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Forest site conditions and other features of Scots pine stands favorable for bark beetles

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The aim of research was to evaluate the dependence of bark beetles foci distribution on forest site conditions as well as on Scots pine stands origin and other characteristics.

Field studies were carried out in 2014-2016 in Scots pine stands of Teterivske Forestry of the State Enterprise "Teterivske Forest Enterprise" (Ukraine, Central Polissya). Data on bark beetles foci location were obtained by inspection of Scots pine stands of this forestry. Data on Scots pine stands characteristics were taken from Forest inventory Database of Production Association "Ukrderzhlisproekt" (database of forest inventory for short) as of 2014.

The distribution of bark beetles infested "spots" in forest subcompartments depending on stand origin (plantations or natural stands), forest site conditions, stand age, relative density of stocking and bonitet class was compared with respective distribution of all Scots pine stands using chi-square analyses (χ^2 test) and Kolmogorov-Smirnov test (λ).

It was found that in Teterivske Forestry bark beetles foci occupy 5.4 % area of Scots pine plantations and 13.1 % of natural Scots pine stands. Confinement of bark beetles foci to Scots pine stands of natural origin is statistically confirmed.

Bark beetles foci are absent in stands growing in dry and moist relatively poor forest site conditions (B_1 and B_4 respectively).

In frame of relatively poor (B) and relatively fertile (C) forest site conditions bark beetles foci are confined to humid forest site conditions (B_3 and C_3), but age and tree species composition of stand override the effect of forest site conditions.

Percentage of bark beetles foci area from Scots pine stands area increases with stand age: 52.7 % of Scots pine stands over 100 years old were infested by bark beetles. Weighted average age of all pine stands of Teterivske Forestry is 67.9 years old and in the bark beetles foci it increased from 96.5 years old in 2014 to 105.2 years old in 2016. Average age of forest stands infested by "spring" generation of bark beetles was less than infested by "summer" generation.

Confinement of bark beetles foci to Scots pine stands with relative stocking density 0.6–0.8 is proved statistically. Weighted average relative stocking density of infested Scots pine stands decreased from 0.73 in 2014-2015 to 0.67 in 2016 in result of selective sanitary felling in the first years of bark beetles outbreak.

Confinement of bark beetles foci to pure Scots pine stands is proved statistically for plantations and natural forests.

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Hypothesis about bark beetles foci confinement to the stands with bonitet class I was proved both for plantations and natural forests.

Key words: *outbreak; focus of insect mass propagation; pine engraver beetle (Ips acuminatus); natural forest; plantation; relative density of stocking; stand age; participation of pine in stand composition.*

Introduction. Periodic outbreaks of bark beetles can destroy thousands of hectares of forest, resulting in economic losses and degradation of ecosystem services (Wermelinger, 2008; Winter et al., 2017). However, over the past 20 years, forest disturbances have increased in size, intensity, and frequency in many regions of the world (Faccoli et al., 2011, 2012; Colombari et al., 2013; Siitonen, 2014; Lieutier et al., 2016), and particularly in Ukraine, where Scots pine (*Pinus sylvestris* L.) forest decline covers considerable part of Polissya and spreads to other natural zones (Andreieva, 2016; Turko et al., 2016; Andreieva & Martynchuk, 2018; Andreieva et al., 2018; Burdulanyuk et al., 2018). Bark beetles complex with dominance of pine engraver beetle *Ips acuminatus* (Gyllenhal, 1827: Curculionidae, Scolytinae) is the main visible cause of Scots pine mortality (Meshkova & Borysenko, 2017a).

According to P. Manion concepts (Manion, 1981), *predisposing factors* (long-term factors) create preconditions that determine the stand susceptibility to *inciting factors* (short-term factors), which provoke forest health worsening.

Thus, the growth of air temperature and reduction of precipitation are registered in many regions (Lausch et al., 2013; Siitonen, 2014), including Polissya (Balabukh et al., 2013). Reduction of precipitation decreases tree resistance, and growth of annual temperature accelerates development of insects, promotes their survival, propagation and range expansion (Bigler et al. 2006; Berner et al., 2017).

With climate change some insect species increased their participation in forest decline. *Ips acuminatus* is one of such insects because of its ability to develop several generations and sister broods per season, to weaken trees during maturation feeding and vectoring plant pathogenic fungi (Davydenko et al., 2017; Meshkova, 2017; Meshkova et al., 2017c). However, despite low precipitation in 2015–2016, the intensity of Scots pine decline in different forest plots was not the same (Meshkova & Borisenko, 2017a). Stem pests infesting weakened trees are *contributing factors* (Manion, 1981), which "accompany" the forest decline.

Usually bark beetles outbreaks develop after disturbance caused by wind, fire, recreation, or forest management operations which result in considerable changes in stand structure (and microclimate) and provide large amount of breeding substrate for bark beetles (Bouget & Duelli, 2004; Lopez & Goldarazenam, 2012; Lausch et al. 2013; Williams et al., 2017; Winter et al., 2017).

At the same time every insect has some preferences for forest type and structure parameters, which are favorable for its survival and development.

Thus a rating of forest plots preferences for the main species of foliage browsing insects considers the type of forest site conditions, age of stand, relative density of stocking, and the part of pine in the stand composition (Meshkova, 2006). The plots with maximal threat of foliage browsing insects' outbreaks were recommended for high priority field inspection in different regions of Ukraine (Meshkova & Borysenko, 2017b).

Similar approach was used in research of stem pests. Particularly it was shown, that southern pine beetle (*Dendroctonus frontalis* Zimmermann) spread in southeastern United States does not depend on site index, and effects of stand type (wetland or upland) are overridden by the effect of stand composition (Aoki et al., 2018). Usually, bark beetles preferentially attack older trees and stands in later stages of development. However investigations in Colorado show that due to climate warming the stands in early stages of development now are being affected by outbreaks (Mietkiewicz et al. 2018).

The aim of this research was to evaluate the dependence of bark beetles foci distribution on forest site conditions as well as on Scots pine stands origin and other characteristics.

Objects and methods. Distribution of bark beetles foci in Scots pine stands was the object of research, which was carried out in 2014-2016 in Scots pine stands of Teterivske Forestry of the State Enterprise "Teterivske Forest Economy" (50 °41 ‘ N; 29 °36 ‘ E) (Ukraine, Central Polissya).

Data on bark beetles foci were obtained by inspection of Scots pine stands of the State Enterprise "Teterivske Forest Economy". Data on Scots pine stands characteristics were taken from Forest inventory Database of Production Association "Ukrderzhlisproekt" (database of forest inventory for short) as of 2014. This database was converted into Access and Excel tables using applications developed in Ukrainian Research Institute of Forestry & Forest Melioration named after G. M. Vysotsky (URIFFM).

The distribution of bark beetles foci in forest subcompartments depending on stand origin (plantations or natural stands), forest site conditions, stand age, relative density of stocking, Scots pine participation in the stand composition, and bonitet classes was compared with respective distribution of all Scots pine stands using chi-square analyses (χ^2 test) and Kolmogorov-Smirnov test (λ) (Atramentova and Utevskaya 2008) using *MS Excel*.

Results and discussion. Analysis of model trees show, that pine engraver beetle (*Ips acuminatus*) dominated among other stem pests, which infested visually healthy trees. Six-toothed pine bark beetle (*Ips sexdentatus* Boerner 1776) infested more often the trees already being colonized by pine engraver beetle.

Dependence of bark beetles foci distribution on stand origin. Data analysis shows that from 3961.2 hectares of Scots pine stands 79.1 % (3132.1 ha) are

plantations, and 20.9 % (829.1 ha) have natural origin. At the same time in bark beetles foci plantations cover 60.9 % of area, and natural stands cover 13.1 % of area (Fig. 1). It means that the foci occupy 5.4 % of Scots pine plantations area and 13.1 % of natural Scots pine stands area. Difference of bark beetles foci distribution in Scots pine stands of different origin is proved statistically ($\chi^2 = 19.93$; $\chi^2_{0.05} = 3.84$).

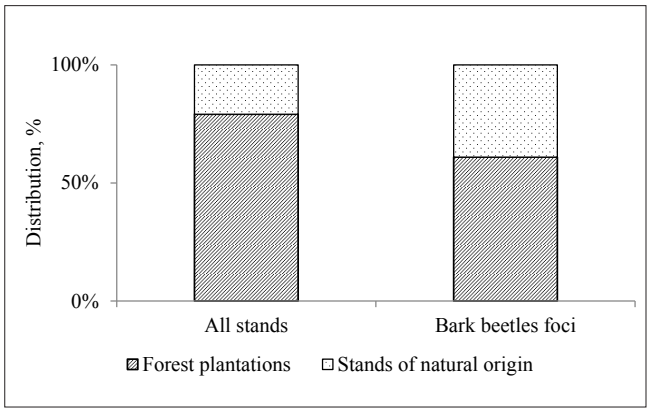

Fig. 1. Distribution by origin of all Scots pine stands of Teterivske Forestry ("all stands") and Scots pine stands in bark beetles foci

Taking into account this conclusion we analyzed the distribution of bark beetle foci by other forest characteristics separately for stands of artificial and natural origin.

Dependence of bark beetles foci distribution on forest site conditions. Natural Scots pine stands of Teterivske Forestry grow in nine types of forest site conditions. Plantations grow in seven types of forest site conditions and are absent in dry (B_1) and moist relatively poor (B_4) forest site conditions (Table 1).

Bark beetles foci in Scots pine plantations were revealed in five types of forest site conditions, and were absent in dry poor (A_1), and dry relatively poor (B_1) forest site conditions. In natural forest bark beetles foci occurred in six types of forest site conditions from eight existing types. Bark beetles foci were absent in natural stands growing in dry and moist relatively poor forest site conditions (B_1 and B_4 respectively).

The largest part of Scots pine stands grow in fresh relatively poor forest site conditions (B_2). Such percentage in B_2 is almost the same in all pine plantations and in bark beetles foci in pine plantations (77 and 77.2 % respectively). Percentage of natural Scots pine stands in B_2 is 80.1 %, and it is much less in bark beetles foci (56.1 %). It may be explained by different forest stand composition or stand age in such forests.

Scots pine stands of artificial and natural origin in fresh poor forest site conditions (A_2) are represented almost the same (3.8 and 3.4 %). However, in bark beetles foci the percentage of artificial and natural stands area in A_2 is 0.2 and 12.2 % respectively. Thus in such forest site conditions the part of bark beetles infested area is 17 times less, than in all plantations of such forest site conditions, and in natural stands the part of bark beetles infested area is 3.6 times more. Obtained data are statistically proved for natural stands ($\chi^2 = 22.3$; $\chi^2_{0.05} = 3.84$), but it may be also connected with different forest stand composition or stand age.

Percentage of area of humid relatively poor (B_3) and humid relatively fertile (C_3) forest site conditions in bark beetles foci is considerably more than in all stands of respective origin (see Table 1). Thus in artificial stands humid relatively poor and humid relatively fertile forest site conditions occupy each only 0.2 % of the area, and in bark beetles foci they occupy 1.9 and 3,9 % of the area respectively, and the difference is significant ($\chi^2 = 195.9$ for B_3 and $\chi^2 = 771.5$ for C_3; $\chi^2_{0.05} = 3.84$).

Obtained data prove the confinement of bark beetles foci to more humid forest site conditions. It may be explained by the fact, that pine roots in such stands are located closer to the soil surface. Recent deepening of ground water level in result of low precipitation (Meshkova & Borysenko, 2017a) caused stand weakening and increase of tree susceptibility to bark beetles attacks.

However Kolmogorov-Smirnov test (λ) does not prove significant differences in all Scots pine stand distribution by forest site conditions and such distribution in bark beetles foci (for artificial stands $\lambda = 0.27$; for natural stands $\lambda = 0.58$; $\lambda_{0.05} = 1.36$).

Table 1

Distribution (%) by forest site conditions the area of all Scots pine stands in Teterivske Forestry ("all stands") and pine stands in bark beetles foci (average for 2014–2016)

Forest site conditions type. Index and name	Forest plantations		Stands of natural origin	
	all stands	bark beetles foci	all stands	bark beetles foci
A_1 – dry poor	0.1	0.0	0.8	0.4
A_2 – fresh poor	3.8	0.2	3.4	12.2
B_1 – dry relatively poor	0.1	0.0	0.1	0.0
B_2 – fresh relatively poor	77.0	77.2	80.1	56.1
B_3 – humid relatively poor	0.2	1.9	0.9	12.9
B_4 – moist relatively poor	0.0	0.0	0.2	0.0
C_2 – fresh relatively fertile	18.6	16.8	14.3	11.7
C_3 – humid relatively fertile	0.2	3.9	0.1	6.7

In artificial stands share of Scots pine area in fresh relatively poor forest site conditions (B_2) was the highest (61.9–78.4 % from all bark beetles foci area) in 2014–2016 (Fig. 2). The stands in the fresh relatively fertile forest site conditions (C_2) are on the 2nd place by area (17.5–37.8 % from total foci area). The rest types of forest site conditions were characteristic for 4.5 %, 0.3 % and 0.4 % of foci area in 2014, 2015 and 2016 respectively.

In 2015 share of bark beetles foci area decreased by 16.5 % in fresh relatively poor forest site conditions (B_2) and increased by 20.3 % in fresh relatively fertile (C_2) forest site conditions. In 2016 proportion of bark beetles foci area increased by 13 % in fresh relatively poor forest site conditions (B_2) and decreased by 13.1 % in fresh relatively fertile forest site conditions (C_2). It may be connected with the change of attractiveness of certain stands for bark beetles in result of low precipitation of 2015 (Meshkova & Borysenko, 2017a).

In natural stands, bark beetles foci occurred in the more diverse forest site conditions, than in forest plantations (see Fig. 2b). Although the most proportion of foci area occurred in the fresh relatively poor forest site conditions (B_2), it was slightly more than half of the total foci area (56.1 and 56.7 % in 2014 and 2015 respectively, and in 2016 increased up to 86.4 %. Number of types of forest site conditions with bark beetles foci decreased from six in 2014 to three in 2015. Like in plantations, in natural forest stands in 2015 the share of foci area in the fresh relatively poor site conditions increased from 11.7 to 41.1 %. One can assume that in 2014 forest weakening was provoked by certain climatic events, and then bark beetles colonized trees in the most represented forest site conditions.

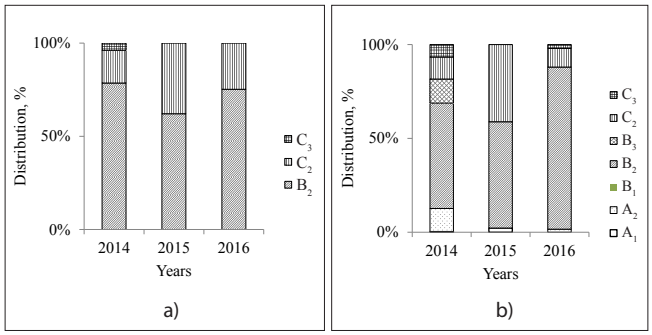

Fig. 2. Distribution by the types of forest site conditions the Scots pine stands area in bark beetles foci in different years (a – forest plantations; b – stands of natural origin)

Dependence of bark beetles foci distribution on stand age. In total bark beetles foci area in Teterivske Forestry for 3 years made up 22 % of Scots pine forest area. However Scots pine stands distribution by age was not similar in all pine stands and in bark beetles foci (Fig. 3).

Scots pine stands of Teterivske Forestry represented by I to XVIII ten-years age classes, and in bark beetles foci (for 2014–2016) by V to XVIII age classes.

In the stands of I, II and IV age classes, bark beetles foci were not revealed, and in the stands of III class their area was 0.3 % from all Scots pine stands area of such age. In the stands of the V age class it was 2.8 %, and in VI age class it was 9.5 % (see Fig. 3).

Proportion of bark beetles foci area from Scots pine stands area increases with age. It is almost 50 % in IX age class and exceeds this value in X–XII age classes.

In Scots pine stands over 100 years old 52.7 % were infested by bark beetles.

Obtained data show that young pine stands were not infested by bark beetles. It is possible that these stands formed their root systems in changed climatic conditions and are adapted to them.

Analysis of forest inventory database shows, that weighted average age of all pine stands of Teterivske Forestry is 67.9 years old (Fig. 4). However it is 114.5 and 55.6 years old in natural Scots pine stands and plantations respectively.

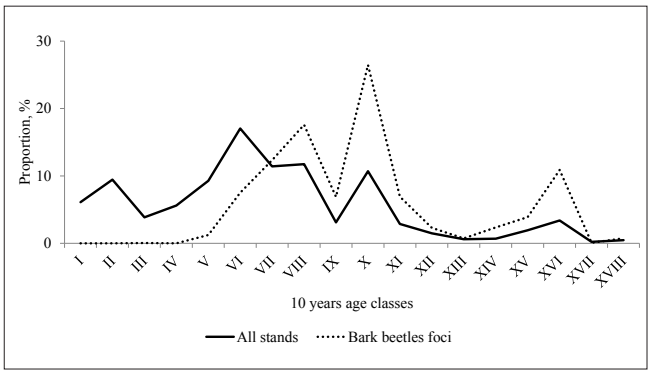

Fig. 3. Distribution of all Scots pine stands ("all stands") and bark beetles foci area by ten-years age classes (Teterivske Forestry; 2014–2016)

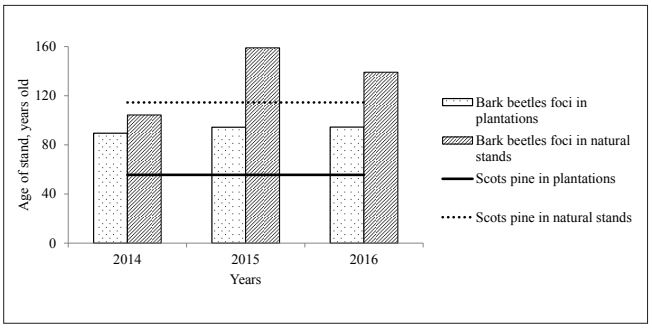

Fig. 4. Weighted average age of all Scots pine stands of Teterivske Forestry and bark beetles foci in plantations and natural stands

Weighted average age of Scots pine stands in the bark beetles foci increased from 96.5 years old in 2014 to 105.2 years old in 2016. In plantations it was from 89.4 to 94.5 years old and in 1.6–1.7 times exceeded weighted average age of all Scots pine stands. Weighted average age of natural stands in bark beetles foci in 2014 (104.3 years old) was in 1.1 times less than age of all natural Scots pine stands, and in 2015–2016 this index in bark beetles foci was in 1.2–1.4 times more than in all natural Scots pine stands.

It should be noticed, that in 2014 the age of plantations and natural Scots pine stands in bark beetles

foci differed only by 15 years (in 1.2 times), and in 2015 by 66 years (in 1.7 times). Trend to increase the age of Scots pine stands in bark beetles foci during outbreak of bark beetles may be connected with decrease of trees resistance as well as with larger crowns and lateral surface available for bark beetles infestation.

Ips acuminatus, which plays the main role in Scots pine decline in the region of our research, develops in two main partly overlapping generations per year and sister broods. "Spring" generation is started by adults after hibernation, and "summer" generation is a progeny of "spring" generation (Meshkova et al., 2017c).

Each year an average age of stands infested by "spring" generation of bark beetles was less than age of forest stands infested by "summer" generation (Fig. 5).

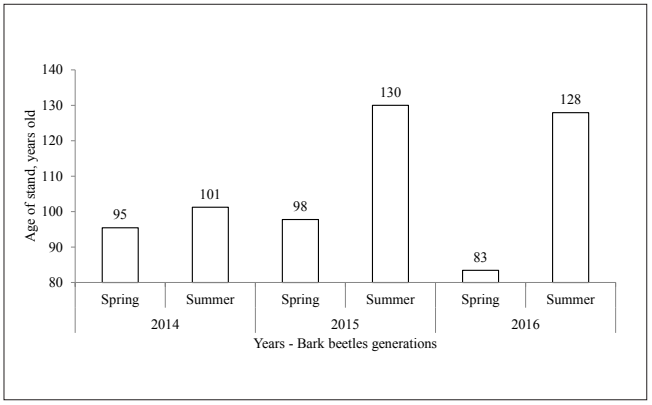

Fig. 5. Average age of forest stands in bark beetles foci during development of *Ips acuminatus* "spring" and "summer" generations

In 2014 the difference was only 5.8 year, but in 2015 and 2016 it increased up to 32.2 and 44.5 year respectively. Such phenomena may be connected with large number of young shoots per tree in old stands or with low intensity of protective chemicals synthesis after termination of shoot growth.

Dependence of bark beetles foci distribution on relative stocking density. Relative stocking density of Scots pine stands in Teterivske Forestry is from 0.3 to 0.9, and it is from 0.4 to 0.9 in the bark beetles foci (Fig. 6).

Proportion of bark beetles foci area from whole area of Scots pine stands with relative stocking density 0.6–0.8 is the largest (24.7–33.2 %), which is proved statistically (χ^2 = 225.6; $\chi^2_{0.05}$ = 3.8). Significance of confinement of bark beetles foci to relative stocking density 0.6 is the highest (χ^2 = 48.5; $\chi^2_{0.05}$ = 3.8), it is less for relative stocking density 0.7 (χ^2 = 36.8; $\chi^2_{0.05}$ = 3.8), and the least for relative stocking density 0.8 (χ^2 = 6.1; $\chi^2_{0.05}$ = 3.8). Obtained data show, that the stands with relative stocking density 0.6 and 0.7 must be inspected in the first turn for bark beetles foci detection.

Analysis of bark beetles foci area distribution shows, that in 2014-2015 the stands with larger relative stocking density were infested (Fig. 7).

Weighted average relative stocking density of infested Scots pine stands was 0.73 in 2014-2015, and it was 0.67 in 2016. It may be explained by a decrease of relative stocking density of Scots pine stands in result of selective sanitary felling in the first years of bark beetles outbreak.

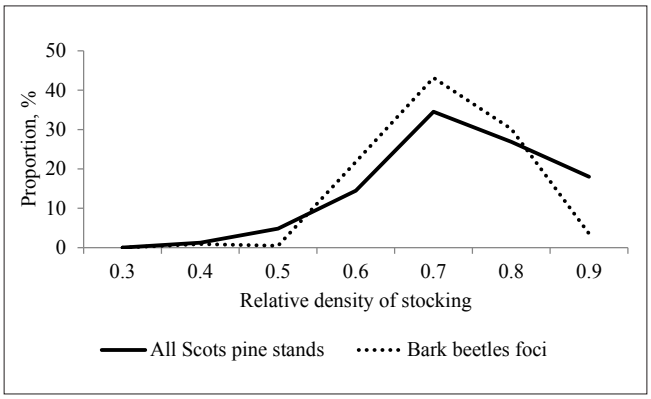

Fig. 6. Distribution of area in all Scots pine stands and bark beetles foci by relative stocking density (Teterivske Forestry, 2014-2016)

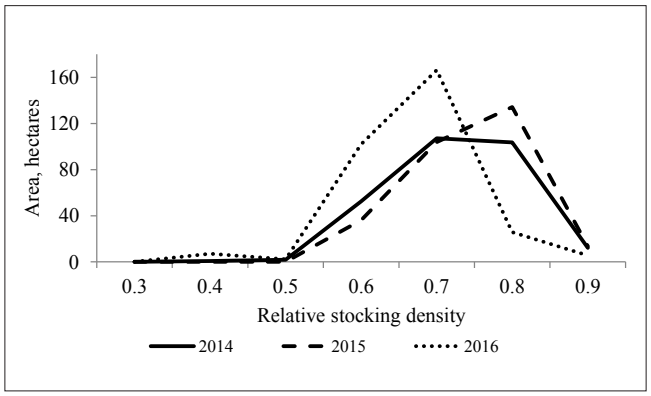

Fig. 7. Distribution of bark beetles foci area by relative stocking density in 2014, 2015 and 2016

Dependence of bark beetles foci distribution on Scots pine participation in the stand composition. The greater resistance of mixed stands compared with pure Scots pine stands was proved by many studies of foliage browsing insects, pests of unclosed plantations, stem pests etc. (Meshkova, 2006; Lieutier et al., 2016).

Since prolonged outbreak of *Ips acuminatus* in large area earlier has not been registered, its spread in pure and mixed stands was not yet studied.

The stands with 3 to 10 units of Scots pine grow in Teterivske Forestry (Fig. 8).

The share of Scots pine stands area increased with larger part of this tree species in the forest composition. At the same participation of Scots pine in the forest composition the area of plantations exceeded the area of natural Scots pine stands.

Bark beetles foci area increased with Scots pine participation in stands composition and was the highest in pure Scots pine stands both in plantations and natural stands. Proportion of area with 8, 9 and 10 units of Scots pine in stand composition was 18.4, 21.9 and 47.2 % in plantations and 15.3, 18.4 and 42.1 % in natural stands respectively (see Fig. 8). Weighted average part of Scots pine in forest stand composition

was 8.9 and 8.6 units in plantations and natural stands respectively.

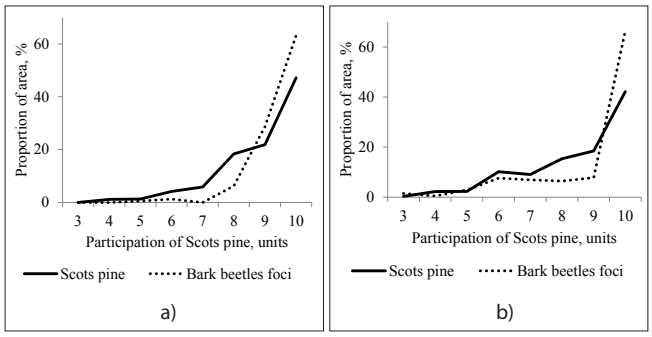

Fig. 8. Distribution by Scots pine proportion in all pine stands of Teterivske Forestry and in bark beetles foci (a – forest plantations; b – stands of natural origin)

However, in bark beetles foci the pure Scots pine stands occupy 63.2 and 66.4 % of all foci bark beetles area for plantations and natural stands respectively, and the stands with 9 units of Scots pine in forest stand composition occupy 28.7 and 7.8 % of area respectively. Weighted average part of Scots pine in stand composition in bark beetles foci is 9.5 and 9 units in plantations and natural stands respectively. Confinement of bark beetles foci to pure Scots pine stands is proved statistically for plantations ($\chi^2 = 17.9$; $\chi^2_{0.05} = 3.8$) and natural forests ($\chi^2 = 27.9$; $\chi^2_{0.05} = 3.8$).

Dependence of bark beetles foci distribution on stand bonitet. The most proportion of Scots pine plantations area in Teterivske Forestry (50.6 %) is characterized by Ia bonitet class, and 35.2 % by I bonitet class (Fig. 9).

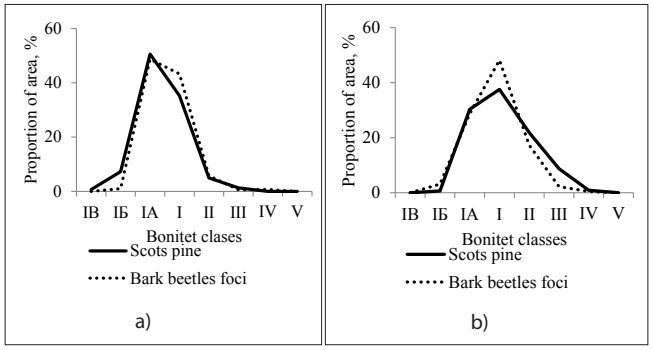

Fig. 9. Distribution by bonitet classes of all Scots pine stands and Scots pine stands in bark beetles foci of Teterivske Forestry (a – forest plantations; b – natural stands)

Bark beetles foci are also often located in the stands of Ia and I bonitet classes (48.7 and 43.3 % of plantations and natural forests respectively). Weighted average bonitet class is Ia and I for all Scots pine plantations and bark beetles foci there respectively. Proportion of natural Scots pine stands of Ia, I, II and III bonitet class is 30.3, 37.5, 21.8 and 8.7 %, and weighted bonitet class is I. The largest area of bark beetles foci in natural Scots pine stands (48.2 %) is located in I bonitet class. Proportion of bark beetles foci area in natural stands of Ia and II bonitet classes is 28.7 and 17.3 % respectively. Weighted average bonitet class of all natural Scots pine stands and of stands in bark beetles foci is I.

Differences of area distribution by bonitet classes are significant between plantations and natural Scots pine stands ($\chi^2 = 101.6$, $\chi^2_{0.05} = 3.8$), between Scots pine stands and bark beetles foci in plantations ($\chi^2 = 42.5$, $\chi^2_{0.05} = 3.8$), as well as between Scots pine stands and bark beetles foci in natural Scots pine stands ($\chi^2 = 25.3$, $\chi^2_{0.05} = 3.8$). Hypothesis about bark beetles foci confinement to the stands with bonitet classes Ia and II was not proved both for plantations and natural forests. Hypothesis about bark beetles foci confinement to the stands with bonitet class I was proved both for plantations ($\chi^2 = 5.1$, $\chi^2_{0.05} = 3.8$) and natural forests ($\chi^2 = 6.0$, $\chi^2_{0.05} = 3.8$).

Conclusions. In Teterivske Forestry, bark beetles foci occupy 5.4 % area of Scots pine plantations and 13.1 % of natural Scots pine stands. Confinement of bark beetles foci to Scots pine stands of natural origin is statistically confirmed.

Bark beetles foci are absent in stands growing in dry and moist relatively poor forest site conditions (B_1 and B_4 respectively).

In frame of relatively poor (B) and relatively fertile (C) forest site conditions bark beetles foci are confined to more humid forest site conditions (B_3 and C_3), but age and tree species composition of stand override the effect of forest site conditions.

Percentage of bark beetles foci area from Scots pine stands area increases with stand age: 52.7 % of Scots pine stands over 100 years old were infested by bark beetles. Weighted average age of all pine stands of Teterivske Forestry is 67.9 years old and in the bark beetles foci it increased from 96.5 years old in 2014 to 105.2 years old in 2016. Average age of forest stands infested by "spring" generation of bark beetles was less than infested by "summer" generation.

Confinement of bark beetles foci to Scots pine stands with relative stocking density 0.6–0.8 is proved statistically. Weighted average relative stocking density of infested Scots pine stands decreased from 0.73 in 2014–2015 to 0.67 in 2016 in result of selective sanitary felling in the first years of bark beetles outbreak.

Confinement of bark beetles foci to pure Scots pine stands, as well as to the stands with bonitet class I was proved both for plantations and natural forests.

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Лісорослинні умови та інші характеристики насаджень сосни звичайної, сприятливі для короїдів

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Дослідження 2014-2016 рр. свідчать, що площа осередків короїдів у насадженнях сосни звичайної Тетерівського лісництва Державного підприємства «Тетерівське лісове господарство» становить 5,4 % площі лісів штучного походження та 13,1 % площі природних соснових лісів. Статистично підтверджено приуроченість осередків короїдів до природних соснових лісів.

Осередки короїдів відсутні у сухих і мокрих суборах (B_1 та B_4 відповідно). У межах суборів і сугрудів осередки короїдів приурочені до вологих умов (B_3 та C_3), але вік і склад насаджень впливають на поширення осередків більше, ніж тип лісорослинних умов.

Частка площі осередків короїдів від площі соснових лісів збільшується з віком деревостанів: 52,7 % соснових насаджень віком понад 100 років заселено короїдами. Середній зважений вік усіх соснових насаджень Тетерівського лісництва становить 67,9 років, а вік насаджень в осередках короїдів збільшився від 96,5 року у 2014 р. до 105,2 року у 2016 році. Короїди "літнього" покоління заселяли насадження більш старшого віку, ніж короїди "весняного" покоління.

Приуроченість осередків короїдів до соснових насаджень із відносною повнотою 0,6-0,8 доведена статистично. Середня зважена відносна повнота заселених короїдами соснових насаджень зменшилася від 0,73 у 2014-2015 рр. до 0,67 у 2016 р. внаслідок проведення вибіркових санітарних рубок у перші роки спалаху цих шкідників.

Приуроченість осередків короїдів до чистих соснових деревостанів доведена статистично для штучних і природних соснових насаджень.

У штучних і природних насадженнях осередки короїдів приурочені до деревостанів І класу бонітету.

Ключові слова: спалах; осередок масового розмноження комах; верхівковий короїд (*Ips acuminatus*); насадження природного походження; лісові культури; відносна повнота; вік насаджень; участь сосни у складі насаджень.

Лесорастительные условия и другие характеристики насаждений сосны обыкновенной, благоприятные для короедов

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Исследования проведены в 2014-2016 гг. в насаждениях сосны обыкновенной Тетеревского лесничества Государственного предприятия «Тетеревское лесное хозяйство» (Украина, Центральное Полесье). Данные относительно распространения очагов короедов получены при обследовании насаждений сосны обыкновенной в лесном фонде этого предприятия. Анализ лесорастительных условий и

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характеристик сосновых насаждений проведен по данным базы лесоустройства Производственного Объединения «Укргослеспроект» по состоянию на 2014 год.

Распространение очагов короедов в зависимости от происхождения насаждений (искусственное или естественное), типа лесорастительных условий, возраста, относительной полноты и класса бонитета сопоставляли с распространением всех насаждений сосны обыкновенной с использованием критериев χ^2 и λ (Колмогорова-Смирнова).

Путем анализа модельных деревьев подтверждено доминирование вершинного короеда (*Ips acuminatus*), заселяющего здоровые на вид деревья. Шестизубчатый короед (*Ips sexdentatus*) чаще заселял деревья, ранее заселенные вершинным короедом.

Установлено, что площадь очагов короедов в Тетеревском лесничестве составляет 5,4 % площади лесов искусственного происхождения и 13,1 % площади лесов естественного происхождения. Статистически подтверждена приуроченность очагов короедов к лесам естественного происхождения.

Очаги короедов не были обнаружены в сухих и мокрых суборях (B_1 и B_4 соответственно).

В пределах суборей (B) и сугрудков (C) очаги короедов приурочены к влажным условиям (B_3 и C_3), но возраст и состав насаждений влияет на распространение очагов больше, чем тип лесорастительных условий.

Доля площади очагов короедов от площади сосновых лесов увеличивается с возрастом древостоя: 52,7 % сосновых насаждений, которые старше 100 лет, заселены короедами. Средневзвешенный возраст всех сосновых насаждений Тетеревского лесничества составляет 67,9 лет, в очагах короедов этот показатель возрос от 96,5 года в 2014 году до 105,2 года в 2016 году. Короеды «летнего» поколения заселяли насаждения более старшего возраста, чем короеды «весеннего» поколения.

Приуроченность очагов короедов к сосновым насаждениям с относительной полнотой 0,6-0,8 доказана статистически. Средневзвешенная относительная полнота заселенных короедами сосновых насаждений уменьшилась с 0,73 в 2014-2015 гг. до 0,67 в 2016 гг. в результате проведения выборочных санитарных рубок в первые годы вспышки этих вредителей.

Приуроченность очагов короедов к чистым сосновым древостоям доказано статистически для сосновых насаждений искусственного и естественного происхождения.

В искусственных и естественных насаждениях очаги короедов приурочены к древостоям I класса бонитета.

Ключевые слова: вспышка; очаг массового размножения насекомых; вершинный короед (*Ips acuminatus*); насаждения естественного происхождения; лесные культуры; относительная полнота; возраст насаждений; участие сосны в составе насаждений.