Biol. Stud. 2023; 17(3): 139–166 • DOI: https://doi.org/10.30970/sbi.1703.722
www.http://publications.lnu.edu.ua/journals/index.php/biology

UDC: 582.641.6:(581.5+9):[477.42+81+82]

VISCUM ALBUM SUBSP. *AUSTRIACUM* (SANTALACEAE R. BR.) IN VOLYN POLISSIA AND ZHYTOMYR POLISSIA (UKRAINE): CURRENT DISTRIBUTION, ECOLOGY AND PREDICTION OF FUTURE SPREAD

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Orlov, O., Danylyk, I., Zhukovskyi, O., Budzhak, V., Fedonyuk, T., Borodavka, V., & Borodavka, O. (2023). *Viscum album* subsp. *austriacum* (Santalaceae R. Br.) in Volyn Polissia and Zhytomyr Polissia (Ukraine): current distribution, ecology and prediction of future spread. *Studia Biologica*, 17(3), 139–166. doi:10.30970/sbi.1703.722

Background. One of the subspecies of the European mistletoe, the so called pine mistletoe (*Viscum album* subsp. *austriacum* (Wiesb.) Vollm.) is a hemiparasitic, evergreen, epiphytic phanerophyte that parazitizes predominantely on the Scots pine (*Pinus sylvestris* L.) in Ukraine. The pine trees infested with *V. album* subsp. *austriacum* lack moisture for transpiration and photosynthesis, which reduces their primary productivity, viability and health.

The purpose of this study was: 1) to determine the current distribution of *V. album* subsp. *austriacum* in Volyn and Zhytomyr Polissia regions using GIS-technology; 2) study the main taxation parameters of pine stands infested with *V. album* subsp. *austriacum*; 3) predict the possible further spread of *V. album* subsp. *austriacum* in the studied Region.

Materials and Methods. The grid mapping method based on GIS technology, with a grid size of 10×10 km and 20×20 km, was used to create the map of the species distribution. The spatial distribution of soil moisture in the forest soils of Drevlyanskyi Nature

Reserve was determined using satellite images and data on soil moisture from the Earth Engine Data Catalog. The taxation parameters of the mistletoe-infested pine stand (i.e., participation of the Scots pine in the stand composition, area distribution of pine stands by age, relative completeness, stand quality class, trophotope, and hygrotope) were obtained from standard taxation descriptions.

Results and Discussion. The study found that *V. album* subsp. *austriacum* is more widespread in Volyn Polissia than in Zhytomyr Polissya – 87 and 20 localities respectively. It was shown that the forest plantations colonized by *V. album* subsp. *austriacum* in Drevlyansky Nature Reserve are located in areas with the lowest moisture content, with a moisture reserve of 16–70 mm in the 0–100 cm soil layer, which corresponds to dry and fresh hygrotopes.

Conclusions. *V. album* subsp. *austriacum* is more widely distributed in such nature reserves of the region as Shatskyi National Nature Park and Drevlianskyi Nature Reserve, and less so in Rivne, Cheremskyi, Polissia Nature Reserves and Pripyat-Stokhid National Nature Park.

In the region under study, *V. album* subsp. *austriacum* mostly affects pure pine forests aged 80–140 years, of medium completeness (0.5–0.7), and relatively high and high stand quality classes – I^c–II, in fresh hygrotopes – 67.3 % of the area and in fairly infertile pine site type (trophotope B) – 51.5 %. Based on the distribution of forest site types in the region and their susceptibility to *V. album* subsp. *austriacum,* the possibility of its further intensive spread in the study region can be predicted.

Keywords: Scots pine (*Pinus sylvestris* L.) stands, distribution mapping, stand quality class, trophotope, hygrotope

INTRODUCTION

According to up-to-date molecular-genetic studies (Bilonozhko *et al.*, 2021; etc.), three subspecies of *Viscum album* L. are spread in Ukraine: *V. album* subsp. *album* L., *V. album* subsp. *austriacum* (Wiesb.) Vollm. and *V. album* subsp. *abietis* (Wiersb.) Janch. (Zuber & Widmer, 2009; Krasylenko *et al.*, 2020).

V. album subsp. *austriacum* is a hemiparasitic, evergreen, dioecious, epiphytic phanerophyte of spherical shape with the diameter of 30–60 cm and dichotomous branching, whose lifespan may reach 27–30 years (Catal & Carus, 2011). Being a photophilous species, this mistletoe mainly grows in the upper part of the crown of different species of pine (*Pinus* L.), much less frequently in spruce (*Picea* A. Dietr.) and larch (*Larix* Mill.) (Dobbertin *et al.*, 2005). In Ukraine, the species was recorded only on individuals of *Pinus sylvestris* L. (Krasylenko *et al.*, 2020). The geographic range of *V. album* subsp. *austriacum* spans the northwest of Africa (Morocco), the Iberian Peninsula, Central and Southern Europe, the western part of Eastern Europe, the Caucasus, and Asia Minor (Loranthaceae Juss., 2022). The morphological characteristics and life cycle of *V. album* subsp. *austriacum* are well studied (Zuber, 2004; Jäger *et al.*, 2017), however we have noted a number of important biological and ecological features of the species. In particular, *V. album* subsp. *austriacum* can be considered a barochore – since its ripe fruits spontaneously fall from the maternal plants and tops of the crowns due to gravity, creating the so-called “seed rain”, which explains the presence of *V. album* subsp. *austriacum* individuals on branches in the lower parts of tree crowns and on understory plants under the tree canopy. In southern Spain, for example, in favourable high mountain conditions “seed rain” under *Pinus* species reached 830 ± 183.8 seeds·m^{-2} (Zamora & Mellado, 2019).

V. album subsp. *austriacum* is mainly dispersed by means of ornithochory. The main vectors of its seed dispersal are three species of birds – *Bombycilla garrulus* (Linnaeus, 1758), *Turdus viscivorus* (Linnaeus, 1758), and *T. pilaris* (Linnaeus, 1758) that eat the mistletoe berries together with the seeds, which are then transported to the crowns of new pines with excremnets – through endoornitochory (Krasylenko *et al.*, 2020). These three species are responsible for the long-distance transport of seeds. It should be noted that the aforementioned bird species are known mainly as vectors of spread of *Viscum album* (Krasylenko *et al.*, 2020). In the region under study, they were observed in infested pine stands (Rivne Nature Reserve, M. Franchuk, pers. comm.). In addition, a significant increase in the number of *Bombycilla garrulus* and *Turdus viscivorus* in the Region (compared to other regions), was observed (M. Franchuk, pers. comm.). Another, more numerous group of birds – *Sylvia atricapilla* (Linnaeus, 1758), *Parus major* (Linnaeus, 1758), *Periparus ater* (Linnaeus, 1758), and others – consume only the juicy endocarp of berries (Mellado & Zamora, 2014). In this case, the seeds stick to the birds' beaks and feet (the endocarp contains sticky viscin, also called "bird's glue"). Eventually, the birds get rid of the seeds by rubbing against the branches, to which the seeds adhere and subsequently germinate. This type of dispersal is referred to as ectornitochory. This group of birds provides for primarily short-distance transport of *V. album* subsp*. austriacum* seeds, mostly in close proximity of the mother plant.

The relationships between *V. album* ssp. a*ustriacum* and its host tree are rather dramatic. As research shows (Mathiasen *et al.*, 2008), the level of transpiration in *V. album* subsp. *austriacum* is much higher than in *P. sylvestris*, and with a significant infestation of a pine tree by mistletoe, the water-use efficiency of *P. sylvestris* decreases almost tenfold (Bilgili *et al.*, 2018). A mistletoe-infested *P. sylvestris* suffers from the lack of water for its own transpiration and photosynthesis (Rigling *et al.*, 2010); as a result, stomata on the needles close and carbon dioxide is not assimilated (Zweifel *et al.*, 2012), which substantially decreases the synthesis of carbohydrates (by up to 42 %) and primary production (C-parasitism hypothesis). The situation is further aggravated by the decrease in the content of chlorophyll in the needles of mistletoe-infested pine trees (Rigling *et al.*, 2010). *V. album* subsp. *austriacum* deprives the host trees of water and nutrients, disrupting their growth processes and negatively affecting their health and resistance to stress factors. The pine needles gradually shorten and thin out, becoming yellowish; the young shoots wither first, followed by the older ones. The crown becomes sparse, and eventually the tree dies (Szmidla *et al.*, 2019). The negative impact is particularly noticeable during the drought periods when mistletoe causes not only hydrothermal but also oxidative stress in pine trees (Multu, Ilhan & Turkoglu, 2016), which may lead to the death of the host plant. Noteworthy, climate change contributes to the further spread of *V. album* subsp. *austriacum* i (Walas *et al.*, 2022). Researchers emphasize that the reduction of primary production, a decrease in annual radial growth of pine (up to 64 %), and mechanical degradation of pine wood are extremely negative ecological and economic consequences of the extensive colonization of pine stands by *V. album* subsp*. austriacum* (Yan *et al.*, 2016; Bilgili *et al.*, 2018; Kollas *et al.*, 2018).

With the above in view, our study addressed the following goals: 1) to determine the current distribution of *V. album* ssp. *austriacum* in the study area, create a database and draw a map based on GIS technology, 2) study the main taxation parameters of pine stands affected by *V. album* subsp. *austriacum,* and 3) predict the possible further spread of *V. album* subsp. *austriacum* in the studied area.

MATERIALS AND METHODS

Physical and geographical boundaries of Volyn Polissia and Zhytomyr Polissia Regions were established according to the official physical and geographical zoning of Ukraine (Marynych *et al.*, 2007).

Information sources. Elementary forest stands were chosen as specific localities of *V. album* subsp. *austriacum* where this species occured. To create a GIS database of records of *V. album* subsp. *austriacum* in the study region, we used four types of sources: literature data (Krasylenko *et al*., 2020); floristic databases – GBIF (GBIF, 2023), iNaturalist (iNaturalist, 2022), UkrBIN (UkrBIN, 2022); herbarium collections (KW, KWHA, KWU, LWKS, LWS, LW, CHER, Herbarium of Lesya Ukrainka Volyn National University (LUU), Herbarium of the Zhytomyr Regional Museum of Local Lore (ZHM), Herbarium of Rivne Nature Reserve (RNR)); and data from modern field observations, both our own and provided to us by other researchers, and in most cases confirmed by photographs.

Mistletoe distribution mapping. For the general presentation of the chorological data, we used the method of grid mapping based on GIS technology, according to "Atlas Florae Europaeae..." (Jalas & Suominen, 1972), adapted for the local territories (Budzhak *et al*., 2016; Budzhak *et al*., 2020). The basic map of Volyn and Zhytomyr Polissia with a grid of 10×10 km and 20×20 km (projection WGS 84 [EPSG:4326]) was created using the MapInfo program (MapInfo Professional 7.5 Product – 20MIRU750WP, Serial Number – MIPWRS0750400147, developer Pitney Bowes Software) based on electronic multi-layered maps of Ukraine with a scale of 1:200,000. The working layers represent a database that includes textual and digital information, on the basis of which a special map was created.

Construction of the forest soil moisture reserve map. Spatial distribution of forest soil moisture reserve in Drevlianskyi Nature Reserve was performed using composite image metrics that were created using all available Landsat 8-9 OLI/TIRS C2 L1, Landsat 7 ETM+ C2 L1, Landsat 4-5 TM C2 L1, and Landsat 1-5 MSS C2 L1 images that covered the territory of Drevlianskyi Nature Reserve during the second decade of August and the first decade of September 2021–2022, downloaded from the Earth Explorer of the Geological Survey (USA) and the EROS data center (USGS, 2023) (L1C_T36UXU_A018151_20200827T084601, Cloud cover = 0.06080), as well as data on moisture reserve in the layer 0-100 cm from the Earth Engine Data Catalog (ERA5-Land Monthly Averaged, 2020). Sentinel-2 band spectra were obtained using the extraction tool in the Spatial Analysis Toolbox in ArcGIS Pro 3.1.0. This method has already been used in previous studies for data processing in the analysis of both biodiversity and sanitary state of forests, and showed considerable informativeness (Fedonyuk *et al.*, 2020; Skydan *et al.*, 2022).

Evaluation of taxation parameters of mistletoe-infested forest stands. Taxation parameters of elementary forest stands colonized by *V. album* subsp. *austriacum* were obtained from standard taxation descriptions of corresponding forest sites, and their evaluation was performed using standard parameters (participation of the Scots pine in the stand composition, area distribution of pine stands by age, relative completeness, stand quality class, trophotope, and hygrotope) (Hrom, 2007; Mostepaniuk *et al.,* 2017). Distribution graphs of taxation parameters of pine stands infested with *V. album* subsp. *austriacum* were constructed using the Microsoft Excel (2016). For calculation of mistletoe individuals per pine tree, three most infested model trees on some sites were cut, and individuals of mistletoe of all ages were counted on each tree.

RESULTS AND DISCUSSION

The compiled data on the current distribution of *V. album* subsp. *austriacum* in the study region (**Fig. 1**; **Appendix 1**) indicates a significantly greater frequency of its occurrence in Volyn Polissia than in Zhytomyr Polissia – 87 and 20 localities, respectively. The recorded number of localities is much higher than the number reported by previous studies for this region (Krasylenko *et al.*, 2020): new records include two localities in Cheremskyi Nature Reserve, four in Shatskyi National Nature Park, and all localities in Zhytomyr Polissia.

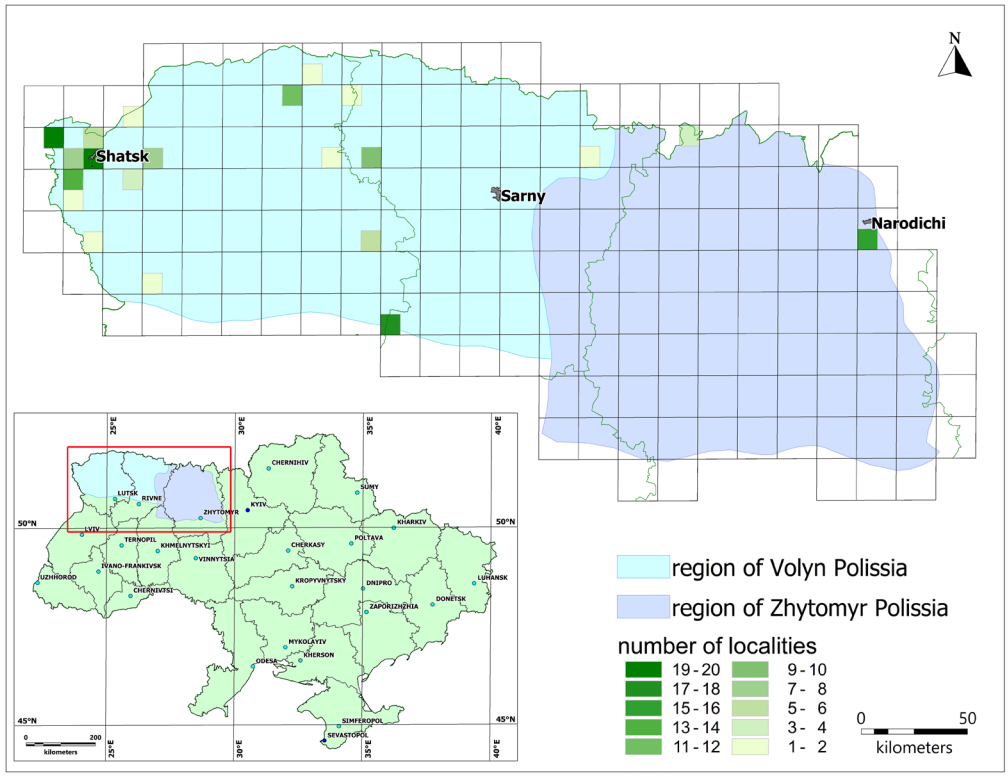

Fig. 1. Current distribution of pine mistletoe in Volyn Polissia and Zhytomyr Polissia

In Volyn Polissia (Volyn Region), the largest locality of pine mistletoe is Shatskyi National Nature Park (Svityaz and Melnykivske forestries) as well as forestry enterprises – branches of the State Enterprise "Forests of Ukraine" – located in the surrounding area: Liubomlske Forest Range (Shatske, Zamlynske, and Hushchanske forestries), Kovelske Forest Range (Dubechnivske and Liubokhynivske forestries), Volodymyr-Volynske Forest and Hunting Range (Stenzharychivske forestry), Ratnivske Forest and Hunting Range (Zabolotivske forestry). Besides, a number of pine mistletoe localities have been found near the administrative border between Volyn and Rivne Regions: in Volyn Region – the Prypiat-Stokhid National Nature Park, Liubeshivske Forest Range (Derevkivske forestry), Kolkivske Forest Range (Kolkivske forestry), Kivertsivske Forest Range (Moshchanytske forestry), Cheremskyi Nature Reserve; in

Rivne Region – Kostopilske Forest Range (Novostavske forestry), Rafalivske Forest Range (Mulchynske forestry), Rivne Nature Reserve (Biloozerske and Bilske forestries).

The specific feature of the distribution of *V. album* subsp. *austriacum* in Volyn Polissia lies in the fact that only in this region of Ukraine the species is found on old suppressed pine trees in mature forest wetland ecosystems, namely, in sphagnum mesotrophic and meso-oligotrophic habitats (Rivne Nature Reserve and Cheremsky Nature Reserve), as well as in pine forests along lake shores (Rivne Nature Reserve and Shatskyi National Nature Park).

An average area of *V. album* subsp. *austriacum* localities in Volyn Polissia is 3 ± 0.5 ha, the minimum area – 0.1 ha, the maximum – 25.0 ha. The maximum number of pine mistletoe individuals per one pine tree was 35.

This research presents records of *V. album* subsp. *austriacum* distribution in Zhytomyr Polissia for the first time. The species was found in the northern and northeastern parts of the region, namely in Polissia Nature Reverve (Kopyshchanske forestry), Drevlianskyi Nature Reserve (Narodnytske forestry). In the former nature reserve, only two localities of *V. album* subsp. *austriacum* were found on a relatively small area, whereas in the latter one, where the distribution of the species is massive, 18 localities were recorded. An average area of *V. album* subsp. *austriacum* locality in Zhytomyr Polissia is 5 ± 1.3 ha, the minimum area – 0.1 ha, the maximum – 18.4 ha. The maximum number of *V. album* subsp. *austriacum* per one pine tree was 28 individuals.

In the studied area, *V. album* subsp. *austriacum* is widely distributed in Shatskyi National Nature Park and Drevlianskyi Nature Reserve, and to a much lesser extent in Rivne, Cheremskyi, and Polissia Nature Reserves and the Pripyat-Stokhid National Nature Park.

The insufficient (until recently) knowledge about the distribution of *V. album* subsp. *austriacum* in the studied area has resulted in the fact that despite its damaging effect, especially in the protected areas, this species was included in the lists of rare plant species of Zhytomyr (Orlov & Vergeles, 2011) and Volyn Regions (Danylyk *et al.*, 2022). It is therefore impossible to launch an eradication campaign of *V. album* subsp*. austriacum* in the mentioned Regions, which results in deteriorating the sanitary condition of pine forests, loss of their ecological stability and the reduction of their annual growth rate. Furthermore, it was established that *V. album* subsp. *austriacum* spreads rapidly in pine stands. For instance, in the Federal State of Brandenburg (Germany), the infection rate of pine trees by *V. album* subsp. *austriacum* significantly increased in a six-year period, from 1 % in 2009 to 11 % in 2015 (Sachsen-Anhalt, 2015).

Due to the fact that *V. album* subsp. *austriacum* causes significant damage to pine forests in Europe, it has been included in the list of harmful species of the European Plant Protection Organization (EPPO) subject control and eradication (EPPO, 2004). Considering the extensive distribution of *V. album* subsp. *austriacum* in the region under study, the large number of individuals in its current localities, and their significant harmfulness to the host trees, we believe that *V. album* subsp. *austriacum* should be excluded from the lists of rare plant species of Volyn and Zhytomyr Regions.

Evaluation of the main taxation parameters of pine stands infested with pine mistletoe. As numerous studies have shown (Kartoolinejad *et al.*, 2007; Kollas *et al.*, 2018; Krasylenko *et al.*, 2020; Lorenc & Véle, 2022), taxation indices of plantations largely determine the susceptibility of pine forests to pine mistletoe infestation. Therefore, we have analyzed the most important indices of pine stands infected by the mentioned species in the region under study.

Analysis of the area distribution of pine stands infected by pine mistletoe by the share of the Scots pine in their species composition (**Fig. 2**) demonstrated that pure pine forests dominated among the affected stands (47.1 % of the area); the proportion of stands with a 95 % share of Scots pine in their tree canopy constituted 23.1 %.

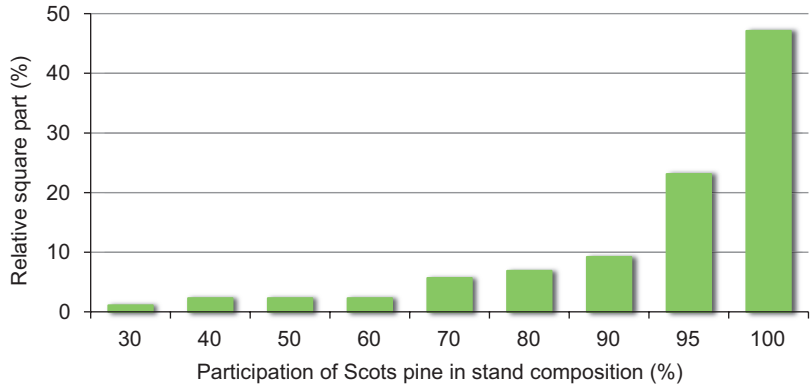

Fig. 2. Area distribution of forest stands by share of Scots pine in species composition

The relative proportion of the area of mixed (coniferous-deciduous) forests with the 30–40 % share of the Scots pine amounted only to 3.4 %. The share of mixed forests with the 50–70 % of Scots pine trees was also insignificant – from 2.3 % to 5.7 %.

V. Yukhnovskyi *et al*. (2019) noted that the age of plantations largely determines the susceptibility of pine forests to infestation by pine mistletoe. Therefore, our study addressed the area distribution of mistletoe-infested pine stands by age (**Fig. 3**).

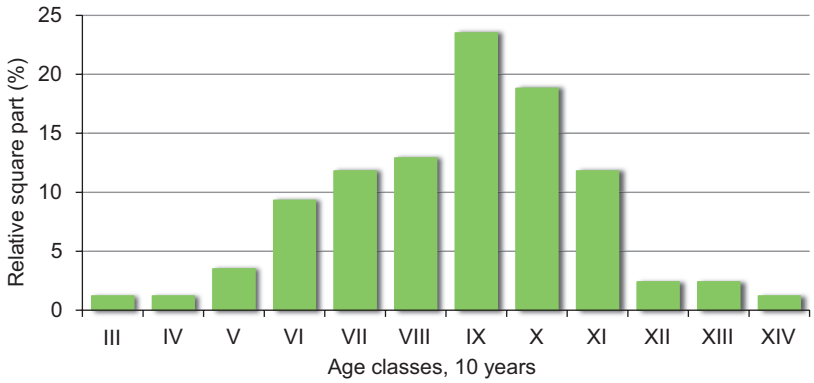

Fig. 3. Area distribution of pine stands by age

In particular, it was found that *V. album* subsp. *austriacum* mainly affects mature and overmature pine forests (age classes IX–XII and XIII–XIV, respectively (Hrom, 2007), which account for 60.1 % of the total area, as well as pre-mature stands (24.7 % of the total area). The smallest proportion of the total area is represented by young stands of age class III–IV, which account for 2.4 %. The proportion of middle-aged stands (age classes V–VI) is also relatively small, accounting for 12.8 % of the total area.

The completeness of pine stands and crown closure strongly influence the spread of pine mistletoe in forests, which is due to its heliophilic nature. In addition, these factors determine the formation of favorable conditions in tree crowns for the settlement and presence of birds – the main vectors for the European mistletoe seed dispersal (Krasylenko *et al.*, 2020). It has been found that the main part of the pine forest area affected by mistletoe is characterized by medium completeness (relative completeness of 0.5–0.7) – a total of 78.8 % (**Fig. 4**); this indicator is normal for old-growth pine forests. The share of pine forests with a high completeness index (relative completeness of 0.8–0.9) affected by mistletoe is 18.8 % of the total area, while the share of forests with low completeness is 2.4 % of the area.

To assess the possible losses of forest resources from the infection of pine stands by *V. album* subsp. *austriacum*, we analyzed the pine stand area distribution by stand quality class (**Fig. 4**). It was found that the majority of the mistletoe-infested pine stands (49.4 %) were of relatively high productivity – stand quality class II. The share of highly productive pine forests with stand quality classes I–I^{c} constituted 26.0 % in total. Low-productivity pine forests – with stand quality class IV – constituted the smallest share of the area in the region (5.9 %). These are typical for the ecological conditions of dry lichen infertile pine site type (A_1) of sandy dunes or wet infertile pine site type (A_5) of meso-oligotrophic sphagnous mires. Thus, it was proven that *V. album* subsp. *austriacum* affects the most productive stands – with stand quality classes I^{c}–II, which can lead to significant negative ecological and economic consequences in the best pine forests of the region under study.

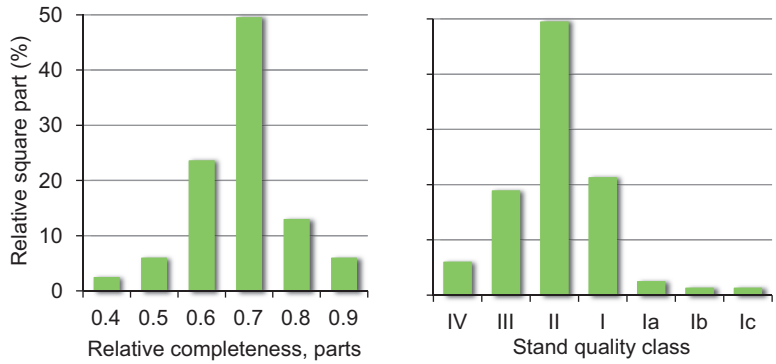

Fig. 4. Area distribution of pine stands by relative completeness and stand quality class

To prognose a possible spread of *V. album* subsp. *austriacum* in the pine forests of the region under study, we have conducted analysis of area distribution of mistletoe-infested pine stands by trophotope and hygrotope (Pohrebniak, 1955).

The analysis of the distribution of the areas of pine forests infested by *V. album* subsp. *austriacum* by trophotope is of significant interest (**Fig. 5**). Our findings show that *V. album* subsp. *austriacum* prefers the infertile pine site type (trophotope A), the share of which in the area of pine forests infested by mistletoe is 30.7 %, which is 1.8 times higher compared to the relative share of this trophotope in the forests of the study region (17.1 %). The relative share of the area of fairly infertile site type (trophotope B) pine forests affected by *V. album* subsp. *austriacum* is approximately equal to the share of this trophotope in the forests of the study region – 51.5 % and 48.8 %, respectively. However,

the relative share of the area of fairly fertile site type (trophotope C) pine forests affected by mistletoe is almost twice smaller compared to the share of this trophotope in the forests of the study region – 17.8 % and 34.1 %, respectively. Thus, a conclusion can be drawn about the particularly favorable environmental conditions of the infertile site type (trophotope A) pine forests for infestation by *V. album* subsp. *austriacum*.

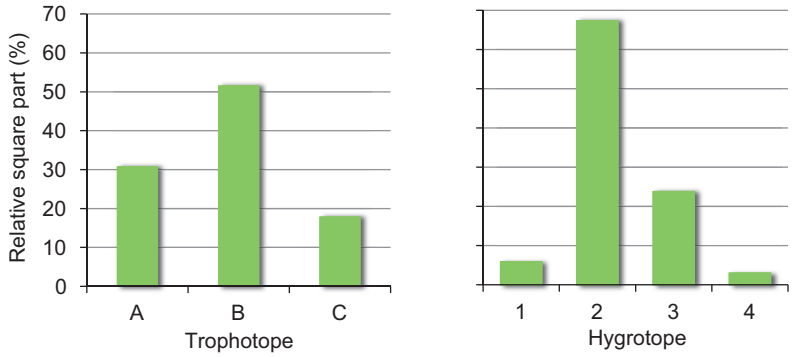

Fig. 5. Area distribution of pine stands by hygrotope (dry (1), fresh (2), moist (3), damp (4) and trophotope (infertile pine site type (A), fairly infertile pine site type (B), fairly fertile site type (C)

The analysis of data presented in **Fig. 5** shows that *V. album* subsp. *austriacum* is most widely spread in fresh hygrotope accounting for 67.3 % of the area of mistletoe-infested pine stands of the study region. Comparing the area of mistletoe-infested pine stands in fresh hygrotopes with the relative share of the area of this hygrotope in the region under study – 39.5 % (Tkachuk, 2004) – we can see that the former is 1.9 times as big as the latter. Similarly, the proportion of the area of pine stands infected by *V. album* subsp. *austriacum* in dry hygrotope (5.9 %) is 2.4 times higher than the relative proportion of this hygrotype in forests of the region (2.4 % of the area). These data indicate the particular susceptibility of pine forests in fresh and dry hygrotypes to infestation by *V. album* subsp. *austriacum*, and lower susceptibility of moist and damp hygrotopes, the shares of which in the area of mistletoe-infected pine stands are 23.8 % and 3.0 %, respectively. These data are well consistent with the findings of other researchers (Rigling *et al*., 2010).

Figure 6 demonstrates higrotope impact, expressed through forest soil moisture reserve in 0–100 cm soil layer, for Drevlianskyi Nature Reserve.

The research data indicate that all elementary forest stands infested with *V. album* subsp. *austriacum* in the nature reserve are associated with forest sites with the lowest moisture reserve level, its content being in the range of 16–70 mm in 0–100 cm soil layer, which corresponds to dry and fresh hygrotopes. Taking into account the prevalence of the mentioned conditions in the reserve and the research region as a whole, we can preliminarily predict the possibility of further intensive spread of *V. album* subsp. *austriacum* in the forests of both the reserve and the whole region under study. Besides, this conclusion can be sustained by a sharp increase in the number of *V. album* subsp. *austriacum* records in the studied region after 2000 – from 3 before 2000 to 107 records in 2023. Climate changes were also analysed for the studied region. In particular, such data have been published for Volyn Polissia (Getmanchuk *et al*., 2017): the mean annual temperature increased from +6 °C in 1984 to 9.9 °C in 2015, and for vegetation period – from +15.5 °C to 17.8 °C; while the average annual precipitation decreased

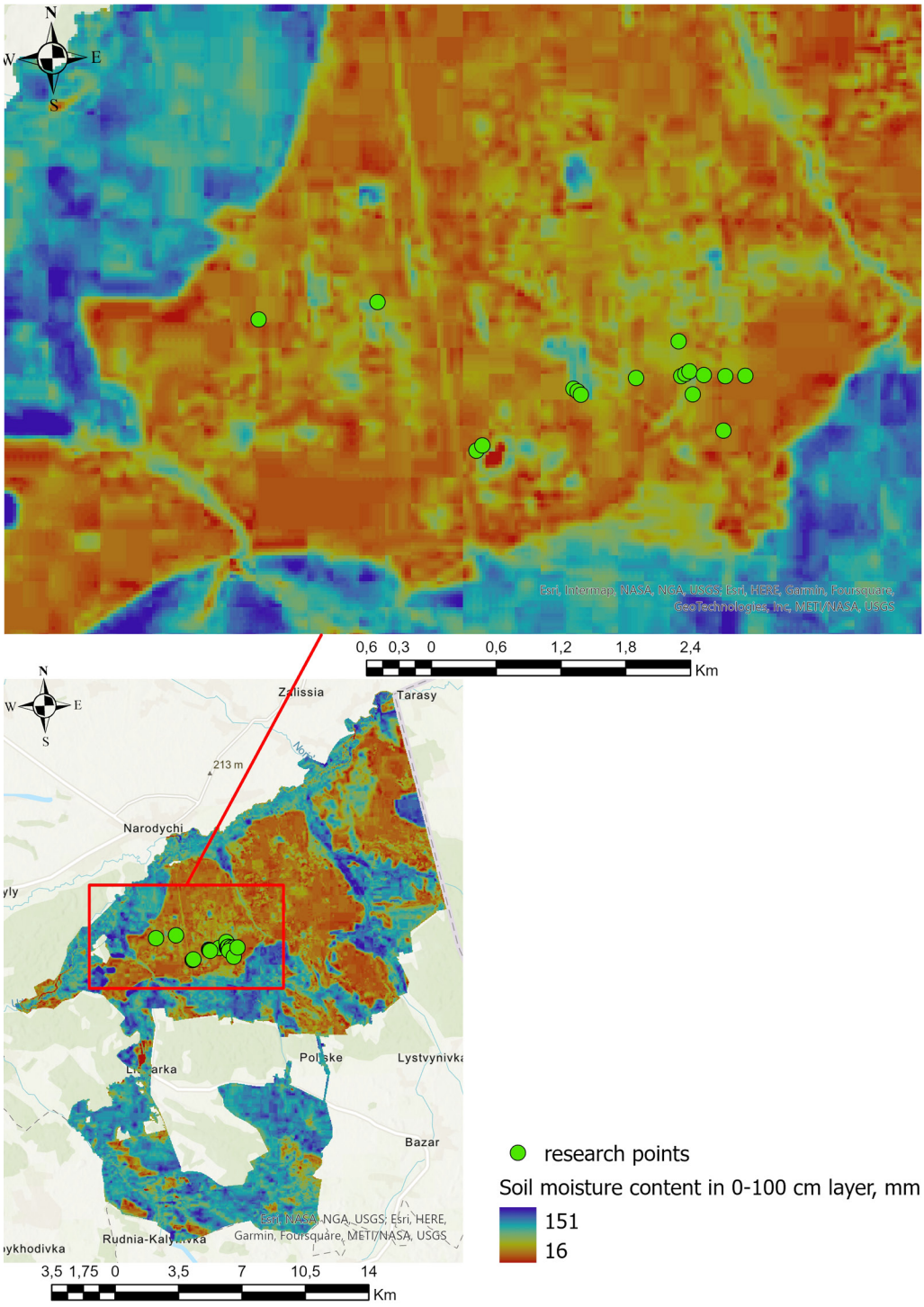

Fig. 6. The map of soil moisture reserve in 0–100 cm layer in Drevlianskyi Nature Reserve, Ukraine

from 726 mm in 2006 to 541 mm in 2015, and for vegetation period – from 499 mm to 339 mm. Similar results have also been obtained for Zhytomyr Polissia. For example, during the period of 1991–2010 the mean annual temperature increased by 1 °C, the mean winter temperature – by 1.7 °C, the mean summer temperature – by 1.3 °C. At the same time winter precipitation decreased by 12.6 % and summer precipitation – by 5 % (Zhyla & Balabukh, 2013).

Convincing results were obtained by researchers concerning the influence of climate change on the spread of *V. album* subsp. *austriacum.* In particular, in Europe researches made a conclusion that the annual temperature range is the most significant index for predicting the increase of mistletoe spread on the continent as well as the annual amplitude of temperature less than 30 °C (Walas *et al.*, 2022). Polish researchers showed rapid spread of *V. album* subsp. *austriacum* in the country and made a conclusion that "warm and dry conditions of vegetation period and mild winter months may have contributed to the spread of mistletoe in Polish forests in recent years" (Lech *et al.*, 2020, p. 13). The same situation can be predicted for Ukrainian Polissia.

CONCLUSIONS

1. *V. album* subsp. *austriacum* is much more widespread in the Volyn Polissia region than in the Zhytomyr Polissia region, with 87 and 20 localities, respectively. It is widespread in such nature reserves as Shatskyi National Nature Park and Drevlyanskyi Nature Reserve, and much less so in Rivne, Cheremskyi, and Polissia Nature Reserves as well as Pripyat-Stokhid National Nature Park.
2. The most severely affected by *V. album* subsp. *austriacum* in the study region are pure pine forests, aged 80–140 years, of medium completeness and relatively high and high stand quality classes – I^c–II.
3. In the studied area, *V. album* subsp. *austriacum* is most widespread in fresh hygrotope, with 67.3 % of the area infected by pine mistletoe, and in fairly infertile pine site type (trophotope B), with 51.5 % of mistletoe-infested area. The area distribution of forest site types in the study region and their susceptibility to pine mistletoe infestation allowes us preliminary predict an intensive further spread of *V. album* subsp. *austriacum* in this region.
4. Pine mistletoe should be excluded from the official lists of rare and threatened plant species of Volyn and Zhytomyr Regions.

ACKNOWLEDGMENTS AND FUNDING SOURCES

The authors express their gratitude to all the naturalists who kindly provided their information, in particular to: Mykhailo Khimin and Yuriy Korh (Prypiat'-Stokhid National Natural Park), Vitaliy Turych and Vasyl Mateychyk (Shatskyi National Natural Park), Mykhailo Franchuk (Rivne Nature Reserve), Olga Belska (Polisky Nature Reserve), Vasyl Voytiuk (Lesya Ukrainka Volyn National University).

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Animal Rights: This article does not contain any studies with animal subjects performed by the any of the authors.

AUTHOR CONTRIBUTIONS

Conceptualization, [O.O.; O.Zh.]; methodology, [O.O.; O.Zh.; V.B.; T.F.]; validation, [O.O.; O.Zh.]; formal analysis, [O.O.; V.B.; T.F.]; investigation, [O.O.; O.Zh.; V.B.; I.D.; T.F.; V.B.; O.B.]; resources, [O.O.; O.Zh.; V.B.; I.D.; T.F.; V.B.; O.B.]; data curation, [O.O.; O.Zh.]; writing – original draft preparation, [O.O.; V.B.; I.D.; T.F.]; writing – review and editing, [O.O.; I.D.]; visualization, [O.Zh.; V.B.; T.F.], supervision, [O.O.; V.B.; I.D.]; project administration, [O.O.]; funding acquisition, [-].

All authors have read and agreed to the published version of the manuscript.

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VISCUM ALBUM SUBSP. *AUSTRIACUM* (*SANTALACEAE R. BR.*) У ВОЛИНСЬКОМУ ТА ЖИТОМИРСЬКОМУ ПОЛІССІ (УКРАЇНА): СУЧАСНЕ ПОШИРЕННЯ, ЕКОЛОГІЧНІ УМОВИ ТА ПРОГНОЗ МАЙБУТНЬОГО ПОШИРЕННЯ

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Вступ. Омела біла австрійська (*Viscum album* subsp. *austriacum* (Wiesb.) Vollm.) – напівпаразитичний, вічнозелений, епіфітний фанерофіт, який в Україні трапляється лише на сосні звичайній (*Pinus sylvestris* L.). Сосні, на якій паразитує цей підвид омели, не вистачає вологи для підтримання транспірації та фотосинтезу, що зменшує продукування нею вуглеводів і первинної продукції, послаблює життєздатність і санітарний стан. Метою цього дослідження було: 1) на основі ГІС-технологій встановити сучасне поширення *V. album* subsp. *austriacum* у досліджуваному регіоні; 2) вивчити головні таксаційні параметри соснових насаджень, заселених *V. album* subsp. *austriacum*; 3) спрогнозувати ймовірне подальше поширення *V. album* subsp. *austriacum* у досліджуваному регіоні.

Матеріали і методи. Для створення мапи поширення *V. album* subsp. *austriacum* використано метод сіткового картування на основі ГІС-технології, зі сіткою 10×10 км і 20×20 км. Просторовий розподіл запасу вологи у лісових ґрунтах природного заповідника Древлянський проведено з використанням супутникових знімків і запасу вологи у ґрунтах з Earth Engine Data Catalog. Таксаційні параметри виділів, колонізованих омелою австрійською, отримані зі стандартних таксаційних описів.

Результати й обговорення. Виявлено, що *V. album* subsp. *austriacum* більше поширена у Волинському Поліссі, ніж у Житомирському Поліссі – 87 і 20 локалітетів відповідно. З'ясовано, що лісові насадження, колонізовані *V. album* ssp. *austriacum* у природному заповіднику Древлянський, трапляються переважно у місцях із найменшою забезпеченістю вологою, з її запасом 16–70 мм у 0–100 см шарі ґрунту, що відповідає сухому та свіжому гігротопам.

Висновки. *V. album* subsp. *austriacum* масово поширена у таких природоохоронних об'єктах регіону, як Шацький НПП і природний заповідник Древлянський, і менше – у Рівненському, Черемському, Поліському природних заповідниках і НПП Прип'ять-Стохід. У регіоні досліджень найбільше уражені *V. album* subsp. *austriacum* чисті соснові ліси, віком 80–140 років, середньої повноти (0,5–0,7), відносно високих і високих бонітетів – I^c–II, у свіжому гігротопі – 67,3 % площі та трофотопі суборів (B) – 51,5 %. Розподіл площі лісорослинних умов у регіоні та їхні сприятливі сластивостідля ураження *V. album* subsp. *austriacum* дає змогу прогнозувати можливість її подальшого інтенсивного поширення в дослідженому регіоні.

Ключові слова: насадження сосни звичайної, мапа поширення, бонітет, трофотоп, гігротоп

APPENDIX 1

Records of *Viscum album* subsp. *austriacum* in Volyn and Zhytomyr Polissia

No	Location	Georgaphical coordinates (GPS coordinates)	Author, date of finding	Source of data
1	2	3	4	5
Volyn Polissia				
1.	Volyn Region, Volodymyr-Volynsk District, 1 km to the west from vil. Blazhenyk, State Enterprise (SE) “Forests of Ukraine”, Branch “Volodymyr-Volynsk Forest Hunting Range”, Stenzharychivske forestry, forest quartier 43, elementary forest stand 40	50°57′50.9″N; 24°21′33.5″E (50.964145N; 24.359292E)	O. Baranskyi, 17.03.2022	iNaturalist: 108817763
2.	Volyn Region, Kovel District, Shatsk, lands of Shatsk Territorial Community	51°29′13.8″N; 23°55′46.1″E (51.487177N; 23.929465E)	S. Melnyk, 06.05.1973	Herbarium LWS
3.	Volyn Region, Kovel District, near Pisochne lake, 12 km to the west from vil. Shatsk, on the outskirts of Lviv State University biostationary, Shatsk NNP, Melnykivske forestry, forest quartier 23, elementary forest stand 34	51°34′07.3″N; 23°53′56.3″E (51.568683N; 23.898978E)	O. Kagalo, 17.06.1982	Herbarium LWKS, No 06988
4.	Volyn Region, Kovel District, vil. Hayivka, near 1 km to the south-west from vil. vil. Shatsk, Shatsk NNP, Melnykivske forestry, forest quartier 42, elementary forest stand 6	51°32′54.5″N; 23°53′43.5″E (51.548482N; 23.895404E)	V. Honcharenko, 19.06.2019	Herbarium VH (Lviv), No 4210
5.	Volyn Region, Kovel District, north-east bank of Pisochne lake, Shatsk NNP, Melnykivske forestry, forest quartier 25, elementary forest stand 13	51°34′18.9″N; 23°55′25.8″E (51.571913N; 23.923839E)	I. Danylyk, V. Shelvinskyi, 11.09.2021	Herbarium LWKS
6.	Volyn Region, Kovel District, 0,5 km to the west from vil. Pidmanove, Shatsk NNP, Svityazke forestry, forest quartier 11, elementary forest stand 13	51°28′18.7″N; 23°47′21.8″E (51.471852; 23.789388E)	Y. Bengus, 23.08.2018	iNaturalist: 123860602
7.	Volyn Region, Kovel District, 1,5 km west of vil. Pidmanove, Shatsk NNP, Svityazke forestry, forest quartier 11, elementary forest stand 7	51°28′03.5″N; 23°46′29.4″E (51.467649N; 23.774820E)	Y. Bengus, 23.08.2018	iNaturalist: 123860603
8.	Volyn Region, Kovel District, outskirt vil. Pidmanove, Shatsk NNP, Svityazke forestry, forest quartier 11, elementary forest stand 9	51°28′09.5″N; 23°46′57.7″E (51.469306N; 23.782694E)	Y. Bengus, 23.08.2018	UkrBin: 99098
9.	Volyn Region, Kovel District, outskirt vil. Pidmanove, Shatsk NNP, Svityazke forestry, forest quartier 11, elementary forest stand 11	51°28′13.1″N; 23°47′09.1″E (51.470306N; 23.785861E)	M. Burlaka, 06.07.2017	UkrBin: 49719
10.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 29, elementary forest stand 16	51°25′55.0″N; 23°51′09.7″E (51.431939N; 23.852680E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo

ISSN 1996-4536 (print) • ISSN 2311-0783 (on-line) • Біологічні Студії / Studia Biologica • 2023 • Том 17 / № 3 • С. 139–166

1	2	3	4	5
11.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 29, elementary forest stand 15	51°25′47.5″N; 23°50′58.4″E (51.429866N; 23.849547)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
12.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 29, elementary forest stand 12	51°25′47.2″N; 23°50′27.8″E (51.429766N; 23.841051E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
13.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 28, elementary forest stand 32	51°26′03.7″N; 23°50′23.2″E (51.434373N; 23.839773E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
14.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 28, elementary forest stand 17	51°26′20.2″N; 23°50′29.0″E (51.438942N; 23.841388E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
15.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 25, elementary forest stand 20	51°25′46.1″N; 23°49′02.0″E (51.429477N; 23.817212E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
16.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 25, elementary forest stand 8	51°26′09.3″N; 23°49′23.8″E (51.435912N; 23.823271E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
17.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 25, elementary forest stand 30	51°25′35.8″N; 23°49′23.8″E (51.426621N; 23.823271E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
18.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 25, elementary forest stand 40	51°25′32.2″N; 23°48′50.5″E (51.425607N; 23.814040E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
19.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 13	51°27′42.0″N; 23°56′17.9″E (51.461666N; 23.938306E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
20.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 14	51°27′40.3″N; 23°56′18.6″E (51.461205N; 23.938485E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
21.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 16	51°27′38.2″N; 23°56′24.1″E (51.460601N; 23.940016E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo

1	2	3	4	5
22.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 18	51°27′36.4″N; 23°56′00.9″E (51.460108N; 23.933573E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
23.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 21	51°27′34.3″N; 23°55′57.3″E (51.459536N; 23.932578E)	V. Mateychyk, V. Turych, 12.01.2023	Field observation, photo
24.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 37, elementary forest stand 32	51°27′13.7″N; 23°55′56.9″E (51.453800N; 23.932472E)	V. Mateychyk, V. Turych, 22.01.2023	Field observation, photo
25.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 39, elementary forest stand 13	51°27′35.9″N; 23°57′22.7″E (51.459963N; 23.956315E)	V. Mateychyk, V. Turych, 22.01.2023	Field observation
26.	Volyn Region, Kovel District, Shatsk NNP, Svityazke forestry, forest quartier 40 elementary forest stand 8	51°26′55.4″N; 23°55′47.4″E (51.448733N; 23.929829E)	L. Arvat, 04.10.2020	Field observation, photo
27.	Volyn Region, Kovel District, 0,7 km to the south-west from vil. Zamlynnya, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Zamlynske forestry, forest quartier 26, elementary forest stand 30	51°07′09.0″N; 23°57′26.6″E (51.119171N; 23.957396E)	O. Baranskyi, 05.08.2006	iNaturalist: 69000276
28.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 25, elementary forest stand 12.1	51°27′33.0″N; 23°55′31.7″E (51.459154; 23.925463E)	V. Mateychyk, V. Turych, 22.01.2023	Field observation
29.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier25, elementary forest stand 12.2	51°27′34.5″N; 23°55′45.9″E (51.459583N; 23.929424E)	V. Mateychyk, V. Turych, 22.01.2023	Field observation
30.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 25, elementary forest stand 22	51°27′33.0″N; 23°55′37.5″E (51.459159N; 23.927091)	V. Mateychyk, V. Turych, 22.01.2023	Field observation
31.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 21, elementary forest stand 2	51°27′43.5″N; 23°58′41.8″E (51.462086N; 23.978277E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation
32.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 21, elementary forest stand 3	51°27′49.2″N; 23°58′25.7″E (51.463671N; 23.973808E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation

1	2	3	4	5
33.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 21, elementary forest stand 21	51°27′33.4″N; 23°58′58.2″E (51.459282; 23.982840E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation
34.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 21, elementary forest stand 22	51°27′19.2″N; 23°58′42.2″E (51.455331N; 23.978377E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation
35.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 22, elementary forest stand 11	51°27′35.1″N; 23°59′49.1″E (51.459737N; 23.996964E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation
36.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 22, elementary forest stand 16	51°27′26.3″N; 23°59′14.6″E (51.457317N; 23.987385E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation
37.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Shatske forestry, forest quartier 23, elementary forest stand 14	51°27′18.9″N; 23°58′18.6″E (51.455236N; 23.971822E)	V. Borodavka, O. Borodavka, 04.09.2018	Field observation, data from experimental plots, photos
38.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Luboml Forest Range”, Hushchanske forestry, forest quartier 10, elementary forest stand 23	51°16′33.8″N; 23°47′36.9″E (51.276060N; 23.793583E)	V. Borodavka, O. Borodavka, 15.06.2018	Field observation
39.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 28, elementary forest stand 15	51°31′37.8″N; 24°21′02.2″E (51.527170N; 24.350614E)	V. Borodavka, A. Behal, 23.03.2023	Field observation
40.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 28, elementary forest stand 16	51°31′39.2″N; 24°21′07.2″E (51.527544N; 24.352009E)	V. Borodavka, A. Behal, 23.03.2023	Field observation
41.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 28, elementary forest stand 17	51°31′41.0″N; 24°21′14.0″E (51.528065N; 24.353876E)	V. Borodavka, A. Behal, 23.03.2023	Field observation
42.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 28, elementary forest stand 18	51°31′42.3″N; 24°21′18.6″E (51.528419N; 24.355163E)	V. Borodavka, A. Behal, 23.03.2023	Field observation
43.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 31, elementary forest stand 11	51°31′50.4″N 24°22′28.1″E (51.530661N, 24.374483E)	V. Borodavka, O. Borodavka, 16.06.2018	Field observation

1	2	3	4	5
44.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 31, elementary forest stand 22	51°31′30.2″N; 24°22′44.9″E (51.525067N; 24.379124E)	V. Borodavka, O. Borodavka, 16.06.2018	Field observation
45.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 31, elementary forest stand 45	51°31′48.5″N; 24°22′19.4″E (51.530128N; 24.372041E)	V. Borodavka, O. Borodavka, 16.06.2018	Field observation
46.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Dubechnivske forestry, forest quartier 31, elementary forest stand 54	51°31′29.4″N; 24°22′29.6″E (51.524839N; 24.374891E)	V. Borodavka, O. Borodavka, 16.06.2018	Field observation
47.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Lyubokhynivske forestry, forest quartier 41, elementary forest stand 36	51°26′24.0″N; 24°10′01.0″E (51.439994N; 24.166940E)	V. Borodavka, O. Borodavka, 17.08.2019	Field observation
48.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Kovel Forest Range”, Lyubokhynivske forestry, forest quartier 41, elementary forest stand 46	51°26′17.3″N; 24°09′43.1″E (51.438144N; 24.161962E)	V. Borodavka, O. Borodavka, 17.08.2019	Field observation
49.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Ratne Forest Hunting Range”, Zabolotivske forestry, forest quartier 4, вид. 5	51°41′40.6″N; 24°12′30.4″E (51.694611N; 24.208444E)	L. Arvat, 13.04.2020	Field observation, photo
50.	Volyn Region, Kovel District, SE “Forests of Ukraine”, Branch “Ratne Forest Hunting Range”, Zabolotivske forestry, forest quartier 49, elementary forest stand 18	51°38′13.0″N; 24°19′48.4″E (51.636930N; 24.330096E)	V. Borodavka, D. Novik, 22.03.2023	Field observation
51.	Volyn Region, Kovel District, SE “Forests of Ukraine″, Branch “Ratne Forest Hunting Range”, Zabolotivske forestry, forest quartier 66, elementary forest stand 24	51°36′17.7″N; 24°20′36.6″E (51.604924N; 24.343494E)	V. Borodavka, D. Novik, 22.03.2023	Field observation
52.	Volyn Region, Kamin-Kashyrsk District, Cheremsky Nature Reserve, Cheremske swamp	51°31′31.6″N; 25°34′55.3″E (51.525448N; 25.582037E)	V. Konishchuk, 28.06.2002	Herbarium KW, No 040693
53.	Volyn Region, Kamin-Kashyrsk District, near vil. Pozhih, NNP “Pripyat-Stokhid″, Lyubeshivske forestry, forest quartier 17, forest tract Horky	51°47′38.2″N; 25°36′27.2″E (51.793950N; 25.607547E)	Y. Korkh, 02.12.2021	Field observation
54.	Volyn Region, Kamin-Kashyrsk District, NNP “Pripyat-Stokhid”, Lyubyazke forestry, forest quartier 19, forest tract Dubky	51°51′54.9″N; 25°26′36.5″E (51.865242N; 25.443476E)	Y. Korkh, 06.05.2022	Field observation
55.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 29, elementary forest stand 21	51°46′47.2″N; 25°17′50.4″E (51.779775N; 25.297325E)	V. Borodavka, 17.08.2019	Field observation

1	2	3	4	5
56.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 30, elementary forest stand 30	51°46′50.5″N; 25°19′17.1″E (51.780680N; 25.321413E)	V. Voytyuk, 03.06.2019	Field observation, photo
57.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 38, elementary forest stand 2	51°46′45.5″N; 25°17′58.1″E (51.779297N; 25.299460E)	V. Borodavka, 17.08.2019	Field observation
58.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 38, elementary forest stand 4	51°46′47.1″N; 25°18′22.0″E (51.779744N; 25.306098E)	V. Borodavka, 17.08.2019	Field observation
59.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 38, elementary forest stand 5	51°46′48.2″N; 25°18′39.2″E (51.780042N; 25.310898E)	V. Borodavka, V. Voytyuk, 03.06.2019	Field observation, photo
60.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 38, elementary forest stand 9	51°46′44.3″N; 25°18′32.8″E (51.778964N; 25.309097E)	V. Borodavka, 17.08.2019	Field observation
61.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine”, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 39, elementary forest stand 1	51°46′48.6″N; 25°18′47.0″E (51.780155N; 25.313061E)	V. Borodavka, 17.08.2019	Field observation
62.	Volyn Region, Kamin-Kashyrsk District, SE “Forests of Ukraine″, Branch “Lyubeshiv Forest Hunting Range”, Derevkivske forestry, forest quartier 39, elementary forest stand 5	51°46′45.5″N 25°18′49.7″E (51.779302N, 25.313818E)	V. Borodavka, 17.08.2019	Field observation
63.	Volyn Region, Lutsk District, SE “Forests of Ukraine″, Branch “Kolky Forest Range”, Kolkivske forestry, forest quartier 8, elementary forest stand 55	51°06′36.5″N 25°46′35.1″E (51.110151N, 25.776418E)	V. Borodavka, O. Borodavka, 25.03.2019	Field observation
64.	Volyn Region, Lutsk District, SE “Forests of Ukraine”, Branch “Kolky Forest Range”, Kolkivske forestry, forest quartier 10, elementary forest stand 22	51°06′25.5″N; 25°46′33.2″E (51.107078N; 25.775887E)	V. Borodavka, O. Borodavka, 25.03.2019	Field observation
65.	Volyn Region, Lutsk District, SE “Forests of Ukraine”, Branch “Kolky Forest Range”, Kolkivske forestry, forest quartier 11, elementary forest stand 2	51°06′32.8″N; 25°46′38.6″E (51.109111N; 25.777398E)	V. Borodavka, O. Borodavka, 25.03.2019	Field observation
66.	Volyn Region, Lutsk District, SE “Forests of Ukraine”, Branch “Kivertsi Forest Range”, Moshchanytske forestry, forest quartier 49, elementary forest stand 48	50°45′54.0″N; 25°52′34.6″E (50.765006N; 25.876267E)	O. Zhukovskyi, 13.07.2020	Field observation

1	2	3	4	5
67.	Volyn Region, Lutsk District, SE “Forests of Ukraine”, Branch “Kivertsi Forest Range”, Moshchanytske forestry, forest quartier 49, elementary forest stand 52	50°45′51.9″N; 25°52′43.2″E (50.764403N; 25.878673E)	O. Zhukovskyi, 13.07.2020	Field observation
68.	Volyn Region, Lutsk District, SE “Forests of Ukraine”, Branch “Kivertsi Forest Range”, Moshchanytske forestry, forest quartier 49, elementary forest stand 53	50°45′48.2″N; 25°53′01.1″E (50.763399N; 25.883634E)	O. Zhukovskyi, 13.07.2020	Field observation
69.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 51	50°45′45.3″N; 25°53′11.4″E (50.762592N; 25.886486E)	O. Zhukovskyi, 13.07.2020	Field observation
70.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 52	50°45′43.7″N; 25°53′19.2″E (50.762143N; 25.888660E)	O. Zhukovskyi, 13.07.2020	Field observation
71.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 54	50°45′41.8″N; 25°53′27.4″E (50.761622N; 25.890946E)	O. Zhukovskyi, 13.07.2020	Field observation
72.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 55	50°45′40.4″N; 25°53′33.8″E (50.761219N; 25.892722E)	O. Zhukovskyi, 13.07.2020	Field observation
73.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 56	50°45′39.1″N; 25°53′39.5″E (50.760869N; 25.894302E)	O. Zhukovskyi, 13.07.2020	Field observation
74.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 57	50°45′38.5″N; 25°53′42.2″E (50.760706N; 25.895064E)	O. Zhukovskyi, 13.07.2020	Field observation
75.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 58	50°45′37.4″N; 25°53′47.7″E (50.760377N; 25.896582E)	O. Zhukovskyi, 13.07.2020	Field observation
76.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 59	50°45′35.9″N; 25°53′54.0″E (50.759981N; 25.898337E)	O. Zhukovskyi, 13.07.2020	Field observation
77.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 35, elementary forest stand 61	50°45′32.6″N; 25°54′07.9″E (50.759057N; 25.902196E)	O. Zhukovskyi, 13.07.2020	Field observation

1	2	3	4	5
78.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 36, elementary forest stand 54	50°45′30.2″N; 25°54′18.5″E (50.758397N; 25.905141E)	O. Zhukovskyi, 13.07.2020	Field observation
79.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 36, elementary forest stand 62	50°45′29.3″N; 25°54′22.4″E (50.758139N; 25.906225E)	O. Zhukovskyi, 13.07.2020	Field observation
80.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 36, elementary forest stand 65	50°45′27.9″N; 25°54′29.6″E (50.757745N; 25.908231E)	O. Zhukovskyi, 13.07.2020	Field observation
81.	Rivne Region, Rivne District, SE “Forests of Ukraine”, Branch “Kostopil Forest Range”, Novostavske forestry, forest quartier 36, elementary forest stand 66	50°45′26.3″N; 25°54′37.2″E (50.757297N; 25.910323E)	O. Zhukovskyi, 13.07.2020	Field observation
82.	Rivne Region, Varash District, SE “Forests of Ukraine”, Branch “Rafalivka Forest Range”, Mulchytske forestry, forest quartier 90, elementary forest stand 6	51°29′06.3″N; 25°44′04.6″E (51.485083N; 25.734611E)	M. Franchuk, Yu. Bulan, 28.04.2021	Herbarium RNR
83.	Rivne Region, Varash District, SE “Forests of Ukraine”, Branch “Rafalivka Forest Range”, Mulchytske forestry, forest quartier 90, elementary forest stand 10	51°29′21.3″N; 25°44′13.8″E (51.489235N; 25.737176E)	M. Franchuk, Yu. Bulan, 28.04.2021	Herbarium RNR
84.	Rivne Region, Varash District, Rivne Nature Reserve, Beloozerske Department, forest quartier 42, elementary forest stand 11	51°29′31.4″N; 25°45′04.4″E (51.492047N; 25.751222E)	M. Franchuk, Yu. Bulan, 28.04.2021	Herbarium LWKS
85.	Rivne Region, Varash District, vicinities of vil. Rudka, Rivne Nature Reserve, Beloozerske Department, forest quartier 41, on the border of elementary forest stands 46 and 48	51°29′33.9″N; 25°44′20.7″E (51.492750N; 25.739074E)	R. Zhuravchak, 30.03.2017	Herbarium RNR
86.	Rivne Region, Varash District, Rivne Nature Reserve, Beloozerske Department, forest quartier 39, elementary forest stand 37	51°29′23.7″N; 25°44′12.5″E (51.489923N; 25.736807E)	M. Franchuk, Yu. Bulan, 28.04.2021	Herbarium RNR
87.	Rivne Region, Sarny District, Rivne Nature Reserve, Bilske Department, forest quartier 18, elementary forest stand 3	51°30′52.9″N; 27°14′55.3″E (51.514700N; 27.248700E)	V. Mysyukevych, M. Skakovets, 2014	Field observation

1	2	3	4	5
	Zhytomyr Polissia			
1.	Zhytomyr Region, Korosten District, 2 km to the north-east from vil. Maidan-Kopyshchanskyi, Polisky Nature Reserve, Kopyshchanske forestry, forest quartier 22, elementary forest stand 7	51°33′01.9″N; 27°53′05.7″E (51.550520N; 27.884927)	O. Orlov, 07.10.2021	Field observation
2.	Zhytomyr Region, Korosten District, 2 km to the north-east from vil. Maidan-Kopyshchanskyi, Polisky Nature Reserve, Kopyshchanske forestry, forest quartier 22, elementary forest stand 21	51°32′58.7″N; 27°53′04.0″E (51.549646N; 27.884441E)	P. Linkevych, O. Orlov, 23.03.2010	Herbarium KW
3.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Rozsokhivske Department, forest quartier 55, elementary forest stand 10	51°08′53.9″N; 29°04′32.5″E (51.148306N; 29.075694E)	O. Zhukovskyi, 05.06.2020	Field observation
4.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Rozsokhivske Department, forest quartier 72, elementary forest stand 4	51°08′52.1″N; 29°04′32.6″E (51.147791N; 29.075721E)	O. Zhukovskyi, 05.06.2020	Field observation
5.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Rozsokhivske Department, forest quartier 75, elementary forest stand 1	51°08′56.2″N; 29°05′29.4″E (51.148931N; 29.091490E)	O. Zhukovskyi, 05.06.2020	Field observation
6.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 78, elementary forest stand 21	51°08′28.6″N; 29°07′01.6″E (51.141280N; 29.117107E)	O. Orlov, 22.03.2023	Field observation, photo
7.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 78, elementary forest stand 22	51°08′27.7″N; 29°07′03.5″E (51.141032N; 29.117641E)	O. Orlov, 22.03.2023	Field observation, photo
8.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 79, elementary forest stand 22	51°08′31.2″N; 29°07′31.6″E (51.142003N; 29.125435E)	O. Orlov, 22.03.2023	Field observation, photo
9.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 79, elementary forest stand 24	51°08′31.4″N; 29°07′53.0″E (51.142056N; 29.131389E)	O. Orlov, O. Zhukovskyi, 07.03.2020	Field observation, Herbarium KW
10.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 80, elementary forest stand 13	51°08′41.8″N; 29°07′52.3″E (51.144946N; 29.131202E)	O. Orlov, 07.03.2020	Field observation

1	2	3	4	5
11.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 80, elementary forest stand 17	51°08′32.0″N; 29°07′55.0″E (51.142222N; 29.131944E)	O. Orlov, O. Zhukovskyi, 07.03.2020	Field observation
12.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 80, elementary forest stand 18	51°08′32.8″N; 29°07′57.0″E (51.142446N; 29.132492E)	O. Orlov, O. Zhukovskyi, 07.03.2020	Field observation
13.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 80, elementary forest stand 20	51°08′31.6″N; 29°08′03.9″E (51.142105N; 29.134419E)	O. Orlov, 22.03.2023	Field observation, photo
14.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 94, elementary forest stand 2	51°08′10.9″N; 29°06′14.5″E (51.136347N; 29.104022E)	O. Orlov, 22.03.2023	Field observation, photo
15.	Zhytomyr Region, Korosten District, 1 km to the North from vil. Loznytsya, to the North from Mertve Lake, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 94, elementary forest stand 10	51°08′12.3″N; 29°06′17.3″E (51.136754N; 29.104816E)	O. Orlov, 17.06.2018	Herbarium KW
16.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 96, elementary forest stand 2	51°08′26.7″N; 29°07′05.1″E (51.140752N; 29.118076E)	O. Orlov, 22.03.2023	Field observation, photo
17.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 98, elementary forest stand 3	51°08′31.0″N; 29°08′14.1″E (51.141944N; 29.137250E)	O. Orlov, O. Zhukovskyi, 07.03.2020	Field observation
18.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 98, elementary forest stand 6	51°08′25.8″N; 29°07′58.3″E (51.140512N; 29.132867E)	O. Orlov, 22.03.2023	Field observation, photo
19.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 98, elementary forest stand 9	51°08′14.7″N; 29°08′12.4″E (51.137423N; 29.136769E)	O. Orlov, 22.03.2023	Field observation, photo
20.	Zhytomyr Region, Korosten District, Nature Reserve “Drevliansky”, Narodytske Department, forest quartier 99, elementary forest stand 1	51°08′31.0″N; 29°08′23.6″E (51.141944N; 29.139889E)	O. Zhukovskyi, 07.03.2020	Field observation

APPENDIX 2

Fig. 1. Pine mistletoe on a pine twig in the lower crown part (age – 12 years, height 2 m, Drevliansky Nature Reserve). Photo by O. Orlov

Fig. 2. Heavy mistletoe infestation of pine crown. “Shats’k Forest Hunting Range”, Shatsk forestry. Photo by O. Borodavka

Fig. 3. Scots pine top crown thinning because of heavy infestation with pine mistletoe. “Shatsk Forest Hunting Range”, Shatsk forestry. Photo by O. Borodavka

Fig. 4. 50-year old Scots pine infested with mistletoe. Drevliansky Nature Reserve. Photo by O. Orlov

Fig. 5. Cut model of 50-year old Scots pine tree infested with mistletoe – for counting of its individuals. "Shatsk Forest Hunting Range", Shatsk forestry. Photo by O. Borodavka

Received / Одержано 11 May, 2023 | Revision / Доопрацьовано 04 August, 2023 | Accepted / Прийнято 31 August, 2023 | Published / Опубліковано 27 September, 2023