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Symptoms of dwarf elm (*Ulmus pumila* L.) health condition in the Left-bank Ukraine

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Ulmus pumila L. is widely spread in arid and semi-arid regions of China as a soil-conservation, sand-fixing, and resistant plant. Due to its rapid growth, winter hardiness, low demand for soil fertility and moisture, tolerance of drought, resistance to gaseous pollution and soil salinization, and ability to spread under favorable conditions, *U. pumila* has been widely cultivated in forests, urban plantations, and along transportation right-of-ways. In some regions, *U. pumila* is resistant to Dutch elm disease (DED), and verticillium wilt but it is susceptible to bacterial wetwood disease. The trees' health is usually assessed according to crown and trunk appearance. We assumed that some symptoms may be associated with specific types of pathologies or indicate the latent development of the disease, which is difficult to diagnose visually. The study aimed to search the relations between the distribution of visually detectable symptoms of *U. pumila* weakening and tree groups with apparent signs of bacterial wetwood and Dutch elm disease. In June-September 2023, the health condition of *Ulmus* sp. was examined in forest shelterbelts along the M 03 highway, passing through the territory of Kyiv, Poltava, and Kharkiv regions. In this study, the data on 624 *U. pumila* trees in 11 sample plots were used, particularly, the diameter at breast height (DBH), the class of the health condition, defoliation, the prevalence of dry branches, epicormic shoots, bark beetle infestation, local bark death, and collar rots. Based on these indicators, four groups were examined – with symptoms of bacterial wetwood, DED, weakening of unknown etiology (symptomatic trees), and without visual symptoms of weakening (asymptomatic trees). DBH of symptomatic trees was significantly less than that in asymptomatic and DED-infected trees. The average HCI was from 2.5 for asymptomatic to 3.3 for wetwood disease-infected trees, and 3.5 for DED-infected trees. DED-infected trees were found to have the highest level of defoliation and the lowest prevalence of epicormic shoots. Among wetwood-infected trees, the bark beetle infestation significantly increased with an increase in HCI and defoliation and decreased as the diameter of the trunks decreased. Principal components analysis confirmed the highest association of bark beetle infestation with DED, epicormic shoots with wetwood disease, and dry branches with other symptomatic trees. Symptomatic trees occupied an intermediate position by HCI. Although they have no direct signs of fungal or bacterial disease, health worsening may indicate a latent infection.

Key words: Dutch elm disease; wetwood disease; defoliation; dry branches; epicormic shoots; bark beetle infestation.

Introduction. *Ulmus pumila* L. (*Ulmaceae*) is known as the Asiatic elm, the Siberian elm, and the dwarf elm (*Hirsch et al.*, 2017), and has many synonyms in other languages, particularly in Ukrainian

“dribnolystyi”, and “nyzkyi” (Жигалова, 2016). *U. pumila* is native to Central Asia, eastern Siberia, the Russian Far East, Mongolia, Tibet, northern China, India (northern Kashmir) and Korea. This tree species

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is widely spread in arid and semi-arid regions of China as a soil-preserving, sand-fixing, and resistant plant (Jiang et al., 2024). Due to its rapid growth, winter hardiness, low demand on soil fertility and moisture, and tolerance of mild salinity, drought, *resistance to gaseous pollution and soil salinization*, and ability to spread rapidly under favorable conditions (Solla et al., 2005), *U. pumila* has been widely cultivated throughout Asia, North America, Argentina, and southern Europe (Hirsch et al., 2017; Шлапак, Маслова, 2017). *U. pumila* is often found along right-of-ways of railroads, neglected sites, and disturbed ground because it prefers the well-drained, nutrient-poor soil, high light intensity, and the corridors facilitating its spread (Jiang et al. 2024). However, due to its high sunlight requirements, *U. pumila* sometimes invades mature forests growing in the cities, and areas along transportation right-of-ways (Zalapa et al., 2008; Lykholat et al., 2018), and becomes invasive in the natural reserve areas (Зав'ялова, 2017).

U. pumila has considerable variability in resistance to Dutch elm disease, particularly it is more tolerant in north-western and north-eastern China than in central and southern China (Zalapa et al., 2008). It was the most resistant of all the elms to verticillium wilt and is highly susceptible to damage from elm leaf beetle *Xanthogaleruca luteola* (O.F. Müller, 1766) (Coleoptera: Chrysomelidae) (Miller, & Ware, 2001), and the Asian 'zigzag' sawfly *Aproceros leucopoda* Takeuchi, 1939 (Hymenoptera: Argidae) (Brasier et al., 2013).

The assessment of three *Ulmus* species' health in the shelterbelts along the Kyiv-Kharkiv highway showed tree damage by bacterial disease (wetwood), Dutch elm disease (DED), collar rots, and bark beetles (Кузнецова та ін., 2023). On average for three elm species, bacterial disease was most widespread in a fragment of the shelterbelt within Kyiv region, and in *U. pumila* it was most widespread within Kharkiv region.

According to "Sanitary Forests Regulations in Ukraine" (2016), the trees' health is assessed by classes according to crown and trunk appearance. However, the trees with central rot or the initial stage of stem pest infestation often have healthy crowns and are assessed as healthy (Vasaitis, 2013, 2024). Conversely, deciduous trees with many dry branches are assessed as class 4 of health condition but they can restore the crown and remain viable for decades (Meshkova, & Davydenko, 2016).

At the same time, some symptoms of crown and trunk damage can be caused by various factors. In some cases, the health of the tree irreversibly deteriorates, while in other cases it improves (Мешкова, Зінченко, 2016; Мешкова, Коленкіна, 2016; Meshkova et al., 2021).

We assumed that some symptoms may be characteristic or associated with specific types of pathologies or indicate the latent development of the disease, which is difficult to diagnose visually.

The object of research was the symptoms of *U. pumila* damage. The subject of research was the

prevalence of various damage symptoms in *U. pumila* trees with signs of different diseases. The study aimed to search the relations between the distribution of visually detectable symptoms of *U. pumila* weakening and tree groups with confirmed signs of bacterial wetwood and Dutch elm disease.

Material and methods. In June-September 2023, the health condition of *Ulmus* sp. was examined in forest belts along the M 03 highway, passing from the West to the East through the territory of Kyiv, Poltava, and Kharkiv regions of Ukraine. The sample plots were located at the parts of the shelterbelt with the dominance of one or several *Ulmus* species. *U. pumila* L. was presented in 5, 4, and 2 sample plots in Kharkiv, Poltava, and Kyiv regions, respectively. In different sample plots, *U. pumila* comprised 26 to 96 % of all trees and elms (Table 1).

When examining the trees, the diameter at breast height (DBH) was measured with an accuracy of 1 cm, the class of the health condition of the trees, the presence and prevalence of weakening symptoms, and their severity for some of them were evaluated.

Each tree was referred to one of six classes of health condition (1st – healthy; 2nd – weakened; 3rd – severely weakened; 4th – drying-out; 5th – recently died; 6th – dead over a year ago). A health condition index (HCI) was calculated as a mean of the health condition classes of inspected trees for each sample plot (Sanitary Forests Regulations in Ukraine, 2016).

During the field inspection, Dutch elm disease (DED) was identified by specific symptoms – wilting and curling of leaves that remain on the tree for a while even without changing color, the gradual dying-off of thin and then thick branches, the presence of dark brown stripes on the longitudinal section of the branch – capped vessels, and rings of points on the transverse section. The coremia with conidia were found on heavily infested trees in the bark beetles' galleries. The pathogen identified was confirmed by specific laboratory techniques (Menkis et al., 2016; Кузнецова та ін., 2023).

Bacterial wetwood was identified by fresh or dried exudate on the bark, resulting from bark fermentation. An analysis made at the Institute of Microbiology and Virology of the National Academy of Sciences of Ukraine has identified the pathogen as *Lelliottia nimipressuralis* (Carter 1945) (Мешкова, Мороз, Кузнецова, 2024).

Because of the inability to cut down trees, their infestation by bark beetles was assessed only by the exit holes in the lower part of the trunks.

The prevalence of each symptom of elm damage was estimated as the proportion of trees with certain symptoms from the total number of inspected trees.

The local bark death, butt rot, and bark beetle infestation in the lower part of the trunk, as well as infectious diseases, were pointed in two gradations: 1 – presence; 0 – absence. The severity of symptoms was assessed only for defoliation, dry branches, and epicormic shoots. Defoliation was visually evaluated with

an accuracy of 5 % and then scored: 0 point – 0-10%; 1 point – 11 – 25%; 2 points – 26 – 60%; 3 points – 61 – 94%, and 4 points – 95 – 100%. The score for dry branches was: 0 points – absence; 1 point – up

to 10%; 2 points – 11-50 %; 3 points – 51-75%; 4 points – > 75%. The score for epicormic shoots was: 1 – single; 2 – abundant; 3 – the trunk is completely covered with epicormic shoots (Мешкова, 2020).

Table 1. Location of sample plots with proportion of elms, incl. *Ulmus pumila*

No	Latitude, °	Longitude, °	Number of trees			Proportion of trees, %		
			all species	all elms	<i>U. pumila</i>	elms from all trees	<i>U. pumila</i> from all trees	<i>U. pumila</i> from all elms
Kharkiv region								
1	49.7646	35.2982	48	48	39	100.0	81.3	81.3
2	49.8633	35.7077	25	25	23	100.0	92.0	92.0
3	49.9606	36.0486	101	101	73	100.0	72.3	72.3
4	49.7986	35.5034	100	100	82	100.0	82.0	82.0
5	49.7911	35.4922	151	151	64	100.0	42.4	42.4
Poltava region								
6	50.2278	32.1337	75	68	57	90.7	76.0	83.8
7	49.6957	33.4371	224	204	166	91.1	74.1	81.4
8	50.2481	32.2741	50	50	13	100.0	26.0	26.0
9	50.2443	32.2593	50	50	15	100.0	30.0	30.0
Kyiv region								
10	50.2292	32.0853	101	86	68	85.1	67.3	79.1
11	50.2323	31.9921	25	25	24	100.0	96.0	96.0
Total			950	908	624	95.6	65.7	68.7

Since the prevalence of *U. pumila* on the sample plots did not depend on the longitude of their location ($r=0.21$; $t=0.66$), the data on all sample plots were pooled for subsequent analysis.

The Shapiro-Wilk test did not confirm the normality of the indicators obtained. Therefore, we compared the groups of trees using non-parametric methods (The Mann-Whitney pairwise test) and calculated Spearman’s coefficient for the correlation of indicators. Microsoft Excel and statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer, Harper, & Ryan, 2001) were used for data analysis and visualization. The proportions of symptoms or indicators were compared using a z-test [Peck, Short, & Olsen, 2020]. The difference between the proportions was considered significant for $P = 0.05$ at $Z > 1.96$.

Results. Based on the totality of indicators, four groups of trees were examined – with symptoms of bacterial wetwood (bacteriosis), with symptoms of DED, with symptoms of weakening of unknown etiology, and without visual symptoms of weakening.

DBH of all trees varied from 14 to 48 cm with an average 24-26 cm (Fig. 1).

According to the Mann-Whitney pairwise test, the diameter of symptomatic trees was significantly less

than that in asymptomatic and DED-infected trees. The diameter of trees with bacteriosis did not differ from other groups of trees.

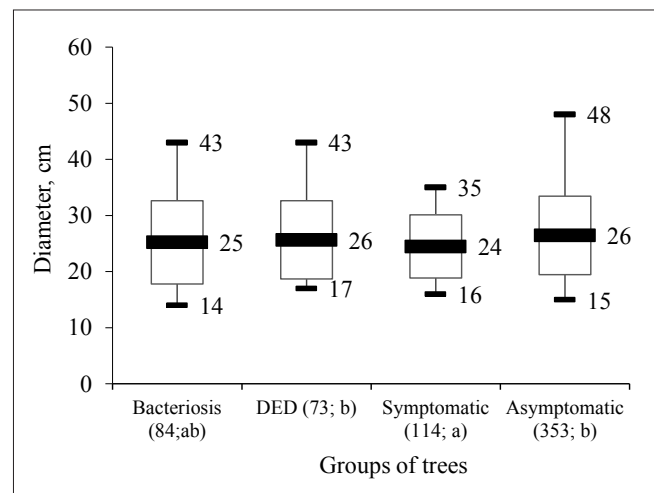


Fig. 1. Diameter of *U. pumila* in various groups by health (the numbers indicate the minimum, mean, and maximum; box length is one sigma; whiskers are max-min; in parentheses: numbers of trees in each group and letters showing the significant differences at $p < 0.05$)

The trees of 2nd–5th health classes are presented among assessed elms. An average HCI of asymptomatic was significantly less than in other groups of trees. This indicator was the highest among the trees with wetwood (Fig. 2).

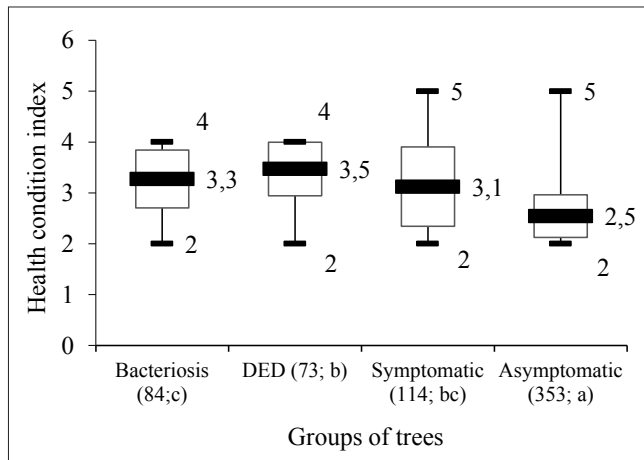


Fig. 2. Health condition index (HCI) of *U. pumila* in various groups by health (the numbers indicate the minimum, mean, and maximum; box length is one sigma; whiskers are max-min; in parentheses: numbers of trees in each group and letters showing the significant differences at $p < 0.05$)

The absence of dead trees among elms infected by wetwood indicates a chronic disease development. Symptomatic trees occupy an intermediate position by HCI. They do not have symptoms of fungal or bacterial disease but the deterioration of the health condition may be a sign of latent infection. The proportion of drying up elms (of health condition class 4) was significantly higher among trees with wetwood and DED than among other groups (Fig. 3). The differences between symptomatic and asymptomatic trees are not significant.

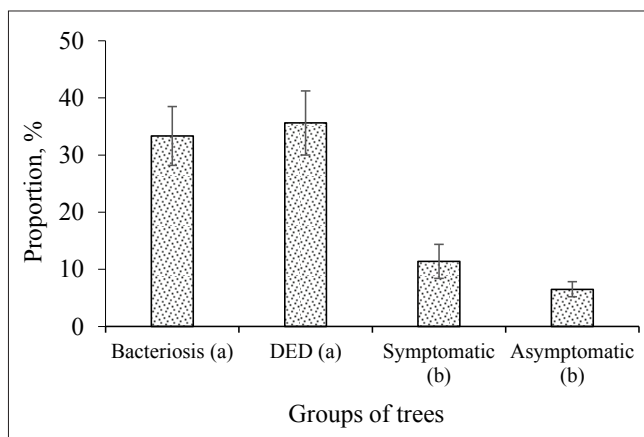


Fig. 3. Proportion of drying up trees (health condition class 4) in various groups of trees (letters showing the significant differences at $p < 0.05$ in parentheses)

Average defoliation both in percentage and in points was the lowest in asymptomatic trees (Fig. 4). This indicator in elms with signs of wetwood or DED

has no significant differences with symptomatic trees of unknown etiology, however, mean defoliation was the highest in the DED-infected trees.

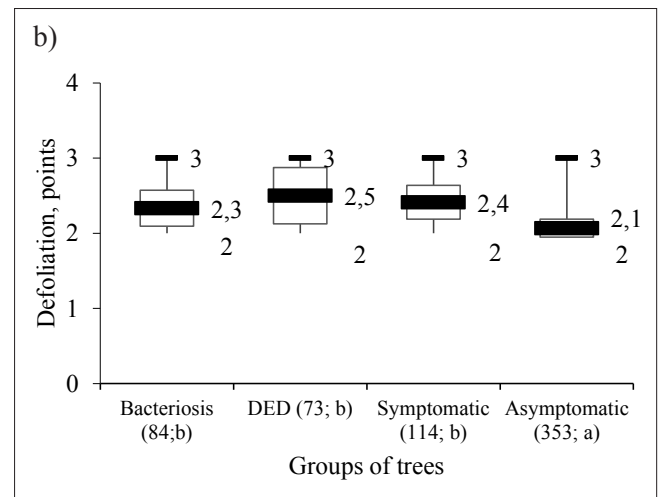
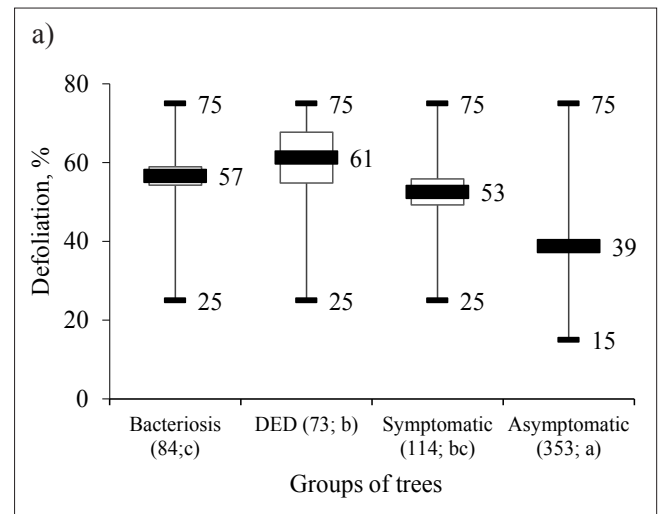


Fig. 4. Defoliation of *U. pumila* in various groups by health (the numbers indicate the minimum, mean, and maximum; box length is one sigma; whiskers are max-min; in parentheses: numbers of trees in each group and letters showing the significant differences at $p < 0.05$) (a – assessed in percentage; b – recalculated to points)

All symptoms appeared to varying degrees in trees with signs of bacteriosis, DED, and in the group of other symptomatic trees (Fig. 5).

Trees with epicormic shoots are the most often represented, and trees with dry branches and bark beetle infestation are less frequent. The proportion of trees with local bark death and collar rots was the lowest in all analyzed groups of trees. Trees with the signs of wetwood epicormic shoots occurred most often, followed by dry branches and bark beetle infestation. Among trees with signs of DED, bark beetle infestation dominated, followed by epicormic shoots, and dry branches. Among other symptomatic trees, epicormic shoots occurred most often, followed by dry branches and bark beetle infestation. The proportion of bark beetle-infested trees was the highest (26 %) among the trees with signs of DED (see Fig. 5).

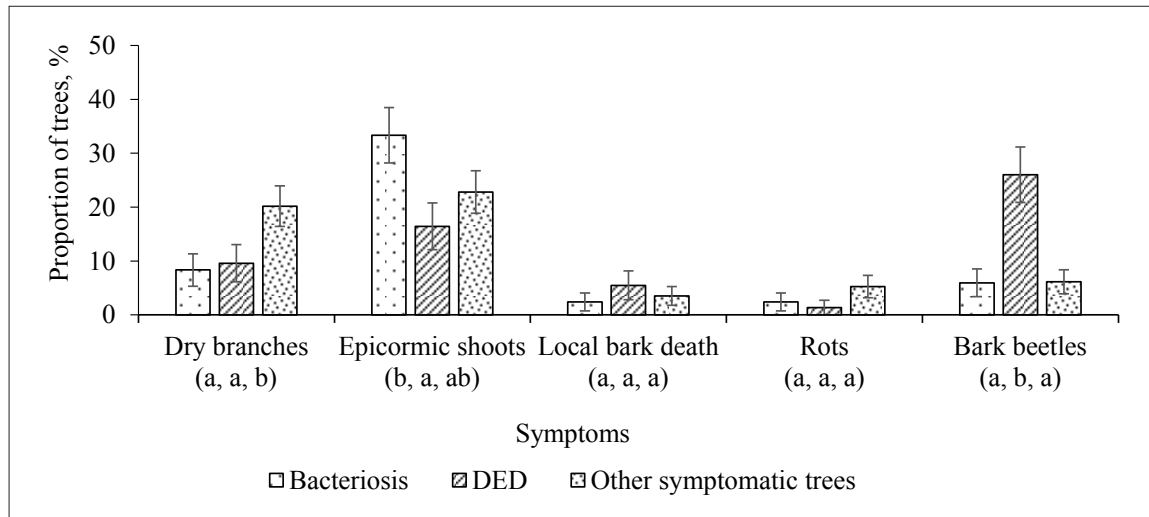


Fig. 5. Comparison of the prevalence of some *U. pumila* health condition symptoms in various groups of trees (symptoms prevalence evaluated as the proportion of symptomatic trees in %; letters show the significant differences in each symptom at $p < 0.05$ between tree groups: bacteriosis, DED, and other symptomatic trees)

The severity of dry branches was the highest among other symptomatic trees and the lowest among trees with signs of bacterial wetwood (Fig. 6). The severity of epicormic shoots was the highest among trees with signs of bacterial wetwood.

For trees with signs of bacterial wetwood, the highest significant positive Spearman correlation was obtained between HCI and defoliation, the moderate

correlation – for pairs of bark beetle infestation – HCI and bark beetle infestation – defoliation, and Local bark death – Dry branches, the low correlation – for pairs of HCI – Dry branches, HCI – Local bark death, Bark beetles – Local bark death, and Dry branches – Defoliation.

No significant correlation with any symptom was obtained for DBH and epicormic shoots (see Table 2).

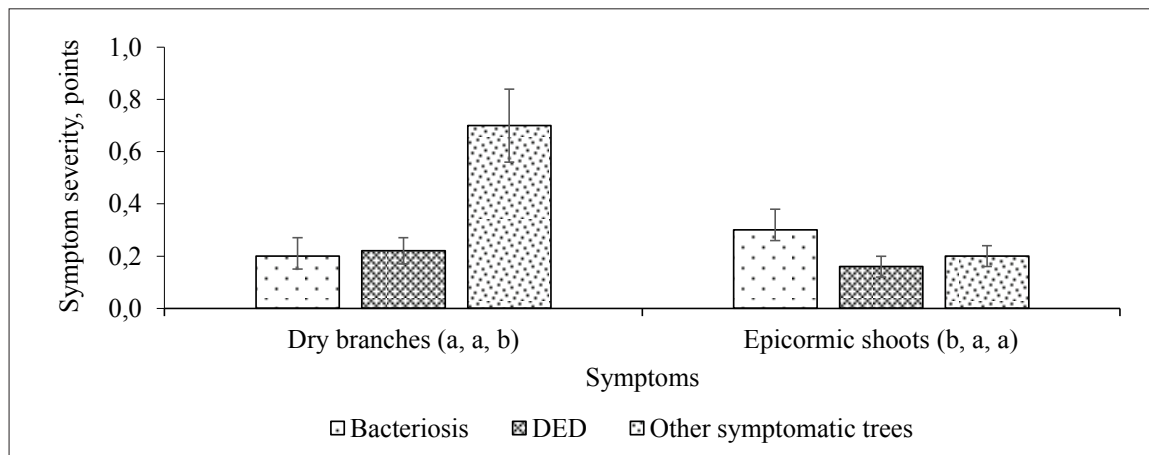


Fig. 6. Comparison of the severity of the two most prevalent symptoms of *U. pumila* health condition in various groups of trees (letters show the significant differences in each symptom at $p < 0.05$ between tree groups: bacteriosis, DED, and other symptomatic trees)

Table 2. Spearman correlation between various health condition symptoms of *U. pumila* trees with bacterial wetwood

Parameters	HCI	DBH, cm	Def., %	Def., score	Dry branches	Epicormic shoots	Bark beetle	Local bark death
1	2	3	4	5	6	7	8	9
DBH, cm	-0,10 (0.37)	1						
Defoliation, %	0.97 (<0.001)	-0.07 (0.54)	1					

1	2	3	4	5	6	7	8	9
Defoliation, score	0.95 (<0.001)	-0.11 (0.31)	0.93 (<0.001)	1				
Dry branches	0.24 (0.03)	-0.05 (0.64)	0.24 (0.03)	0.25 (0.02)	1			
Epicormic shoots	0.06 (0.56)	0.07 (0.52)	0.03 (0.78)	0.05 (0.67)	0.19 (0.08)	1		
Bark beetle infestation	0.34 (0.002)	0.004 (0.97)	0.33 (0.002)	0.36 (0.001)	0.11 (0.30)	0.03 (0.77)	1	
Local bark death	0.21 (<0.001)	0.03 (0.82)	0.20 (0.06)	0.22 (0.04)	0.51 (<0.001)	0.05 (0.63)	0.29 (0.01)	1
Collar rot	0.21 (0.06)	-0.19 (0.08)	0.20 (0.06)	0.22 (0.04)	-0.05 (0.67)	0.05 (0.63)	-0.04 (0.72)	-0.02 (0.83)

Note: p in parentheses; significant coefficients (p<0.05) are marked in bold

For trees with signs of DED, the highest significant positive Spearman correlation was obtained between HCI and defoliation, the moderate correlation – for pairs of Local bark death – Dry branches, and the low

correlation – for pairs of HCI – Local bark death, and Defoliation – Local bark death (Table 3). A significant negative low Spearman correlation was obtained between DBH and bark beetle infestation (see Table 3).

Table 3. Spearman correlation between various health condition symptoms of *U. pumila* trees with Dutch elm disease

Parameters	HCI	DBH, cm	Def., %	Def., score	Dry branches	Epicormic shoots	Bark beetle	Local bark death
DBH, cm	0.04 (0.75)	1						
Defoliation, %	0.96 (<0.001)	0.08 (0.52)	1					
Defoliation, score	0.96 (<0.001)	0.05 (0.69)	0.97 (<0.001)	1				
Dry branches	0.15 (0.20)	0.14 (0.24)	0.16 (0.19)	0.16 (0.18)	1			
Epicormic shoots	-0.16 (0.17)	0.03 (0.81)	-0.15 (0.20)	-0.13 (0.27)	-0.14 (0.22)	1		
Bark beetle infestation	0.17 (0.14)	-0.25 (0.03)	0.12 (0.31)	0.12 (0.32)	0.02 (0.85)	-0.18 (0.13)	1	
Local bark death	0.24 (0.04)	0.10 (0.38)	0.24 (0.04)	0.25 (0.03)	0.52 (0.001)	-0.11 (0.37)	-0.14 (0.23)	1
Collar rot	0.12 (0.32)	-0.04 (0.74)	0.12 (0.32)	0.12 (0.30)	-0.04 (0.75)	-0.05 (0.66)	-0.07 (0.56)	-0.03 (0.81)

Note: p in parentheses; significant coefficients (p<0.05) are marked in bold

Principal components analysis shows the highest association of bark beetle infestation with DED, epicormic shoots with wetwood disease, and dry branches with other symptomatic *U. pumila* trees (Fig. 7).

Collar rots and local bark death have the lowest associations with all groups of tree pathology. For collar rot, the first principal component (PC1) is 0.086, the second one (PC2) is 0.21, and for local bark death PC1=0.11 and PC2=0.04.

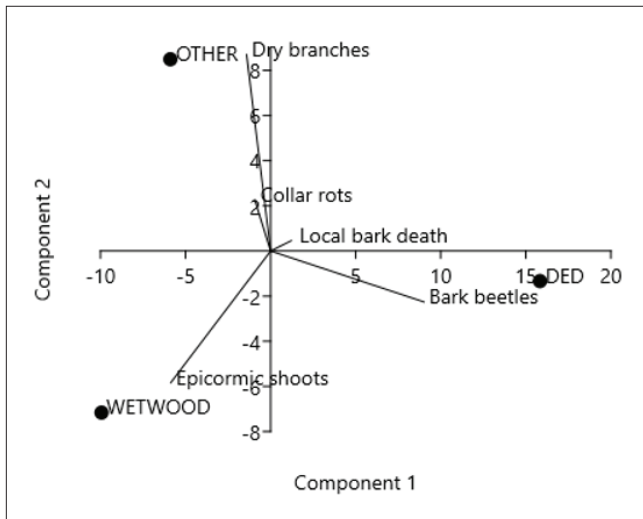


Fig. 7. Principal components analysis, illustrating the relationships between symptoms of *U. pumila* weakening (vectors – dry branches, epicormic shoots, local bark death, bark beetles, and collar rots) and types of pathology (black points: DED – Dutch elm disease, WETWOOD – bacteriosis, and OTHER – other symptomatic trees). The first main component describes 75.41% of variance, and the second one – 24.59%

Discussion. We assessed the distribution of health indicators of 624 *U. pumila* trees in 11 sample plots inspected in the roadside forest shelterbelt over 400 km long. The trees were visually diagnosed with partial laboratory confirmation of diseases caused by fungi (Dutch elm disease, or DED) and bacteria (wetwood disease). Health condition index, defoliation, the prevalence of dry branches, epicormic shoots, bark beetle infestation, local bark death, and collar rots were assessed for each tree. The severity score was assessed for dry branches and epicormic shoots (Мешкова, 2020).

Four groups were examined based on the totality of indicators – with symptoms of bacterial wetwood, DED, weakening of unknown etiology (symptomatic trees), and without visual symptoms of weakening (asymptomatic trees).

DBH of symptomatic trees was significantly less than that in asymptomatic and DED-infected trees (see Fig. 1).

According to Sanitary Regulations (2016), most trees are severely weakened with an average HCI from 2.5 for asymptomatic to 3.3 for wetwood-infected trees. The average HCI for DED-infected trees is 3.5, that is, these trees are drying out (see Fig. 2).

DED-infected trees have the highest level of defoliation (see Fig. 4). It occurs because DED affects vessels and is manifested by curling, wilting, and falling of leaves (Santini, & Faccoli, 2015; Jürisoo et al., 2010), unlike bacteriosis affecting cambium and phloem (Sobiczewski, 2008; Gougherty, 2023).

The proportion of trees with epicormic shoots was the greatest among wetwood-infected trees and the lowest among DED-infected trees (see Fig. 5). It

occurs because bacteriosis develops more often into a chronic form (Goychuk et al., 2023), and due to epicormic shoots, the tree restores its health and prolongs its existence. Unlike them, DED develops more often in an acute form, and trees die within a few weeks (Пузріна, Явний, 2020; Christopher et al., 2023).

The magnitude and significance of correlation coefficients differ in the groups of trees with signs of wetwood and DED. The correlation between HCI and defoliation is the highest and most significant in both groups (see Table 2, and 3).

Among wetwood-infected trees, the bark beetle infestation was significantly higher with higher HCI and defoliation. For DED-infected trees, a significant negative correlation occurred between DBH and bark beetle infestation, that is, bark beetles inhabited trees with a smaller diameter (see Table 3). In both cases, this indicates that bark beetles infested weaker trees and that the trees were weakened due to bark beetle infestation. The role of bark beetles and other xylophages in both diseases' spread is widely published (Santini, & Faccoli, M. 2015; Menkis et al., 2016; Goychuk et al., 2023).

Principal components analysis considering symptoms in individual groups of *U. pumila* trees confirmed the highest association of bark beetle infestation with DED. The presence of epicormic shoots was more typical in wetwood-infected trees, and among other symptomatic trees, dry branches predominated (see Fig. 7).

Symptomatic trees occupy an intermediate position by HCI (see Fig. 2). Although they have no direct signs of fungal or bacterial disease, health deterioration may indicate a latent infection (La Porta, Hietala, & Baldi, 2022).

Conclusions. In the roadside forest shelterbelt, four groups of *U. pumila* trees were identified: with symptoms of bacterial wetwood, DED-infected, weakening of unknown etiology (symptomatic trees), and without visual symptoms of weakening (asymptomatic trees).

Average HCI was from 2.5 for asymptomatic to 3.3 for wetwood-infected trees, and 3.5 for DED-infected trees. DED-infected trees have the highest level of defoliation and the lowest prevalence of epicormic shoots.

Among wetwood-infected trees, the bark beetle infestation significantly increased with an increase in HCI and defoliation and decreased with a decrease in diameter.

Principal components analysis confirmed the highest association of bark beetle infestation with DED, epicormic shoots with wetwood, and dry branches with other symptomatic trees.

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Симптоми санітарного стану в'яза низького (*Ulmus pumila* L.) у Лівобережній Україні

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В'яз низький (*Ulmus pumila* L.) поширений у пустельних і напівпустельних регіонах Китаю, де він захищає ґрунт від ерозії та закріплює піски. Завдяки швидкому росту, зимостійкості, низькій

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вибагливості до родючості й вологості ґрунту та спроможності поширюватися за сприятливих умов, *U. pumila* культивують у лісах, зелених насадженнях населених пунктів і захисних смугах уздовж полів, залізниць та автошляхів. У деяких регіонах *U. pumila* виявився резистентним до голландської хвороби в'язів та вертицильозу, але сприйнятливим до бактеріальної водянки.

Санітарний стан дерев зазвичай оцінюють за виглядом крони та стовбура за категоріями санітарного стану. Водночас листяні дерева, уражені ядровою гниллю або на початкових стадіях заселення ксилофагами, часто за станом крон оцінюють як здорові. І навпаки – листяні дерева з наявністю сухих гілок та оцінені четвертою категорією санітарного стану, можуть відновити крону і залишатися життєздатними на десятки років.

Ми припустили, що деякі симптоми, оцінені візуально, можуть бути пов'язані зі специфічними типами патології або свідчити про латентний розвиток хвороби, яку важко діагностувати візуально.

Метою дослідження було виявлення зв'язків між поширенням візуально оцінюваних симптомів ослаблення *U. pumila* та деревами з підтвердженими ознаками бактеріальної водянки та голландської хвороби в'язів.

У червні-вересні 2023 р. було обстежено лісову смугу уздовж траси М 03, яка проходить територією Київської, Полтавської та Харківської областей. У цьому дослідженні проаналізовано дані стосовно 624 дерев *U. pumila* на одинадцяти пробних площах, зокрема діаметр на висоті 1,3 м (DBH), категорію санітарного стану, дефоліацію, поширення сухих гілок, водяних пагонів, поселень короїдів, окоренових гнилей і сухобочин. За сукупністю показників виділено та розглянуто чотири

групи дерев: із симптомами бактеріальної водянки; голландської хвороби в'язів; ослаблених із невідомою етіологією (симптоматичні дерева); без видимих симптомів ослаблення (асимптоматичні дерева).

Встановлено, що діаметр симптоматичних дерев був значуще меншим, ніж асимптоматичних та уражених голландською хворобою. Діаметр дерев, уражених бактеріальною водянкою, відрізнявся незначуще. Середній індекс санітарного стану становив від 2,5 стосовно асимптоматичних дерев, до 3,3 – для інфікованих бактеріальною водянкою та 3,5 – для інфікованих голландською хворобою. Серед дерев, інфікованих голландською хворобою, визначено найбільший рівень дефоліації та найменше поширення водяних пагонів. Заселеність короїдами дерев, інфікованих бактеріальною водянкою, значуще збільшувалася по мірі збільшення індексу санітарного стану та дефоліації та зменшувалася по мірі зменшення діаметра стовбурів.

Аналіз головних компонент підтвердив найвищу асоційованість заселеності короїдів із ураженням дерев голландською хворобою в'язів, асоційованість поширення водяних пагонів із ураженням дерев бактеріальною водянкою, а поширення сухих гілок у кронах – із іншими симптоматичними деревами.

Серед розглянутих груп дерев симптоматичні дерева посідають проміжне місце за індексом санітарного стану. Хоча вони не виявляють прямих ознак грибної чи бактеріальної хвороби, погіршення їхнього стану може свідчити про латентну інфекцію.

Ключові слова: голландська хвороба в'язів; бактеріальна водянка; дефоліація; сухі гілки; водяні пагони; заселення короїдами.