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Parameters of *Pinus sylvestris* health condition and *Ips acuminatus* population in pure and mixed stands of Sumy region

V. L. Meshkova[1], I. O. Bobrov[2]

Outbreaks of bark beetles have increased in recent years in various regions. Pine engraver beetle (Ips acuminatus (Gyllenhal, 1827); Coleoptera: Curculionidae: Scolytinae) is most common in the pine forests of many European countries. Research on its biology and spread carried out in different natural conditions, phases of pest outbreak and considered various parameters to characterize the population of the pest and forest health condition.

The aim of the research was to compare the health condition of Scots pine stands and population parameters of I. acuminatus in its two generations in pure and mixed stands in Polissya and Forest-steppe parts of Sumy region. Research was carried out in 2017 in the pure Scots pine stands and mixed stands with Scots pine and other forest species in Polissya (State Enterprise «Seredyno-Budsky Agroforest Economy»; State Enterprise «Seredyno-Budsky Forest Economy») and Forest-steppe parts (State Enterprise «Velykopysarivske Agroforest Economy»; State Enterprise «Okhtyrske Forest Economy») of Sumy region at 26 sample plots. In sample plots, parameters of forest health condition and bark beetle population were assessed in June and in September, after completion of development of spring and summer generation of I. acuminatus.

By most of the parameters assessed, significant differences between sample plots in Forest-Steppe and Polissya parts of Sumy region were not found. In pure Scots pine stands the mean area of bark beetles' foci and bark beetles' production were larger in Forest-steppe in June, and the density of Ips acuminatus nuptial chambers in June and September.

In pure Scots pine stands the area of I. acuminatus focus, the number of colonized trees, the proportion of recently died trees, health condition indices, the density of egg galleries and nuptial chambers as well as young beetle's production increased from June to September. In mixed stands the focus area, the number of colonized trees and health condition index increased insignificantly, and population parameters of I. acuminatus decreased from June to September. Pure Scots pine stands changed the health condition from «severely weakened» to «drying up» in three months, and mixed ones remained in the «weakened» category.

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In pure pine stands, the density of egg galleries and beetles of the young generation increased for three months from the lower limit of a moderate level to a high level, the density of nuptial chambers – from low to a high level. In mixed stands, all population parameters of I. acuminatus correspond to a low population level. The parameters characterizing the investigated foci of I. acuminatus in the Sumy region significantly correlated with the participation of pine in the stand composition, and in September the correlation is closer than in June. The data obtained indicate the feasibility of creating predominantly mixed pine stands.

***Key words**: bark beetle; outbreak; health condition index; tree mortality; egg galleries; nuptial chambers; young beetle's production.*

Introduction. Outbreaks of bark beetles have increased in recent years in various regions (Wermelinger, Rigling, Schneider, & Dobbertin, 2008; Siitonen, 2014; Andreieva, Guzii, & Vyshnevskyi, 2018; Meshkova, 2019), which is explained by climate change (Andreieva, & Goychuk, 2018; Andreieva, Korma, Zhytova, Martynchuk, & Vyshnevskyi, 2020) and anthropogenic impacts (Björkman, Bylund, Nilsson, Nordlander, & Schroeder, 2015; Foit, 2015; Shvidenko, Buksha, Krakovska, & Lakyda, 2017; Meshkova, Borysenko, & Pryhornytskyi, 2018; Jaime et al., 2019). Pine engraver beetle (*Ips acuminatus* (Gyllenhal, 1827); Coleoptera: Curculionidae: Scolytinae) is most common in the pine forests of many European countries (Colombari et al., 2012, 2013; Andreieva, Vyshnevskyi, & Boliukh, 2019). Its harmfulness increases due to its possibility of vectoring ophiostomatoid fungi to Scots pine trees (Davydenko, Vasaitis, & Menkis, 2017; Davydenko, 2019).

Recently, much research has been published on the biological characteristics of the pine engraver beetle and its distribution in forest stands (Colombari et al., 2012, 2013; Siitonen, 2014; Meshkova, Borysenko, & Pryhornytskyi, 2018; Meshkova, Kochetova, Zinchenko, & Skrylnik, 2017, Andreieva, Guzii, & Vyshnevskyi, 2018; Andreieva, Vyshnevskyi, & Boliukh, 2019).

Pine engraver beetle is found to inhabit trees and forest residues of pine at the beginning of the growing season – in April, but in a few weeks, the females again lay eggs from which the sister brood develops (Colombari et al., 2012). Due to the ability of the pine engraver beetle to hibernate as larvae and imago, under the bark and in the forest litter, to develop in several generations a year, including sister broodi, tree colonization occurs throughout whole summer (Meshkova, Kochetova, Zinchenko, & Skrylnik, 2017). Infested trees have been dying for several weeks (Meshkova, 2019). External signs of tree colonization by pine engraver beetle are the change in the color shade of needles and the presence within the projection of crowns of fallen twigs and branches with the galleries of this pest (Colombari et al., 2012). The study of the spatial dynamics of the foci of pine engraver beetle revealed that they are formed from a well-lighted forest wall, clear-cuts or other plots where there has been intensive forest thinning or removal (Andreieva, Guzii, & Vyshnevskyi, 2018; Meshkova, Borysenko, & Pryhornytskyi, 2018).

However, each researcher carried out his studies in certain natural conditions, in different phases of pest outbreak and considered various parameters to characterize the population of the pest and forest health condition. We assumed, that decline of Scots pine caused by pine engraver beetle depends on the natural zone and forest stand structure, particularly its tree composition, and the population parameters of this pest vary in different generations of the same pest at the same year.

Objects and methods. *Object of research* – forest health condition and *Ips acuminatus* population parameters. *Subject of research* – parameters of Scots pine (*Pinus sylvestris* L.) health condition and *Ips acuminatus* population in pure and mixed stands.

The aim of the research was to compare the health condition of Scots pine stands and population parameters of *Ips acuminatus* in its two generations in pure and mixed stands in Polissya and Forest-steppe parts of Sumy region.

Research was carried out in 2017 in the pure Scots pine stands and mixed stands with Scots pine and other forest species in Polissya (State Enterprise «Seredyno-Budsky Agroforest Economy»; State Enterprise «Seredyno-Budsky Forest Economy») and Forest-steppe parts (State Enterprise «Velykopysarivske Agroforest Economy»; State Enterprise «Okhtyrske Forest Economy») of Sumy region at 26 sample plots (Tab. 1).

Fresh poor forest site conditions (A_2) and fresh relatively poor forest site conditions (B_2) were presented in sample plots. In fresh poor forest site conditions mainly Scots pine is presented with single silver birch (*Betula pendula* Roth.) trees. In fresh relatively poor forest site conditions from 7 to 10 units of Scots pine were mixed with silver birch, English oak (*Quercus robur* L.) and Northern Red oak (*Quercus rubra* L.).

The age of stands in sample plots was from 40 to 65 years old (see Tab. 1).

Two groups of parameters were analyzed in sample plots. The first group described the health condition of the forest stand, and the second group characterized the bark beetle population. Taking into account the fact that pure pine stands are represented in all sample plots with fresh poor forest site conditions (A_2), and mixed stands in all sample plots with fresh relatively poor forest site conditions (B_2), all the results of comparing the parameters stand health condition and the bark beetle population in the groups of sample plots A_2 and B_2 correspond to a comparison of pure and mixed forests.

Table 1

Characteristics of sample plots in the bark beetles' foci in Sumy region

Sample plot (SP)	Forest plot	Subcompartment	Area, ha	Age, years	Species composition*	Forest site conditions**
State Enterprise «Seredyno-Budsky Agroforest Economy» (Polissya)						
1	92	15	12.5	42	10 Pinsyl	A_2
2	15	2	14.7	54	10 Pinsyl + Betpen	A_2
3	18	1	3.5	44	10 Pinsyl	A_2
4	75	37	9.8	60	10 Pinsyl	B_2
5	84	12	10.7	62	9 Pinsyl 1Betpen	B_2
6	110	12	6.3	54	10 Pinsyl + Betpen	B_2
State Enterprise «Seredyno-Budsky Forest Economy» (Polissya)						
7	43	10	11.9	43	8 Pinsyl 2Betpen	B_2
8	5	14	7.5	51	7 Pinsyl 3Betpen	B_2
9	12	4	17.9	54	8 Pinsyl 2Betpen	B_2
10	72	19	10.4	56	10 Pinsyl	A_2
11	85	27	13.7	45	10 Pinsyl	A_2
12	92	13	18.4	61	10 Pinsyl	A_2
13	94	20	3.7	65	10 Pinsyl	A_2
State Enterprise «Velykopysarivske Agroforest Economy» (Forest-steppe)						
14	2	4	10.7	56	10 Pinsyl	A_2
15	7	12	17.3	55	10 Pinsyl	A_2
16	10	15	8.4	47	10 Pinsyl	A_2
17	10	18	6.7	62	10 Pinsyl	A_2
18	12	8	15.9	51	7 Pinsyl 3 Betpen	B_2
19	12	18	10.4	56	8 Pinsyl 2 Betpen	B_2
20	24	2	18.3	44	9 Pinsyl 1 Betpen	B_2
State Enterprise «Okhtyrske Forest Economy» (Forest-steppe)						
21	124	13	20.5	53	10 Pinsyl	A_2
22	50	3	4.7	62	10 Pinsyl	A_2
23	50	42	5.8	62	10 Pinsyl + Betpen	A_2
24	43	14	6.9	54	8 Pinsyl 1 Betpen 1 Querob	B_2
25	58	24	11.4	67	7 Pinsyl 2 Querob 1 Betpen	B_2
26	62	74	10.1	63	7 Pinsyl 2 Betpen 1 Querub	B_2

Notes: *Pinsyl – *Pinus sylvestris;* Querob – *Quercus robur;* Querub – *Quercus rubra*; Betpen – *Betula pendula;* ** B_2 – fresh relatively poor forest type condition; C_2 – fresh relatively fertile forest type condition; D_2 – fresh fertile forest type condition (classes by Alekseev-Pogrebnyak).

All parameters were assessed twice – in June and in September, after completion of the development of spring and summer generation of *Ips acuminatus*.

Average focus area was evaluated in each subcompartment with a sample plot by stand inspection (Mozolevskaya, Kataev, & Sokolova, 1984). The proportion of trees colonized by *Ips acuminatus* as well as the health condition of trees were evaluated only for Scots pine trees in all sample plots. Category of health condition for each tree was evaluated on a range of visual characteristics according to «Sanitary rules in the forests of Ukraine» (Anonimous, 1995) by the following classes: 1st – healthy; 2nd – weakened; 3rd – severely weakened; 4th – drying up; 5th – recently died; 6th – died over a year ago. Health condition index (HCI) was calculated as mean weighted from trees number of each category of health condition, separately for all living and dead trees (HCI_{1-6}) and for living trees only (HCI_{1-4}).

The number of egg galleries, nuptial chambers, and young beetles was evaluated in model branch sections (with diameter 0.5-2.6 cm and length 10-

15 cm, 7–10 branches per sample plot) and recalculated on 1 dm^2.

Summary statistics, one-way analysis of variance (ANOVA) and correlation analysis (Atramentova & Utevskaya, 2008) were performed using Microsoft Excel applications.

Results and discussion. The analysis shows a significant difference by the mean area of bark beetles' foci in pure and mixed stands both in Polissya and Forest-steppe parts of Sumy region (Fig. 1).

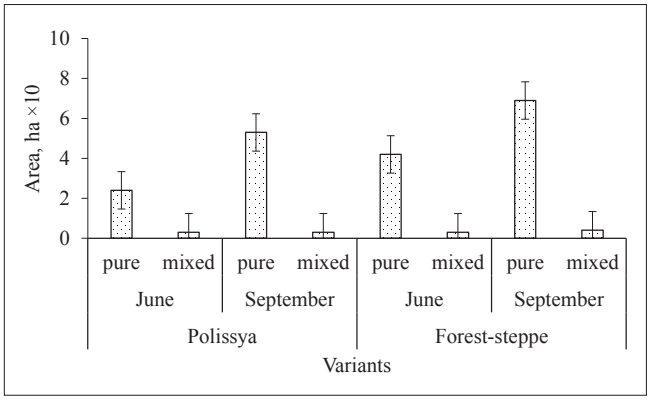

Fig.1. Area of bark beetles' foci in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

The mean area of bark beetles' foci was significantly higher in the Forest-Steppe than in Polissya part of Sumy region in June in pure pine stands in 1.8 times ($F_{fact.}$=4.1; $F_{0.05}$=4.6; p=0.1) and insignificantly in mixed stands 1 ($F_{fact.}$=0.2; $F_{0.05}$=5.3; p=0.7), in September – insignificantly both in pure and mixed stands ($F_{fact.}$=2.1; $F_{0.05}$=4.6; p=0.5 and $F_{fact.}$=0.1; $F_{0.05}$=5.3; p=0.7 respectively).

In the Polissya part of Sumy region, the mean area of bark beetles' foci in pure pine stands was significantly larger than in mixed ones. In June it was 8 times larger ($F_{fact.}$=4.72; $F_{0.05}$=4.70; p=0.05), and in September – 17.7 times larger ($F_{fact.}$=14.0; $F_{0.05}$=4.8; p=0.003). In the Forest-steppe part of Sumy region in June the mean area of bark beetles' foci in pure pine stands was also significantly larger than in mixed ones. In June it was 14 times larger than in mixed ones ($F_{fact.}$=31; $F_{0.05}$=4.8; p<0.001), and in September – 17.3 times larger ($F_{fact.}$=180.6; $F_{0.05}$=4.8; p=<0.001).

In the Polissya part of Sumy region the mean foci area increased in September compared to June in 2.2 times in the pure pine stands ($F_{fact.}$=7.5; $F_{0.05}$=4.5; p=<0.01) and did not increase in the mixed stands ($F_{fact.}$=0.04; $F_{0.05}$=5.99; p=0.85). In the Forest-steppe part of Sumy region the mean foci area increased in September compared to June in 1.6 times in the pure pine stands ($F_{fact.}$=12.5; $F_{0.05}$=4.7; p=0.004) and increased insignificantly in the mixed stands ($F_{fact.}$=0.01; $F_{0.05}$=4.96; p=0.94).

At the time of June assessment, the trees of the 5th and 6th categories of health condition were available in all sample plots. Proportion of trees which have died over a year ago (the 6th category of health condition) could not change during the season, so the comparison of its share was made only according to the assessment made in June (Fig. 2).

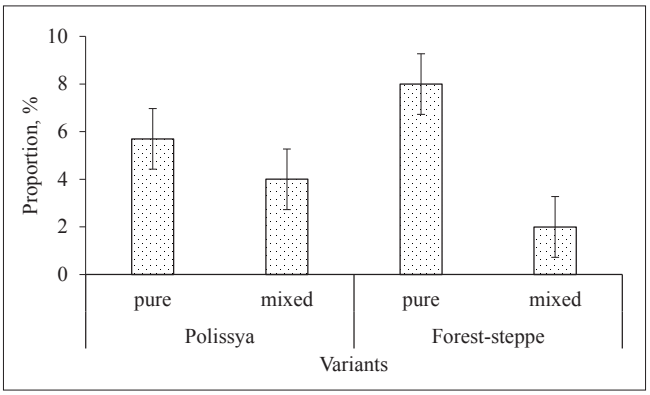

Fig. 2. Proportion of Scots pine trees of the 6th category of health condition in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in June

Proportion of the trees of the 6th category of health condition in June was insignificantly larger in pure pine stands than in mixed ones in Polissya ($F_{fact.}$=0.7; $F_{0.05}$=4.8; p=0.4) and significantly 4 times larger in the Forest-steppe part of Sumy region ($F_{fact.}$=11; $F_{0.05}$=4.8; p=0.01). The differences in this parameter between Polissya and Forest-steppe parts of Sumy region were insignificant both for pure ($F_{fact.}$=0.5; $F_{0.05}$=4.6; p=0.2) and mixed stands ($F_{fact.}$=2.3; $F_{0.05}$=5.3; p=0.2).

Recently died Scots pine trees (the 5th category of health condition) were found in June in all sample plots in the pure Scots pine stands and in 90 % sample plots in mixed stands (Fig. 3). Assessment in September shows an increase the proportion of the trees of the 5th category of health condition compared to June at all sample plots in pure Scots pine stands and in about half of sample plots in mixed stands.

In Polissya part of Sumy region the difference between the proportion of the trees of the 5th category of health condition was significantly (in 3.3 times) larger in pure Scots pine stands than in mixed stands in June ($F_{fact.}$=5.5; $F_{0.05}$=4.7; p=0.04) and in September ($F_{fact.}$=9.5; $F_{0.05}$=4.7; p=0.01). In Forest-steppe part of Sumy region the difference between pure and mixed stands was insignificant in June ($F_{fact.}$=3.7; $F_{0.05}$=4.8; p=0.1) and significant (in 7.4 times) in September ($F_{fact.}$=116.7; $F_{0.05}$=4.8; p<0.001).

In Polissya part of Sumy region the proportion of the trees of the 5th category of health condition was significantly larger in September (in 5.7 times) compared to June in pure stands ($F_{fact.}$=27.9; $F_{0.05}$=4.5; p<0.001) and insignificant in mixed stands ($F_{fact.}$=1.2; $F_{0.05}$=5.0; p=0.3). In Forest-steppe part of Sumy region the proportion of the trees of the 5th category of health condition was also significantly larger (in 5.7 times) in September compared to June in pure stands ($F_{fact.}$=107.7; $F_{0.05}$=4.7; p<0.001) and insignificant in mixed stands ($F_{fact.}$=1.8; $F_{0.05}$=5.0; p=0.2). The proportion of recently dead Scots pine trees differed insignificantly between sample plots in Polissya and Forest-steppe part of Sumy region for pure Scots

pine stands in June ($F_{fact.}$=0.2; $F_{0.05}$=4.6; p=0.6) and September ($F_{fact.}$=1.3; $F_{0.05}$=4.6; p=0.3), as well as for mixed stands in June ($F_{fact.}$=0.8; $F_{0.05}$=5.0; p=0.4) and September ($F_{fact.}$=0.3; $F_{0.05}$=5.0; p=0.6).

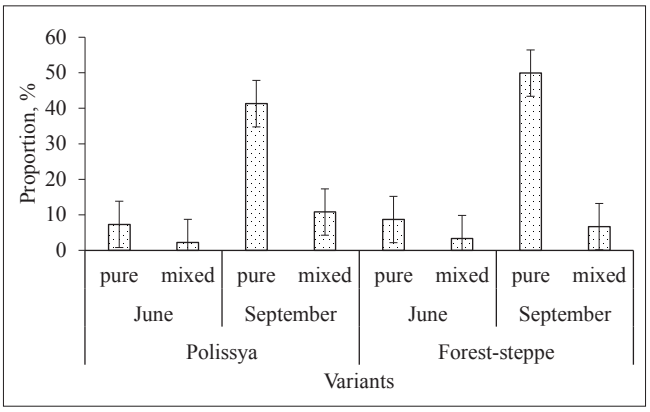

Fig. 3. Proportion of Scots pine trees of the 5th category of health condition in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

Health condition index for all living and dead trees ($HCI_{(1-6)}$) was significantly larger in pure Scots pine stands compared to mixed stands in both natural zones and in both dates of assessment (Fig. 4).

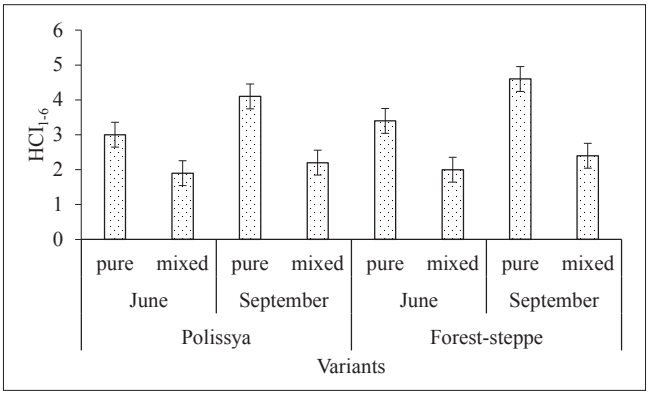

Fig. 4. Health condition index for all living and dead trees (HCI_{1-6}) in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

Such difference of HCI_{1-6} between pure and mixed stands was significant for Polissya part of Sumy region in June ($F_{fact.}$=9.5; $F_{0.05}$=4.8; p=0.01) and September ($F_{fact.}$=20.5; $F_{0.05}$=4.8; p=0.001) as well as for Forest-steppe part of Sumy region in June ($F_{fact.}$=59.9; $F_{0.05}$=4.8; p<0.001) and September ($F_{fact.}$=223.7; $F_{0.05}$=4.8; p<0.001).

The HCI_{1-6} increased significantly in September compared to June in pure ($F_{fact.}$=8.3; $F_{0.05}$=4.5; p<0.01) and insignificantly in mixed stands of Polissya ($F_{fact.}$=4.4; $F_{0.05}$=6.0; p<0.1). However, the difference was significant both in pure ($F_{fact.}$=54.8; $F_{0.05}$=4.7; p<0.001) and mixed stands of Forest-steppe part of Sumy region ($F_{fact.}$=6.1; $F_{0.05}$=5.0; p=0.03).

The difference of HCI_{1-6} between Polissya and Forest-steppe parts of Sumy region was insignificant for pure Scots pine stands in June ($F_{fact.}$=1.6; $F_{0.05}$=4.6; p=0.2) and September ($F_{fact.}$=2.0; $F_{0.05}$=4.6; p=0.2), as well as for mixed stands in June ($F_{fact.}$=0.1; $F_{0.05}$=5.3; p=0.7) and September ($F_{fact.}$=1.6; $F_{0.05}$=5.3; p=0.2).

Health condition index for living trees (HCI_{1-4}) was significantly larger in pure Scots pine stands compared to mixed stands in both natural zones and in both dates of assessment (Fig. 5).

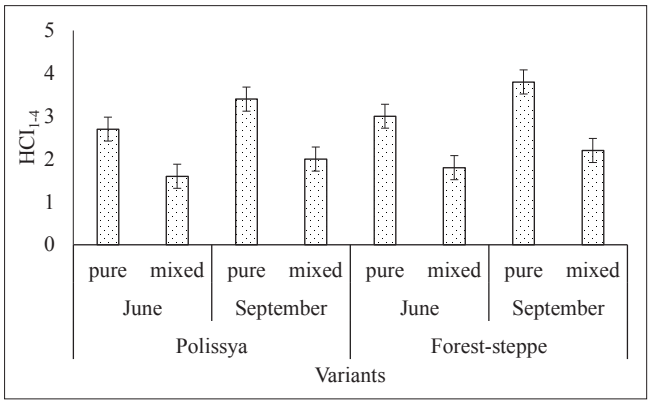

Fig. 5. Health condition index for living trees (HCI_{1-4}) in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

The difference in HCI_{1-4} was significantly larger in pure Scots pine stands compared to mixed stands of Polissya in June ($F_{fact.}$=11.0; $F_{0.05}$=4.8; p=0.01) and September ($F_{fact.}$=13.9; $F_{0.05}$=4.8; p=0.003), as well as of Forest-steppe part of Sumy region in June ($F_{fact.}$=90.7; $F_{0.05}$=4.8; p<0.001) and September ($F_{fact.}$=156.0; $F_{0,05}$=4.8; p<0.002).

The HCI_{1-4} insignificantly increased in September compared to June in pure ($F_{fact.}$=4.3; $F_{0.05}$=4.5; p=0.1) and mixed stands of Polissya part of Sumy region ($F_{fact.}$=4.4; $F_{0.05}$=6.0; p=0.1). However, such an increase of HCI_{1-4} was significant in the Forest-steppe part of Sumy region both for pure ($F_{fact.}$=29.9; $F_{0.05}$=4.7; p<0.001) and mixed stands ($F_{fact.}$=9.8; $F_{0.05}$=5.0; p=0.01).

The difference of HCI_{1-4} between Polissya and Forest-steppe parts of Sumy region was insignificant for pure Scots pine stands in June ($F_{fact.}$=1.4; $F_{0.05}$=4.6; p=0.3) and September ($F_{fact.}$=2.1; $F_{0.05}$=4.6; p=0.2), as well as for mixed stands in June ($F_{fact.}$=0.7; $F_{0.05}$=5.3; p=0.4) and September ($F_{fact.}$=0.8; $F_{0.05}$=5.3; p=0.4).

The number of trees colonized by pine engraver beetle was higher in pure stands compared to mixed ones (Fig. 6).

This difference in Polissya part of Sumy region was 7.8 times in June ($F_{fact.}$=12.3; $F_{0.05}$=4.8; p=0.005) and 5.2 times in September ($F_{fact.}$=12.2; $F_{0.05}$=4.8; p=0.005). In the Forest-steppe part of Sumy region the difference between a number of colonized trees in pure and mixed stands was 4.8 times in June ($F_{fact.}$=13.3; $F_{0.05}$=5.0; p=0.005) and 9.4 times in September ($F_{fact.}$=34.2; $F_{0.05}$=5.0; p=0.00025).

Increase of colonized trees from June to September in Polissya part of Sumy region in pure stands (3.8 times) is significant ($F_{fact.}$=17.4; $F_{0.05}$=4.7; p=0.001),

and in mixed stands (5.8 times) is not significant ($F_{fact.}$=1.0; $F_{0.05}$=5.0; p=03) because an amount of such trees is rather low. In the Forest-steppe part of Sumy region, we see the similar situation: the number of trees increased for three months in 2.6 and 1.3 times in pure and mixed stands respectively ($F_{fact.}$=17.1; $F_{0.05}$=5.0; p=0.002 and $F_{fact.}$=0.1; $F_{0.05}$=5.0; p=0.8), but such increase is insignificant in mixed stands.

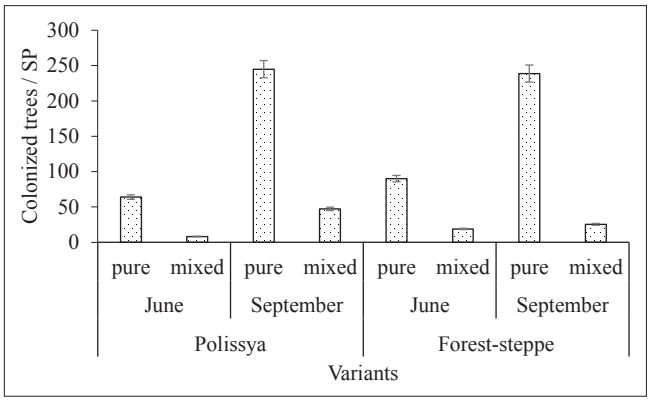

Fig. 6. Number of bark beetle colonized trees in pure and mixed pine stands in Polissya and Forest-steppe parts of Sumy region in different dates of assessment

The differences between sample plots in Polissya and Forest-steppe parts of Sumy region by colonized trees number are insignificant in June ($F_{fact.}$=1.5; $F_{0.05}$=4.8; p=0.3 and $F_{fact.}$=0.9; $F_{0.05}$=5.0; p=0.4 in pure and mixed stands respectively) and in September ($F_{fact.}$=0.01; $F_{0.05}$=4.8; p=0.9 and $F_{fact.}$=0.3; $F_{0.05}$=5.0; p=0.6 in pure and mixed stands respectively).

Mother galleries of pine engraver beetle were found at all sample plots in pure stands and at 20 % sample plots in mixed stands. In the Polissya part of Sumy region in June the density of egg galleries in pure and mixed stands differed insignificantly ($F_{fact.}$=4.3; $F_{0.05}$=4.8; p=0.1), and in September it differed in 18 times which was significant ($F_{fact.}$=15.0; $F_{0.05}$=4.8; p=0.003) (Fig. 7).

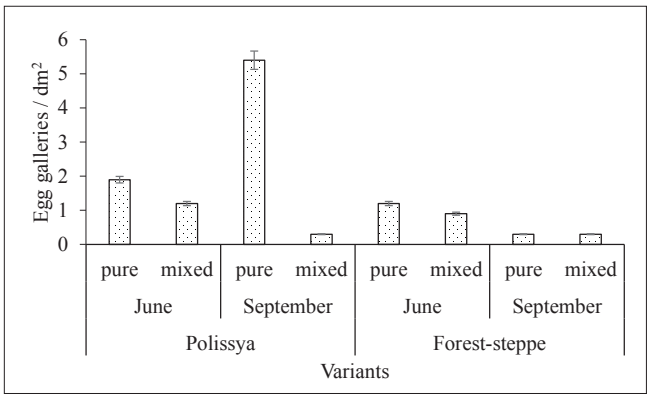

Fig. 7. Density of egg galleries in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

In the Forest-steppe part of Sumy region the density of egg galleries in pure and mixed stands differed significantly both in June ($F_{fact.}$=62.5; $F_{0.05}$=4.8; p<0.001) and in September ($F_{fact.}$=340.4; $F_{0.05}$=4.8; p<0.001).

From June to September the density of egg galleries significantly increased in pure stands of Polissya part of Sumy region ($F_{fact.}$=16.5; $F_{0.05}$=4.5; p<0.001). It significantly decreased mixed stands of Polissya part of Sumy region ($F_{fact.}$=270.0; $F_{0.05}$=4.7; p<0.001), pure ($F_{fact.}$=6.2; $F_{0.05}$=6.0; p=0.05) and mixed stands of Forest-steppe part of Sumy region ($F_{fact.}$=5.7; $F_{0.05}$=5.0; p<0.04).

The differences in density of egg galleries in Polissya and Forest-steppe parts of Sumy region are insignificant in June for pure ($F_{fact.}$=3,1; $F_{0.05}$=4,6; p=0.1) and mixed stands ($F_{fact.}$=1,4; $F_{0.05}$=5.3; p=0.3) and in September for pure ($F_{fact.}$=4,0; $F_{0.05}$=4,6; p=0,07) and mixed stands ($F_{fact.}$=0,03; $F_{0.05}$=5.3; p=0.9).

The density of nuptial chambers of pine engraver beetle in June was almost 5 times more in pure stands compared to mixed ones (Fig. 8). In September this parameter increased in pure stands and decreased in mixed stands.

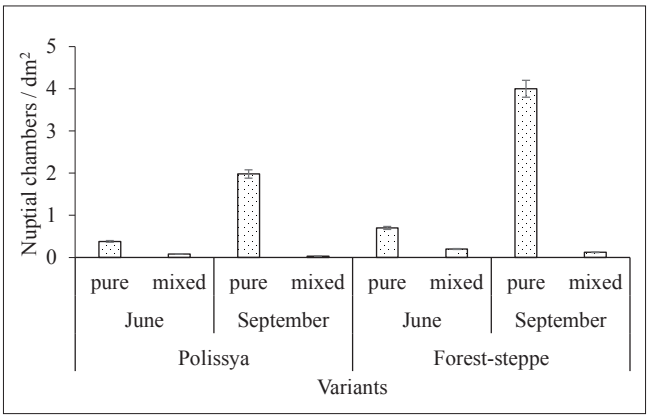

Fig. 8. Density of nuptial chambers in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

In the Polissya part of Sumy region the density of nuptial chambers was significantly larger in pure stands compared to mixed stands in June ($F_{fact.}$=5.9; $F_{0.05}$=4,8; p=0,03) and in September ($F_{fact.}$=9.7; $F_{0.05}$=4,8; p=0,01) – in 4.8 and 66 times in June and September respectively. In the Forest-steppe part of Sumy region the density of nuptial chambers was significantly larger in pure stands compared to mixed stands in June ($F_{fact.}$=28.6; $F_{0.05}$=4,8; p<0,001) and in September ($F_{fact.}$=112.3; $F_{0.05}$=4,8; p<0,001) – in 3.5 and 33.3 times in June and September respectively.

The density of nuptial chambers significantly increased in September compared to June in pure stands of Polissya (in 5.2 times) ($F_{fact.}$=14.9; $F_{0.05}$=4,5; p=0,001) and Forest-Steppe (in 5.7 times) ($F_{fact.}$=98.2; $F_{0,05}$=4.7; p<0.001) and insignificantly decreased in mixed stands of Polissya ($F_{fact.}$=2.4; $F_{0.05}$=6.0; p=0,2) and Forest-Steppe parts of Sumy region ($F_{fact.}$=0.2; $F_{0.05}$=5.0; p=0,7).

In pure stands, the density of nuptial chambers was significantly larger in Forest-steppe compared to Polissya both in June ($F_{fact.}$=7.8; $F_{0.05}$=4.6; p=0,01) and

September ($F_{fact.}$=13.3; $F_{0.05}$=4.6; p=0,003). In mixed stands, the differences between Polissya and Forest-steppe parts of Sumy region were insignificant both in June ($F_{fact.}$=1.9; $F_{0.05}$=5.3; p=0,2) and September ($F_{fact.}$=0.4; $F_{0.05}$=5.3; p=0,6).

The density of young beetles (production) of pine engraver beetle was significantly larger in pure pine stands compared to mixed ones (Fig. 9).

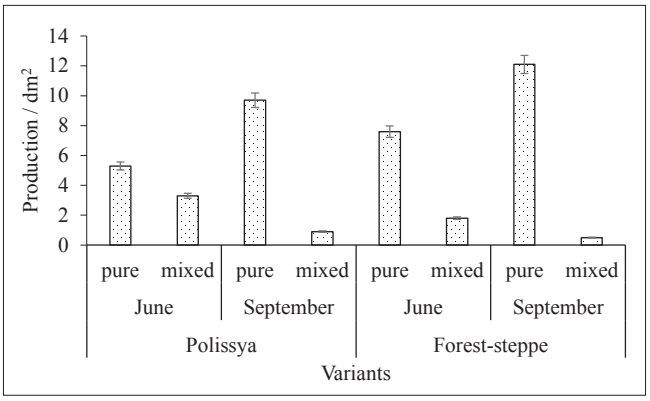

Fig. 9. Production of bark beetles in pure and mixed pine stands in the Polissya and Forest-steppe parts of Sumy region in different dates of assessment

The difference of bark beetles' production in pure and mixed pine stands in the Polissya part of Sumy region was significant in June ($F_{fact.}$=3.1; $F_{0.05}$=4.8; p=0,1) and in September ($F_{fact.}$=16.6; $F_{0.05}$=4.8; p=0,002). In the Forest-steppe part of Sumy region the bark beetles' production was also significantly larger in pure stands in June ($F_{fact.}$=82.1; $F_{0.05}$=4.8; p<0,001) and in September ($F_{fact.}$=206.7; $F_{0.05}$=4.8; p<0,001).

The bark beetles' production increased in 1.8 times from June to September in pure stands ($F_{fact.}$=28.5; $F_{0.05}$=4.7; p<0,001) and decreased 3.7 times in mixed stands ($F_{fact.}$=5.4; $F_{0.05}$=5.0; p=0,04) of Polissya part of Sumy region. In the Forest-steppe part of Sumy region the bark beetles' production increased in 1.6 times from June to September in pure stands ($F_{fact.}$=30.7; $F_{0.05}$=4.7; p<0,001) and decreased 3.6 times in mixed stands ($F_{fact.}$=5.6; $F_{0.05}$=5.0; p=0,04).

The differences on bark beetles' production in pure stands of Polissya and Forest-steppe parts of Sumy region were significant in June ($F_{fact.}$=6.3; $F_{0.05}$=4.6; p=0.03) and insignificant in September ($F_{fact.}$=2.3; $F_{0.05}$=4.6; p=0,2). Such differences in mixed stands were also significant in June ($F_{fact.}$=7.8; $F_{0.05}$=5.3; p=0.02) and insignificant in September ($F_{fact.}$=0.2; $F_{0.05}$=5.3; p=0,6).

Within the age range of Scots pine stands in sample plots (40–65 years old), no dependence of forest condition and bark beetle population parameters was found on the age of stands (r – 0.01-0.18; p>0.1). A significant dependence of foci area, the number of colonized trees, the proportion of recently died trees, HCI_{1-6}, HCI_{1-4}, the density of egg galleries, nuptial chambers, and production from proportion of Scots pine in the stand composition was shown, which was is in September closer than in June (Tab. 2).

Table 2

Correlation of parameters of forest health and *Ips acuminatus* population with Scots pine proportion in Sumy region

Parameters	r		s_r		t*	
	June	September	June	September	June	September
Foci area	0.65	0.8	0.16	0.12	**4.19**	**6.53**
Number of colonized trees	0.6	0.74	0.16	0.14	*3.67*	**5.39**
Proportion of trees of 5 HCI	0.42	0.78	0.19	0.13	2.27	**6.11**
HCI_{1-6}	0.77	0.83	0.13	0.11	**5.91**	**7.29**
HCI_{1-4}	0.81	0.81	0.12	0.12	**6.77**	**6.77**
Density of egg galleries	0.71	0.80	0.14	0.12	**4.94**	**6.53**
Density of nuptial chambers	0.58	0.73	0.17	0.14	*3.49*	**5.23**
Production	0.69	0.81	0.15	0.12	**4.67**	**6.77**

Note: *N = 26; $t_{0.05}$= 2.06; $t_{0.01}$= 2.8 – italic; $t_{0.001}$= 3.75 – bold.

Conclusions. By most of the parameters of *Ips acuminatus* outbreak, significant differences between sample plots in Forest-Steppe and Polissya parts of Sumy region were not found. In pure Scots pine stands the mean area of bark beetles' foci and bark beetles' production were larger in Forest-steppe in June, and the density of *Ips acuminatus* nuptial chambers in June and September.

In pure Scots pine stands the area of *Ips acuminatus* focus, the number of colonized trees, the proportion of recently died trees, health condition indices, the density of egg galleries and nuptial chambers, as well as young beetle's production, increased from June to September. In mixed stands, the focus area, the number of colonized trees and health condition index increased insignificantly, and population parameters of *Ips acuminatus* decreased from June to September. Pure Scots pine stands changed the health condition from «severely weakened» to «drying up» in three months, and mixed ones remained in the «weakened» category.

The abundance of *Ips acuminatus* in pure pine stands by the density of egg galleries and by production (the density of beetles of the young generation) increased for three months from the lower limit of a moderate level to a high level, by the density of nuptial chambers – from low to a high level. In mixed stands, all population parameters of *Ips acuminatus* correspond to a low population level.

The parameters characterizing the investigated foci of *Ips acuminatus* in the Sumy region significantly correlated with the participation of pine in the stand composition, and in September the correlation is closer than in June.

The data obtained indicate the feasibility of creating predominantly mixed pine stands.

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Показники санітарного стану *Pinus sylvestris* та популяцій *Ips acuminatus* у чистих і мішаних насадженнях Сумської області

В.Л. Мєшкова[1], І.О. Бобров[2]

Спалахи масового розмноження короїдів посилилися останнім часом у багатьох регіонах. Верхівковий короїд (*Ips acuminatus* (Gyllenhal, 1827); Coleoptera: Curculionidae: Scolytinae) найбільш поширений у соснових лісах багатьох країн Європи. Дослідження його біології та поширення здійснили у різних природних умовах, фазах спалаху та брали до уваги різні показники для характеристики популяції шкідника і санітарного стану насаджень.

Мета досліджень полягала у порівнянні санітарного стану сосни звичайної та параметрів популяцій верхівкового короїда у двох поколіннях у чистих і мішаних насадженнях поліської та лісостепової частин Сумської області. Дослідження здійснені у 2017 р. на 26 пробних площах, закладених у поліській (ДП «Середино-Будський агролісгосп»; ДП «Середино-Будське лісове господарство») та лісостеповій частинах (ДП «Великописарівський агролісгосп»; ДП «Охтирське лісове господарство») Сумської області. На пробних площах оцінювали показники санітарного стану насаджень і популяцій верхівкового короїда у червні та вересні – після завершення розвитку його весняного і літнього поколінь.

За більшістю оцінених параметрів не виявлено достовірної різниці між пробними площами у поліській і лісостеповій частинах Сумської області. У чистих соснових насадженнях середня площа осередка короїда та його продукція (щільність молодих жуків) були більшими у лісостеповій частині Сумської області у червні, а щільність шлюбних камер – у червні та вересні.

У чистих соснових насадженнях середня площа осередку *I. acuminatus*, кількість заселених дерев, частка свіжого сухостою, індекси санітарного стану сосни, щільність маточних ходів і шлюбних камер короїда, а також його продукція збільшувалися від червня до вересня. У мішаних насадженнях за цей період середня площа осередку *I. acuminatus* та індекси санітарного стану сосни змінилися недостовірно, а параметри популяції *I. acuminatus* зменшилися. За санітарним станом впродовж трьох місяців чисті соснові насадження змінили статус від «сильно ослаблених» до «всихаючих», а мішані залишилися «ослабленими».

У чистих соснових насадженнях щільність маточних ходів і продукція зросли протягом трьох місяців від нижньої межі помірного рівня до високого рівня, а щільність шлюбних камер – від низького до високого рівня. У мішаних насадженнях усі параметри популяції *I. acuminatus* відповідають низькому рівню. Значення показників, які характеризують обстежені осередки *I. acuminatus* у Сумській області, достовірно корелюють із участю сосни у складі насаджень; у вересні зв'язок є тіснішим, ніж у червні.

З погляду біотичної стійкості, одержані дані свідчать про доцільність створення переважно мішаних соснових насаджень.

Ключові слова: короїд; спалах; індекс санітарного стану; відпад дерев; маточні ходи; шлюбні камери; продукція молодих жуків.

Показатели санитарного состояния *Pinus sylvestris* и популяций *Ips acuminatus* в чистых и смешанных насаждениях Сумской области

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Вспышки массового размножения короедов усилились в последнее время во многих регионах. Вершинный короед (*Ips acuminatus* (Gyllenhal, 1827); Coleoptera: Curculionidae: Scolytinae) наиболее распространен в сосновых лесах многих стран

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Европы. Исследования его биологии и распространения провели в разных природных условиях, фазах вспышки и учитывали разные показатели для характеристики популяции вредителя и санитарного состояния насаждений.

Цель исследований заключалась в сравнении санитарного состояния сосны обыкновенной и параметров популяций вершинного короеда двух поколений в чистых и смешанных насаждениях полесской и лесостепной зон Сумской области. Исследования проведены в 2017 г. на 26 пробных площадях, заложенных в полесской (ГП «Середино-Будский агролесхоз»; ГП «Середино-Будское лесное хозяйство») и лесостепной частях (ГП «Великописаревский агролесхоз»; ГП «Ахтырское лесное хозяйства») Сумской области. На пробных площадях оценивали показатели санитарного состояния насаждений и популяций вершинного короеда в июне и сентябре – после завершения развития его весеннего и летнего поколений.

По большинству оцененных параметров не обнаружено достоверных различий между пробными площадями в полесской и лесостепной зонах Сумской области. В чистых сосновых насаждениях средняя площадь очага короеда и его продукция (плотность молодых жуков) были более высокими в лесостепной части Сумской области в июне, а плотность брачных камер – в июне и сентябре.

В чистых сосновых насаждениях средняя площадь очага *I. acuminatus*, количество заселенных деревьев, доля свежего сухостоя, индексы санитарного состояния сосны, плотность маточных ходов и брачных камер короеда, а также его продукция возрастали с июня по сентябрь. В смешанных насаждениях за этот период средняя площадь очага *I. acuminatus* и индексы санитарного состояния сосны изменились недостоверно, а параметры популяции *I. acuminatus* уменьшились. По санитарному состоянию за три месяца чистые сосновые насаждения изменили статус с «сильно ослабленных» на «усыхающие», а смешанные остались «ослабленными».

В чистых сосновых насаждениях плотность маточных ходов и продукция возросли за три месяца от нижней границы умеренного уровня до высокого уровня, а плотность брачных камер – от низкого до высокого уровня. У смешанных насаждениях все параметры популяции *I. acuminatus* соответствуют низкому уровню. Значения показателей, характеризующих обследованные очаги *I. acuminatus* в Сумской области, достоверно коррелируют с долей сосны в составе насаждений, а в сентябре связь более тесна, чем в июне.

С точки зрения биотической устойчивости, полученные данные свидетельствуют о целесообразности создания преимущественно смешанных сосновых насаждений.

Ключевые слова: короед; вспышка; индекс санитарного состояния; отпад деревьев; маточные ходы; брачные камеры; продукция молодых жуков.