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MOST COMMON SPECIES OF DEFOLIATING INSECTS OF BROADLEAVED FORESTS: ICP LEVEL I MONITORING IN 2021

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Abstract: *In order to make conclusions related to the selection of the most appropriate improvement measures, it is necessary to define the condition of forests through monitoring their health state. ICP for Forests Monitoring deals with human factors (mainly air pollution) and biotic factors that impair vitality and hinder the development of forest ecosystems in Europe and Serbia. Since broadleaved forests experience stronger attacks of plant diseases and pests, they have more severe defoliation. Beech is the most common broadleaved species at the ICP sample plots in Serbia. It is followed by oak species – sessile oak, Turkey oak and Hungarian oak. The largest number of insect species develop on the assimilation organs of forest trees. The paper presents the most common species of defoliators detected at SP in Serbia in 2021.*

Key words: pests, monitoring, defoliators, crown condition

NAJZASTUPLJENIJE VRSTE INSEKATA DEFOLIJATORA LIŠĆARSKIH ŠUMA U OKVIRU PRAĆENJA NA BIT NIVO-A I U 2021. GODINI

Apstrakt: *Uvid u stanje šuma radi donošenja zaključaka o neophodnim merama unapređenja, moguće je utvrditi praćenjem zdravstvenog stanja šuma. Predmet ICP-a za praćenje šuma su antropogeni (uglavnom zagađenje vazduha) i biotički faktori štetni po vitalnost i razvoj šumskih ekosistema u Evropi, kao i u Srbiji. Lišćarske šume, zbog jačeg napada biljnih bolesti i štetočina, imaju jače izraženu defolijaciju. Od lišćarskih vrsta, najzastupljenije vrste na bioindikacijskim tačkama Nivo-a 1 u Srbiji je bukva, zatim*

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hrastovi: cer, sladun i kitnjak. Najveći broj insekata razvija se na asimilacionim organima šumskog drveća. U radu će biti prikazane najčešće vrste defolijatora koje su detektovane na BIT u Srbiji u 2021. godini.

Ključne reči: štetočine, monitoring, defolijatori, stanje kruna.

1. INTRODUCTION

Periodic variations in results emphasise the importance of continuous monitoring of defoliation and additional assessments of different environmental data that can contribute to a better understanding of what is detected each year. Having assessed the condition of samples (drying and chlorosis), the next step is to carry out integrated system monitoring by determining soil changes, analysing leaves, assessing deposition and other similar studies (Popović et al., 1995).

Continuous forest condition monitoring at reconstructed Level I sample plots has been conducted according to the Manual of the ICP programme for forest condition monitoring since 2003. The Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia – Forest Administration has entrusted the coordination and management of the ICP for Forests Programme to the Institute of Forestry as the National Focal Center for Forest Condition Monitoring of the Republic of Serbia. Our country has been actively participating in this programme every year since 2003 and reported on the results to the Forest Administration and the ICP Forest Centre. All data collected are entered into a coded database at the end of the year (UNECE, 2010).

Forest ecosystems are exposed to the opposing forces of the debatable discourse of climate change or global warming. Global warming can positively affect plant growth (Saxe et al., 2001; Pretzsch et al., 2014) by prolonging the tree growing season. On the other hand, it can increase the pressure of herbivorous insects on forest ecosystems. Mild winters increase the survival rate of overwintering insects (Pureswaran et al., 2018), and warm climates encourage insect development and increase the number of generational cycles per year.

The defoliator is a collective name for the insects that reduce the assimilation surface. In the years of outbreaks, they cause massive damage that can drastically affect the growth, increment and yield of trees, or change their phenotypic characteristics, such as the tree's natural shape (Mihajlović, 2008).

2. METHOD AND CRITERIA

Faced with the growing concern about the state of forests in Europe in the early 1980s, the UN/ECE established the International Cooperative Program for the Assessment and Monitoring of the Effects of Air Pollution on Forests (ICP Forests) under the Convention on Long-range Transboundary Air Pollution (CLRTAP) in 1985.

In 1986, the European Union adopted a plan to protect forests from air pollution, and the legal basis for co-financing in EU member states was provided by EEC Regulation No.3528 / 86. (UNECE, 2010).

Since then, ICP Forests and the EU have worked closely together to monitor forests. The programme now involves 46 countries (states), including all EU members, Canada and the United States.

Forest condition assessments use standardised methods that form a significant basis for the exchange of expert knowledge (ICP Forests: Manual on methods and criteria for harmonised sampling, assessment, monitoring and analysis of the effects of air pollution on forests).

The methodology was developed as an important platform and is mandatory for all participants in the Programme. The results and recommendations provide a scientific basis for decision-making in the field of air quality control, forestry development policy and strategy, and environmental protection in general.

Monitoring activities, in this way, aim at the resolutions of the Ministerial Conferences on the Protection of Forests in Europe and provide information on three key indicators of sustainable forest management.

Since 2003, 130 observation plots have been installed in the territory of the Republic of Serbia, on a systematic grid of 16 x 16 km (103 sample plots), and since 2004 in a grid of 4 x 4 km too. Monitoring of forest condition at Level I observation plots primarily refers to the observation and assessment of defoliation (mandatory) and discolouration (optional) of tree crowns.

Furthermore, data on soil gathered under the programme are expected to contribute to carbon accumulation estimates, as the EU's input for the implementation of the Kyoto Protocol mechanisms under the UN Climate Change Convention (UNFCCC). Regular observations of Level I plots on the entire territory of Serbia during the growing season (June-September) in 2021, resulted in the assessment of tree defoliation and vitality. The assessment included defoliation and discolouration, as well as monitoring of the damage caused by biotic and abiotic agents. Each individual tree within the observation plot was assessed and any visible damage and change detected were recorded. The research was conducted on all 2,928 trees of Level I observation plots, 359 of which were conifers and 2,569 broadleaves. This shows that broadleaved trees, as well as damage inflicted to them, including the damage caused by insects, have significantly contributed to the complete picture of the state of Serbia's forests in 2021.

All injuries were recorded by cause and classified by type. This paper uses data from the field forms – logbooks that are filled in the field by researchers from the Institute of Forestry.

Undetermined damage causes or the insects themselves (larvae, imago) were later determined in the laboratory of the Institute of Forestry, Belgrade, by the method of cultivation or using identification keys.

Defoliation classes are shown in tables and assessed visually in the field (Table 1).

Table 1. *Defoliation classes by UN/ECE² and EU³ classification*

Defoliation class	Defoliation degree	Loss of foliage (%)
0	None	0-10
1	Slight	10-25
2	Moderate	25-60
3	Severe	60-100
4	Dead	100

Beech is the most common tree species at Level I sample plots, followed by oak species, namely Turkey oak, Hungarian oak and sessile oak, as well as hornbeam and other broadleaved trees.

3. RESULTS AND DISCUSSION

Damage was recorded and classified by cause and tree species. In percentage terms, harmful insects were the most common cause of damage. Regarding tree species, Turkey oak and sessile oak were most endangered by insects, with beech following them (Table 2).

The formation of a large number of insects in a growing season can have adverse effects on the vitality and growth of plants (Bebber et al., 2013; Bacon et al., 2014). Furthermore, with the migration of invasive species, new insect species are introduced into our country. This phenomenon can be observed in the whole world (Pureswaran et al., 2018).

An increase in the frequency, intensity and duration of the so-called heatwaves with an increasingly smaller number of ice days are expected (Brašanac-Bosanac, Ćirković-Mitrović, 2013).

Heat extremes of this type have been recorded continuously: a heatwave from 21 to 24 June in the West Bačka, Srem, Mačva and Kolubara districts, from 22 to 25 June in the city of Belgrade, South Bačka, North Banat, Central Banat, South Banat, Braničevo, Šumadija, Danube and Pomoravlje districts, and from 22 to 24 June in the Zlatobor district. Also, a heatwave started on 23 June on the territory of Raška, Moravica, Rasina, Bor and Zaječar districts and ended on 25 June. There was another heatwave from 7 to 9 July in the area of Belgrade, Central Banat, Central Bačka, West Bačka, South Bačka, Srem, Mačva, Kolubara, Danube and Rasina districts (RHMS). A heatwave was registered from 12 to 15 July in the territory of the Braničevo, Bor, Pomoravlje, Nišava and Jablanica districts. In the period from 26 to 28 July, a heatwave was recorded in the South Bačka district and the Kolubara district from 25 to 28 July. A heatwave was also recorded in the Zaječar district from 31 July to 2 August.

Climate data indicate that the air temperature in Serbia during the summer of 2021 was above the average values (RHMS).

The Wind Chill Index (WCI) was made for the period from December to February (RHMS). It is a measure of relative discomfort caused by heat loss from

² United Nations Economic Commission for Europe

³ European Union

the human body at a specific combination of extremely low air temperatures and wind speed. This index shows the likelihood of frostbite, freezing and other acute symptoms of body stress (WMO No.182 Internat. Meteorolog. Vocabulary).

These data on the winter of 2020/21 indicate a moderate to mild winter (RHMS), which affected, for instance, the survival rate of insects that overwinter at different stages.

Leaf-destroying insects were detected – from their egg litters (gypsy moth) to the visible damage caused by feeding. Various larvae that feed on wood were registered, as well as adult insects and egg-laying grounds. Gall-making insects from the family of the gall wasps or the gall midges were identified based on the galls they form. The leaves of apical shoots attacked by leaf scales curled and died due to the injury caused both by larvae and adult insects sucking the tissues with their piercing mouth. Leaf mines were photographed, and the species were determined later in the laboratory. The presence of oak powdery mildew and stunted leaves pointed to the attack of early oak defoliators (before going out in the field), tortrix moths (Tortricidae) and geometrid moths from the family of Geometridae.

Table 2. Tree damage causes in 2021

	Insect damage	Fungus damage	Damage by abiotic agents	Human damage	Fire damage	Local pollution damage	Other damage	TOTAL damage
All species %	16.0	15.7	2.0	0.9	0.1	0	2.7	37.5
Broadleaves %	17.7	13.5	2.1	0.7	0.2	0	1.8	36.0
Conifers %		33.5	0.9	2.1		0	10.0	46.5
Beech %	11.4	9.2	3.3	1.5	0.5	0	2.7	28.6
Fir %	0	20.6	0	0	0	0	4.8	25.4
Spruce %		3.2	1.6	3.7		0	16.0	24.6
Austrian pine %	0	73.5	0	0	0	0	0	0
Turkey oak %	12.9	13.9	0.4	0.4		0	1.2	28.7
Sessile oak %	51.5	29.9	1.2	0	0	0	3.6	86.2

3.1. Lepidoptera ORDER

Gypsy moth (*Lymantria dispar* L.), the most dangerous pest this season, was in the latency phase. Observing the foliar damage, it can be concluded that the gypsy moth caterpillars occurred only individually. Several egg broods were also recorded individually (Figure 1, SP 37).

Figure 1. *Gypsy moth egg litter (freshly laid), August 2021, SP 37 (Orig.)*

Figure 2. *Ticheria ekebladella (Bjerk) on oak seedlings, SP 56 (Orig.)*

Miners were found in great numbers on oaks and beeches, but this season they were also extremely abundant on locusts. Regarding oaks, the most common was *Ticheria ekebladella* (Bjerk), whose mines often cover the entire leaf surface (Figure 2).

A leaf miner of the family Gracillariidae, *Phyllonorycter messaniella* Zell. (Figure 3, SP 413) was found at almost all sample plots where beech is the dominant species. A strong attack of *Phyllonorycter robinie* Clemens, a moth of this family commonly found on the underside of locust trees, was recorded (SP 19, 428). It occurred together with the digitate leafminer *Parectopa robiniella* that attacks the upper side of the leaf (Figure 4).

Figure 3. *Phyllonorycter messaniella Zell. SP 413 (Orig.)*

Figure 4. *SP 19 Locust miners, Phyllonorycter robinie Clemens and Parectopa robiniella Clemens (Orig.)*

Geometrid moths (Geometridae) and leafroller moths (Tortricidae) – early-season oak defoliators were the most common insects found on the oak leaves. The intensity of the damage caused by winter moths in this season was low – a weak attack. Regarding Tortricidae, several different types of damage were observed, based on which it could be concluded species of the genera *Alleimma*, *Tortrix*,

Torticoides, *Choristoneura* sp were present at SP (Figure 5). Although they are not directly the subject of this paper, seed pests indirectly affected the vitality of this year's acorn crop by affecting the seed crop. It was particularly the case with Hungarian oak trees that were attacked by the seed rollers. Figure 6 shows a caterpillar of *Cydia splendana* Hbn., before hibernation.

Figure 5. Damage caused by *Tortricidae*, Hungarian oak leaf, SP 60 (Orig.)

Figure 6. *Cydia splendana* Hbn., a caterpillar before hibernation (Orig.)

3.2. Hymenoptera ORDER

Cynipidae, gall wasps, have an extremely rich diversity in Serbia. There are over 40 different species so far determined based on different and variable forms of galls that they produce and the species on which they form them (Zúbrik, et al. 2008). A fairly common species on SP in Serbia is *Neuroterus quercus baccarum* L., found in great numbers on Turkey oak. Although they have a button-sized round body and attack the underside of a leaf, when in large numbers, they reduce the leaf area and hinder the transpiration. Besides *Neuroterus quercus baccarum* L., common species include *Cynips quercusfolii* L., *Andricus quercuscalicis* (Bur.), *Andricus quercustozae* (Bosc), *Andricus caputmedusae* (Htg.), *Biorhiza pallida* (Ol.), (Figure 7-10), etc.

In addition to gall wasps, miners were also very common agents of damage to oak leaves, especially sessile oak.

Figure 7. *Andricus quercustozae* (Bosc)
(Orig.)

Figure 8. *Andricus quercuscalicis*
(Bur.) (Orig.)

Figure 9. *Andricus caputmedusae*
(Htg.) (Orig.)

Figure 10. *Biorhiza pallida* (Ol.),
an old gall (Orig.)

3.3. Diptera ORDER

Apart from oak, most sample plots include beech (*Fagus sylvatica* L) forests. According to the Flora of Serbia II (Stevanović, 2012), Moesian beech (*Fagus moesiaca* (K. Maly) Czech.) has recently got the status of a subspecies of European beech (*Fagus sylvatica* L.) in Serbia – *Fagus sylvatica* subsp. *moesiaca*. Despite its good technical properties, beechwood is known to be not so resistant and susceptible to attacks of numerous parasitic and saprophytic organisms. Trees physiologically weakened and diseased by their action become an easy target for the attack of various primary and secondary harmful insect species, which ultimately leads to the death of individual trees or groups of trees (Tabaković-Tošić, Marković, 2004).

Insect damage, mainly from miners and gall wasps, was registered on beech leaves. From the order of Diptera, the species that affect the assimilation function of the leaf blade include *Hartigiola annulipes* (Hartig), *Mikiola fagi* Htg., and *Dryomyia circicanns* (Girauld) (Figures 11-13). Gall midges from the Cecidomidae family are also present with the most common species (Figure 14).

Figure 11. *Hartigiola annulipes* (Hartig), SP 76, (Orig.)

Figure 12. *Dryomia circicanns* (Girauld) (Htg.), SP 97, (Orig.)

Figure 13. *Mikiola fagi* Htg. SP 412, (Orig.)

Figure 14. *Cecidomidae*, galls on Tartar maple, *Acer tataricum*, SP 39 (Orig.)

3.4. Coleoptera ORDER

The most significant and recognizable insect–forest pest of the beetle order is the beech leaf-mining weevil, *Orchestes fagi* L that causes significant foliage damage (Figures 15 and 16). The oak leaf beetle, *Agelastica quercetorum* Foudr. is another common oak leaf pest that significantly affects the general vitality of the leaf blade. It is interesting that, like with the beech leaf-mining weevil, its damage starts with snake-like blasting, and continues with the complete decomposition of the oak apical shoots (Mihajlović, 2008).

Figure 15. *Orchestes fagi* L. (Orig.)
SP 412, initial phase (Orig.)

Figure 16. *Orchestes fagi* L. SP 412,
advanced phase (Orig.)

Various agents of curled and wilting leaves were recorded on all oak species. Among other leaf rollers, *Attelabus nitens* Scop was particularly abundant on Hungarian oak trees.

3.5. Homoptera ORDER

A season favourable in terms of weather conditions bring a mass swarm of *Phyllaphis fagi* L., woolly beech aphid (Fig. 17), a species that was introduced to other continents from Europe and causes significant damage. When the attack is extremely strong, the damage can be substantial. This insect was observed in our country as well, especially at the base of the leaf veins (Figure 18).

Figure 17. *Phyllaphis fagi* L., Swarming SP
85 (Orig.)

Figure 18. Damage caused by
Phyllaphis fagi L., SP 85 (Orig.)

Individual shields of females of *Parthenolecanium rufulum* Chll., the oak soft scale, were also found. In large numbers, i.e. just like the plum soft scale, it can greatly affect the growth and development of shoots at the bases of petioles, buds and twigs (Figure 19). Oaks often have species from the genus of *Phylloxera*, recognisable by the secretion of honeydew, which covers the entire lamina and thus causes stagnation and interrupts transpiration (Figure 20). The given reaction (here

honeydew secretion) is a mechanism determined by the tree species attacked and is regulated by the natural resistance to defoliation (Češljarić et al., 2014).

Figure 19. A shield of a female of *Parthenolecanium rufulum* Chll., oak soft scale, SP 60 (Orig.)

Figure 20. Effects of honeydew of leaf scales on leaf veins, *Phylloxera* sp., oak shoots, SP 80, (Orig.)

4. CONCLUSIONS

The vitality of forests depends on environmental conditions and numerous biotic and abiotic effects – climate characteristics, atmospheric deposition, pathogenic organisms, wood destructors, forest fires, direct atmospheric influences, wildlife, rodents, etc. Harmful insects are perhaps the most important link needed to draw the final conclusions about the tree crown vitality. Their huge number of species and diversity in Serbia is to be linked to the state of forest ecosystems at LEVEL I SP in Serbia.

Regarding insect pests, defoliators are proven to be the most decisive factor of tree vitality, given the mentioned abundance of broadleaved species at SP and the percentage of insect damage inflicted to beech, sessile oak, Turkey oak and broadleaved trees in general (Table 2). The damage that in the defined extent affects parts of lamina significantly hinders the normal transpiration of forest trees. Since broadleaved trees are more often attacked by these insects and have more serious mechanical injuries, they generally have more pronounced defoliation and greater total damage. Numerous harmful agents, i.e. insect pests were recorded and identified on sampled trees. These were insects from the orders of Homoptera, Coleoptera, Lepidoptera, Hymenoptera, Diptera.

Since harmful insects are one of the important links necessary to draw the final conclusions about the tree crown vitality, further research should address the issues related to the impact of a huge number of species of harmful insects on the state of forest ecosystems and their diversity at the LEVEL I SP in Serbia.

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Summary

The International Program for Monitoring the Condition of Forests in Europe (ICP for Forests) implemented at ICP Level I sample plots in Serbia aims to determine the vitality of forests at the local and regional levels. Tree crown vitality assessed through discolourisation and the extent of damage caused by pests at established sample plots in 2021 should help draw final conclusions about the vitality of forests. It combines adverse effects of complex abiotic and biotic factors on trees as living organisms and complex natural processes within the forest, such as transpiration described in this paper. The effects of diverse insect orders may be the key to finding solutions and improving knowledge about forest ecosystems. These are topical issues that must be further addressed by research in our country and worldwide.

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Rezime

Međunarodni program za praćenje stanja šuma Evrope (ICP Forests of Europe), koji se takođe odvija na ICP oglednim parcelama prvog nivoa u Srbiji, pruža priliku da se utvrdi vitalnost šuma na lokalnom i regionalnom nivou. Procena stanja krošnji šuma, kroz dekolorizaciju, i utvrđivanje stepena oštećenja stabala od štetočina, na BIT-u u 2021. godine, doprinoseći davanju konačnih zaključaka o vitalnosti šuma. Nastaje kao rezultat štetnog dejstva kompleksnih faktora abiotičkog i biotičkog porekla drveća kao živih organizama i složenih prirodnih procesa u okviru šumske biocenoze – gde je to transpiracija

koja je ugrožena insektima ovde opisana. Uticaj različitih redova insekata je ključ za pronalaženje rešenja u budućem ostvarivanju znanja o poboljšanju šumskih ekosistema, u smislu značaja pojedinih redova i njihovih predstavnika na ugroženost oglednih stabala. Ove teme su veoma aktuelne i biće predmet istraživanja kod nas i sveta u daljem periodu.