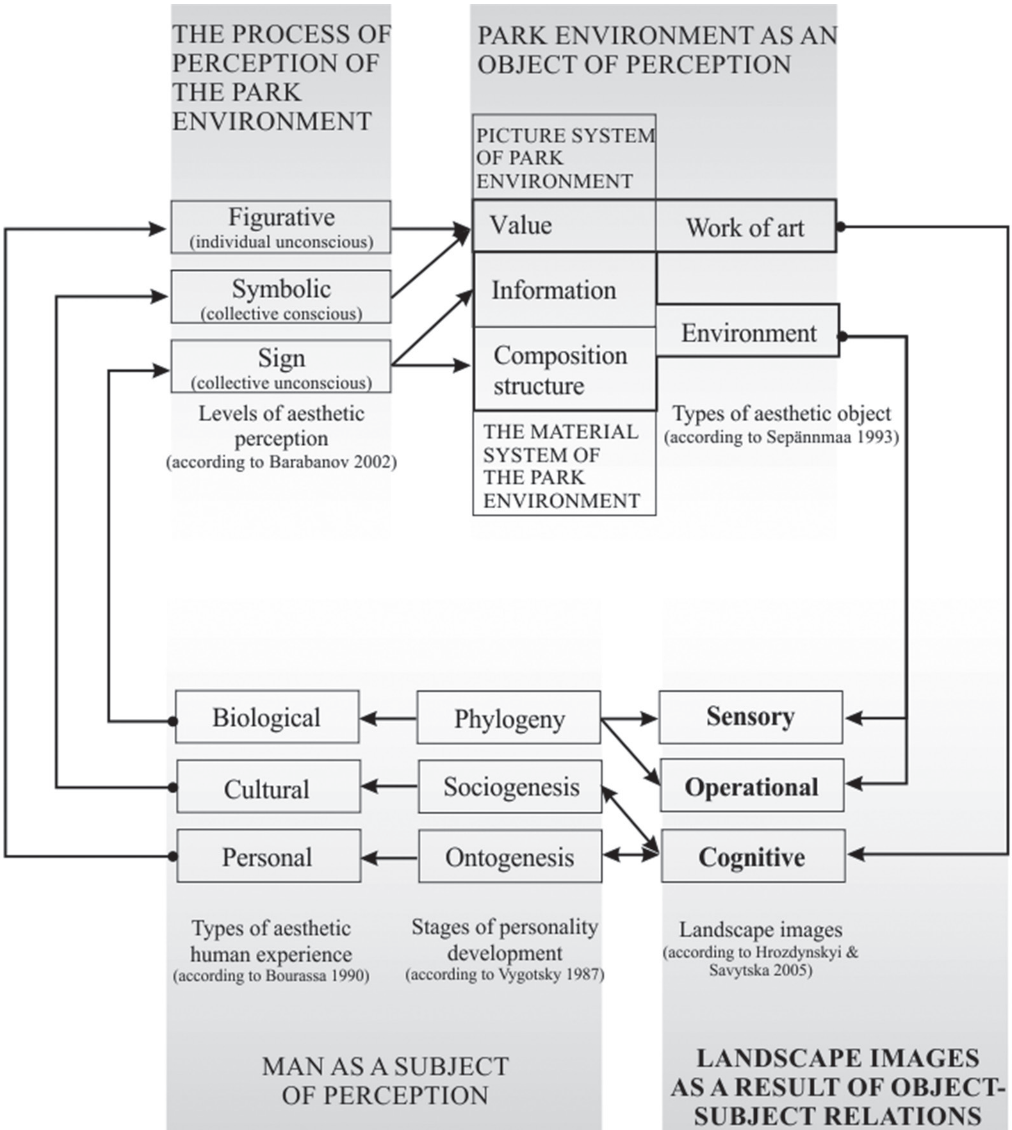

Fig. 3. Conceptual model of subject-object relations between man and the park environment.

formed as a result of sensory perception of the material system of the park environment. Ontogenesis and sogogenesis determine the peculiarities of the cognitive image of the landscape, which is formed on the figurative (individual unconscious) and symbolic (collective conscious) levels of aesthetic perception (according to Barabanov 2002), a figurative system of the park environment – its value and information structures. Those levels of aesthetic perception are determined by the kinds of aesthetic experience Bourassa (1990), which are formed as a result of the corresponding stages of personality development.

The cognitive image is the most complex and individual in nature, since it is determined by sociology and ontogenesis, whereas the sensory and operative images are similar to most people and are due to phylogeny. In this context, one should pay attention to the notion of a perceptive-cognitive system (Osychenko 2014), in which the subject and object of perception act as its components, and as a result of this interaction, we have the mutual change of state of both an object and the subject. The author emphasizes on the dynamics and self-development of the perceptive-cognitive system and allocates three levels of its organization: micro, macro, megawave.

Thus, a perceptually cognitive microsystem is formed under the influence of the need for information about an object or phenomenon that unfolds within the sensory field of the individual, that is, the ′material′ and informational image system of the park environment is ′read′. As a result, sensory and operational images of a particular park landscape in a certain time period or a series of landscapes in relatively small spatial boundaries are formed. The cognitive image formed by the perceptively cognitive macrosystem is more complicated and wider than in space and time. Formation of the image occurs as a result of ′reading′ a valuable figurative system of the park environment, comparing the one seen with its own normative and value system of the individual, which was formed as a result of socio- and ontogenesis.

Megasystem is the largest within the time and space, its formation occurs throughout the life of the individual, and the images formed as a result of the perception of the medium are stored in the long-term memory and serve as a context that allows the subject to extrapolate the sensory characteristics of reality, to match what has been seen with the previous experience, to consider park landscapes from a philosophical point of view. At the same time, Osychenko (2014) distinguishes the individual and external mega-image and notes that the first one can arise only in the context of the second, formed during this historical period in the culture of the national or world community.

Time as a Limiting Factor in the Development of Subject-object Relations between Man and the Park Environment

An important aspect of the analysis of the subject-object relations of man and the park environment in the context of studying the aesthetics of the latter is to determine the peculiarities of changes that occur under the influence of time. The aesthetic object is the park environment, which has (as noted above) a material and figurative system. The material is formed by the components of the park landscape, most of which are natural objects, which determines their development in time and space, and the most dynamic are plantations. At the time, as one of the changing components of the park space – emphasizes Bell (2004), who considers time in different aspects – from time to time, it is spent on the movement of the landscape object to natural cycles, the development of the universe and our lives. In addition, the author distinguishes cyclic (change of day and night, seasonal dynamics) and progressive time changes, which are related to the linear motion from the past through the present to the future Bell (2004). Accordingly, the spatial relationship of the park environment changes over time, and the peculiarities of the changes are defined as external (biotic and abiotic factors) and internal – biological and ecological peculiarities of plants, which usually form the basis of the composition structure of the park. The life cycle of plants, along with spatial changes in the park environment, causes continuous variability (seasonal dynamics). In turn, the variability of the material system of the park environment determines the transformation of the information and value structures of the figurative system (Fig. 4).

Man (or socium) as a subject of perception of the park environment as an aesthetic object is also changing over time under the influence of external – sociocultural and internal – personal factors. Accordingly, the figurative and symbolic level of aesthetic perception is changing, which irreversibly affects the interpretation of the content of the information and value system of the park environment and, as a result, the interpretation of the cognitive image of the landscape.

Interpretation of the content is conditioned by the human need to endow the surrounding objects and phenomena with content, and in this way long-term memory is formed, which, unlike short-term, uses meaning, not an image. It is the empowerment of the seen with the meaning allows you to memorize the information about them. In turn, objects that are attracting attention are remembered, and in the park environment the emphasis components are changing. However, the volatility of the emphasis of the material system, the park environment changes several times a year, while changing aesthetic views of a person as a subject of perception requires much longer period of time or significant socio-cultural or political events.

Conclusions

Park landscapes, depending on their features, can be considered as a part of the natural landscape (natural landscape parks, biosphere reserves) or as a part of the urban environment (urban parks of various functional purposes, located within the settlements and characterized by the presence of a significant proportion of artificially created components). Speaking of natural landscapes, it's worth noting that the aesthetic object is a natural form, while in the park – natural objects are formed in accordance with certain views and human needs.

Focusing on the process of creating a park landscape as an aesthetic object, it is advisable to note its proximity to urban planning, since the park, like the urban environment, is a product of various authors, which sometimes do not intersect in time both with each other and with the subject of perception. While the natural landscape is formed without the participation of man, and the visual perception, definition of aesthetics and, moreover, the symbolic interpretation depends solely on the subject of perception. Such circum-

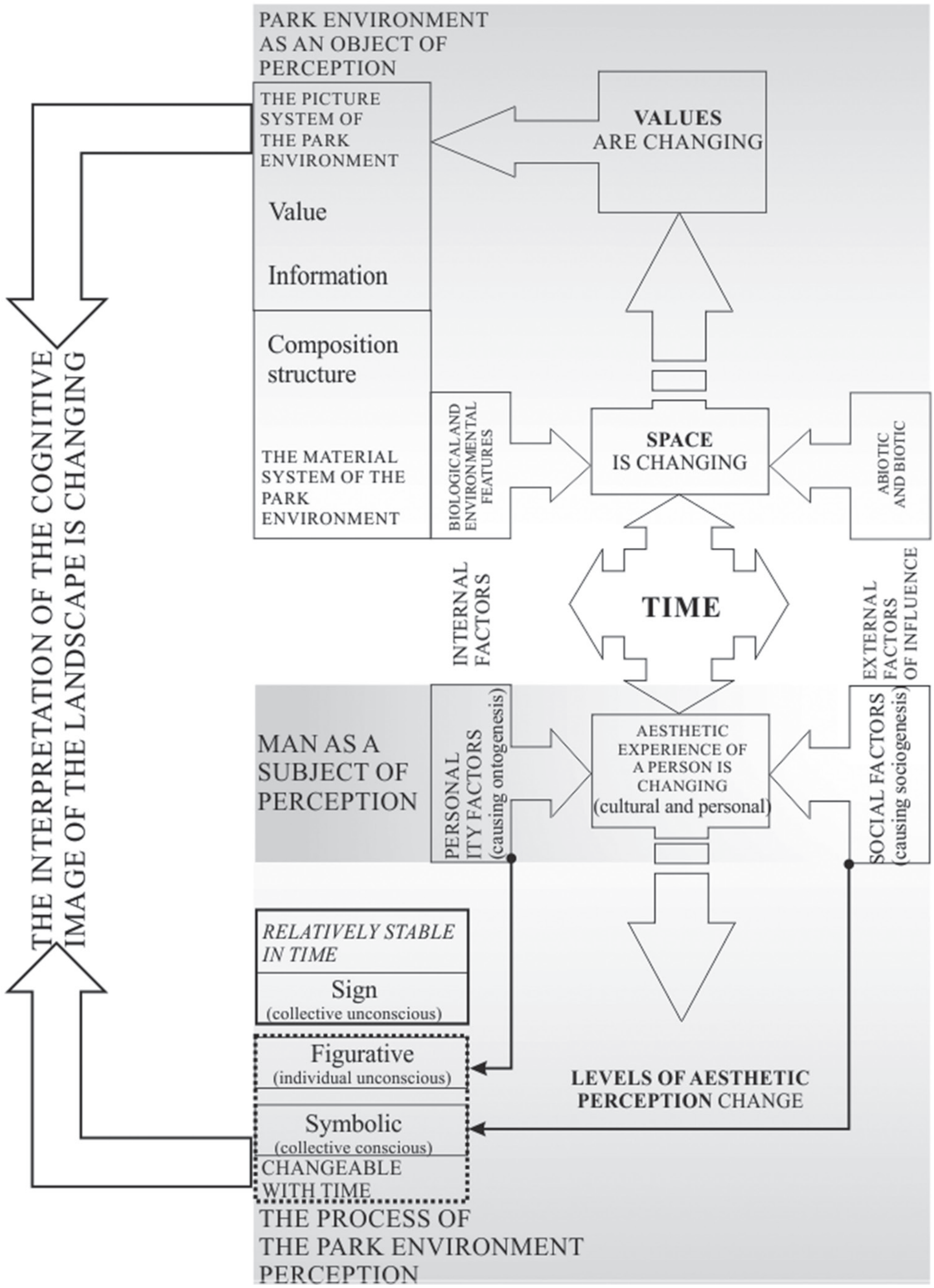

Fig. 4. Structural-logical scheme of changes of subject-object relations of man and the park environment under the influence of time.

stances determine the unpredictability of the aesthetic assessment of the natural landscape, while the park was formed as an expression of certain aesthetic representations of the author(s) and provided for the emergence of certain emotional impressions in the observer. However, the aesthetic and informational value put forward by the author may differ significantly from the value perceived by the observer.

An important general aspect of perceiving the natural, urban and park landscape as an aesthetic object is multisensory (perception occurs at the expense of all senses), which is fundamentally different from works of art that are designed for the visual sphere of perception (works of fine arts) or rumour (music). Along with the richness of the perception of the park landscape, as a rule, it is impossible to reach immediately, perception occurs as a series of landscapes. The main factors that limit the formation and the perception of the park landscape as a communicative-informational aesthetic object is the time that affects the variability of the material forms of the object, on one hand, and the aesthetic experience of man – on the other. Such circumstances determine the changes in the information-value function of the landscape in the structure of the object-subject relations between man and the park environment.

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