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INFLUENCE OF THE STRESS FACTOR UNDER THE CONDITIONS OF CLIMATE CHANGES ON WEAKINING OF TREES AND APPERANCE OF PATHOGENIC AND EPYXILOUS FUNGI IN NATURAL BEECH STRANDS

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Abstract: *The paper presents the examination of the health condition of beech stands from the aspect of mechanical and abiotic damage on trees. The research was conducted in Forest Management Office Kucevo, in a hillside beech forest Fagetum moesiacae submontanum of generative origin. The research included 505 trees on 28 sample plots. A strong correlation was found between the appearance of fungi and the presence of injuries – 51.88%, as well as between the presence of fungi and abiotic damage – 47.96%. It was determined that the health condition of high beech forest heavily depended on careful and proper manipulation during logging, while every injury sustained by standing beech trees during felling opened an access point to dangerous microorganisms.*

Keywords: mechanical damage, abiotic damage, beech, fungi

UTICAJ FAKTORA STRESA U USLOVIMA PROMENE KLIME NA SLABLJENJE STABALA I POJAVU PATOGENIH I EPIKSILNIH GLJIVA U PRIRODNIM SASTOJINAMA BUKVE

Sažetak: *U radu je prikazano ispitivanje zdravstvenog stanja bukovih sastojina sa aspekta prisustva mehaničkih i abiotičkih ozleda na stablima. Istraživanja su vršena u šumskom gazdinstvu Kučevo, u brdskoj šumi bukve Fagetum moesiacae submontanum, generativnog porekla. Ispitivanjem je obuhvaćeno 505 stabala na 28 oglednih parcela. Konstatovano je da postoji jaka korelaciona veza između pojave gljiva i prisustva ozleda - 51.88%, kao i između prisutnih gljiva i abiotičkih oštećenja - 47.96%. Konstatovano je da za zdravstveno stanje visokih bukovih sastojina izuzetan značaj ima pažljivo i pravilno manipulisanje prilikom seče, a svaka ozleda na bukovim dubećim stablima počinjena pri seči je otvoren put za zarazu opasnim mikroorganizmima.*

Ključne reči: mehanička i abiotička oštećenja, bukva, gljive

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1. INTRODUCTION

According to the internationally adopted definition, sustainable management of forest resources means the stewardship and use of forests and forest lands in a way that preserves biodiversity while maintaining their regeneration capacity, vitality and potential to fulfil relevant ecological, economic and social needs, without compromising and causing damage to other ecosystems (Medarevic et al., 2007).

Relative to the global aspect, forest cover in Serbia is close to the worldwide level of 30%, but significantly below the European average of 46%. Out of the total 29.1% of forest area in Serbia, 7.1% is in Vojvodina whereas 37.6% of forests are located in Central Serbia. In the National inventory of forests in Serbia, beech dominates in the total volume and volume increment with the participation of 42.4% and 32.3% respectively (Bankovic et al., 2009).

Due to their abundance in the forest reserves of Serbia, beech forests undoubtedly have the greatest significance, which makes the stewardship of these forests a much more complex and difficult task compared to management of any other tree species. In addition, available references most frequently speak of the quality of tall beech forests in descriptive and general terms – that it is unsatisfactory and in need of improvement (Stojanovic & Krstic, 2003; Koprivica et al., 2009). Natural rejuvenation is the only regeneration method of beech forests, which is the reason why Serbia has no artificially established beech forests or forest cultures (Vučković et al., 2005). All of this makes up the foundation of their biological diversity, stability and sustainability. The biological properties, ecological demands, natural distribution and generally beneficial functions of beech forests make beech the fundamental tree species in Serbian forestry (Karadžić & Milijašević, 2005), although the use of beech lumber on a wider scale is limited by its short lifespan and sensitivity to incidence of diseases and pests.

Beech wood is vulnerable and represents an excellent base for development of numerous parasitic and saprophytic organisms, first and foremost of fungi. In beech coppice forests in Serbia, the total of 147 species of fungi were found on beech trees, out of which 33 species occur on fruits and young crop, 56 species occur on leaves and bark of the branches and the trunk, whereas 58 species cause rot and wood coloration (Karadžić & Milijašević, 2004).

The cause of beech forests dieback is a consequence of simultaneous negative impact of a range of factors. Among these a special place belongs to man, whose irrational exploitation of beech forests almost halved the forest area in Serbia (Markovic et al., 2019; Miletic et al., 2006; Markovic et al., 2011).

Due to increasing sensitivity of forest ecosystems under the conditions of climate changes, and the fact that the vitality of beech trees in forests under stress is directly linked to the interactions in the immediate surroundings, it is necessary to pay more heed to mutual influences of abiotic and biotic factors on withering of tree crowns (Chakraborty et al., 2017; Bayat et al., 2021; Stajić et al., 2022). This paper researched the aspect of incidence of pathogenic microorganisms on beech trees alongside with the presence of injuries on trees, with the aim to contribute to a more rational approach to beech forest protection and maximum preservation of beech stands in Serbia.

2. MATERIAL AND METHODS

The beech and stands that it forms are widely present in Serbia and throughout Europe, making the beech the most important species in this area from both economic and environmental standpoints. As such, the beech is central to preservation of stability and biodiversity of forest ecosystems across Europe (Vasić, 2018). For the purposes of preservation and protection of natural beech stands, the site selected for this research was the one on which the observation method revealed a large number of injuries on trees. The paper provides an analysis of the impact of tree injuries on the incidence of pathogenic and epixylic fungi on live beech trees. The research was carried out in the forest holding "Severni Kucaj" (*North Kucaj)* in Kucevo, forest administration Kucevo, in a hillside beech forest *Fagetum moesiacae submontanum* of generative origin. The researched site is located in the forest management unit Crni Vrh, section 42, divisions a and b. The research included the total of 505 beech trees on 28 sample plots.

Circular 500m^2 trial experimental plots were placed and marked in the stands at 100 x 100 m distances. Each experimental plot included between 8 and 27 researched trees. Injuries noted on each tree were classified as mechanic (injuries from felling and hauling during harvest) and abiotic (injuries from wind, snow, ice, frost and excessive insulation that caused bark inflammation). In addition, any presence of pathogenic and epyxilic fungi on trees was also noted. On the basis of the obtained data, statistical analysis was conducted in order to determine the correlation link.

3. RESULTS

The fungus of high significance which most frequently appears on the researched plots and individual trees is *Apiognomonia errabunda* (Roberge ex Desm.) Höhn. (82.0% of plots and 15.1% of beech trees). In this category, the rarest is the occurence of fungus causing root rot *Armillaria mellea* (Vahl) P.Kumm., which was found on only 7.0% of plots and 0.6% of trees.

In the medium significance category, wood-decaying fungus *Coriolus versicolor* (L.) Quél. was found on all the examined plots (100.00%) but only on 18.3% of trees, while the least frequent was *Dedalea quercina* (L.) Pers., which appeared on 3.6% of plots and 0.2% of trees.

Once of the most significant fungi identified on the tested site was *Neonectria coccinea* (Pers.) Rossman & Samuels, which was present on almost two-thirds of the sample plots (64.3%), and which together with the insect *Cryptococcus fagisuga* Lind. causes the dangerous beech bark disease. As of late, this disease is being regarded as a major factor compromising normal development of beech trees, and merits special attention in view of the fact that it is spreading over ever-larger areas. Measures undertaken against this fungus are classified into several categories: biological preventive measures, which include use of predators and super-parasites against insects (prior to infection with fungus); bio-control of the fungus by means of antagonists (once the infection occurs); silvicultural measures – removal of diseased trees (in advanced stages of the infection), and chemical measures, which are non-economical in forests and thus applied only in parks and tree alleys.

It is important to note that following the infection of beech trees with this fungus, the necrotic bark sections very quickly get infested by wood-decaying fungi and wood-destroying insects, which play a role in rapid tree decay and extinction of beech trees (Karadzic, 2003; Ivković et al., 2007).

Table 1 shows a statistical analysis – simple and multiple linear regression between all pairs of the presented columns and the correlation matrices made between columns x', y_1, y_2 and y_3, as well as columns x_1, x_2, x_3 and x_3/ x'.

Table 1. *Comparative analysis of attacks by fungi and injuries on beech trees in Forest Management Office Kucevo, Managemet Unit Crni Vrh*

(x') Number of trees on plot	**Fungi**			**Injuries**			**Index (x_3/ x')**
	(y_1) Dangerous fungi	(y_2) Other fungi	(y_3) Total number of fungi	(x_1) Mechanical injuries	(x_2) Abiotic injuries	(x_3) Mechanical and abiotic injuries	
20	5	6	11	16	42	58	2.90
27	3	3	6	12	7	19	0.70
22	5	3	8	16	34	50	2.27
20	4	2	6	4	34	38	1.90
21	3	3	6	10	17	27	1.29
9	1	2	3	4	8	12	1.33
11	0	3	3	7	7	14	1.27
14	0	2	2	2	7	9	0.64
22	3	2	5	5	7	12	0.54
17	4	2	6	8	37	86	5.06
10	1	2	3	2	19	19	1.90
12	2	2	4	8	14	22	1.83
16	2	2	4	10	7	17	1.06
23	3	2	5	10	3	13	0.56
21	3	2	5	14	2	16	0.76
25	2	5	7	16	27	43	1.72
19	1	3	4	11	9	20	1.05
14	1	2	3	3	11	14	1.00
23	4	2	6	14	10	24	1.04
19	3	2	5	5	17	22	1.16
11	0	2	2	6	8	14	1.27
23	3	2	5	1	18	19	0.83
20	1	2	3	3	9	12	0.60
20	0	2	2	1	3	4	0.20
8	0	2	2	1	15	16	2.00
26	3	2	5	12	20	32	1.23
18	3	2	5	15	15	30	1.67
13	3	2	5	7	8	15	1.15

Statistical processing of the obtained data on the researched site showed that there is a significant statistical link between all the presented columns, including the number of abiotic injuries and the occurence of fungi. The strongest correlation link, amounting to 51.88%, is the one between the total number of fungi and mechanical injuries (columns y_3 and x_1). The link between the total number of fungi and abiotic injuries (columns y_3 and x_2) is only slightly weaker but also strong at 47.96%. Links between the number of dangerous and other fungi (y_1, y_2) and mechanical and abiotic injuries (x_1, x_2) are significant and range from 26.70% to 36.47%, where links between the fungi and mechanical injuries are stronger by approximately 2% - 5% than the links between the occurrence of fungi and abiotic injuries. That means that

the occurrence of fungi – column y_3 (both dangerous and other fungi) is directly linked to the presence with mechanical and abiotic injuries - x_1 and x_2. In other words, the number of injuries is the determining factor linking the occurrence of fungi and the injuries on trees (figure 1). On sites with a smaller number of injuries the correlation links between the occurrence of fungi and tree injuries are weaker, and vice versa.

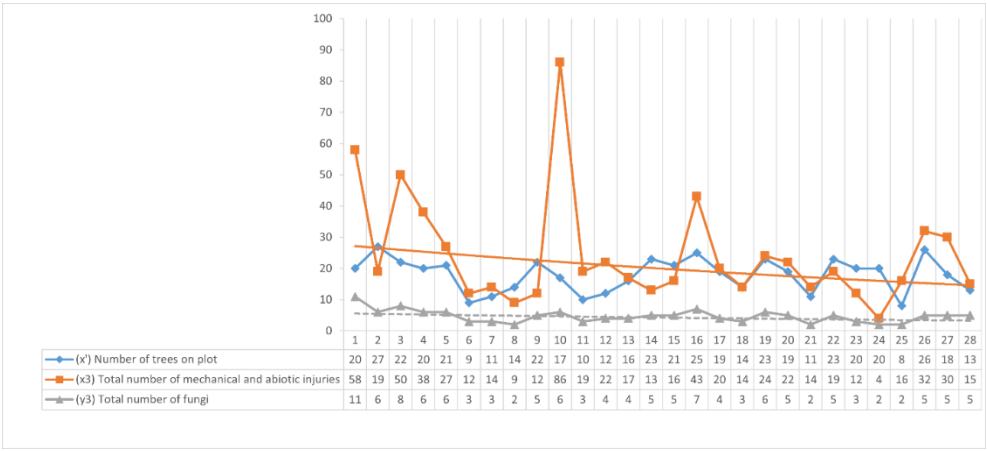

Figure 1. *Ratio of attacks by fungi, injuries and number trees on plot*

It is a well-known fact that health status of the stands is contingent upon a large number of factors, among which year-round climatic conditions must be considered as one of the most critical. Rainy, humid and relatively warm weather favours the activity of the fungi and increases the yield, thus enabling faster colonization by the fungi as well as a more precise identification of the existing microflora. It should also be noted that diagnosis of the disease is greatly impeded by prolonged incubation periods of the fungi colonizing vital trees, while primary symptoms appear on the surface only after several years of attack (reproductive organs – visible carpophores may not appear at all or their appearance might be extended over a number of years).

4. DISCUSSION

In addition to an accurate diagnosis, it is essential to make a precise prognosis of the dynamics of development of pathological processes in the plant. However, this prognosis cannot be determined with any reliable level of accuracy for the upcoming calendar years, as climatic conditions are a determining factor for the development of the infection. It is thus possible to make only a rough prognosis, based on mapping the parts of the forest under attack according to the destructor species and attack intensity, and use it as basis for planning the sanitary and silvicultural activities.

Sanitation felling and other phytosanitary measures, which may or may not be carried out in forests, certainly have a great impact on the overall health condition of the stands. Proper stewardship can minimize the existing infections and thus

eliminate or greatly mitigate any new infection, which significantly contributes to having the health status of the stands restored and maintained on a satisfactory level.

5. CONCLUSION

On the researched site a significant statistical link was found between all columns, including the number of abiotic injuries and the occurence of fungi, which is a consequence of a large number of injuries. The strongest correlation link, amounting to 51.88%, is the one between the total number of fungi and mechanical injuries. The link between the total number of fungi and abiotic injuries is also strong at 47.96%. Links between the number of dangerous and other fungi and mechanical and abiotic injuries are significant and range between 26.70% and 36.47%. This practically means that the incidence of fungi is directly linked to the presence of both mechanical and abiotic injuries.

The number of injuries may be identified as the determining factor linking the occurrence of fungi and the damage on trees. On sites with fewer injuries the correlation links between the occurrence of fungi and the injuries are less strong, and vice versa. Careful and proper handling of trees during felling is critical for the health condition of tall beech stands. Every injury sustained by live beech trees during felling opens the door to infection by pathogenic microorganisms. Proper stewardship may minimize the existing infections and thus eliminate or greatly mitigate any new infection, which significantly contributes to having the health status of the stands restored and maintained on a satisfactory level.

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Summary

Due to their abundance in the forest reserves of Serbia, beech forests undoubtedly have the greatest significance, which makes the stewardship of these forests a much more complex and difficult task compared to management of any other tree species. Due to increasing sensitivity of forest ecosystems under the conditions of climate changes, and the fact that the vitality of beech trees in forests under stress is directly linked to the interactions in the immediate surroundings, it is necessary to pay more heed to mutual influences of abiotic and biotic factors on withering of tree crowns. Beech wood is vulnerable and represents an excellent base for development of numerous parasitic and saprophytic organisms, first and foremost of fungi. In beech coppice forests in Serbia, the total of 147 species of fungi were found on beech trees, out of which 33 species occur on fruits and young crop, 56 species occur on leaves and bark of the branches and the trunk, whereas 58 species cause rot and wood coloration. It is a well-known fact that health status of the stands is contingent upon a large number of factors, among which year-round climatic conditions must be considered as one of the most critical. Rainy, humid and relatively warm weather favours the activity of the fungi and increases the yield, thus enabling faster colonization by the fungi as well as a more precise identification of the existing microflora. It should also be noted that diagnosis of the disease is greatly impeded by prolonged incubation periods of the fungi colonizing vital trees, while primary symptoms appear on the surface only after several years of attack (reproductive organs – visible carpophores may not appear at all or their appearance might be extended over a number of years). In addition to an accurate diagnosis, it is essential to make a precise prognosis of the dynamics of development of pathological processes in the plant. However, this prognosis cannot be determined with any reliable level of accuracy for the upcoming calendar years, as climatic conditions are a determining factor for the development of the infection. It is thus possible to make only a rough prognosis, based on mapping the parts of the forest under attack according to the destructor species and attack intensity, and use it as basis for planning the sanitary and silvicultural activities. The research was conducted in Forest Management Office Kucevo, in a hillside beech forest Fagetum moesiacae submontanum of generative origin. The research included 505 trees on 28 sample plots. On the researched site a significant statistical link was found between all columns, including the number of abiotic injuries and the occurence of fungi, which is a consequence of a large number of injuries. The strongest correlation link, amounting to 51.88%, is the one between the total number of fungi and mechanical injuries. The link between the total number of fungi and abiotic injuries is also strong at 47.96%. Links between the number of dangerous and other fungi and mechanical and abiotic injuries are significant and range between 26.70% and 36.47%. This practically means that the incidence of fungi is directly linked to the presence of both mechanical and abiotic injuries.

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Rezime

Zbog zastupljenosti u šumskom fondu Srbije, bukove šume svakako imaju najveći značaj, zbog čega je gazdovanje bukovim šumama mnogo kompleksniji i teži zadatak u odnosu na sve druge vrste drveća. Zbog sve veće osetljivosti šumskih ekosistema u uslovima promena klime i činjenice da je vitalnost bukovog drveća u šumama pod stresom direktno povezana sa interakcijama u okruženju, neophodno je više pažnje posvetiti međusobnim uticajima abiotičkih i biotičkih činilaca na odumiranje krošnji drveća. Bukovo drvo je neotporno i predstavlja odličnu podlogu za razvoj mnogih parazitnih i saprofitnih organizama, a među njima na prvo mesto dolaze gljive. U izdanačkim šumama bukve u Srbiji, na stablima bukve konstatovano je 147 vrsta gljiva, od kojih se 33 vrste javlja na plodovima i poniku, 56 vrsta na lišću i kori grana i stabla, a 58 vrsta prouzrokuju trulež i obojenost drveta. Poznato je da zdravstveno stanje sastojina zavisi od velikog broja činilaca, pa svakako ne treba zaboraviti da je jedan od presudnih klimatske prilike u toku godine. Kišovito, vlažno i relativno toplo vreme favorizuje aktivnost gljiva i pojačava plodonošenje, što omogućava bržu kolonizaciju gljiva, a i precizniju identifikaciju postojeće mikoflore. Treba napomenuti i da dijagnozu bolesti jako otežava duga inkubacija gljiva koje koloniziraju vitalna stabla, a primarni simptomi se javljaju na površini tek posle višegodišnjeg napada (reproduktivni organi – pojava vidljivih karpofora može da izostane ili da se produži na više godina). Pored tačne dijagnoze, neohodna je i tačna prognoza dinamike razvoja patoloških procesa u biljci, a nju je nemoguće precizno utvrditi za naredne kalendarske godine, jer su opredeljujući faktor za razvoj zaraze vremenske prilike. Zato se prognoza može izvršti samo u grubim crtama, na osnovu kartiranja napadnutih delova šuma po vrsti destruktora i intenzitetu napada i na osnovu toga se moraju planirati sanitarno – uzgojni radovi. Istraživanja su vršena u šumskom gazdinstvu Kučevo, u brdskoj šumi bukve Fagetum moesiacae submontanum, generativnog porekla. Ispitivanjem je obuhvaćeno 505 stabala na 28 oglednih parcela. Na ispitivanom lokalitetu postoji značajna statistička veza između svih kolona, pa i između broja abiotičkih oštećenja i pojave gljiva, što je posledica velikog broja oštećenja. Najjača korelaciona veza postoji između ukupnog broja gljiva i mehaničkih oštećenja i iznosi 51.88%. Veza između ukupnog broja gljiva i abiotičkih oštećenja je takođe jaka i iznosi 47.96%. Veze između broja opasnih i ostalih gljiva i mehaničkih i abiotičkih oštećenja su značajne i iznose 26.70% do 36.47%. To praktično znači da je pojava gljiva u direktnoj vezi sa prisustvom i mehaničkih i abiotičkih oštećenja.