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IMPACT OF OAK LACE BUG *CORYTHUCHA ARCUATA* ON THE HEIGHT OF PEDUNCULATE OAK PLANTS DEPENDING ON THE WAY OF REGENERATION

UTJECAJ HRASTOVE MREŽASTE STJENICE *Corythucha arcuata* NA VISINU BILJAKA HRASTA LUŽNJAKA OVISNO O NAČINU PODMLAĐIVANJA

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SUMMARY

Oak lace bug *Corythucha arcuata* represents a new pest of oaks in Europe, introduced from North America in year 2000. Damage is caused by adults and larvae that feed on the underside of leaves. The paper presents the results of investigation of impact of *Corythucha arcuata* on pedunculate oak growth. The two variant experiment was established in 2019 and included the evaluation of the effect of oak lace bug on the height of the seedlings (i) grown under the shade of the adult trees after the intermediate felling and (ii) seedlings grown unshaded after the final felling. Both variants included eight plots of which four were treated with the insecticide thiamethoxam, while other four were untreated. Assessment of the intensity of the attack was performed in June, July and August in 2019, 2020 and 2021, while the height of the plants was measured at the end of the vegetation period in 2019, 2020 and 2021.

The results indicate significant decrease in the intensity of the attack on seedlings grown unshaded by the old trees. After first year, there was no difference in average height of the treated and untreated seedlings grown after the intermediate felling, while the difference was evident after second and third year. Such results indicate cumulative effect of the oak lace bug attack on the seedlings of the penduculate oak. On the other hand, during whole experiment, the differences between treated and untreated plant average height after the final felling were not evident.

KEY WORDS: oak lace bug, damage, Quercus robur, regeneration, height, seedlings

INTRODUCTION
UVOD

Oak lace bug *Corythucha arcuata* Say (Heteroptera: Tingidae) is alien invasive species introduced from its natural habitats in USA and Canada to Europe (Rabisch, 2008). First finding on European continent was recorded in Italy in 2000 (Bernardinelli and Zandigiacomo, 2000). After the introduction, the species has spread relatively fast across the continent with records in over 20 countries by 2019 (Paulin et al., 2020). After the first record in Serbia in 2013 (Poljaković-Pajnik et al., 2015), it has rapidly spread and today it is present across the entire country (Drekić et al.,

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2021). Research conducted by Csoka et al. (2019) found that 27 of total 48 oak species are suitable for the development of oak lace bug. Besides the oak, the insect was recorded on 33 additional species from 10 plant families (Csoka et al., 2019).

Adults and nymphs cause damage to the leaves by sap feeding on the lower side of the leaves, while symptoms are expressed as yellow or pale spots to appear on the upper leaf surface and eventually spread across the entire leaf area and whole tree crown. Damage caused by this insect can result in tree weakening and defoliation (Hrašovec et al., 2013). Feeding can decrease leaf physiological activity such as net photosynthesis (-58,48%), transpiration (-21,66%) and stomatal conductance (-35,71) (Nikolić et al., 2019). In North America, in its natural habitat, there are rare reports of damage caused by *C. arcuata* on american autochthonous oak species. Only Connell and Beacher (1947) reported damage in the form of defoliation and tree weakening of oaks. The data on the impact of oak lace bug on the height and growth of pedunculate oak is very limited. During the initial phase of the development, young oak seedlings in the regenerated stand have high demand for the upper light in order to compete with the weed vegetation (Drekić et al., 2019). Considering the above mentioned, the idea of this research was to determine the effect of the oak lace bug feeding on the height of the oak seedlings at the beginning of forest regeneration process. This manuscript presents three-year study on the influence of oak lace bug feeding on an oak seedling's height in two different methods of the forest regeneration.

Figure 1. Unshaded young oak seedlings in July 2020
Slika 1. Podmladak hrasta na čistini u srpnju 2020

Figure 2 Adult oak stand after the intermediate felling in September 2019
Slika 2. Hrast lužnjak nakon oplodne sječe u rujnu 2019

MATERIALS AND METHODS
MATERIJALI I METODE

The experiment was established in spring of 2019 in the forest managed by PE "Vojvodinašume" Forest Estate Sremska Mitrovica at the locality Varadin (N 44° 57′ 30′′; E 19° 15′ 04′′) with the aim of investigation of the influence of oak lace bug feeding on the height of young oak seedlings (Fig. 1, 2). Experimental design included two neighboring plots with different forest regeneration methods where the seedlings emerged either (i) under shelterwood system prior to the final felling (shaded seedlings) or (ii) after the final cut (unshaded seedlings).

Forest regeneration was conducted by acorn sowing in the autumn of 2017 on both plots. On each plot, we selected separated and marked 8 subplots sized 1.5 x 1.5 m of which four were treated with insecticide Actara 25 WG (thiamethoxam) in the concentration 0,02% three times during each vegetation period (10. 6. 2019; 3.7. 2019; 1. 8. 2019; 29. 05. 2020; 30. 06. 2020; 29. 07. 2020; 3. 6. 2021; 1. 7. 2021 and 6. 8. 2021) with the aim to suppress oak lace bug adults and nymphs, while four plots remained untreated. The insecticide Actara 25WG was selected for the treatment because it was in the time of investigation allowed to be used in Serbia and proven to be efficient in suppression of the pest (Drekić et al., 2019). For the application, we used portable back sprayer (Stihl SR 420). In addition, all 16 subplots were preventively treated against the powderly mildew with the fungicide Falcon (Spiroxamine + Tebuconazole + triadimenol) and Impact (flutriafol).

The assessment of the intensity of the attack was performed on 40 selected plants within the untreated subplots and expressed by the percentage of the number of the attacked leaves. Intensity of the attack assessments were performed by the end of June, July and August in 2019, 2020 and 2021. Height measurements were performed in autumn of 2019, 2020 and 2021.

Statistical analysis included two- and three-way ANOVA and Tukey`s test. Percentage of the damaged leaves was

transformed by arcsin√X transformation with the aim of complying with the normal distribution, as a presumption for applied parametric statistics. The average value for each subplot was the basis for further statistical analysis that was performed with the Statistica® software (TIBCO Software Inc., 2020).

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

The assessment of the damage caused by the oak lace bug on untreated subplots performed at the end of June 2019 showed higher damage of the leaves on shaded seedlings compared to unshaded amounting 56,2% and 0,4% respectively (Fig 3). July assessment showed the increase of the damage on both shaded and unshaded untreated subplots, while the August results showed that 99,4% of the damaged leaves on the shaded seedlings, compared to 41,8% of the attacked leaves on the unshaded untreated seedlings.

Results of the damage assessment on the oak leaves of shaded seedlings in late June of 2019 showed higher damage intensity when compared to 2020 and 2021. On the other hand, unshaded oak seedlings showed low damage intensity in June of 2019; 2020 and 2021 indicating the lower number of overwintered adults of the oak lace bug. July assessment showed significant increase of damage on oak leaves of shaded seedlings when compared to June. The values for the August assessment of the damage intensity on shaded seedlings varied from 88,1% (2021) to 99,9% (2019) with statistical differences between 2019 and 2021 values. Highest percentage of damaged leaves at the end of the August 2019 compared to the end of August 2020 and 2021 can be explained by warm spring in 2019 that positively affected the development and the reproduction of the oak lace bug combined with the low leaf mass of the young seedlings in 2019. Although varied, the damage intensity on unshaded seedling did not show significant difference. Obtained results for August assessments in 2019, 2020 and 2021 indicate two-fold higher damage intensity in shaded seedlings compared to unshaded ones. Such results indicate lower susceptibility to the oak lace bug leaf damage on the oak seedlings that are developing without the presence of the adult trees from the shelterwood regeneration system.

According to Paulin et al. (2021), most of the adults of oak lace bug are overwintering on the trunk and branches of the adult trees or on dead timber on the ground, with fewer number overwintering in the litter. Considering above mentioned, we hypothesize that the lack of the standing old trees and logs creates unfavorable conditions for overwintering of adults of the oak lace bug. In addition, crowns of adult trees present the source of the insects that can potentially cause damage on the young oak seedlings.

Statistical analysis showed that there was no significant difference regarding the average height of the oak seedlings in 2019 between the treated or untreated plants within both plots (shaded vs. unshaded) (Fig. 4, 6). On the other hand, differences between shaded and unshaded seedlings were significant in both treated and untreated plants. Such result can be explained by the more favorable growth conditions for unshaded seedlings, especially considering the heliophilous nature of the oaks. Such difference was even more evident in the following years.

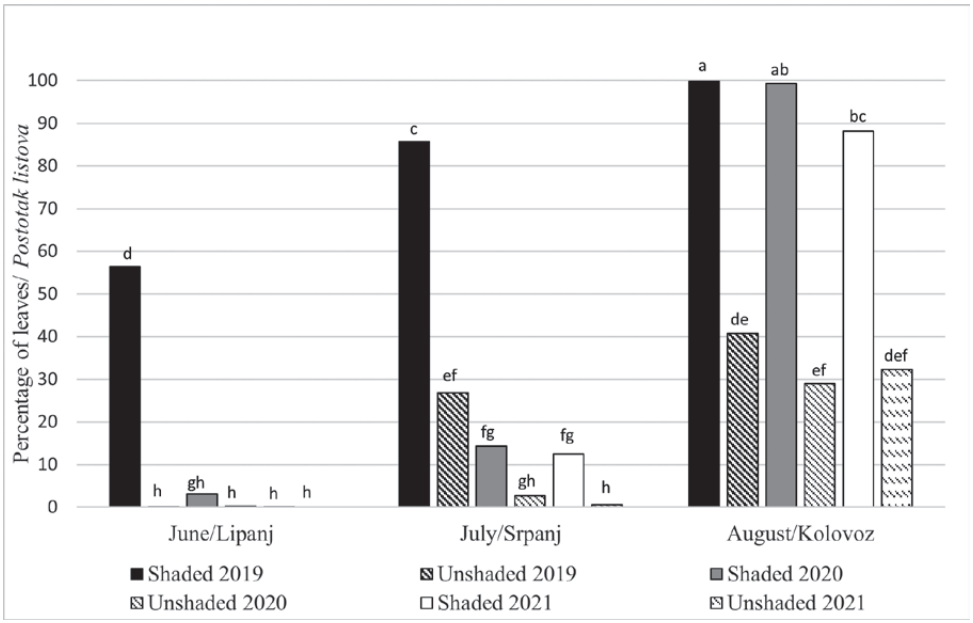

Figure 3 Results of the Tukey`s on the percentage of the damaged oak leaves by *Corythucha arcuata*
Slika 3. Rezultati Tukey-evog testa postotka oštećenosti lišća hrasta od *Corythucha arcuata*

Figure 4 Shaded seedlings untreated with the insecticides on September 5, 2019
Slika 4. Podmladak hrasta lužnjaka u sjeni koji nije tretiran inskticidom (5. rujan 2019)

Figure 5 Shaded seedlings treated with the insecticides on September 8, 2020
Slika 5. Podmladak hrasta lužnjaka u sjeni tretiran inskticidom (8. rujan 2020)

Spring defoliation in oaks can lead to the decrease of the diameter increment (Muzika and Liebhold, 1999). Most of radial growth in oaks occurs in the first part of the growing season (Szőnyi, L., 1962; Járó and Tátraaljai, 1985; Hirka, 1991), while oak lace bug attack happens in the second part of the growing season. Therefore, Paulin et al. (2020) concludes that oak lace bug attack will express itself cumulatively in the following years. Bălăcenoiu et al. (2021) showed that, in Romania, oak lace bug occurrence has two peaks during the growing season in July and August. Considering the above mentioned, our experiment was continued in 2020 and 2021 with the aim to test the cumulative effect of the oak lace bug on the growth of the oak seedlings.

In 2020 measurements showed significantly higher average height of the seedlings grown unshaded, when compared to shaded on both treated and untreated subplots (Fig 5, 7). Also, the height of the treated shaded seedlings was significantly higher than the shaded seedlings that were not treated by 35,3%. Such results confirm the hypothesis on the effect of the insect attack in 2019 on the growth in the following year. Average height of the unshaded plants did not significantly differ between the untreated (85,9 cm) and treated plants (93,1 cm).

Similar results were obtained in the autumn of 2021 where shaded treated plants had significantly higher height values of the shaded untreated plant by 44,6 % with the average

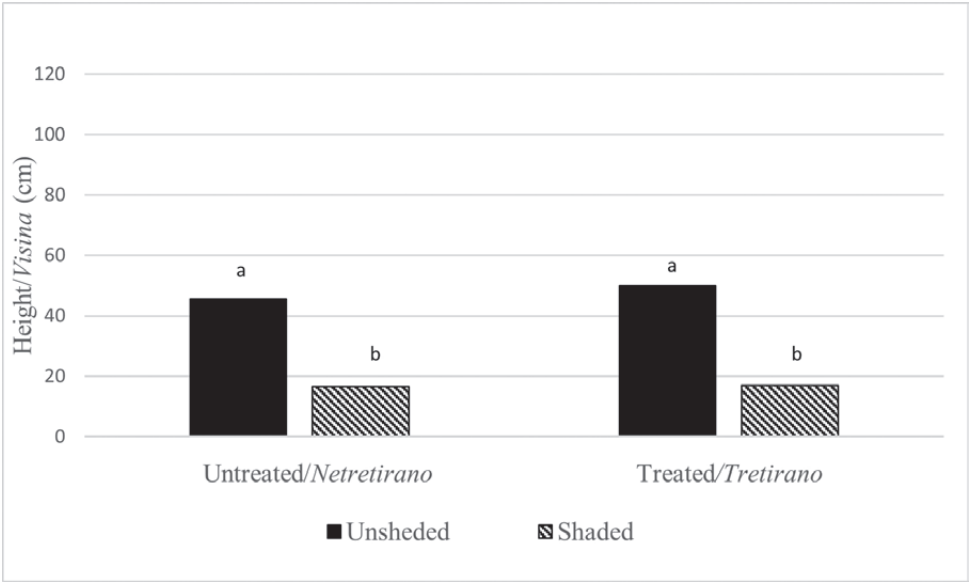

Figure 6 Results of the Tukey`s test on the average heights of the pedunculate oak seedlings in the autumn of 2019
Slika 6. Rezultati Tukey-evog testa prosječne visine podmlatka hrasta lužnjaka u jesen 2019.

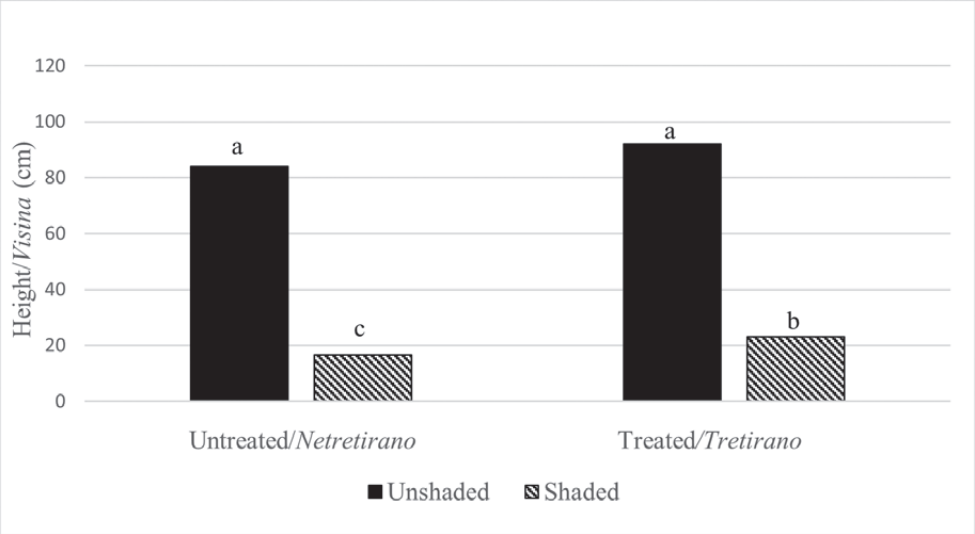

Figure 7 Results of the Tukey`s test on the average heights of the pedunculate oak seedlings in the autumn of 2020
Slika 7. Rezultati Tukey-evog testa prosječne visine podmlatka hrasta lužnjaka u jesen 2020.

height of 29,3 cm, compared to the 20,2 cm average height of the shaded untreated plants (Fig 8). Difference between the treated and untreated unshaded plant did not differ significantly in 2021 also.

The effect of the disturbance of the physiological processes in oaks during the insect attack was elaborated previously (Nikolić et al., 2019; Pilipović et al., 2020). Nikolić et al., (2019) recorded that the oak lace bug attack can cause decrease of net photosynthesis and stomatal conductance in oaks. Like other stressful processes that can lead to the disturbance of the productivity and water use efficiency (WUE) in oaks (Galle et al., 2010). Oak lace bug attack can lead to the increase of the use of the stored assimilated carbon for the cell respiration instead for the growth in which these losses can amount between 30% and 50% of the assimilated carbon (Ripulone et al., 2004).

Considering that the attack of the oak lace bug on unshaded oak seedlings remained in the range between 28,9% and 40,8% of damaged leaves, there was no significant decrease of average height of the investigated seedlings neither for treated nor untreated plants. Such results lead to the conclusion that there is no need for the oak lace bug suppression if the oak seedlings are developing after the final felling of the shelterwood forest regeneration system. In the case of artificial regeneration, the recommendation is to do the acorn sowing on the areas where the adult trees are re-

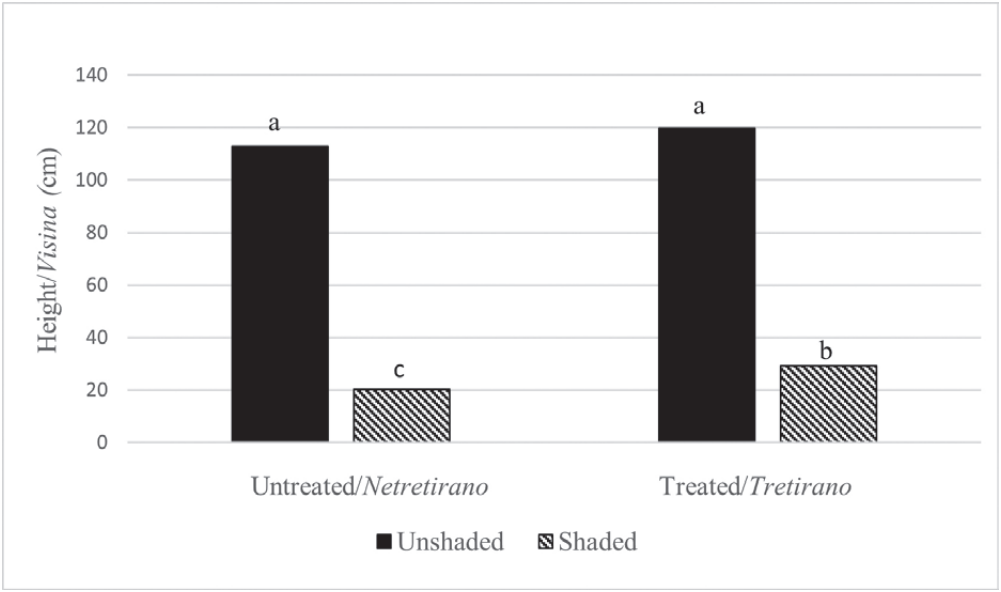

Figure 8 Results of the Tukey`s test on the average heights of the pedunculate oak seedlings in the autumn of 2021
Slika 8. Rezultati Tukey-evog testa prosječne visine podmlatka hrasta lužnjaka u jesen 2021.

moved before sowing. In that way, the damages that can be caused on young oak plants during felling would also be avoided. In the case of the necessity of the shelterwood regeneration system, it is recommended to perform final felling as soon as possible, after the acorn sowing and prior to the plant emergence. According to the presented results, in the case of the development of the oak seedlings under the shade of the remaining adult trees, there is a need to perform suppression of oak lace bug in accordance with local legislation.

CONCLUSIONS
ZAKLJUČCI

This research showed significantly lower intensity of the attack of oak lace bug on young oak seedlings developed unshaded, compared to the seedling shaded by the adult trees. First year of the experiment did not show difference between the average height of the treated and untreated plants, while the differences were evident after second and third year between shaded treated and untreated plants indicating the cumulative effect of the damage. On the other hand, three-year research did not show the difference between the height of the treated and untreated plants grown without the shade of the adult trees. In addition, oak seedlings grown unshaded were significantly higher than the shaded seedlings due to the more direct sunlight. Such results suggest that the regeneration should be made either after the final felling or with the shortest possible time between the acorn sowing and the final felling. In the case of the necessity of the traditional shelterwood system, the oak seedlings should be protected in accordance with local legislation from the oak lace bug during their growth under the shade of the adult trees.

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SAŽETAK

Hrastova mrežasta stjenica *Corythucha arcuata* novi je štetnik hrastova u Europi, unešena je 2000. godine iz Sjeverne Amerike. Štete uzrokuju imago i ličinke koje se hrane sišući biljne sokove s donje strane lišća. U radu je analiziran utjecaj hrastove mrežaste stjenice na rast mladih hrastovih biljaka. Pokus je postavljen u ožujku 2019. u dvije varijante, od kojih je prva bila praćenje utjecaja napada stjenice na prosječnu visinu podmlatka hrasta lužnjaka na površini sa završenom oplodnom sječom, odnosno u sjeni djela stare šume koji ostaje za dovršnu sječu, a druga je bio praćenje utjecaja napada stjenice na prosječnu visinu podmlatka koji je rastao na otvorenom prostoru (Slika1,2). U obje varijante pokusa na četiri pokusne površine je uporabljen insekticid tiametoksam radi suzbijanja hrastove stjenice, a preostale četiri nisu tretirane, već su bile izložene napadu stjenice. Procjene intenziteta napada hrastove stjenice provedene su krajem lipnja, srpnja i kolovoza 2019., 2020. i 2021. godine. Mjerenje visine tretiranih i netretiranih biljaka u obje varijante pokusa obavljeno je na kraju vegetacije 2019, 2020 i 2021. godine.

Istraživanja su pokazala znatno manji intenzitet napada hrastove stjenice na podmladak hrasta koji je rastao na čistini u odnosu na podmladak ispod starih stabala hrasta lužnjaka (Slika 3). U prvoj godini nije bilo značajnih razlika u prosječnoj visini tretiranih i netretiranih mladica u sjeni, ali su značajne razlike uočene nakon dvije i tri godine, što ukazuje na kumulativni učinak napada stjenice na visinu hrastovog podmlatka (Slike 6,7,8). Tijekom trogodišnjeg istraživanja nisu utvrđene značajne razlike u prosječnoj visini biljaka između tretiranih i netretiranih pokusnih ploha na otvorenom, što je rezultat značajno slabijeg napada stjenica na čistini. Podmladak hrasta lužnjaka na čistini je puno viši od podmlatka u sjeni starih hrastova, što je izravan utjecaj svjetla na biljake. To ukazuje da je s obzirom na manji intenzitet napada hrastove stjenice i brži rast biljaka pri punoj svjetlosti, povoljnije izvršiti obnovu na čistini ili je potrebno obaviti dovršnu sječu prije pojave hrastovog podmlatka. Podmladak hrasta lužnjaka koji se razvija ispod stabala stare sastojine nakon oplodne sječe potrebno je zaštititi od stjenice dok je u sjeni.

KLJUČNE RIJEČI: hrastova mrežasta stjenica, štete, *Quercus robur*, obnavljanje, visina, podmladak