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EUROPEAN ASH HEALTH CONDITION
IN THE FOREST-STEPPE PART OF SUMY REGION

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Average health condition index of European ash (*Fraxinus excelsior* L.) in inspected stands of the State Enterprise "Trostyanetske Forest Economy" is 2 points. European ash mortality was the highest in Krasnyanske forestry (0.8 % and 3.5 % of recently died trees and the trees died over a year ago respectively). The highest proportion of healthy European ash trees were inspected in Makivske and Krasnyanske forestries (85.3 % and 50.1 % respectively). The trees of European ash of the 1st category of health condition can be reliably distinguished from the trees of other categories of health condition. A total score of "0" for all parameters of health condition (defoliation, dieback, and epicormic shoots occurrence) reliably points the healthy tree. The trees can be assigned to the 1st category of health condition with defoliation, caused by insects, up to 50 %, with up to 10 % dry branches and single epicormic shoots. Multiple epicormic shoots are characteristic for the trees of the 3rd category of health condition. Ambiguous results in distinguishing of European ash trees of the 2nd and the 3rd, the 3rd and the 4th categories of health condition confirm the need for improvement of its assessment and annual monitoring the forest health at key plots.
Key words: *Fraxinus excelsior*, health condition, defoliation, dieback, epicormic shoots occurrence.

Introduction. European ash (*Fraxinus excelsior* L.) is one of the most spread tree species in broadleaved forests of the Left-bank Forest-Steppe of Ukraine (Borysova 2016, Davydenko & Meshkova 2014, 2017).

In recent years the health condition of European ash worsens in many European countries, which is often connected with invasive fungus *Hymenoscyphus fraxineus* (Metzler et al. 2012, Cleary et al. 2017). Apart from this disease, which spread is proved for Ukraine too (Davydenko et al. 2013), many other causes of European ash decline have been reported, particularly wood decay fungi (Matsiakh & Kramarets 2014), bacterial cancer (Goychuk & Kulbanska 2014), foliage browsing (Meshkova et al. 2017) and xylophagous insects (Davydenko & Meshkova 2017).

In previous years in permanent sampling plots in Kharkiv region eight types of damage were revealed in inspected European ash stands: frost cracks, mechanical damage of stems, epicormic shoots, branch dieback, symptoms of bacterial disease and butt rot, signs of wood destroying fungi and insect feeding. Their occurrence in different forest site conditions and depending on stand age was evaluated (Meshkova & Borysova 2017a, 2017b). However, the relations of particular symptoms of ash health worsening with health condition index were not studied.

Our previous research of European ash trees in Kharkiv region show, that the categories of health condition do not always objectively describe the real health condition of deciduous trees. Particularly European ash is classified as a healthy tree by crown appearance and to have stem rot inside the stem, which is not visible at the absence of fruiting bodies. In other cases, European ash trees have a high proportion of dry branches and are classified as severely weakened or drying up trees, and at the same time, they develop the secondary crown due to epicormic shoots in stems and branches. Defoliation caused by foliage browsing insects can be seen in June and be the cause of tree classification as severely weakened or even drying up. However, after two months the same tree can recover the crown and be classified as healthy or weakened.

In 2018, the similar research was carried out in the State Enterprise "Trostyanets Forest Economy", which is located in the southern part of Sumy region and in the northern part of the Left-bank Forest-Steppe of Ukraine.

Forest inventory data analysis show that an area of European ash stands for 2008–2018 increased in this forest enterprise more than twice (from 892.6 hectares to 2,035.1 hectares, and its proportion in all forested area increased from 4.4 to 10 %).

The aim of the research was to evaluate the different symptoms of European ash health condition and their relations in the forest-steppe part of Sumy region.

Materials and Methods. Survey of 62 forest plots with European ash participation was carried out in 2018 in Neskuchanske, Lytovske, Makivske and Krasnyanske forestries of the State Enterprise "Trostyanets Forest Economy" (SE "Trostyanets FE") (Table 1).

Table 1

Plot and European ash tree numbers assessed in different forestries of the SE "Trostyanets FE"

Parameter	Krasnyanske	Lytovske	Makivske	Neskuchanske	Total
Number of plots sampled	19	15	8	20	62
Total number of ash trees assessed	513	409	34	573	1529
Mean number of ash trees per plot*±SE	27.0 ± 1.05a (11–33)	27.3 ± 3.56a (1–43)	4.3 ± 1.45b (1–10)	28.7 ± 2.07a (19–61)	24.7 ± 1.51a (1–61)
Proportion of ash trees per plot, %*±SE	54.4 ± 3.17a (32,1–80,0)	46.0 ± 6.01a (3,1–81,8)	10.6 ± 3.73b (2,0–29,4)	51.2 ± 3.19a (27,4–83,7)	45.7 ± 2.70a (2,0–83,7)
Mean tree diameter, cm **	35.8 ± 2.19a (13–54)	31.9 ± 4.44a (3–67)	7.6 ± 1.01b (4–13)	34.4 ± 2.06a (16–53)	30.8 ± 1.82a (3–67)

*Means followed by different letters were significantly different at the 95 % confidence level.
** Figures in brackets show the smallest and largest values in each forestry.

The survey covered 1529 trees of European ash of 5–110 years old in the stands with 0.6–0.8 relative density of stocking and 2–8 units of European ash in forest composition.

In each forest plot, 2–4 subplots of 10×10 m were inspected. The number of plots depended on European ash presence. We tried to assess not less than 25 European ash trees per plot but in inspected stands of Makivske forestry, there were rather few ash trees.

Stand age was not uniform in most of the plots because ashes of vegetative origin and seed specimens of different age were presented. Therefore, we considered the diameter at breast height as a more reliable parameter. Mean ash tree diameter was almost similar in all inspected forestries except Makivske one (see Table 2).

Occurrence (incidence) of each type of damage was evaluated as the proportion of trees with respective symptoms or signs.

The severity of each type of damage as well as tree health condition was estimated using respective scores.

Crown defoliation and proportion of dry branches were estimated as a percentage and then converted to points: 0 – absent; 1 point – up to 10 %; 2 points – 11–50 %; 3 points – 51–75 %; 4 points – over 75 %.

The severity of epicormic shoots was estimated by the score: 0 – absent; 1 – single; 2 – multiple; 3 – completely covered stem.

Category of the health condition of European ash was evaluated on a range of visual characteristics (crown density and color, the presence and proportion of dead branches in the crown, etc.) according to "Sanitary rules in the forests of Ukraine" (Sanitary rules 1995). Each tree was referred to one of six categories of health condition (1st – healthy; 2nd – weakened; 3rd – severely weakened; 4th – drying up; 5th – recently died; 6th – died over a year ago). Health condition index (HCI) for forest stand was calculated as mean weighted from trees number of each category of health condition.

The statistical analyses were carried out using software MS Excel, particularly for descriptive statistics, analysis of variance (ANOVA) as well as a correlation between particular parameters of tree health condition (Atramentova & Utevskaya 2008).

Results and Discussion. According to the "Sanitary rules in the forests of Ukraine", the European ash stands in the SE "Trostyanetske FE" are weakened (Fig. 1). Health condition index of European ash stands, considering all trees (living and dead ones), was 2 points for the whole forest enterprise and for Neskuchanske forestry. It was the highest (2.2 points) for Lytovske forestry and the lowest (1.2 points) for Makivske forestry with the youngest ash stands. Forest health index for living trees was a bit smaller than for all trees in the forestries with European ash mortality. As mortality rate of European ash trees was rather low, therefore forest health index for all trees and for

living trees differed slightly, except Krasnyanske forestry, where ash mortality was 4.3 % (0.8 % and 3.5 % of recently died trees and the trees died over a year ago) (Fig. 2).
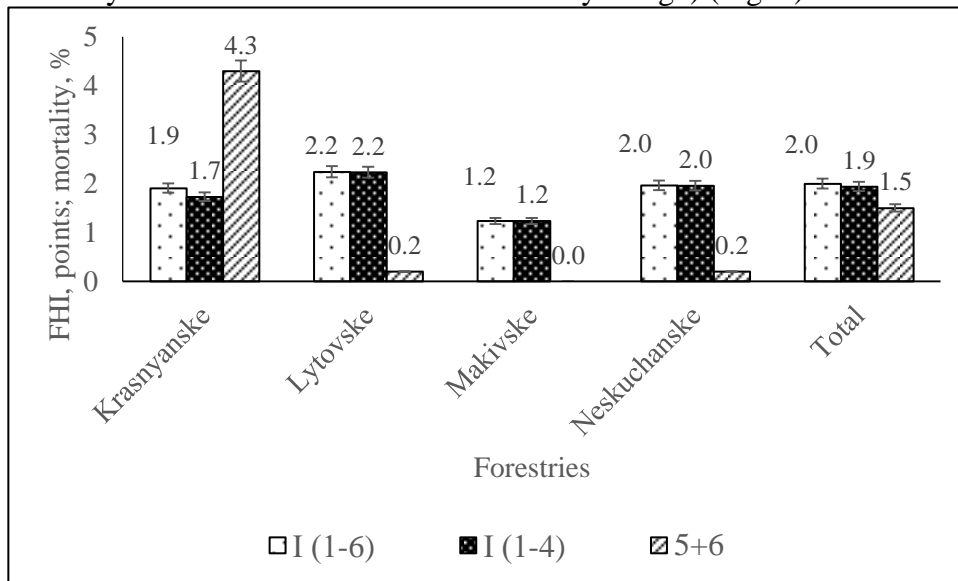

Fig. 1 – Forest health index (FHI) for all European ash trees I$_{1-6}$, living European ash trees I$_{1-4}$ and sum of European ash trees of the 5th and 6th categories of health condition in different forestries of SE "Trostyanetske FE"

The highest proportion of healthy European ash trees were inspected in Makivske and Krasnyanske forestries (85.3 % and 50.1 % respectively). The number of trees of the 2nd and 3rd categories of health condition was rather low as well as the total number of ash trees in inspected plots of Makivske forestry (see Table 1).

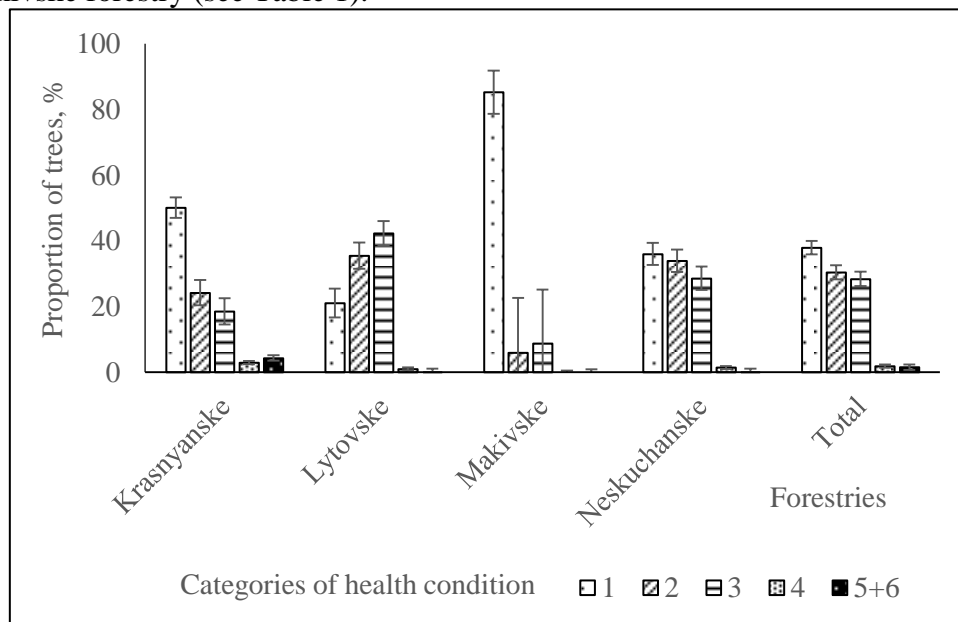**Fig. 2 – Distribution of European ash trees by health condition categories (1–6) in different forestries of SE "Trostyanetske FE" (data on trees of 5th and 6th health condition are pooled)**

In Krasnyanske and Neskuchanske forestries the proportion of European ash trees decreased with an increase of forest health category, however, in Lytovske forestry such proportion increased from 21 % of healthy trees to 42.3 % of severely weakened trees (see Fig. 2).

Our analysis shows that ash defoliation has a trend to increase with the category of health condition (Fig. 3). However, different defoliation may be found for each category of health condition.
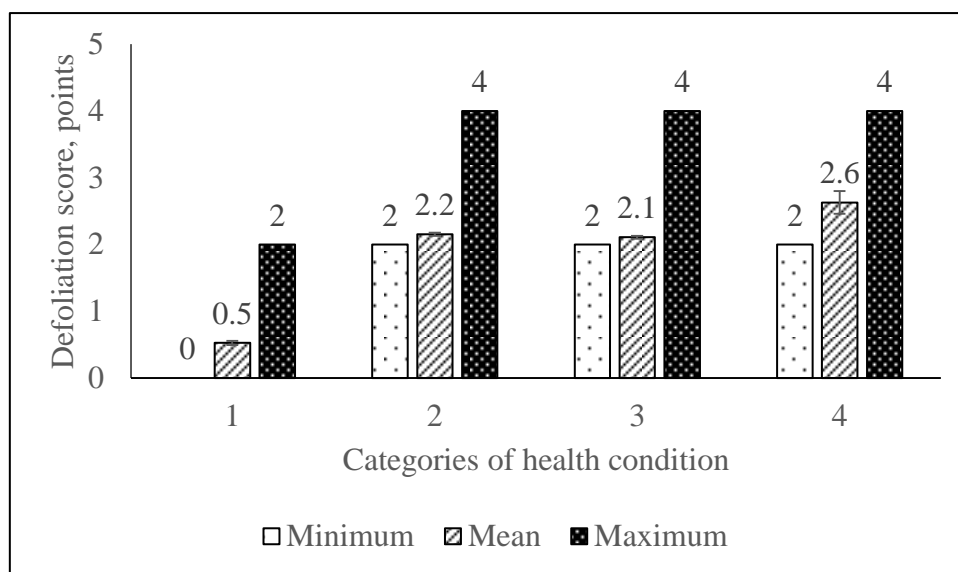
Fig. 3 – Defoliation level for European ash of different categories of health condition
(0 – absent; 1 point – up to 10 %; 2 points – 11–50 %; 3 points – 51–75 %; 4 points – over 75 %)

A significant difference was revealed between defoliation score for the ash trees of the 1st category of health condition on the one side and the trees of the 2nd, 3rd or 4th category of health condition on another side ($p < 0.001$). At the same time, the difference of defoliation score between the ash trees of the 2nd category of health condition on the one side and the trees of the 3rd category of health condition on another side was not significant ($p > 0.1$). Such difference between ash trees of 2nd and 4th or between 3rd and 4th health condition categories was significant only at $p < 0.01$.

The score of ash dieback has a trend to increase with the category of health condition (Fig. 4). However, different dieback scores may be found for each category of health condition.
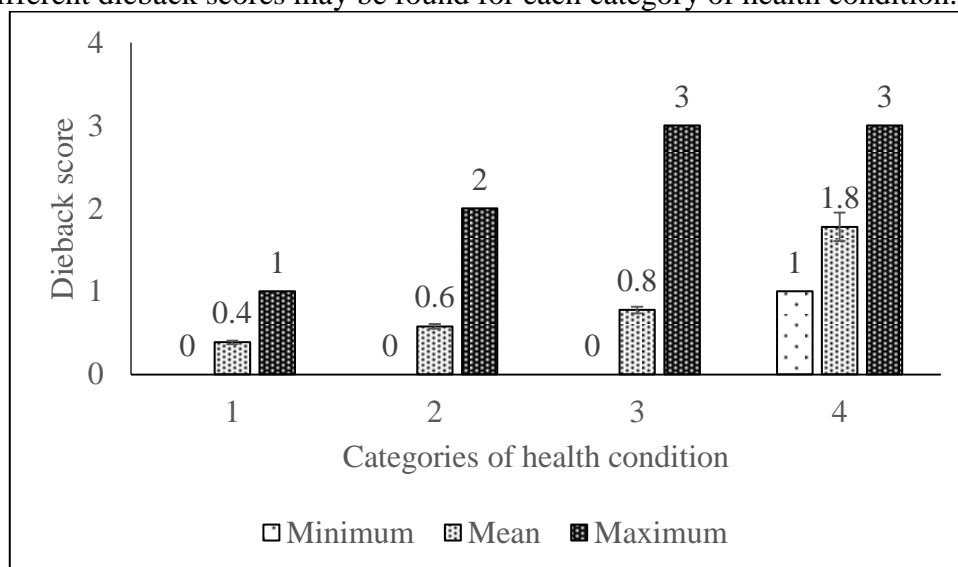

Fig. 4 – Dieback level for European ash of different categories of health condition
(0 – absent; 1 point – up to 10 %; 2 points – 11–50 %; 3 points – 51–75 %; 4 points – over 75 %)

A significant difference was observed between dieback score for the ash trees of the 1st category of health condition on the one side and the trees of the 2nd–4th categories of health condition on another side, as well as between each other pair of categories ($p < 0.001$). At the same time, ash trees with 0–1 dieback score were found for each category of health condition, with 0–2 dieback score for 2nd–4th categories, and with 2–3 dieback score for 3rd–4th categories of health condition (see Fig. 4).

In our research, the epicormic shoots' occurrence takes the values "0" and "1" for any category of health condition, and the values from "0" to "2" for the 3rd category of health condition (Fig. 5).
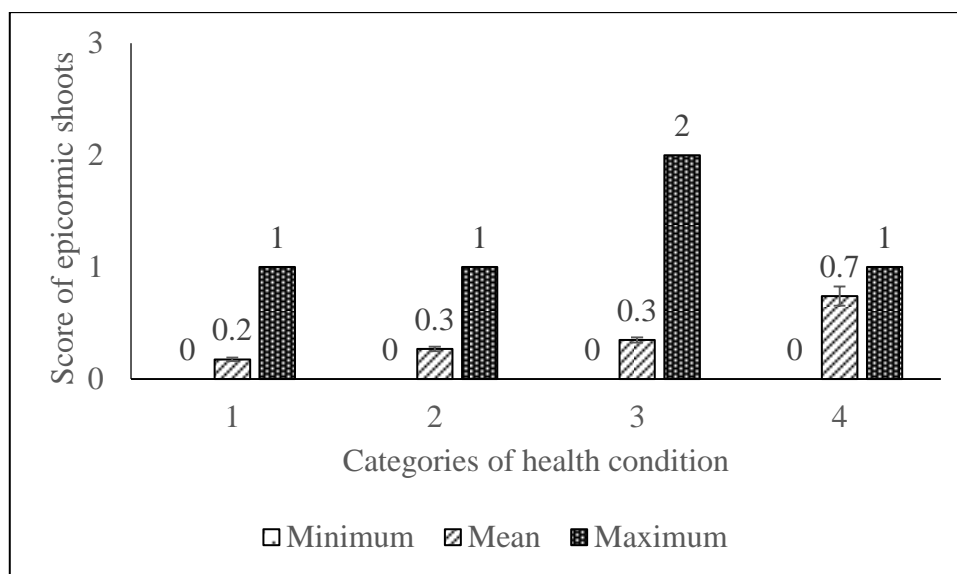

Fig. 5 – Epicormic shoots occurrence for European ash of different categories of health condition
(0 – absent; 1 – single; 2 – multiple; 3 – completely covered stem)

Epicormic shoots development in the ash trees of the 3rd category of health condition is crucial for determining the fate of a tree, which can become "drying up" or recover to "weakened" or "healthy" category.

From the database of field assessment for European ash health condition, the score values of defoliation, dieback and epicormic shoots occurrence were determined for each category of living trees health condition (Table 2).

Table 2

Scoring of European ash health condition by the basic symptoms (points)

Category of health condition	Defoliation score	Dieback score	Epicormic shoots occurrence	Total score range
1st	0; 1; 2	0; 1.	0, 1	0–4
2nd	2, 3, 4	0; 1; 2	0; 1	2–6
3rd	2; 3; 4	0; 1; 2; 3	0; 1; 2	2–7
4th	2; 3; 4	1; 2; 3	0; 1	4–6

It can be seen that the trees of European ash can be assigned to the 1st category of health condition with defoliation score from 0 to 2 points because the tree can recover its foliage after insect damage the current or the next year. Such trees can be healthy with the presence of up to 10 % dry branches and single epicormic shoots. However, the total score of "0" reliably points the healthy tree (see Table 2).

The scores "2"–"4" for defoliation may be characteristic for European ash trees of the 2nd, 3rd and 4th categories of health condition. The scores of dieback can be "0" for the trees of the 1st, 2nd and 3rd categories of health condition. It can be "1" for all health condition of living ash trees, be "2" for the trees of the 2nd, 3rd and 4th categories of health condition, and be "3" for the trees of the 3rd and 4th categories of health condition.

Both the absence of epicormic shoots and single epicormic shoots can be present on the living ash trees of each health condition but multiple epicormic shoots are characteristic mainly for the trees of the 3rd category of health condition. The tree which is not able to recover by forming secondary crown has a trend to become drying up and then die.

Therefore, 82 combinations of scores are possible for defoliation, dieback and epicormic shoots occurrence: 10 combinations for the 1st category, 18 for the 2nd and the 4th categories and 36 for the 3rd category of health condition. Any combination with the total score "0" or "1" is characteristic only for the trees of the 1st category as well as total score "2" with "0" for any one parameter. At the same time total score "2" with "2" points for defoliation and "0" points for other parameters is characteristic only for the trees of the 2nd category of health condition.

The total score "5" or "6" is characteristic for the trees of the 2nd, 3rd and 4th categories of health condition, and the total score "7" only for the trees of the 3rd category of health condition.

Total score distribution of European ash health condition calculated for inspected plots of SE "Trostyanets FE" shows the largest mean and mode values for Krasnyanske forestry and the lowest values for Makivske forestry (Table 3). However, some trees in all forestries were rated by the total score "4" points, in all forestries, except Makivske, the total score exceeded "4" points, and in Krasnyanske forestry several trees were rated even "7" points.

Table 3

Total score range of European ash health condition in different forestries of the SE "Trostyanets FE"

Total score	Krasnyanske	Lytovske	Makivske	Neskuchanske	Total
0	2.2	20.1	85.3	29.9	19.5
1	7.6	1.0	0.0	5.4	4.8
2	21.4	29.9	8.8	30.1	26.7
3	30.8	37.3	2.9	21.3	28.3
4	20.2	9.6	2.9	8.6	12.5
5	11.4	1.7	0.0	3.7	5.6
6	4.5	0.5	0.0	1.0	2.0
7	1.8	0.0	0.0	0.0	0.6
Score statistics:					
Minimum	0	0	0	0	0
Mean	3.2 ± 0.06	2.2 ± 0.07	0.4 ± 0.17	1.9 ± 0.06	2.4 ± 0.04
Maximum	7	6	4	6	7
Mode	3	3	0	2	3
Number of living trees	490	408	34	572	1504

Such ambiguous results confirm the need for a differentiated assessment of European ash health condition and annual monitoring at key plots.

Conclusions. Average health condition index of inspected European ash stands is 2 points. It is the highest (2.2 points) for Lytovske forestry and the lowest (1.2 points) for Makivske forestry. European ash mortality was the highest in Krasnyanske forestry (4,3 %). The highest proportion of healthy European ash trees were inspected in Makivske and Krasnyanske forestries (85.3 % and 50.1 %, respectively).

The trees of European ash of the 1st category of health condition can be reliably distinguished from the trees of other categories of health condition. The total score of "0" for all parameters of health condition reliably points the healthy tree. The trees of European ash can be assigned to the 1st category of health condition with defoliation, caused by insects, up to 50 %, with up to 10 % dry branches and single epicormic shoots. Multiple epicormic shoots and the total score "7" are characteristic for the trees of the 3rd category of health condition.

Ambiguous results in distinguishing of European ash trees of the 2nd and the 3rd, the 3rd and the 4th categories of health condition confirm the need for improvement of its assessment and annual monitoring the forest health at key plots. Further research should be aimed at assessing changes in the viability and productivity of stands, as well as timber quality at certain combinations of parameters of the current health condition.

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САНІТАРНИЙ СТАН ЯСЕНА ЗВИЧАЙНОГО У ЛІСОСТЕПОВІЙ ЧАСТИНІ СУМСЬКОЇ ОБЛАСТІ

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Середній індекс санітарного стану ясена звичайного (*Fraxinus excelsior* L.) в обстежених насадженнях Державного підприємства «Тростянецьке лісове господарство» становить 2 бала. Відпад дерев ясена звичайного є найбільшим у Краснянському лісництві (0,8 та 3,5 % свіжого та старого сухостою відповідно). Найбільшу частку здорових дерев ясена звичайного виявлено у Маківському та Краснянському лісництвах (85,3 % та 50,1 % відповідно). Дерева ясена звичайного I категорії санітарного стану можливо надійно відрізнити від дерев інших категорій санітарного стану. Сумарний бал «0» за всіма параметрами стану (дефоліація, відмирання гілок і наявність водяних пагонів) надійно вказує на здорове дерево. Дерево може характеризуватися I категорією санітарного стану за наявності спричиненої комахами дефоліації до 50 %, відмирання до 10 % гілок і наявності поодиноких водяних пагонів. Наявність численних водяних пагонів характерна для дерев III категорії санітарного стану. Неоднозначні результати у розрізненні дерев ясена звичайного II і III, III та IV категорій санітарного стану підтверджують необхідність удосконалення методів його оцінювання та щорічного моніторингу стану насаджень на ключових ділянках.

К л ю ч о в і   с л о в а : *Fraxinus excelsior*, санітарний стан, дефоліація, відмирання гілок, наявність водяних пагонів.

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САНИТАРНОЕ СОСТОЯНИЕ ЯСЕНЯ ОБЫКНОВЕННОГО В ЛЕСОСТЕПНОЙ ЧАСТИ СУМСКОЙ ОБЛАСТИ

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Средний индекс санитарного состояния ясеня обыкновенного (*Fraxinus excelsior* L.) в обследованных насаждениях Государственного предприятия «Тростянецкое лесное хозяйство» составляет 2 балла. Наибольший отпад деревьев ясеня обыкновенного отмечается в Краснянском лесничестве (0,8 и 3,5 % свежего и старого сухостоя соответственно). Наибольшая доля здоровых деревьев ясеня обыкновенного обнаружена в Маковском и Краснянском лесничествах (85,3 и 50,1 % соответственно). Деревья ясеня обыкновенного I категории санитарного состояния возможно надежно отличить от деревьев других категорий санитарного состояния. Суммарный балл «0» по всем параметрам состояния (дефолиации, отмирания ветвей и наличия водяных побегов) надежно указывает на здоровое дерево. Дерево может характеризоваться I категорией санитарного состояния при наличии вызванной насекомыми дефолиации до 50 %, отмирания до 10 % ветвей и единичных водяных побегов. Наличие многочисленных водяных побегов характерно для деревьев III категории санитарного состояния. Неоднозначные результаты при различении деревьев ясеня обыкновенного II и III, III и IV категорий санитарного состояния подтверждают необходимость усовершенствования методов его оценки и ежегодного мониторинга состояния насаждений на ключевых участках.

К л ю ч е в ы е   с л о в а: *Fraxinus excelsior*, санитарное состояние, дефолиация, отмирание ветвей, наличие водяных побегов.