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Symptoms of *Fraxinus excelsior* damage in Zhytomyr Polissya

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Abstract. Common ash (*Fraxinus excelsior* L.) is an important part of the forest, shelterwood and ornamental stands. The health status of *F. excelsior* has recently deteriorated in many regions, due to climate change, anthropogenic stress, diseases and phytophagous insects. The effects of these factors are manifested in symptoms, the prevalence and severity of which depend on local conditions, in particular forest site conditions, stand composition, and structure. The aim of the

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research was to identify the forest site conditions and other stand characteristics most favourable for the prevalence and severity of symptoms of ash decline in Zhytomyr Polissya. The tasks were: to evaluate the common ash health condition, the symptoms of its decline, and their prevalence and severity in relation to forest category, forest site conditions, main forest forming tree species, ash origin, age, and relative stocking density. The majority of the ash stands surveyed were found to be weak. The health condition of *F. excelsior* deteriorates with age. It is worse in forest belts, in damp relatively fertile forest site conditions (C_4), in the stands of vegetative origin, with a lower relative stocking density, and in the stands with *Alnus glutinosa* as the main forest forming species. Dry branches, epicormic shoots, collar rot, and ash bark beetles were the most common symptoms of ash weakness. The prevalence and severity of most of these symptoms were the highest in the forest shelter belts, in the damp relatively fertile forest site conditions (C_4), in the stands of vegetative origin, with a lower relative density of stocking and older than 60 years. It is necessary to monitor the health status of F. *excelsior* in order to detect pathological processes and to select trees for selective sanitary felling in time. The severity of collar rot increased at the relative stocking density of 0.8. It was proposed to grow *F. excelsior* in mixed stands mainly with *Quercus robur* and to give preference to seed origin. It is necessary to monitor the health status of *F. excelsior* in order to detect pathological processes and to select trees for selective sanitary felling in time

Keywords: tree health condition; dry branches; epicormic shoots; collar rot, bark beetles; prevalence (of symptoms); severity (of symptoms)

Introduction

Ash trees are key species in forest plantations in the Zhytomyr Polissia region, and their health plays a crucial role in maintaining the ecological balance of local forest ecosystems. Damage to these trees can signal alarming changes in the ecosystem, caused by both biotic (pests, diseases) and abiotic factors (climate change, environmental pollution) factors. Identifying and analysing damage symptoms allows for the timely diagnosis and control of diseases and pests, thus contributing to the conservation of ash populations in Polissia. This is particularly important in the context of the spread of dangerous pathogens, such as the emerald ash borer, which has already caused significant damage to ash trees in Europe. Research into damage symptoms will also help to develop effective methods for protecting and restoring forest plantations, which supports the preservation of biodiversity and enhances the resilience of forest ecosystems to external stresses. The conservation of *Fraxinus excelsior* is also of economic importance, as these trees are valuable for forestry and can be used in various industries.

The health status of Common ash (*Fraxinus excelsior* L.) has deteriorated in many regions, due to climate change and anthropogenic stress, which has increased the susceptibility of trees to biotic damage. N. La Porta *et al.* (2022) provide an overview of the main bacterial pathogens of trees, the current methods of bacteria detection, and the efforts to increase tree resistance.

Ash dieback (caused by *Hymenoscyphus fraxineus*) is widespread in many European countries. M.K. Horáková *et al*. (2023) determined the prevalence of ash dieback in Slovakia using species-specific primers. Infected trees were detected in different stands, wherever the host was present.

Mixed infestations of the same trees with different pests and pathogens have been reported in many regions. S. Peters *et al.* (2023) in Germany found a fungal pathogen (*Armillaria* sp.) in the stem collar necrosis without the presence of *H. fraxineus*. In the next study, these authors S. Peters *et al.* (2024) analysed interactions of multilocus genotypes (MLGs) of *H. fraxineus* with other fungi from stem collar necroses. In six German federal states, L. Lysenko *et al.* (2024) analysed the prevalence of fungal communities, including *H. fraxineus*, in soil and fine roots. They estimated a higher diversity in soil samples than in root-associated samples.

R. Vasaitis (2024) mentioned two alien invasive pathogens and pests of ash trees in Ukraine: the fungus *Hymenoscyphus fraxineus*, and the xylophagous beetle *Agrilus planipennis*. The area of *A. planipennis* invasion comprised 13.3 hectares in 2019 in the Luhansk region, expanding to 1211.7 hectares in the Luhansk, Kharkiv, and Kyiv regions by 2023. Infested trees are often colonised by bark beetles *Hylesinus crenatus* and *H. varius*. Observations by B. Laz (2024) in Turkey showed that 28 % of the ash trees (*Fraxinus angustifolia* Vahl) were infested by *Zeuzera pyrina* L. (Lepidoptera: Cossidae).

V. Meshkova *et al.* (2021) confirmed the presence of ash dieback by molecular methods in samples from different natural zones of Ukraine, except for the southern regions. The prevalence of ash dieback among other factors of ash weakening was investigated in geographical provenance tests in the Sumy region. A. Goychuk *et al.* (2022) identified the causes of forest deterioration in Zhytomyr Polissya, and studied the aetiology and pathogenesis of ash diseases. An increase in the prevalence of typical symptoms of bacterial diseases, dieback, vascular (graphiosis, tracheomycosis), and fruiting bodies of wood-destroying fungi was observed. Bacterial disease and dieback were the most acute pathological processes. A. Goychuk *et al.* (2023) characterise the typical symptoms, pathogenesis, and causal agents of bacterial diseases affecting forest trees in Ukraine, in particular of *Fraxinus excelsior* caused by *Pseudomonas syringae* pv. *savastanoi*. Infection has been shown to damage trees when they are two or three years old, affecting stems, branches, shoots, and inflorescences. However, the disease can only be diagnosed when tumours have formed. The data obtained provide an approach for effective disease detection and plant protection. V.L. Borysova (2021) studied the health of common ash in the Left-bank Forest Steppe of Ukraine and evaluated the prevalence of the foliage-damaging insects, bark beetles, wood-destroying fungi, bacteriosis, and ash dieback in the Kharkiv, Sumy, and Poltava regions, taking into account weather, forest site and stand characteristics.

To prevent the deterioration of ash stands the researchers have focused on identifying the direct and indirect causes of ash decline and the main symptoms for their detection in monitoring programmes. Remote sensing technologies can help to obtain fast and repeated information on ash damage on a large spatial scale. M. Gašparović *et al.* (2023) described the monitoring of ash dieback using remote sensing technologies. However, such an approach was effective in Croatia only for narrow-leaved ash, which forms homogeneous forest stands. Therefore, the ground survey remains the most reliable method of forest health monitoring.

The aim of the research was to identify the forest site conditions and other stand characteristics most favourable for the prevalence and severity of symptoms of ash decline in Zhytomyr Polissya. The tasks were: to evaluate the common ash health, the symptoms of its decline, and their prevalence and severity in relation to forest category, forest site conditions, main forest forming tree species, ash origin, age, and relative stocking density.

Materials and Methods

The field research was carried out in 2023 in the forests of the Branch "Zvyagelske Forestry" (Ukraine). The climate was moderately continental and favourable for the growth of trees and shrubs characteristic of the forest vegetation zone (Buzun *et al.*, 2018). In order to select the sub-compartments for sample plots, the database of the Ukrainian State Forest management Planning Association (n.d.) was analysed. As the main forest forming species, common ash grew only on 2.5 ha, but it grew in composition with English oak (*Quercus robur* L.) and Black alder (*Alnus glutinosa* L.) on 180 ha. most of the ash stands were located in the Horodnytsky Forestry.

Among ash sub-compartments, there were three stand categories (forest greenary, commercial forest, and forest shelterbelts), three forest site conditions (moist relatively fertile – C_3; moist relatively fertile – D_3, damp relatively fertile – C_4), three main forest forming tree species (*A. glutinosa*, *Q. robur*, and *F. excelsior*), different origin (vegetative, natural seed and planted seed), age (<30; 31-60, and >60 years) and relative stocking density (0.6, 0.7, and 0.8) were chosen. Fourteen sample plots were laid. For twenty ash trees in each sample plot, the health condition class and the symptoms of ash damage (dry branches, epicormic shoots, collar rots, and bark beetle infestation) were selected.

The health condition class was assessed visually according to the Resolution of the Cabinet of Ministers of Ukraine No. 756 (2016): 1 – healthy; II – weakened; III – severely weakened; IV – desiccated; V – recently diceased; VI – deseased more than one year ago. For each sample plot, two health condition indices were evaluated: HCI_{1-6} – for all trees (living and dead) and HCI_{1-4} (only for living trees) (Guidelines ..., 2020). The prevalence of dry branches, epicormic shoots, collar rots, and bark beetle infestation was estimated as the percentage of trees with the given symptoms in each sample plot.

The prevalence of bark beetles was estimated by the presence of entry or exit holes in the bark in the lower 2 m of the tree. The tree was considered infested if at least one hole was detected. Dry branch severity was scored as a percentage for each tree and then converted into points: 0 – 0%; 1 point – <10%; 2 points – 11-50%; 3 points – 51-75%; 4 points – >75% (Guidelines ..., 2020). The severity of epicormic shoots was scored in three classes: 1 point – single; 2 points – abundant; 3 points – total stem coverage. Collar rot severity was scored in four classes according to the spread of necrosis: 0 – absent; 1 point – <25% of circumference; 2 points – 26-50% of circumference; 3 points – 51-75% of circumference; 4 points – >75% of circumference (Guidelines ..., 2020).

Microsoft Excel and the statistical software package PAST (Hammer *et al.*, 2001) were used for data analysis and visualisation. Prevalences of symptoms were compared using a z-test (Peck *et al.*, 2020). The difference between the proportions was considered significant for $P = 0.05$ at $Z>1.96$. The study met the ethical standards of the Convention on Biological Diversity (1992) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

Results and Discussion

The surveyed stands represent forest green areas, commercial forests, and forest shelter belts. The health condition of *F. excelsior* is the best in forest green areas and worst in the forest shelter belts (Fig. 1a). According to the HCI, which considers all living and dead trees (HCI_{1-6}), the inspected ash trees are "weakened" and according to the HCI, which considers only living trees (HCI_{1-4}), the stands are "healthy". Dry branches in the crown were the most common symptoms of tree weakness (Table 1).

Table 1. The prevalence of certain symptoms of *F. excelsior* weakness in the different stand categories

Stand categories	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
Forest green areas	83.6 ± 3.70a	32.5 ± 4.68a	11.3 ± 3.16a	4.5 ± 2.07a
Commercial forest	84.6 ± 3.61a	38.1 ± 4.86ab	13.1 ± 3.38a	7.3 ± 2.59a
Forest shelter belts	86.5 ± 3.42a	51.5 ± 5.00b	20.0 ± 4.00a	8.5 ± 2.79a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

The lowest proportion of trees with dry branches was found in the forest green areas and the highest in the forest shelter belts. Epicormic shoots, collar rot, and bark beetle infestation were also the most common in the shelter belts but less common than dry branches (Table 1).

The severity of "dry branches" increased from forest green areas to forest shelter belts (Fig. 2a). The severity of epicormic shoots and collar rots was also highest in shelter belts. Ashes have the worst health in the damp relatively fertile forest site conditions (C_4), where both health condition indices are characteristic of weakened trees (Fig. 1b). Tree health in the moist relatively fertile forest site conditions (C_3) was slightly better than in the moist fertile forest site conditions (D_3). However, both health condition indices assess tree health between "healthy" and "weakened".

Dry branches dominate among damage symptoms (Table 2). Dry branches, epicormic shoots, collar rot, and bark beetle infestation were the most common in the damp relatively fertile forest site conditions (C_4) and least common in the moist relatively fertile forest site conditions (C_3).

Table 2. The prevalence of certain symptoms of *F. excelsior* weakness in the different forest site conditions

Forest site conditions	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
C_3	83.6 ± 3.70a	32.2 ± 4.67a	11.1 ± 3.14a	5.3 ± 2.25a
C_4	86.7 ± 3.40a	52.0 ± 5.00b	19.5 ± 3.96a	9.8 ± 2.97a
D_3	84.8 ± 3.59a	40.0 ± 4.90ab	12.0 ± 3.25a	6.0 ± 2.37a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

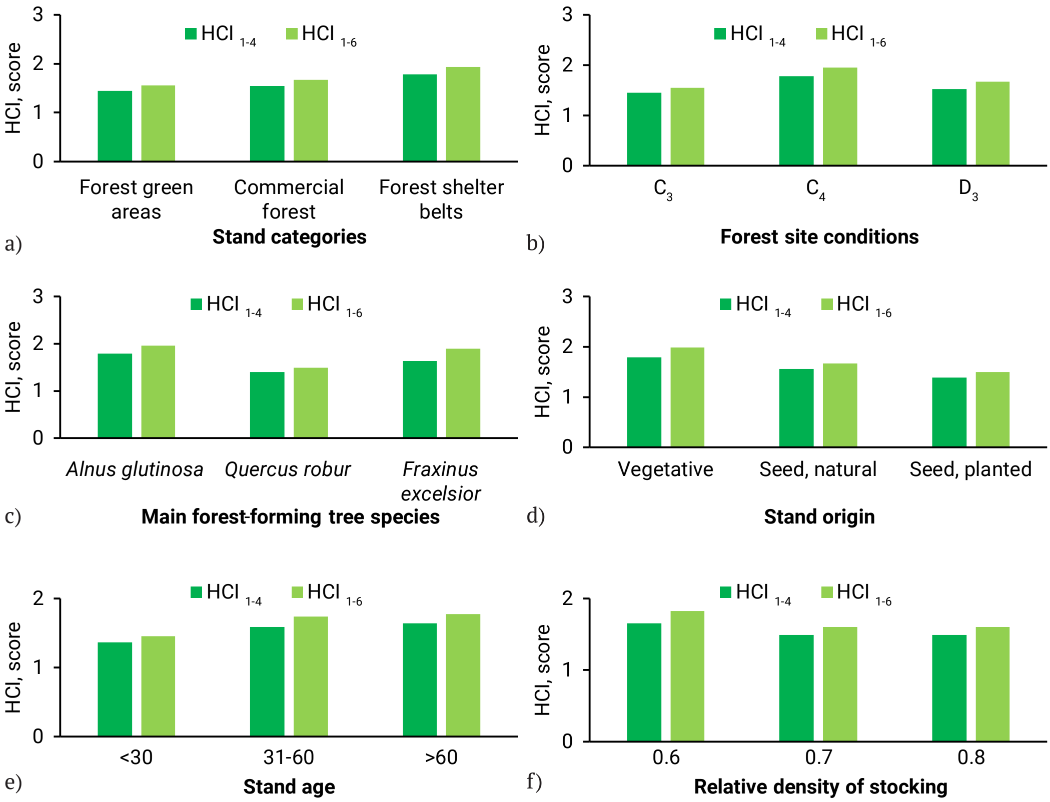

Figure 1. Health condition index of *F. excelsior* depending on site and stand parameters

Note: HCI_{1-4} – health condition index for the trees of the 1st-4th classes of health condition; HCI_{1-6} – health condition index for the trees of the 1st-6th classes of health condition; site and stand parameters: a) stand categories; b) forest site conditions; c) main forest-forming tree species; d) stand origin; e) stand age; f) relative density of stocking

Source: developed by the authors

The severity of most symptoms of tree damage was also the highest in the damp relatively fertile forest site conditions (C_4) and the lowest in the moist relatively fertile forest site conditions (C_3) (Fig. 2b). The severity of collar rot was the same in C_3 and D_3.

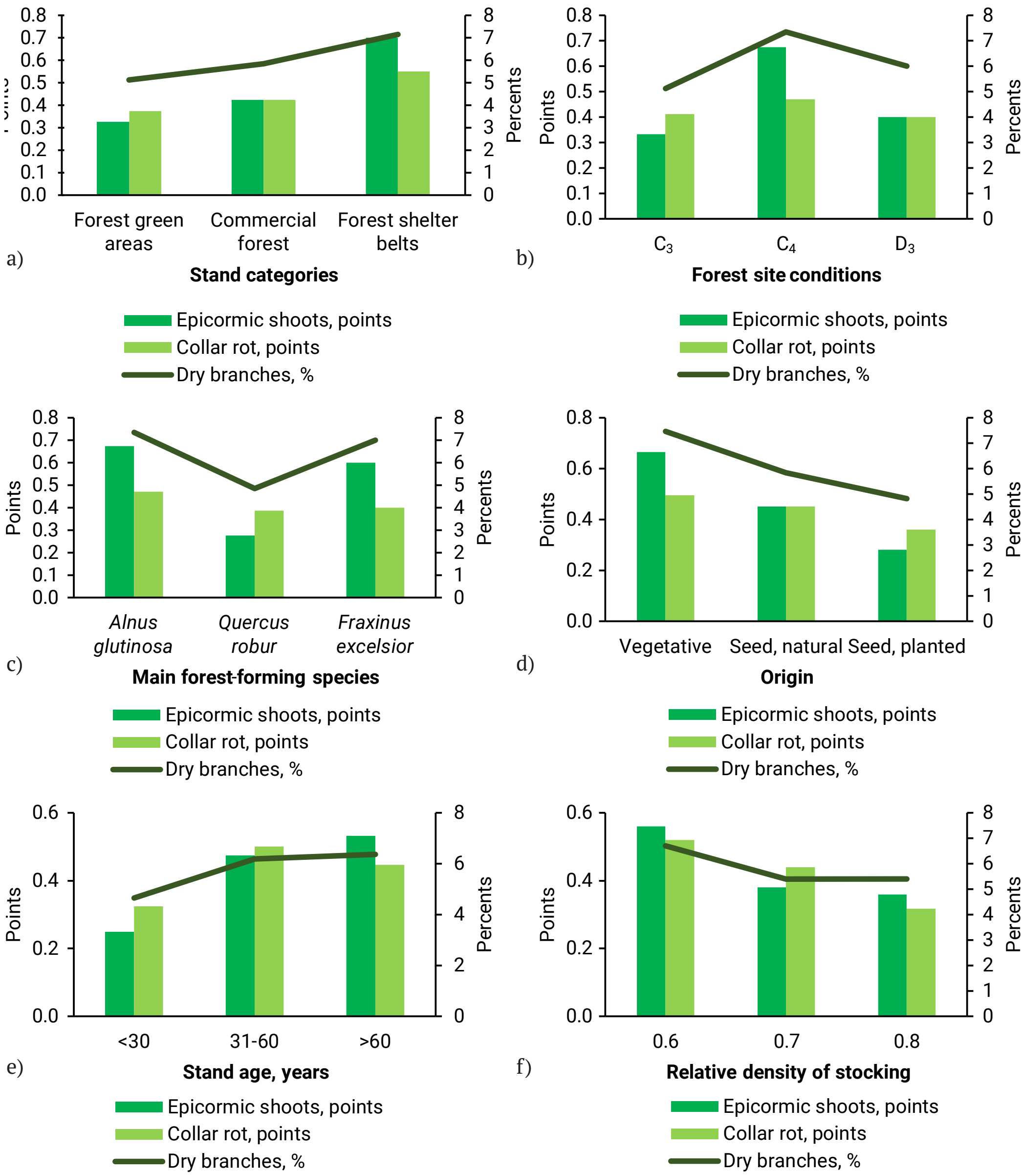

Figure 2. Severity of some symptoms of *F. excelsior* deterioration in relation to site and stand parameterss

Note: site and stand parameters: a) stand categories; b) forest site conditions; c) main forest-forming tree species; d) stand origin; e) stand age; f) relative density of stocking
Source: developed by the authors

The health of ash was worst in the forest stands with Common alder (*A. glutinosa*) as the main forest forming species (Fig. 1c). However, even in these stands, the health condition index of ash does not exceed 2 points. In the stands with English oak (*Q. robur*) the difference between the two health indices is minimal (HCI_{1-6} = 1.5; HCI_{1-4} = 1.4), and in the stands with *F. excelsior* this difference is maximal (HCI_{1-6} = 1.9; HCI_{1-4} = 1.6).

Dry branches in ash trees were the most common in the forest stands with different main forest forming species (Table 3). The proportion of ash trees with dry branches exceeded 80% in all stand groups and was lowest in the stands with oak as the main forest forming species.

Table 3. The prevalence of certain symptoms of *F. excelsior* weakness in the different forest forming species

Forest forming species	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
Alnus glutinosa	86.7 ± 3.40a	52.0 ± 5.00b	19.5 ± 3.96b	9.8 ± 2.97a
Quercus robur	83.2 ± 3.74a	29.4 ± 4.55a	9.3 ± 2.90a	5.3 ± 2.23a
Fraxinus excelsior	86.0 ± 3.47a	50.0 ± 5.00b	20.0±4.00b	6.0 ± 2.37a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

The prevalence of trees with epicormic shoots, collar rot and bark beetle attack was lowest in stands with oak as the main forest forming species (Table 3). The severity of ash damage symptoms was also minimal in oak stands (Fig. 2c). However, the severity of collar rot was similar in the forest stands with oak and ash as the main forest forming species (0.4 points) and lower than in alder stands (0.5 points). *F. excelsior* was present in forest stands of vegetative, natural seed, and planted seed origin. The ash trees of vegetative origin had the worst condition (HCI_{1-6} = = 2.0; HCI_{1-4} = 1.8), the trees of planted seed origin had the best condition (HCI_{1-6} = 1.9; HCI_{1-4} = 1.6) (Fig. 1d).

The prevalence of certain symptoms of ash damage was also the highest in the vegetative stands and the lowest in the planted seed stands (Table 4). However, the prevalence of dry branches exceeded 80% in all origins. The prevalence of ash trees with epicormic shoots in seed stands was significantly lower than in the stands of vegetative origin. The prevalence of collar rot and bark beetle infestation was also the highest in vegetative stands, with a significant difference only for collar rot between vegetative and planted seed stands.

Table 4. The prevalence of certain symptoms of *F. excelsior* weakness depending on the forest stand origin

Stand origin	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
Vegetative	86.8 ± 3.38a	53.3 ± 4.99a	21.3 ± 4.10b	9.3 ± 2.91a
Seed, natural	84.6 ± 3.61a	38.8 ± 4.87b	13.7 ± 3.43ab	6.2 ± 2.41a
Seed, planted	83.2 ± 3.74a	29.0 ± 4.54b	8.8 ± 2.83a	5.6 ± 2.30a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

Despite the high prevalence of dry branches in the crowns of ash trees, the severity of this symptom was relatively low. At the same time, according to this indicator, the same regularity was found – the greatest severity of dry branches in trees of vegetative origin and the least –

in trees of planted seed origin (Fig. 2d). The severity of epicormic shoot development also decreased in ash trees from vegetative to seed origin (Fig. 2d).

Considering the uneven distribution of ash stands by age classes, all surveyed stands were divided into three age intervals for the assessment of tree health and the prevalence and severity of individual symptoms: up to 30 years, 31-60 years and over 60 years. The HCI increased with age (Fig. 1e). According to HCI_{1-4}, ash stands up to 30 years old can be considered healthy. At the same time, by HCI_{1-6}, such stands are weakened. Stands older than 30 years are weakened when considering both viable and all ash trees. The prevalence of dry branches tended to increase with age but without significant differences between age groups (Table 5).

Table 5. The prevalence of certain symptoms of *Fraxinus excelsior* weakness in different age groups

Age, years	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
≤ 30	83.0 ± 3.76a	27.5 ± 4.47a	8.0 ± 2.71a	5.8 ± 2.33a
31-60	85.0 ± 3.57a	42.0 ± 4.94b	15.5 ± 3.62a	6.0 ± 2.37a
> 60	85.3 ± 3.54a	43.3 ± 4.96b	16.0 ± 3.67a	7.7 ± 2.66a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

The prevalence of epicormic shoots, collar rot, and bark beetle infestation also increases with age. However, the differences are significant only for epicormic shoots (Table 5). The severity of dry branches and epicormic shoots also increases with age (Fig. 2e). However, the severity of collar rot over 60 years is less than in 31-60 years. At all levels of relative stocking density (0.6-0.8), the HCI indicates tree weakness (Fig. 1f). The stands with the lowest relative stocking densities had the poorest health. The prevalence of dry branches, epicormic shoots, collar rot, and bark beetle infestation tended to decrease with increasing stocking density of ash stands (Table 6). However, these differences are not significant.

Table 6. The prevalence of certain symptoms of *F. excelsior* weakness at different relative stocking densities

Relative stocking density	Prevalence, %			
	Dry branches	Epicormic shoots	Collar rot	Bark beetles
0.6	85.7 ± 3.50a	46.2 ± 4.99a	17.2 ± 3.77a	7.2 ± 2.58a
0.7	84.0 ± 3.66a	35.0 ± 4.77a	12.0 ± 3.25a	5.2 ± 2.22a
0.8	84.1 ± 3.66a	34.4 ± 4.75a	11.2 ± 3.15a	7.4 ± 2.62a

Note: letters show significant differences inside each column at $p < 0.05$
Source: developed by the authors

The severity of dry branches, epicormic shoots, and collar rot also tended to decrease with increasing relative stocking density of ash stands (Fig. 2f). Thus, the assessment of common ash health and symptoms of its deterioration confirms the dependence of their prevalence and severity on stand category, forest site conditions, main forest forming tree species, ash origin, age, and relative stocking density.

Tree health has deteriorated in many regions. The most common approach is to assesses the degree of ecosystem degradation. J. Maes *et al.* (2023) assessed the health of forest ecosystems in Europe on a scale from 0 (degraded ecosystem) to 1 (pristine or protected forest). One third of the forest area was found to be in decline.

In order to prevent forest degradation and mitigate its consequences, forest health is monitored by the condition of the crown and trunk and some specific signs that allow the identification of the pest or pathogen. According to the Resolution of the Cabinet of Ministers of Ukraine No. 756 (2016), the main criterion for sanitary felling is the tree health class. However, all trees (living and dead) are included in the calculation of the health condition index, which does not show the dynamics of tree mortality. In the present study, both health condition indices (HCI_{1-4} for living trees and HCI_{1-6} for all trees) were calculated and compared for different site and stand parameters: stand categories; forest site conditions; main forest forming tree species; stand origin; stand age; relative stocking density (Fig. 1).

European monitoring programmes assess defoliation and discolouration to compare the dynamics of trees and stand health in various regions (Manual…, 2010). In Ukraine, extensive forest monitoring (I Level), harmonized with the European ICP Forest monitoring programme (Manual…, 2010), has been carried out for 30 years. monitoring data on the health of *Fraxinus* sp. in Ukraine for 15 years have been analysed by T. Pyvovar *et al.* (2022). The highest degree of defoliation was observed in the Steppe zone, the most acute tree mortality in the forest zone, and the most stable health condition in the Forest-Steppe zone. Of all the ash trees surveyed in Polissya, 42% were damaged, with diseases dominating. This was explained by the wetter climate of the forest zone compared to the Forest Steppe and Steppe zones. In the forest-steppe zone, almost half of the ash damage (48.2%) was caused by abiotic factors. At the same time, in the forest-steppe zone, pathogen damage to ash increased by 21.9% over 15 years, reaching 56% in 2011-2015. In the steppe zone, insects were the main cause of damage to ash trees. The prevalence of trees with ash dieback increased from the forest to the steppe zone, and the prevalence of bacteriosis decreased from the forest to the steppe zone. The prevalence of wood-destroying fungi on ash was the highest in the forest-steppe zone, and of tuberculosis – in the forest and forest-steppe zones.

New pests and diseases have spread. An emerald ash borer (*Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae)), originating from Asia, invaded North America and Russia at the end of the 20th century and was discovered in the Luhansk region of Ukraine in 2019 and is already present in Kyiv in 2024 (State Service of Ukraine…, 2024). J. Sun *et al.* (2024) describe the seasonal development of this pest, its characteristics, and tree damage. The larvae develop under the bark and gradually gnaw through the conductive tissues, often bringing pathogens into the tree, leading to tree mortality. They mentioned the importance of searching for resistant trees for more effective forest protection. So-called ash dieback was discovered in Europe in the 1990s. E. Baxter *et al.* (2023) in Ireland described its symptoms – reduction of tree increment, leaf size, discolouration and premature leaf fall, appearance of ulcers on the trunk and shoots, and dieback of small branches. Therefore, assessing defoliation alone is not enough to know the health of a tree.

V. Meshkova *et al.* (2021) studied the prevalence of ash dieback among other factors of ash deterioration in geographical provenance tests in the Sumy region. Root rot, ash dieback, and infestation by ash bark beetle (*Hylesinus crenatus* (Fabricius, 1787): Coleoptera: Scolytidae) were found in all proveniences. Root rot was found in all ash proveniences. The ash bark beetle was not found in the proveniences from the Western and Right Bank Forest Steppes. *Hymenoscyphus fraxineus* was isolated from the trunks of ash trees, and identified by molecular methods and confirmed to be pathogenic. For seven years, the health condition index, incidence, and severity of ash dieback increased in all provenances except the Steppe.

In the current study, the prevalence and severity of dry branches, epicormic shoots, collar rot, and bark beetles were compared for different site and stand parameters: stand categories; forest site conditions; main forest forming tree species; stand origin; stand age; relative stocking density (Fig. 2). The health status of *F. excelsior* was best in green forest areas and worst in forest shelterbelts. This can be explained by the negative impact of timber harvesting on all components of forest ecosystems, especially the soil, the trees, and the regeneration of the forest. I.C. Cântar *et al*. (2022) monitored the health of remaining trees after logging in Romania to determine the tolerance threshold of trees to logging. They developed equations taking into account the relationship between the size of the healed damage and the diameter of the trees.

S.V. Sydorenko *et al.* (2020) studied the protective forest belts in the Kharkiv region (Ukraine). According to their health status, the forest shelterbelts were characterised as weakened and severely weakened. Among the pests, 23 xylophagous and 21 phyllophagous insect species were identified. However, most of them can only colonize weakened and severely weakened trees. The study showed that the combined effect of the absence and neglect of forestry and agrotechnical interventions in the shelterbelts caused partial tree mortality, resulting in the spread of pathogens and insect pests that invaded individual trees in the forest stands. O.A. Kuznetsova *et al*. (2023) assessed such symptoms of decline of *Ulmus* sp. together with some specific indicators which made it possible to establish the characteristics of the spread of bacterial and fungal diseases, and bark beetles in shelter belts along the Kyiv-Kharkiv highway.

In the current survey dry branches in the crowns were the most common symptoms of tree weakening (Table 1). It is known that dry branches can be the result of various causes. S.V. Sydorenko *et al*. (2020) found maple trees with dry branches remaining in the crowns in shelterbelts restored after verticillosis. Long-term retention of dry branches in the crown leads to the classification of such trees as severely weakened or even desiccated, while the crown gradually recovers. An objective assessment of tree health can only be made after several years of monitoring.

Ash dieback is the most serious disease affecting *Fraxinus* sp. in different regions and stands. It is named after the appearance of dry branches in the crowns. A. Benigno *et al*. (2023) in Central-Northern Italy found that the severity of ash dieback was higher in sites under environmental stress (mild dry winters, and hot dry summers) or anthropogenic stress (logging and fires).

In the present study, ashes were least healthy in the damp relatively fertile forest site conditions (C_4), where both health condition indices were characteristic of weakened trees (Fig. 1b), and in the forest stands with common alder (*Alnus glutinosa*) as the main forest-forming species (Fig. 1c). However, under wetter conditions, alder was the dominant species. V. Borysova (2021) studied the health status of common ash in the Left-bank Forest Steppe of Ukraine. In her sample plots, the prevalence of symptoms depended on the cause of the pathology, the type of forest site conditions, and some other forest characteristics. For example, ash dieback was prevalent in fresh fertile forest site conditions and bacteriosis was prevalent in the fresh fertile, humid fertile, and humid relatively fertile forest site conditions.

In the current survey, the prevalence of trees with dry branches, epicormic shoots, collar rot and bark beetle infestation was the lowest in the stands with oak as the main forest forming species (Table 3). However, the severity of collar rot was similar in the forest stands with oak and ash as the main forest forming species (Fig. 2c). This may be explained by the dependence of collar rot severity on soil moisture. G.J. Langer *et al*. (2022) within the FraxForFuture project show that soil moisture promotes the prevalence and severity of collar rot caused by *Phytophthora*, *Armillaria* and ash dieback. These pathogens often occur together and it is sometimes difficult to determine the primary cause of tree decline.

The poorest health of vegetative origin trees in the current survey (Fig. 1d) may be explained by the younger age of the planted trees, which were in the best health (Fig. 1e). The prevalence of most symptoms of tree decline increased with the age of the ash, except for collar rot (Fig. 2e). Such trees are easily detected and could be removed by selective sanitary felling in previous years.

As forest health continues to decline, it is important to identify disease-resistant trees and propagate their progeny for planting in new forests. R.K. Stanley *et al*. (2023) found that *Fraxinus pennsylvanica* marshall trees are resistant to the emerald ash borer. However, many years are needed to support this trait in the offspring. J. Meger *et al*. (2024) in Poland, using six significant single nucleotide polymorphism loci, proposed 300 *F. excelsior* trees from 30 populations for future breeding programmes to control ash dieback. J. Rozsypálek *et al*. (2023) injected ash trees infected with *H. fraxineus* with fungicides and observed a complete cessation of necrosis growth during the first three months after injection. However, until these programmes are implemented, monitoring remains the most effective control measure, along with continued sanitary felling of infested or infected trees. Regular inspections help to identify early signs of damage, allowing timely intervention. In addition, the removal of affected trees prevents the spread of pests and diseases to healthy parts of the forest.

Conclusions

According to the health condition index, the inspected ash stands are weakened and their health deteriorates with age. The health condition of ash is the worst in the shelterbelts, in the damp relatively fertile forest site conditions (C_4), in the stands of vegetative origin, with a lower relative stocking density and in the stands with *Alnus glutinosa* as the main forest forming species. Dry branches are the most frequent symptom of ash tree damage (over 80% of trees). This symptom is most frequent in the shelterbelts, in the damp relatively fertile forest site conditions (C_4), in the stands of vegetative origin, with a lower relative stocking density and older than 60 years.

The prevalence and severity of epicormic shoots were the highest in the forest shelter belts, in damp relatively fertile forest site conditions (C_4), and in the stands of vegetative origin. These indicators increased with tree age and decreased with the relative stocking density. Collar rot was the most frequent and severe symptom of ash damage in the forest shelterbelts, in the stands of vegetative origin, in the damp relatively fertile forest site conditions (C_4), and in the stands with *Alnus glutinosa* as the main forest forming species. The severity of collar rot increased at the relative stocking density of 0.8. The highest prevalence and severity of bark beetle infestation were found in the forest shelter belts and, in the damp, relatively fertile forest site conditions.

The data obtained indicate the need to grow ash of seed origin in mixed stands with oak. In view of the spread of native and alien ash pests, it is necessary to monitor the health of the trees in order to detect pathological processes in good time and to remove infected or infested trees immediately.

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Conflict of Interest

None.

References

[1] Baxter, E., Cooke, L.R., Spaans, F., Grant, I.R., & McCracken, A.R. (2023). The introduction of *Hymenoscyphus fraxineus* to Northern Ireland and the subsequent development of ash dieback. *Forest Pathology*, 53(1), article number e12789. doi: 10.1111/efp.12789.

[2] Benigno, A., Bregant, C., Aglietti, C., Rossetto, G., Tolio, B., Moricca, S., & Linaldeddu, B.T. (2023). Pathogenic fungi and oomycetes causing dieback on *Fraxinus* species in the Mediterranean climate change hotspot region. *Frontiers in Forests and Global Change*, 6, article number 1253022. doi: 10.3389/ffgc.2023.1253022.

[3] Borysova, V.L. (2021). *Health condition of common ash in the Left-bank Forest Steppe of Ukraine*. (PhD thesis, Ukrainian Research Institute of Forestry and Forest Melioration named after G.M. Vysotsky, Kharkiv, Ukraine).

[4] Buzun, V.O., Turko, V.M., & Siruk, Yu.V. (2018). *Book of forests of Zhytomyr region: Historical and economic essay*. Zhytomyr: O.O. Evenok.

[5] Cântar, I.C., Ciontu, C.I., Dincă, L., Borlea, G.F., & Crişan, V.E. (2022). Damage and tolerability thresholds for remaining trees after timber harvesting: A case study from Southwest Romania. *Diversity*, 14(3), article number 193. doi: 10.3390/d14030193.

[6] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[7] Convention on the Trade in Endangered Species of Wild Fauna and Flora. (1973, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.

[8] Gašparović, M., Pilaš, I., Klobučar, D., & Gašparović, I. (2023). Monitoring ash dieback in Europe – an unrevealed perspective for remote sensing? *Remote Sensing*, 15(5), article number 1178. doi: 10.3390/rs15051178.

[9] Goychuk, A., Kulbanska, I., Shvets, M., Pasichnyk, L., Patyka, V., Kalinichenko, A., & Degtyareva, L. (2023). Bacterial diseases of bioenergy woody plants in Ukraine. *Sustainability*, 15(5), article number 4189. doi: 10.3390/su15054189.

[10] Goychuk, A., Kulbanska, I., Vyshnevskyi, A., Shvets, M., & Andreieva, O. (2022). Spread and harmfulness of infectious diseases of the main forest-forming species in Zhytomyr Polissia of Ukraine. *Scientific Horizons*, 25(9), 64-74. doi: 10.48077/scihor.25(9).2022.64-74.

[11] *Guidelines for survey, assessment, and forecasting the spread of forest pests and diseases for the plains of Ukraine*. (2020). Kharkiv: Planeta-print.

[12] Hammer, O., Harper, D.A.T., & Ryan, P.D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4, article number 4.

[13] Horáková, M.K., Barta, M., Adamčíková, K., Ostrovský, R., & Pastirčáková, K. (2023). *Hymenoscyphus fraxineus* on *Fraxinus excelsior* in Slovakia: Distribution and mating types. *Biologia*, 78(5), 1219-1230. doi: 10.1007/s11756-022-01023-9.

[14] Kuznetsova, O.A., Turenko, V.P., Tovstukha, O.V., & Davydenko, K.V. (2023). Pest and disease incidence of *Ulmus* sp. in forest shelter belts along the Kyiv-Kharkiv highway. *Forestry & Forest Melioration*, 143, 102-111. doi: 10.33220/1026-3365.143.2023.102.

[15] La Porta, N., Hietala, A.M., & Baldi, P. (2022). Bacterial diseases in forest trees. In *Forest microbiology* (Vol. 3, No. 2, pp. 139-166). Cambridge: Academic Press. doi: 10.1016/B978-0-443-18694-3.00001-8.

[16] Langer, G.J., Fuchs, S., Osewold, J., Peters, S., Schrewe, F., Ridley, M., Kätzel, R., Bubner, B., & Grüner, J. (2022). FraxForFuture – research on European ash dieback in Germany. *Journal of Plant Diseases and Protection*, 129, 1285-1295. doi: 10.1007/s41348-022-00670-z.

[17] Laz, B. (2024). Observations on *Zeuzera pyrina* L. (Lepidoptera: Cossidae) damage on *Fraxinus angustifolia* Vahl in urban landscape of Kahramanmaras. *Turkish Journal of Forest Science*, 8(1), 53-62.

[18] Lysenko, L., Griem, E., Wagener, P., & Langer, E.J. (2024). Fungi associated with fine roots of *Fraxinus excelsior* affected by ash dieback detected by next-generation sequencing. *Journal of Plant Diseases and Protection*. doi: 10.1007/s41348-024-00923-z.

[19] Maes, J., Bruzón, A.G., Barredo, J.I., Vallecillo, S., Vogt, P., Rivero, I.M., & Santos-Martín, F. (2023). Accounting for forest condition in Europe based on an international statistical standard. *Nature Communications*, 14(1), article number 3723. doi: 10.1038/s41467-023-39434-0.

[20] *Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests*. (2010). Hamburg: UNECE.

[21] Meger, J., Ulaszewski, B., Pałucka, M., Kozioł, C., & Burczyk, J. (2024). Genomic prediction of resistance to *Hymenoscyphus fraxineus* in common ash (*Fraxinus excelsior* L.) populations. *Evolutionary Applications*, 17(5), article number e13694. doi: 10.1111/eva.13694.

[22] Meshkova, V., Samoday, V., & Davydenko, K. (2021). Ash dieback and contributing factors of forest weakening in provenance tests in the Sumy region. *Central European Forestry Journal,* 67*,* 113-121. doi: 10.2478/forj-2021-0001.

[23] Peck, R., Short, T., & Olsen, C. (2020). *Introduction to statistics and data analysis*. Boston: Cengage Learning.

[24] Peters, S., *et al.* (2024). The fungal predominance in stem collar necroses of *Fraxinus excelsior*: A study on *Hymenoscyphus fraxineus* multilocus genotypes. *Journal of Plant Diseases and Protection*. doi: 10.1007/s41348-024-00912-2.

[25] Peters, S., Fuchs, S., Bien, S., Bußkamp, J., Langer, G.J., & Langer, E.J. (2023). Fungi associated with stem collar necroses of *Fraxinus excelsior* affected by ash dieback. *Mycological Progress*, 22(7), article number 52. doi: 10.1007/s11557-023-01897-2.

[26] Pyvovar, T., Lialin, O., & Meshkova, V. (2022). Causes and trends in defoliation of *Fraxinus excelsior* L. in Ukraine according to forest monitoring data. *Proceedings of the Forestry Academy of Sciences of Ukraine*, 24, 36-46. doi: 10.15421/412203.

[27] Resolution of the Cabinet of Ministers of Ukraine No 756 "Sanitary Forests Regulations in Ukraine". (2016, October). Retrieved from https://zakon.rada.gov.ua/laws/show/756-2016-%D0%BF#n11.

[28] Rozsypálek, J., Martinek, P., Palovčíková, D., & Jankovský, L. (2023). The protection of ash trees against ash dieback by tree injections. *Urban Forestry & Urban Greening*, 88, article number 128071. doi: 10.1016/j.ufug.2023.128071.

[29] Stanley, R.K., *et al.* (2023). Emerald ash borer (*Agrilus planipennis*) infestation bioassays and metabolic profiles of green ash (*Fraxinus pennsylvanica*) provide evidence for an induced host defensive response to larval infestation. *Frontiers in Forests and Global Change*, 6, article number 1166421. doi: 10.3389/ffgc.2023.1166421.

[30] State Service of Ukraine on Food Safety and Consumer Protection. (n.d.). *Phytosanitary monitoring*. Retrieved from https://dpss.gov.ua/fitosanitariya-kontrol-u-sferi-nasinnictva-ta-rozsadnictva/fitosanitarnij-kontrol/fitosanitarnij-monitoring.

[31] Sun, J., Koski, T.M., Wickham, J.D., Baranchikov, Y.N., & Bushley, K.E. (2024). Emerald ash borer management and research: decades of damage and still expanding. *Annual Review of Entomology*, 69(1), 239-258. doi: 10.1146/annurev-ento-012323-032231.

[32] Sydorenko, S.V., Zinchenko, O.V., Skrylnyk, Yu.Ye., Kukina, O.M., & Sydorenko, S.H. (2020). Entomocomplex and health condition of forest shelterbelts of the State Enterprise "Elitne Research Farm of Plant Production Institute named after V.Ya. Yuryev of NAAS". *Forestry&Forest Melioration*, 136, 184-193. doi: 10.33220/1026-3365.136.2020.184.

[33] Ukrainian State Forest Management Planning Association. (n.d.). Retrieved from https://lisproekt.gov.ua/.

[34] Vasaitis, R. (2024). Alien invasive pathogens and pests in the changing environment: Focus on North Europe. *Baltic Forestry*, 30(1), article number id750. doi: 10.46490/BF750.

Симптоми пошкодження *Fraxinus excelsior* у Житомирському Поліссі

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Анотація. Вивчення ясеня звичайного (*Fraxinus excelsior* L.) є важливим через його погіршений санітарний стан, який спричинений зміною клімату, антропогенним навантаженням, хворобами та пошкодженнями фітофагів, що залежать від локальних умов і типу насаджень. Метою дослідження було визначити лісорослинні умови та інші характеристики насаджень, які найбільшою мірою сприятливі для поширення та розвитку симптомів ослаблення ясена у Житомирському Поліссі. Дослідження проведено на прикладі філії «Звягельське лісове господарство». Оцінено санітарний стан дерев ясена звичайного, симптомів їхнього ослаблення та залежності їхніх поширення та інтенсивності від категорії лісів, типу лісорослинних умов, головної лісоутворювальної породи, походження дерев ясена, віку та відносної повноти насаджень. Більшість обстежених насаджень виявилися ослабленими. Встановлено, що санітарний стан *F. excelsior* погіршується з віком. Він є найгіршим у лісових смугах, у сирому сугруді (C_4), у насадженнях вегетативного походження, з найменшою відносною повнотою та з *Alnus glutinosa* як головною лісоутворювальною породою. Найбільш поширені симптоми ослаблення ясена – сухі гілки, водяні пагони, окоренкові гнилі та поселення ясенових лубоїдів. Поширеність та інтенсивність більшості симптомів біли найвищими у лісових смугах, сирому сугруді (C_4), у насадженнях вегетативного походження, з відносною повнотою 0,6 і віком понад 60 років. Інтенсивність розвитку окоренкових гнилей була більшою за відносної повноти 0,8. Рекомендовано вирощувати *F. excelsior* у мішаних насадженнях, переважно разом із *Quercus robur* і надавати перевагу насіннєвому походженню. Зазначено, що для вчасної ідентифікації патологічних процесів та відбору дерев у вибіркові санітарні рубки необхідно здійснювати моніторинг санітарного стану дерев *F. excelsior*. Результати дослідження можна враховувати для виявлення осередків шкідників і збудників хвороб і запобігання ослабленню й загибелі лісів

Ключові слова: санітарний стан дерев; сухі гілки; водяні пагони; окоренкові гнилі, короїди; поширення симптомів; інтенсивність розвитку симптомів