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Causes and trends in defoliation of *Fraxinus excelsior* L. in Ukraine according to forest monitoring data

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The aim of the research was to evaluate the main causes and trends in the defoliation of common ash (Fraxinus excelsior L.*) trees in different natural zones of Ukraine according to forest monitoring data. Mean defoliation of common ash in 2001-2015 was the highest in the Steppe zone, and the highest proportion of damaged trees (42%) was in the Forest zone. In the Forest zone, diseases played the greatest role in damage to common ash trees, and the proportion of trees damaged by pathogens increased over three five-year periods. In the Forest-Steppe, about half of the damage to common ash trees (48.2%) was associated with abiotic factors, however, it decreased from 64.5% in 2001-2005 to 34.9% in 2011-2015. The proportion of trees affected by pathogens (41.6%) increased from 21.9% in 2001-2005 to 56% in 2011-2015. In the Steppe zone, the proportion of common ash trees damaged by insects prevailed, however, in 2006-2010, it was comparable to drought damage.*

The proportion of trees affected by ash dieback and foliage diseases increased from the Forest zone to the Steppe zone. The proportion of trees affected by bacterial cancer (tuberculosis) decreased from the Forest zone to the Steppe zone, and the proportion of trees affected by wood-decaying fungi was the largest in the Forest-Steppe zone.

In the Forest zone and Forest-Steppe zone, bacterial cancer was most common. However, in the Forest-Steppe zone proportion of infected trees decreased from 72.4% in 2001-2005 to 38.9% in 2011-2015.

The proportion of trees affected by ash dieback (caused by invasive fungus Hymenoscyphus fraxineus) increased in all zones and made up 25.8%, 5.9%, and 81.7% of all trees affected by diseases in the Forest, Forest-Steppe, and Steppe zones, respectively. However, in some cases, similar symptoms in the Steppe could be related to non-infectious dieback as a result of a lack of moisture.

Key words*: common ash; proportion of damaged trees; ash sawfly; ash dieback; rot; bacterial cancer; foliage diseases.*

Introduction. The health condition of many forest tree species has been deteriorating in recent decades (Мацях, Крамарець, 2014; Enderle, Metzler, Riemer, & Kändler, 2018; Гойчук, Дрозда, Кульбанська, 2018; Meshkova, Pyvovar, & Tovstukha, 2019a; Meshkova, Borysova, Didenko, & Nazarenko, 2019b). The reasons for this deterioration can be abiotic, biotic, and anthropogenic factors, all of which interact and lead to a decrease in resistance, in particular to insect colonization and attack by pathogens (Shvidenko, Buksha, Krakovska, & Lakyda, 2017; Linnakoski, Kasanen, Dounavi, & Forbes, 2019).

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The first signs of deterioration in the forest health condition can be detected directly by noting an increase in the number of pests or indirectly by changing the appearance of the crown or stem (Букша та ін., 2011). Obtaining information about forest health over a large area is ensured by forest monitoring which is carried out using the same methodology on a statistically justified network of sample plots. In Ukraine, extensive forest monitoring (I Level) harmonized with European ICP Forest monitoring program (Manual…, 2010) has been developing for more than 30 years, and since 2001, it has been carried out at the national level. However, after the expiration of the State Program "Forests of Ukraine 2010-2015" (Forests of Ukraine, 2009), national-scaled monitoring observations were suspended. After 2015 assessments were carried out only at a limited number of sample plots by scientists from the Forest Monitoring and Certification Laboratory of the Ukrainian Research Institute of Forestry & Forest Melioration named after G. M. Vysotsky.

In forest monitoring sample plots, many parameters are assessed, among which defoliation is considered the most informative (Manual…, 2010). It characterizes not only the direct loss of foliage as a result of damage by various factors (insects, diseases, drought, etc.), but also the insufficient development of foliage due to the deterioration of the health condition of trees.

Common ash (*Fraxinus excelsior* L.) is one of the common forest tree species, which has been deteriorating catastrophically in recent decades in different countries (Davydenko, Vasaitis, Stenlid, & Menkis, 2013; Davydenko et al., 2019; Goberville et al., 2016; Langer, 2017). The area of forests with common ash dominated in the stand composition is 3% of the forested lands of the forest fund of the State Forest Resources Agency of Ukraine and 6% of the total deciduous forests of the country (General characteristics…, 2022). Common ash is represented in different natural zones of Ukraine and grows mainly on fertile fresh, and moist soils, where it is often the second main tree species after English oak (*Quercus robur* L.) (Gordienko, Гойчук, Гордієнко, Леонтяк, 1996).

In Europe, since the 1990s, ash dieback caused by the fungus *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz & Hosoya appeared to be the main cause of the *Fraxinus* sp. mortality (Skovsgaard et al., 2017). The presence of this pathogen has also been confirmed in different natural zones of Ukraine (Davydenko et al., 2013, 2019). Emerald ash borer (*Agrilus planipennis* Fairmaire, 1888) (Coleoptera: Buprestidae) penetrated the eastern regions of Ukraine (Meshkova et al., 2021). This pest caused the death of *Fraxinus* sp. over a large area in the United States (Schrader et al., 2021) and in many regions of Russia (Selikhovkin et al., 2022). The spread of bacterial cancer (the pathogen – *Pseudomonas syringae* subsp. *savastanoi* pv. *fraxini*) (Janse, 1981; Гойчук та ін., 2018), wood-decaying fungi (Gonthier, & Nicolotti, 2013; Vasaitis, 2013), and foliage browsing insects (in particular, the black ash sawfly *Tomostethus nigritus* (Fabricius, 1804) (Hymenoptera; Tenthredinidae) (Meshkova, Kukina, Zinchenko, & Davydenko, 2017) are also reported.

An analysis of long-term monitoring data can reveal trends in the general health condition of individual tree species, in particular, common ash, and determine the most important damaging factors in different natural zones of Ukraine. This will make it possible to predict further negative changes and prevent them through forest management or forest protection measures.

An object of research is the health condition of common ash. *The subject of research* is the trends in the health condition dynamics of European ash stands in different natural zones of Ukraine.

The aim of the research was to evaluate the main causes and trends in the defoliation of common ash trees in different natural zones of Ukraine according to forest monitoring data.

Objects and methods. The database of the 1st level forest monitoring for 2001-2015 contains field materials collected by the researchers of the laboratory for Monitoring and Certification of Forests of Ukrainian Research Institute of Forestry & Forest Melioration named after G. M. Vysotsky, the specialists of Production Association "Ukrderzhlisproekt" and State Forestry enterprises. In the analysis, all monitoring plots with at least 3 common ash trees in three natural zones: Forest zone, or Polissia (13 sample plots), Forest-Steppe (112 sample plots), and Steppe (34 sample plots) (Table 1) were included.

Common ash forest stands in a wide range of forest site conditions (from C_1 to D_3), age of stands (from 20 to 140 years old), and origin (vegetative and seed) were presented in the sample.

Crown defoliation was estimated visually as a percentage and then converted to classes: 0 class = defoliation up to 10% (healthy, undamaged tree); 1 class = 11-25% (slightly damaged); 2 class = 26-60% (moderately damaged); 3 class = 60-99% (severely damaged); 4 class – over 99% (dying) (Manual…, 2010).

The causes of damage were identified visually using manuals and guides (Manual…, 2010, Field Guide…, 2017). The proportion of damaged trees was calculated as a percentage of trees with any signs of damage.

Summary statistics, and one-way analysis of variance (ANOVA) with a significance level of $p < 0.05$ (Антраментова, Утєвська, 2008) were performed using Microsoft Excel applications and the statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer, Harper, & Ryan, 2001).

Results. Mean defoliation of common ash varied by sample plots and years of assessment, with the smallest fluctuations in the Forest-Steppe zone (Fig. 1).

Thus, during the period of observation, the annual mean defoliation of ash trees in the pooled sample ranged from 7.8±0,22% to 10.8±0,34%, exceeding the "damaged" level (defoliation > 10%) only in 2012, 2013, and 2015. At sample plots in the Forest-Steppe zone, annual mean defoliation ranged from 7.6 ± 0.19% to 9.8 ± 0.36, which means that ash trees in the region can be considered "not damaged".

Table 1. **Natural zones, administrative regions, and forestry enterprises of common ash health condition assessment**

Natural zone	Region	Forestry Enterprise
Forest	Chernihiv	Chernihivske, Kholminske, Semenivske
	Lviv	Radekhivske, Zolochivske
	Rivne	Dubenske
	Volyn	Volodymyr-Volynske
Forest-Steppe	Cherkasy	Cherkaske, Chigirynske, Kamianske, Korsun-Shevchenkivske, Lysianske, Smileanske, Umanske, Zvenyhorodske
	Chernihiv	Borznyanske, Prylutske
	Chernivtsi	Khotynske
	Kharkiv	Chuhuievo-Babchanske, Gutyanske, Skrypaivske, Vovchanske, Zhovtneve, Zmiivske
	Khmelnytskyi	Khmelnytske, Starokostiantynivske, Yarmolynetske
	Kirovohrad	Chornoliske
	Kyiv	Bilotserkivske, Boguslavske
	Odesa	Baltske, Savranske
	Poltava	Kremenchutske, Lubenske, Novosanzharske, Poltavske
	Rivne	Mlynivske, Ostrozke
	Sumy	Konotopske, Krasnopilske, Krolevetske, Lebedynske, Okhtyrske, Romenske, Sumske, Trostianetske
	Ternopil	Berezhanske, Buchatske, Chortkivske, Kremenetske, Medobory, Ternopilske
	Vinnytsia	Bershadske, Chechelnitske, Dashivske, Gajsynske, Illinetske, Khmilnytske, Kryzhopilske, Mogyliv-Podilske, Tulchinske, Vinnytske
Steppe	Dnipropetrovsk	Kryvorizke, Novomoskovske, Verkhnyodniprovske
	Donetsk	Lymanske, Slovianske, Torezke, Velykoanadolske
	Kharkiv	Blyzniukivske, Iziumske, Kupianske
	Kherson	Skadovske
	Kirovohrad	Kompaniivske
	Luhansk	Bilokurakinske, Bilovodske, Ivanivske, Severodonetske, Svativske
	Odesa	Ananivske, Kotovske, Odeske, Velykomykhailivske
	Zaporizhzhia	Melitopolske, Zaporizke

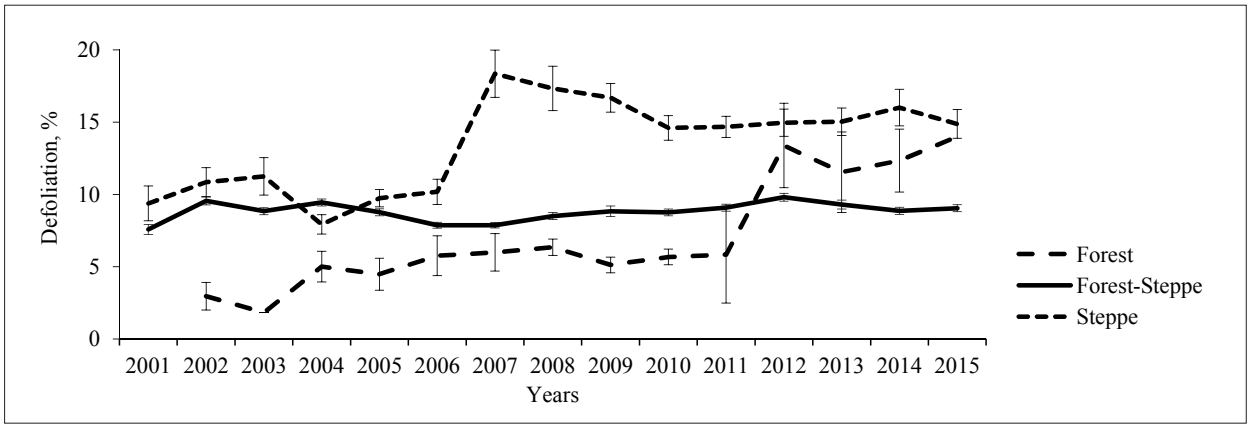

Fig. 1. Dynamics of mean defoliation of common ash trees in different natural zones of Ukraine according to forest monitoring data for 2001-2015 (bars – standard error)

Annual mean defoliation of common ash trees in the Forest zone ranged from 1.8±0.01% to 14.0±3.35%, however, the average annual values for 2001-2015 did not differ significantly from those observed in the Forest-Steppe zone (8.8 and 7.2% in the Forest-Steppe and Forest zones, respectively; $F_{fact.} = 2.56$; $F_{0.05} = 4.21$). At the same time, in the Forest Zone, the average common ash defoliation increased sharply in 2012 and remained at the level of 12-14% until the end of the observation period (see Fig. 1). Annual average defoliation of common ash trees in the Steppe zone ranged from 7.9±0.6% to 18.4±1.64%, and the average long-term value for the entire observation period (13.5%) was significantly higher than in Forest and Forest-Steppe zones ($F_{fact.} = 18$; $F_{0.05} = 3.2$; $P = 2.5E^{-0.6}$). In the Steppe zone, the defoliation rate of common ash trees exceeded 10% in 2002-2003 and 2006, and in 2007-2015, ranging from 14.7 to 18.4%, which corresponds to a level of "slightly damaged".

Taking into account the variation in the defoliation of common ash trees by years and by sample plots, we evaluated the average values and the corresponding standard errors for three five-year periods (Fig. 2).

Analysis of Fig. 2 shows that in 2001-2005 the defoliation of the common ash was the lowest in the Forest zone, medium in the Forest-Steppe, and the highest in the Steppe, and only in the latter case the trees can be considered slightly damaged. In 2006-2010, the minimum common ash defoliation was also registered in the Forest zone, however, the difference with Forest-Steppe is not significant, while in the Steppe, the defoliation remained significantly higher than in other zones, and the trees can be considered "slightly damaged".

In the last assessment period (2011-2015), the average defoliation of common ash at the sample plots in the Forest-Steppe and Steppe did not significantly differ from the values of the previous period, while in the Forest zone, health condition significantly worsened – ash defoliation increased by 1.84 times and did not significantly differ from that in the Steppe (see Fig. 2). So, despite the relatively worth health condition of ash trees in Steppe during all the observation period, the most rapid worsening of health condition is observed in Forest zone, so we can assume the impact of some negative factors in the region.

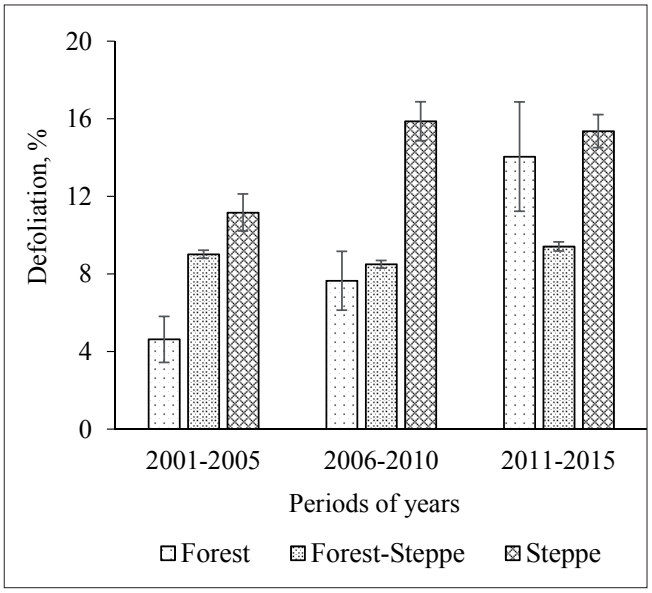

Fig. 2. Mean defoliation of common ash trees in different natural zones of Ukraine according to forest monitoring data for successive periods of 2001-2015 (bars – standard error)

The dynamics of the proportion of damaged trees ("extensiveness" of damage) (Fig. 3) were somewhat different from the dynamics of defoliation (see Fig. 1).

The highest long-term average proportion of damaged trees (42%) was evaluated in the Forest zone ($F_{fact.} = 4.8$; $F_{0.05} = 3.2$; $P = 0{,}01$), while in the Forest-Steppe and Steppe (24.9 and 25.4%, respectively) the indicator had no significant differences in the pooled data set ($F_{fact.} = 0.02$; $F_{0.05} = 4.2$; $P = 0.90$).

Analysis of the proportion of damaged trees grouped by five-year periods (Fig. 4) also indicates a relatively stable value of the extensiveness of ash damage in the Forest-Steppe, a trend toward an increase in this indicator in the Steppe and an increase with a subsequent decrease in the Forest zone.

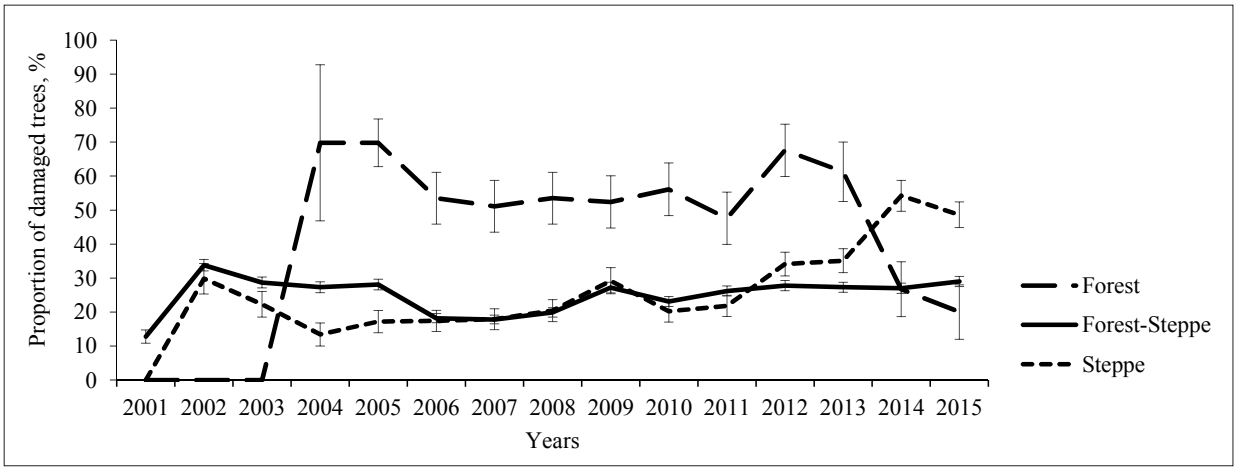

Fig. 3. Dynamics of the proportion of damaged common ash trees in different natural zones of Ukraine according to forest monitoring data for 2001-2015 (bars – standard error)

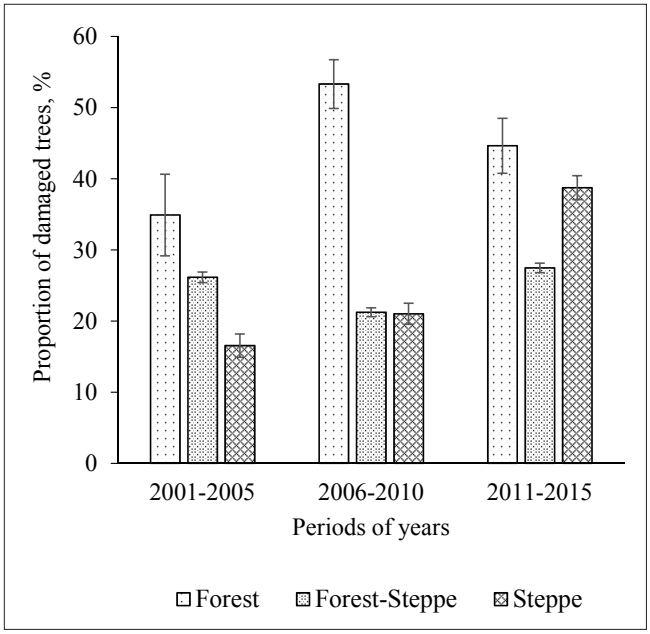

Fig. 4. The proportion of damaged common ash trees in different natural zones of Ukraine according to forest monitoring for successive periods of 2001-2015 (bars – standard error)

In all the periods under consideration, the extensiveness of common ash damage was the highest in the Forest zone.

Analysis of damaging factors (Table 2) showed, that in the Forest zone, diseases played the greatest role in damage to common ash trees, and the proportion of trees damaged by pathogens increased over three five-year periods. Insect damage was the most common in 2001-2005 and subsequently decreased significantly.

A slight increase in the role of abiotic and anthropogenic factors in common ash damage in the Forest zone can be noted when comparing data from three five-year periods (see Table 2).

In the Forest-Steppe, about half of the damage to common ash trees (48.2%) is associated with abiotic factors, however, the proportion of this factor decreases from 64.5% in 2001-2005 to 34.9% in 2011-2015 (Table 2). The proportion of trees affected by pathogens on average over 15 years of observations (41.6%) is slightly inferior to the proportion of trees damaged by climatic factors, but it increases from 21.9% in 2001-2005 to 56% in 2011-2015. The proportion of ash trees damaged by insects in the Forest-Steppe is the highest in 2001-2005, but the level of damage can be considered weak (Manual…, 2010).

Table 2. **The proportion of common ash trees damaged by different causes (numerator) and its proportion from all damaged trees (denominator) according to forest monitoring for successive periods of 2001-2015**

Causes of damage	Periods of years			
	2001-2005	2006-2010	2011-2015	2001-2015
1	2	3	4	5
		Forest zone		
Abiotic	0.6±1.20 / 3.9	1.5±1.75 / 5.3	1.9±2.04 / 5.4	1.4±1.53 / 5.1
Diseases	9.3±4.42 / 58.2	24.6±6.15 / 85.9	29.8±6.82 / 83.9	21.2±5.41 / 79.5
Insects	5.6±3.51 / 35.3	2.1±2.05 / 7.3	0.4±0.94 / 1.1	2.7±2.15 / 10.1
Anthropogenic	0.4±0.99 / 2.6	0.4±0.92 / 1.5	3.4±2.7 / 9.6	1.4±1.56 / 5.3
Total	15.9±5.58 / 100.0	28.6±6.46 / 100.0	35.5±7.13 / 100.0	26.7±5.86 / 100.0
		Forest-Steppe zone		
Abiotic	17.1±1.25 / 64.5	10.1±0.99 / 46.9	10.4±0.99 / 34.9	12.5±0.99 / 48.2
Diseases	5.8±0.78 / 21.9	9.8±0.98 / 5.5	16.7±1.21 / 56.0	10.8±0.93 / 41.6
Insects	3.4±0.60 / 12.8	1.4±0.39 / 6.5	2.4±0.50 / 8.1	2.4±0.46 / 9.3
Other biotic	0.1±0.12 / 0.5	0.1±0.12 / 0.6	0.2±0.14 / 0.7	0.2±0.12 / 0.6
Anthropogenic	0.1±0.08 / 0.2	0.1±0.10 / 0.5	0.1±0.10 / 0.3	0.1±0.07 / 0.2
Total	26.5±1.47 / 100.0	21.5±1.35 / 100.0	29.8±1.48 / 100.0	25.9±1.32 / 100.0

Continuation of Table 2

1	2	3	4	5
		Steppe zone		
Abiotic	5.1±1.73 20.6	8.8±2.15 40.7	1.5±0.88 4.8	5.1±1.44 19.7
Diseases	5.7±1.83 3.0	4.0±1.49 18.5	10.9±2.25 34.6	6.9±1.66 26.6
Insects	12.7±2.62 51.2	8.4±2.11 38.9	19.1±2.84 60.6	13.4±2.24 51.7
Anthropogenic	1.3±0.89 5.2	0.4±0.48 1.9	0,0 0,0	0.5±0.46 1.9
Total	24.8±3.40 100.0	21.6±3.13 100.0	31.5±3.36 100.0	25.9±2.88 100.0

In the Steppe zone, during the entire analyzed period, the proportion of common ash trees damaged by insects prevails (Table 2). Only in 2006-2010, this proportion is comparable to the proportion of trees damaged by abiotic factors, mainly by drought.

The proportion of trees affected by diseases was the smallest in the Steppe compared to other natural zones. The maximum distribution of trees damaged by anthropogenic factors was registered in 2001-2005 but amounted to only 5.2% of all types of damage.

The periods of increase in the proportion of common ash trees with damaged foliage differed in natural zones (Fig. 5). In the Forest zone in 2004-2005, the proportion of trees with damaged (presumable by insects) foliage reached 13-14% (see Fig. 5). At the same time, crown defoliation did not exceed 5% (see Fig. 1).

In the Forest-Steppe, the proportion of damaged common ash trees was 0.9-3.4% without pronounced peaks and declines (Fig. 5), and defoliation did not exceed 10% (see Fig. 1).

In the Steppe in 2002-2003, more than 10% of the assessed trees were damaged by insects (Fig. 5) with average defoliation of more than 10%. In subsequent years, there was a monotonous increase in average defoliation to 18.4% in 2007, and its maintenance was at a level of over 15% until 2015 (Fig. 1). However, the proportion of trees damaged by insects decreased monotonically from 2003 to 2009 and then increased during 2010-2014 with peak in 2014 (19.1%) (Fig. 5).

All detected diseases of ash trees were divided into four main groups: dieback, rot (wood-decaying fungi), bacterial cancer, and foliage diseases.

In the monitored common ash stands, according to long-term data, an increase in the proportion of trees affected by dieback and leaf diseases was revealed from the Forest zone to the Steppe zone (Table 3).

At the same time, the proportion of ash trees affected by bacterial cancer decreased from the Forest zone to the Steppe zone, and the proportion of trees affected by wood-decaying fungi (rot) was the largest in the Forest-Steppe.

In the Forest zone, bacterial cancer (tuberculosis) was most common. Leaf diseases and rots were much less revealed. Symptoms of ash dieback were first recorded in 2006-2010, and in the next period, the trees affected by it accounted for 25.8% of all those affected by diseases (see Table 3).

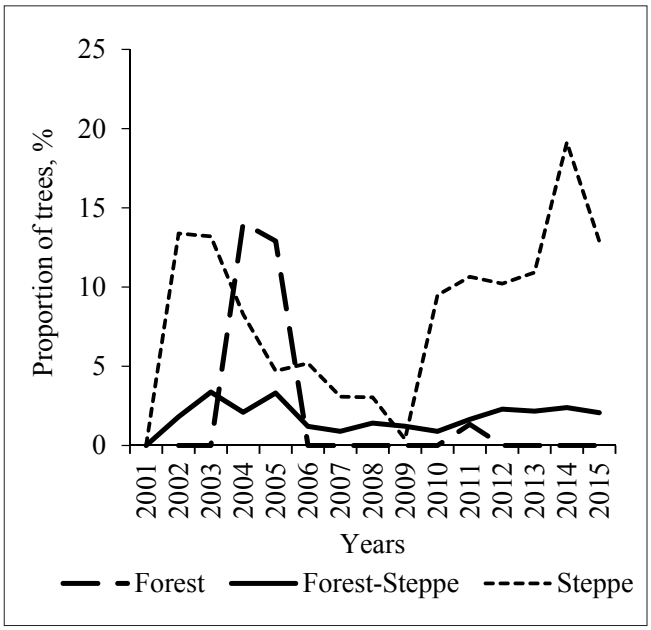

Fig. 5. Dynamics of the proportion of common ash trees, damaged by insects-defoliators in different natural zones of Ukraine according to forest monitoring from 2001 to 2015

In the Forest-Steppe zone, the proportion of trees affected by bacterial cancer also prevailed but tended to decrease from 72.4% in 2001-2005 to 38.9% in 2011-2015. The proportion of trees with rots and leaf diseases has also been decreasing in the last five years. At the same time, the proportion of trees affected by ash dieback increased intensively among all common ash trees affected by diseases (from 3.4% in 2001-2005 to 53.9% in 2011-2015).

In the Steppe zone from 2000 to 2005, most diseased ash trees had symptoms of drying out of the tops and branches. In 2006-2010, this proportion is half as much, and in 2011-2015 it is again quite high (81.7%). Ash trees affected by rot, bacterial cancer, and leaf diseases prevailed in 2006-2010 (Table 3).

Table 3. **The proportion of common ash trees damaged by different diseases types (numerator) and its proportion from all diseased trees (denominator) according to forest monitoring for successive periods of 2001-2015**

Type of disease	Periods of years			
	2001-2005	2006-2010	2011-2015	2001-2015
Forest zone				
Dieback	0.0 / 0.0	0.2±0.64 / 0.8	7.7±3.97 / 25.8	2.6±2.11 / 12.3
Rot (wood-decaying fungi)	0.0 / 0.0	0.1±0.45 / 0.4	0.7±1.24 / 2.3	0.2±0.59 / 0.9
Bacterial cancer	9.3±4.43 / 100.0	24.3±6.13 / 98.8	21.2±6.09 / 71.1	18.3±5.12 / 86.3
Foliage diseases	0.0 / 0.0	0.0 / 0.0	0.2±0.67 / 0.7	0.1±0.42 / 0.5
Total	9.3±4.43 / 100.0	24.6±6.15 / 100.0	29.8±6.82 / 100.0	21.2±5.41 / 100.0
Forest-Steppe zone				
Dieback	0.2±0.15 / 3.4	1.5±0.40 / 15.3	9.0±0.93 / 53.9	3.5±0.55 / 32.4
Rot (wood-decaying fungi)	0.8±0.30 / 13.8	1.4±0.39 / 14.3	0.9±0.31 / 5.4	1.1±0.31 / 10.2
Bacterial cancer	4.2±0.67 / 72.4	6.5±0.81 / 66.3	6.5±0.80 / 38.9	5.7±0.70 / 52.8
Foliage diseases	0.6±0.26 / 10.3	0.4±0.18 / 4.1	0.3±0.18 / 1.8	0.5±0.21 / 4.6
Total	5.8±0.78 / 100.0	9.8±1.21 / 100.0	16.7±1.21 / 100.0	10.8±0.93 / 100.0
Steppe zone				
Dieback	5.4±1.78 / 94.7	1.9±1.04 / 47.5	8.9±2.06 / 81.7	5.4±1.48 / 78.3
Rot (wood-decaying fungi)	0.0 / 0.0	0.4±0.48 / 10.0	0.4±0.46 / 3.7	0.2±0.29 / 2.9
Bacterial cancer	0.3±0.43 / 5.3	0.4±0.48 / 10.0	0.6±0.56 / 5.5	0.5±0.46 / 7.2
Foliage diseases	0.0 / 0.0	1.3±0.86 / 32.5	1.0±0.72 / 9.2	0.8±0.58 / 11.6
Total	5.7±1.83 / 100.0	4.0±1.49 / 100.0	10.9±2.25 / 100.0	6.9±1.66 / 100.0

Discussion. The average defoliation of ash trees at the sample plots did not exceed 10% in most years of assessment (Fig. 1). As is known (Иерусалимов, 2004), deciduous trees can withstand up to 30% defoliation without worsening their health condition. However, even 100% foliage damage can bring tree mortality only in the case of a threefold repetition. The minimum fluctuations in the defoliation in the Forest-Steppe zone are explained by the fact that this zone has the largest number of sample plots. In the Steppe zone, ash defoliation has changed cyclically over the years of assessment, which is typical for outbreaks of foliage-browsing insects (Meshkova, Pyvovar, & Tovstukha, 2019a).

Among the pests of ash foliage in the Forest-Steppe and Steppe of Ukraine in the analyzed years, the black ash sawfly (*Tomostethus nigritus*) prevailed, the ash weevil *Stereonychus fraxini* (DeGeer, 1775) (Curculionidae) and Spanish fly (*Lytta vesicatoria* (L., 1758) (Coleoptera: Meloidae)) were less common (Meshkova et al., 2017). These insects feed on ash leaves in May, therefore, during the monitoring period (end of July – beginning of August), there is no information about these pests in the Forest zone although they may be found in low numbers. Therefore, it can be assumed that the intensive increase in the level of defoliation in the Forest zone, especially since 2011, is associated with underdevelopment or premature fall

of ash leaves as a result of diseases. In particular, these symptoms are characteristic also of ash dieback caused by *Hymenoscyphus fraxineus* (Enderle et al., 2018).

If the level of defoliation describes the severity of tree damage, then the proportion of trees with damage characterizes its extensiveness (Селиховкин та ін., 2018). The dynamics of these parameters differed from each other and in each natural zone (see Fig. 1 and Fig. 3). The greatest extensiveness of ash foliage damage in the Forest zone (Fig. 4) may be due to the different importance of damage factors in each natural zone. In the Forest zone, diseases prevailed (Мацях, Крамарець, 2014; Гойчук та ін., 2018). And even defoliation mentioned as a result of insect damage in 2001-2005 could be the result of overestimation, due to an incorrect diagnosis of the cause of leaf damage. So, with some leaf diseases, necrotic areas fall out, leaving an almost regular rounded hole (Field Guide…, 2017).

The proportion of anthropogenic factors of forest damage in the Forest Steppe zone is surprisingly low (see Table 2) since their action is often indirect, however, it creates conditions for tree attacks by insects and pathogens, and these causes are mentioned as the main. In the Forest-Steppe zone, in contrast to other zones, damage to common ash trees by other biotic factors, namely, wild animals, mainly ungulates, was also registered (see Table 2). The proportion of trees damaged by wild animals was low (average 0.6%). It was possible because the trees over 20 years old were assessed, which were more resistant to damage by ungulates compared to young trees (Євтушевський, 2012). Contrary to expectations, the damage by wild animals was not found in the Forest zone. It is possible that ungulates in the Forest zone are more provided with food (undergrowth and shrubs) than in the Forest-Steppe zone, and therefore damage trees less (Євтушевський, 2012). The absence of this factor in the Steppe zone can be explained by the lower populations of ungulates in the Steppe zone; however, this issue has not been specifically studied.

The lowest proportion of diseased trees in the Steppe compared to other natural zones (Table 2) may be due to the fact that a certain level of humidity is necessary for the development of pathogens (Gonthier, & Nicolotti, 2013). It is interesting to note that in the Steppe zone in the years of the greatest negative impact of abiotic factors (drought) on the health condition of common ash trees (2006-2010), the lowest prevalence of its diseases (proportion of damaged trees) was also registered (see Table 2).

The high proportion of trees with foliage damage and the low defoliation in the Forest zone indicates that the damage was not caused by foliage-browsing insects. Sometimes leaf damage in the form of small holes can be noted with the development of certain diseases (Field Guide…, 2017). The upward trend in mean ash defoliation in the Forest zone (see Fig. 1), especially after 2011 with a low proportion (about 1%) of trees with insect-damaged foliage (Fig. 5), also indicates that the causes of leaf damage were not insects. Such errors in diagnostics are explained by the fact that monitoring of the health condition of trees is carried out in late July-August (Manual…, 2010), and the majority of foliage-browsing insects feed in May-June (Meshkova et al., 2019a).

Features of the dynamics of defoliation and dynamics of the proportion of trees damaged by insects in the Steppe zone are typical for foliage-browsing insects, in particular, for the black ash sawfly, which during the outbreak in different years damages different groups of trees. Therefore, the defoliation can be high, and the proportion of damaged trees (the most preferred) is low (Meshkova et al., 2017).

In contrast to damage caused by insects at an earlier time than monitored, the symptoms and signs of disease could be detected over a long period of time (Gonthier, & Nicolotti, 2013).

Although the existence of ash dieback has been confirmed in the Steppe zone (Davydenko et al., 2013), mortality of branches and tops can still be observed with other types of damage, for example, with a lack of moisture (Meshkova et al., 2019a).

It is known that visually bacterial cancer and leaf diseases are the most easily diagnosed (Гойчук та ін., 2018). At the same time, the rots can be recognized only in the presence of fruiting bodies of wood-decaying fungi, which are absent in years with insufficient moisture, and less reliably – by indirect signs. Branch mortality may be one of the hallmarks of ash dieback caused by the fungus *Hymenoscyphus fraxineus* but it may also be the result of the deteriorating water supply to the trees (Gonthier, & Nicolotti, 2013).

The results obtained indicate that the health of common ash is deteriorating in different natural zones of Ukraine, but in each of them, its own causes prevail. However, when assessing a large area by different performers, it is possible to underestimate or overestimate individual factors of tree weakening, which complicates the development of measures to prevent the development of pathological processes or mitigate their consequences.

Conclusions. Defoliation of common ash for 15 years had the highest level in the Steppe zone. However, from 2011 to 2015, in the Forest zone defoliation increased by 1.84 times and did not significantly differ from that in the Steppe. The highest average proportion of damaged trees (42%) was in the Forest zone.

In the Forest zone, diseases played the greatest role in damage to common ash trees, and the proportion of trees damaged by pathogens increased over three five-year periods. In the Forest-Steppe, about half of the damage to common ash trees (48.2%) was associated with abiotic factors, however, it decreased from 64.5% in 2001-2005 to 34.9% in 2011-2015. The proportion of trees affected by pathogens (41.6%) increased from 21.9% in 2001-2005 to 56% in 2011-2015. In the Steppe zone, the proportion of common ash trees damaged by insects prevailed. However, in 2006-2010, it is comparable to the proportion of trees damaged by abiotic factors, mainly by drought.

The proportion of trees affected by dieback and leaf diseases increased from the Forest zone to the Steppe zone. The proportion of trees affected by bacterial cancer decreased from the Forest zone to the Steppe zone,

and the proportion of trees affected by wood-destroying fungi was the largest in the Forest-Steppe zone.

In the Forest zone and Forest-Steppe zone, bacterial cancer (tuberculosis) was the most common. However, in the Forest-Steppe zone proportion of infected trees decreased from 72.4% in 2001-2005 to 38.9% in 2011-2015.

The proportion of trees affected by ash dieback (caused by invasive fungi *Hymenoscyphus fraxineus*) increased in all zones and made up 25.8%, 53.9%, and 81.7% of all trees affected by diseases in the Forest, Forest-Steppe, and Steppe zone, respectively. However, in some cases, similar symptoms in the Steppe could be related to non-infectious dieback as a result of a lack of moisture.

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Причини і тенденції дефоліації *Fraxinus excelsior* L. в Україні згідно з даними моніторингу лісів

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Мета роботи полягала в оцінюванні основних причин і тенденцій динаміки дефоліації дерев ясена звичайного у різних природних зонах України за даними моніторингу лісів. База даних моніторингу лісів І рівня за 2001-2015 рр. містить резуль-

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тати польових спостережень, проведених науковцями лабораторії моніторингу і сертифікації лісів Українського науково-дослідного інституту лісового господарства та агролісомеліорації ім. Г. М. Висоцького, фахівцями ВО «Укрдержліспроект» і лісогосподарських підприємств. До аналізу включено ділянки з наявністю не менше трьох дерев ясена звичайного у Поліссі (Лісова зона), Лісостепу і Степу.

Найвищий рівень дефоліації ясена впродовж 15 років відзначено у Степу, а найменшу її мінливість – у Лісостепу. Водночас протягом 2011-2015 рр. дефоліація ясена у Лісовій зоні збільшилася в 1,84 раза та значуще не поступалася показнику у Степу.

Найбільшу середню частку дерев з наявністю пошкоджень (42%) встановлено у Лісовій зоні. Показник був порівняно стабільним у Лісостепу, мав тенденцію до збільшення у Степу з наступним зменшенням у Лісовій зоні.

У Лісовій зоні в ураженні дерев ясена провідну роль посідають хвороби. Частка уражених дерев мала тенденцію до збільшення впродовж трьох п'ятирічних періодів. У Лісостепу близько половини пошкоджень дерев ясена (48,2%) пов'язані з абіотичними чинниками, причому ця частка зменшилася від 64,5% у 2001-2005 рр. до 34,9% у 2011-2015 роках. Частка дерев, уражених патогенами (41,6%), збільшилася з 21,9% у 2001-2005 рр. до 56% у 2011-2015 роках. У Степу переважає частка дерев, пошкоджених комахами, переважно чорним ясеновим пильщиком (*Tomostethus nigritus* (Fabricius, 1804)). Водночас у 2006-2010 рр. цей показник дуже близький до частки дерев, пошкоджених абіотичними чинниками, зокрема посухою.

Основними групами хвороб ясена були такі: халаровий некроз (збудник – *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz & Hosoya (Queloz et al. 2011)), гнилі (спричинені дереворуйнівними грибами), бактеріальний рак або туберкульоз (збудник – *Pseudomonas syringae* subsp. *savastanoi* pv. *fraxini*) та хвороби листя.

Частка дерев з ознаками периферійного відмирання крони і хворобами листя збільшувалася від Лісової до Степової зон. Частка дерев, уражених бактеріальним раком, зменшувалася від Лісової до Степової зон, а частка дерев, уражених дереворуйнівними грибами, була найбільшою у Лісостепу.

Бактеріальний рак ясена найчастіше виявляли у Лісовій і Лісостеповій зонах. Водночас у Лісостеповій зоні частка уражених дерев зменшилася від 72,4% у 2001-2005 рр. до 38,9% – у 2011-2015 роках.

Частка дерев, уражених халаровим некрозом, збільшувалася в усіх природних зонах і становила у 2011-2015 рр. 25,8; 53,9 і 81,7% від усіх уражених хворобами дерев у Лісовій, Лісостеповій і Степовій зонах відповідно. Водночас у деяких випадках у Степу подібні симптоми можуть бути пов'язані з неінфекційним периферійним відмиранням крони внаслідок дефіциту вологи.

Ключові слова: ясен звичайний; частка пошкоджених дерев; чорний ясеневий пильщик; халаровий некроз; гнилі; дереворуйнівні гриби; бактеріальний рак; хвороби листя.