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Proceeding Paper

Emerald Ash Borer in the Park with a Long-Time History of Black Ash Sawfly Defoliation †

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Abstract: The emerald ash borer (EAB) was found in Kharkiv (Ukraine) in 2022, infesting ash trees in the permanent focus of the ash black sawfly. We aimed to recognize the characteristics of trees that attract EAB. Ash tree defoliation, dieback, epicormic shoots, health condition class, and ash bark beetle infestation were analyzed with EAB presence or absence. The EAB preferred to infest the trees with higher defoliation, epicormic shoots, and ash bark beetle infestation more than in the trees without these symptoms. Despite the deterioration in the health of most trees in the EAB outbreak, some specimens have maintained and even improved their health. This confirms the possibility of selecting resistant trees with subsequent reproduction.

Keywords: *Fraxinus excelsior* L.; *Agrilus planipennis*; Tomostethus nigritus; Hylesinus sp.; tree health; defoliation; epicormic shoots; resistant trees

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1. Introduction

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae) is native to temperate Northeast Asia [1]. The EAB was accidentally introduced into North America and European Russia at the beginning of the 21st century and has destroyed tens of millions of ash trees (*Fraxinus* spp.) in parkland, nurseries, urban areas, and forests. Despite the efforts of researchers and practitioners, the EAB's spread is documented in 36 U.S. states, 5 Canadian provinces, and 20 regions of Russia [1]. It has been added to the A2 list of pests recommended for regulation as quarantine for the EPPO region, meaning that the pest is locally present in the EPPO region [2]. In 2019, the pest was found in the Luhansk region of Ukraine [3], and by 2021 it had spread to Kharkiv [4] and then to the Kyiv region [5]. In the Molodezhny Park (50°00′ N; 36°25′ E) of Kharkiv, the EAB began to infest *Fraxinus excelsior* L., which had been regularly damaged by the ash black sawfly *Tomostethus nigritus* (Fabricius, 1804) (Hymenoptera: Tenthredinidae) for more than 20 years [6]. Each labeled tree in this park was surveyed yearly, assessing its health indicators. In 2022, the EBA infestation of trees in Kharkiv was confirmed, but planting inspection in the Molodezhny Park was impossible because of military hostilities. As we knew the history of defoliation and each tree's health, we aimed to find the tree characteristics that attract the EAB.

2. Materials and Methods

Ash tree defoliation, dieback, epicormic shoots, health condition class, and ash bark beetle (*Hylesinus* sp.) infestation were analyzed [7]. Regarding health condition, each tree

was referred to one of the following classes: 1—healthy; 2—slightly weakened; 3—weakened; 4—drying up; 5—recently dead; or 6—died more than one year ago [8]. EAB presence in 2023 and 2024 was identified by exit holes and indirect symptoms (traces of woodpecker feeding).

All data were organized using Microsoft Excel (2019, Microsoft Corporation, Redmond, WA, USA, 2019). PAST (4.12, Øyvind Hammer, Natural History Museum, University of Oslo, Oslo, Norway, 2023) [9] was used for data analysis and visualization. EAB infestations in various groups of trees were compared using a z-test for two-proportion comparisons [10]. A difference between the proportions was considered significant for $p < 0.05$ at $z > 1.96$.

3. Results

Over 2013–2024, mean ash tree defoliation by ash black sawfly larvae reached a maximum in 2015 (94.7%) and a minimum in 2017 (13.5%) (Figure 1). In 2020, defoliation exceeded the long-term average (43.4%). In 2024 it was 82.4%, with individual tree defoliation ranging from 40 to 98%.

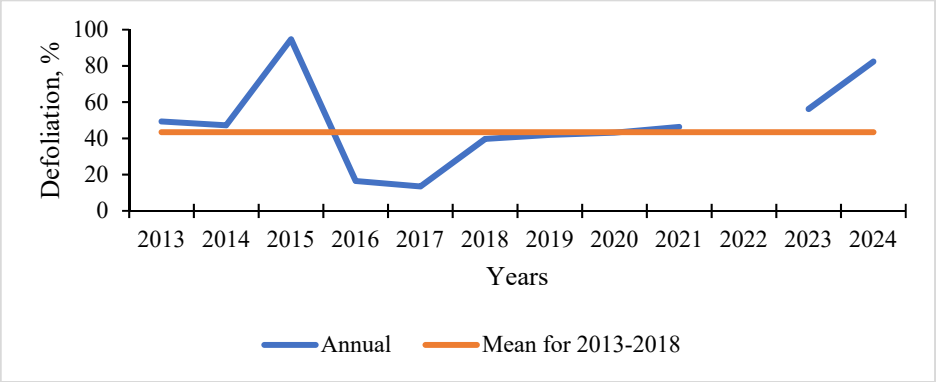

Figure 1. Dynamics of ash defoliation in 2013–2024 in the focus of the ash black sawfly and EAB.

In 2024, the EAB equally infested trees with and without traces of woodpeckers (z = 0.52) and dieback (z = 1.24) in 2023 (Figure 2). The EAB has infested trees with epicormic shoots (z = 6.17) or symptoms of ash bark beetle infestation (z = 5.35) more than trees without these symptoms.

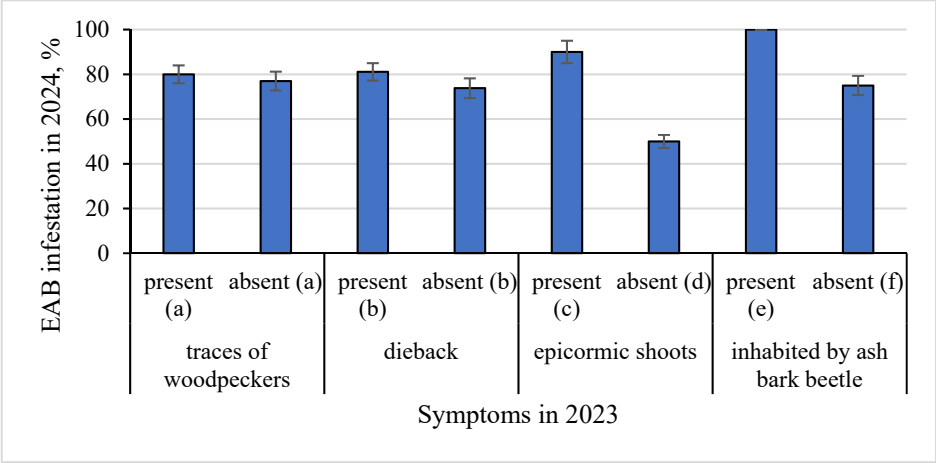

Figure 2. Percentage of EAB-infested trees in 2024 depending on symptoms in 2023 (The infestation of groups of trees with the same letters in parentheses has no significant difference at $p < 0.05$).

The proportion of EAB-infested trees in 2024 was higher in tree groups with higher levels of damage by *T. nigritus* (Figure 3). The proportion of trees with EAB exit holes increased, while the proportion with traces of woodpeckers decreased.

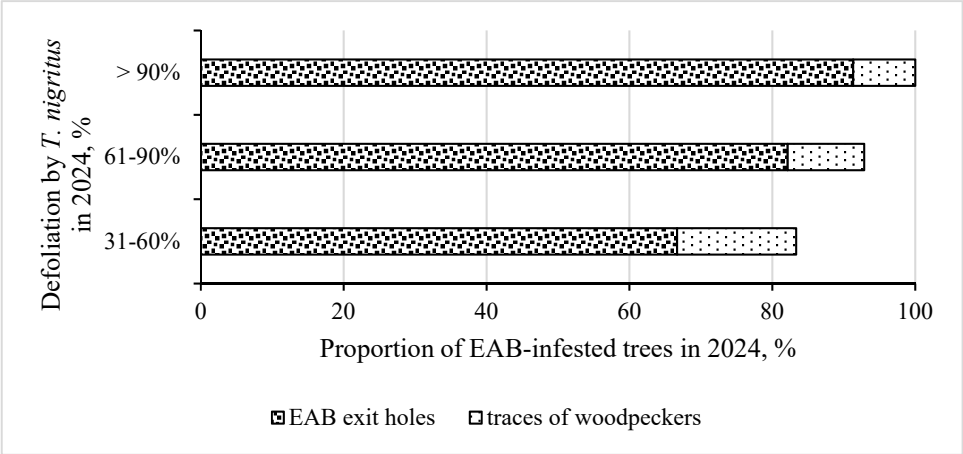

Figure 3. The proportion of EAB-infested trees identified by EAB exit holes and the traces of woodpeckers at different levels of damage by *T. nigritushis*.

A comparison of tree distribution by health class showed that slightly weakened (class 2) trees prevailed in August 2018 (Figure 4). After the EAB infestation, the share of class 2 trees decreased from 45 to 7.5% in August 2023, while weakened (class 3) trees increased from 17.5 to 70%. The share of drying up trees (class 4) also increased, and dead trees appeared. In May 2024, the shares of healthy and slightly weakened trees decreased, while the shares of weakened and drying up trees increased. In September 2024, the share of class 1–2 trees did not change, class 3–4 trees decreased slightly, and dead trees accounted for 12.5% of the total. The health condition index (HCI) increased from 2 to 4 from August 2018 to September 2024.

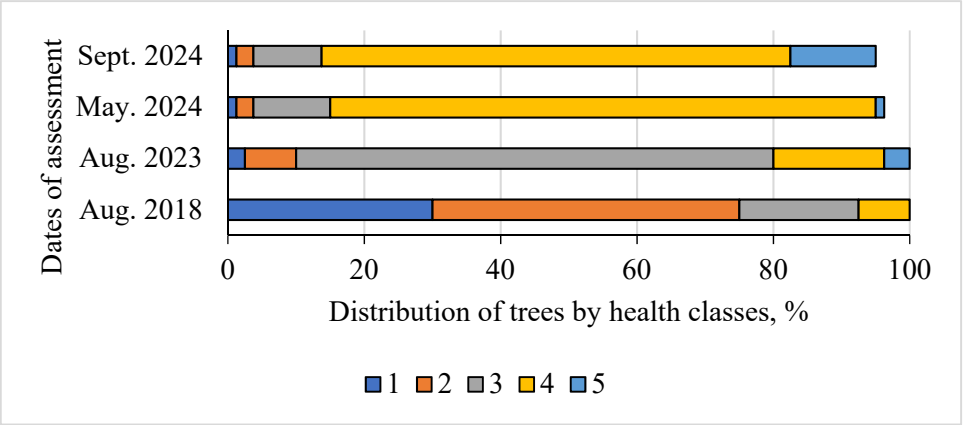

Figure 4. Distribution of ash trees by health condition classes depending on assessment dates (health condition classes: 1—healthy; 2—slightly weakened; 3—weakened; 4—drying up; and 5—dead).

The change in the distribution of the trees, which were characterized by a certain health class in August 2018, on each subsequent survey date is presented in Tables 1–3.

From August 2018 to August 2023, the health condition of trees in classes 1 and 2 worsened, and 14.3% of trees in class 3 improved their condition (Table 1). From August 2018 to May 2024, the health condition of 2.8% of class 2 trees improved, but most trees of all classes worsened their health (Table 2). Even 2.8% of trees from class 2 in 2018 had died by May 2024. In September 2024, the deterioration of the health of the trees continued, but several trees remained in classes 1 and 2 (Table 3).

A comparison of the proportions of EAB-infested ash trees with different initial health classes on different survey dates shows that the EAB has infested mainly severely weakened and dying trees in August 2023 (Table 4).

Table 1. Distribution of *Fraxinus excelsior* trees by health classes in August 2023 depending on their health in 2018.

Distribution of Trees by Health Classes (1–6), %								Total for Given Health Class in August 2023
Before EAB Invasion, August 2018	After EAB Invasion, August 2023 **							
	2018 *	Health Class 1	Health Class 2	Health Class 3	Health Class 4	Health Class 5	Health Class 6	
Health class 1	30.0	8.3	0.0	87.5	4.2	0.0	0.0	100.0
Health class 2	45.0	0.0	11.1	83.3	5.6	0.0	0.0	100.0
Health class 3	17.5	0.0	14.3	35.7	50.0	0.0	0.0	100.0
Health class 4	7.5	0.0	0.0	0.0	50.0	50.0	0.0	100.0
Total	100.0	2.5	7.5	70.0	16.3	3.8	0.0	100.0

Note: *—the proportion of trees in each health class from the total amount in August 2018, %; **—the proportion of trees from each health class in August 2018 in the assessment in August 2023. HCI in August 2018 was 2.0; HCI in August 2023 was 3.1.

Table 2. Distribution of *Fraxinus excelsior* trees by health classes in May 2024 depending on their health in 2018.

Distribution of Trees by Health Classes (1–6), %								Total for Given Health Class in May 2024
Before EAB Invasion, August 2018	After EAB Invasion, May 2024 **							
	2018 *	Health Class 1	Health Class 2	Health Class 3	Health Class 4	Health Class 5	Health Class 6	
Health class 1	30.0	0.0	8.3	12.5	79.2	0.0	0.0	100.0
Health class 2	45.0	2.8	0.0	13.9	80.6	2.8	0.0	100.0
Health class 3	17.5	0.0	0.0	7.1	92.9	0.0	0.0	100.0
Health class 4	7.5	0.0	0.0	0.0	50.0	0.0	50.0	100.0
Total	100.0	1.3	2.5	11.3	80.0	1.3	3.8	100.0

Note: *—the proportion of trees in each health class from the total amount in August 2018, %; **—the proportion of trees from each health class in August 2018 in the assessment in May 2024. HCI in August 2018 was 2.0; HCI in May 2024 was 3.9.

In May 2024, all trees from class 3 and most from classes 2 and 4 in 2018 were EAB-infested. Indirect symptoms of EAB infestation were observed only on trees initially (in 2018) sorted into health classes 1 and 2. The number of trees with direct and indirect symptoms of EAB infestation did not change from May to September 2024.

Table 3. Distribution of *Fraxinus excelsior* trees by health classes in September 2024 depending on their health in 2018.

Distribution of Trees by Health Classes (1–6), %								Total for Given Health Class in September 2024
Before EAB Invasion, August 2018	After EAB Invasion, September 2024 **							
	2018 *	Health Class 1	Health Class 2	Health Class 3	Health Class 4	Health Class 5	Health Class 6	
Health class 1	30.0	0.0	8.3	4.2	79.2	8.3	0.0	100.0
Health class 2	45.0	2.8	0.0	16.7	63.9	13.9	2.8	100.0
Health class 3	17.5	0.0	0.0	7.1	78.6	14.3	0.0	100.0
Health class 4	7.5	0.0	0.0	0.0	33.3	16.7	50.0	100.0
Total	100.0	1.3	2.5	10.0	68.8	12.5	5.0	100.0

Note: *—the proportion of trees in each health class from the total amount in August 2018, %; **—the proportion of trees from each health class in August 2018 in the assessment in September 2024. HCI in August 2018 was 2.0; HCI in September 2024 was 4.0.

Table 4. Proportions of EAB-infested ash trees in 2023–2024 depending on their health in 2018.

Health Classes in 2018	Number of Trees in August 2018 by Health Classes	Proportion of EAB-Infested Ash Trees, % ± SE				
		Direct Symptoms of EAB			Indirect Symptoms of EAB	
		August 2023	May 2024	September 2024	May 2024	September 2024
1	24	0.0 ± 0.00	66.7 ± 9.62	66.7 ± 9.62	8.3 ± 5.64	8.3 ± 5.64
2	36	1.0 ± 1.66	72.2 ± 7.47	72.2 ± 7.47	22.2 ± 6.93	22.2 ± 6.93
3	14	4.0 ± 5.24	100.0 ± 0.00	100.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00
4	6	2.0 ± 5.72	83.3 ± 15.21	83.3 ± 15.21	0.0 ± 0.00	0.0 ± 0.00
Total	80	7.0 ± 2.85	72.5 ± 4.99	72.5 ± 4.99	12.5 ± 3.70	12.5 ± 3.70

4. Discussion

In the inspected plantings, *T. nigritus* damages ash foliage annually. Usually, the larvae feed for several weeks and at the end of May descend into the soil, where they overwinter and pupate in the spring; and at the end of April through the beginning of May, the adults emerge [11]. As was shown earlier [5], the defoliation of each tree varies in individual years. Therefore, even with 100% defoliation, trees have time to restore part of the crown in the following months of vegetation. Over the years of observation, individual trees perished and were cut down to ensure the safety of people. Increases in the *T. nigritus* population occur at intervals of 10–12 years, as is typical for many leaf-eating insects [12]. The maximum tree defoliation levels in the studied plantings occurred in 2002 [6], 2015, and 2024. The last maximum coincided with the infestation of the EAB.

The trees with and without traces of woodpeckers were equally infested by the EAB in 2024 (Figure 2). This may be due to several reasons: (i) the relatively small sample size, only two years of EAB invasion, and lack of possibility of felling infested trees for full analysis; (ii) woodpeckers typically prey on mature EAB larvae in pupal cells [1]; and (iii) woodpeckers kill more EAB larvae in declining ash stands [13]. This may be also because the EAB initially infested the upper part of the trunks, which cannot be detected during a ground survey without felling. The equal shares of dieback trees with EAB absence and presence can be explained by the fact that this symptom is not specific and is

characteristic of other reasons for ash deterioration, in particular, *Hymenoscifus fraxineus* [4]. The EAB has infested trees with higher levels of *T. nigritus* damage (Figure 3). The EAB usually infests trees at the end of May–June [14]. At this time the crowns were maximally defoliated by the sawfly, the trees had not yet restored their foliage, and their resistance to the EAB was reduced. EAB adults also damaged foliage during maturation feeding.

The distribution of trees by health classes changed as the EAB spread (Figure 4). At the same time, during the entire period of surveys, individual trees did not deteriorate in health, and some even improved (Tables 1–3). This confirms the possibility of identifying trees resistant to emerald ash borer infestation [1] with subsequent reproduction. The preservation of such trees is hampered by the rules for the complete felling of ash trees in EAB foci if this pest is included on the A1 quarantine list [5].

The number of EAB-infested trees did not change from May to September 2024 (Table 4). This may be because the EAB inhabited the upper part of the crown [13], which was inaccessible for surveying.

Infested trees must be felled before the larvae have completed their development to reduce the spread of any stem pest. However, the territory of eastern Ukraine has been under constant shelling since February 2022. In such conditions, we can recommend mainly visual inspections in shelterbelts, forest edges, declining ash stands, urban parks, and wood-processing zones based on crown dieback, epicormic shoots, thinning crowns, and woodpecker activity. Pheromone traps and girdled trap trees may be used where possible.

5. Conclusions

The maximum tree defoliation by *T. nigritus* in Molodezhny Park occurred in 2024 and coincided with the infestation of the EAB. The EAB equally infested the trees with and without woodpeckers' traces in 2024. The EAB has infested trees with higher levels of *T. nigritus* damage, epicormic shoots, and symptoms of ash bark beetle infestation more than it has infested trees lacking these symptoms. The development of the EAB outbreak provoked the deterioration of ash trees. However, some individual trees improved their health. This confirms the possibility of selecting resistant trees with subsequent reproduction. An increase in the EAB-infested trees was not found from May to September 2024. This can be explained by the EAB inhabiting the upper part of the crown, which was inaccessible for survey.

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References

1. Sun, J.; Koski, T.M.; Wickham, J.D.; Baranchikov, Y.N.; Bushley, K.E. Emerald ash borer management and research: Decades of damage and still expanding. *Annu. Rev. Entomol.* **2024**, *69*, 239–258. [CrossRef] [PubMed]
2. EPPO. EPPO A2 List of Pests Recommended for Regulation as Quarantine Pests. 2022. Available online: https://www.eppo.int/ACTIVITIES/plant_quarantine/A2_list (accessed on 2 July 2024).
3. Drogvalenko, A.N.; Orlova-Bienkowskaja, M.J.; Bienkowski, A.O. Record of the Emerald Ash Borer (*Agrilus planipennis*) in Ukraine is confirmed. *Insects* **2019**, *10*, 338. [CrossRef] [PubMed]

4. Davydenko, K.; Skrylnyk, Y.; Borysenko, O.; Menkis, A.; Vysotska, N.; Meshkova, V.; Olson, Å.; Elfstrand, M.; Vasaitis, R. Invasion of Emerald Ash Borer *Agrilus planipennis* and Ash Dieback Pathogen *Hymenoscyphus fraxineus* in Ukraine—A Concerted Action. *Forests* **2022**, *13*, 789. [CrossRef]
5. State Service of Ukraine on Food Safety and Consumer Protection. Phytosanitary Monitoring. Available online: https://dpss.gov.ua/fitosanitariya-kontrol-u-sferi-nasinnictva-ta-rozsadnictva/fitosanitarnij-kontrol/fitosanitarnij-monitoring (accessed on 1 November 2024).
6. Meshkova, V.; Kukina, O.; Zinchenko, O.; Davydenko, K. Three-year dynamics of common ash defoliation and crown condition in the focus of black sawfly *Tomostethus nigritus* F. (Hymenoptera: Tenthredinidae). *Balt. Forest.* **2017**, *23*, 303–308.
7. Meshkova, V. *Methodical Guidelines for a Survey, Assessment and Forecasting of the Spread of Forest Pests and Diseases for the Lowland Part of Ukraine*; Planeta-Print: Kharkiv, Ukraine, 2020; pp. 1–93. ISBN 978-617-7897-00-1.
8. Sanitary Forests Regulations in Ukraine. [Electronic Resource]. Resolution of the Cabinet of Ministers of Ukraine No 756 Dated 26 October 2016. 2016. Available online: https://zakon.rada.gov.ua/laws/show/756-2016-%D0%BF#n11 (accessed on 1 November 2024).
9. Hammer, O.; Harper, D.A.T.; Ryan, P.D. PAST: Paleontological statistics software package for education and data analysis. *Palaeontol. Electron.* **2001**, *4*, 1–9.
10. StatisticsLectures.com. Z-Test for Proportions, Two Samples. 2017. Available online: http://www.statisticslectures.com/topics/ztestproportions/ (accessed on 1 November 2024).
11. Zinchenko, O.V.; Kukina, O.M. Some biological features of ash black sawfly *Tomostethus nigritus* Fabricius, 1804 (Hymenoptera: Tenthredinidae). *Kharkiv Entomol. Soc. Gaz.* **2015**, *23*, 70–74.
12. Meshkova, V. Proc and Cons of Climate Change for Forest Phytophagous Insects. In Proceedings of the 1st International Electronic Conference on Entomology, Basel, Switzerland, 1–15 July 2021. [CrossRef]
13. Wilson, C.J.; Petrice, T.R.; Poland, T.M.; McCullough, D.G. Tree species richness and ash density have variable effects on emerald ash borer biological control by woodpeckers and parasitoid wasps in post-invasion white ash stands. *Environ. Entomol.* **2024**, *53*, 544–560. [CrossRef] [PubMed]
14. Meshkova, V.; Borysenko, O.; Kucheryavenko, T.; Vysotska, N.; Skrylnyk, Y.; Davydenko, K.; Holusa, J. Forest Site and Stand Structure Affecting the Distribution of Emerald Ash Borer, *Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae), in Eastern Ukraine. *Forests* **2024**, *15*, 511. [CrossRef]