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V. MESHKOVA[1], YU. SKRYLNYK[2], O. TOVSTUKHA[3]

STEM INSECT PESTS IN WIND DAMAGED PINE STANDS AND PRIORITIES FOR SANITARY FELLING

In the pine stands of the northern east of Ukraine species composition of stem insects and severity of colonization depends on the terms of wind damage (summer or winter windstorm) and differs for windbroken and uprooted trees, which depends on different rate of phloem drying. Therefore total sanitary felling must be carried out in the first turn in the isolated forest plots with obligatory exportation, debarking or treatment of timber with insecticides. In the case, when all damaged trees can be removed from windstorm plot during one year, windbroken trees must be felled in the first turn. In the case, when all damaged trees cannot be removed from windstorm plot during one year, uprooted trees must be felled in the first turn. Dead trees of previous years and windbroken trees, which do not belong to industrial timber and do not colonized by physiological stem pests, must be removed in the last turn.

Key words: *pine stands, wind damage, uprooted trees, windbroken trees, stem insect pests*

Introduction. In result of climate change and high anthropogenic load, frequency and severity of droughts, fires, windstorms and outbreaks of pests have increased recently [8, 17–19], which has negative impact on forest vitality and productivity. The threat of stem insects' dissemination increases usually after such catastrophic events in result of accumulation of high amount of substrate for colonization [6, 9, 10].

It is known [1, 3, 18], that timely sanitary felling after windstorm is necessary for prevention of decrease of timber quality in result of colonization by insects, as well as for prevention of dissemination of their foci. In consideration of limited possibilities of simultaneous sanitary felling in large area of wind damaged forest, it is important to determine the priorities of such measures. Such priorities must take into account species composition of stem pests in the region and their demands to substrate for colonization.

Investigations in different regions show, that after fires the phloem of damaged trees rapidly becomes unsuitable for stem insects [1, 9, 19], but after wind damage the foci of stem pests develop for several years [3, 6, 18]. The last is also related with the presence of invisible damage of roots of bent trees and decrease of resistance of trees, which were mechanically damaged by windfall and during sanitary felling. At the same time, the most of researches was carried out in the northern or mountain regions, mainly in spruce stands with predomination of *Ips typographus* (Linnaeus, 1758) [2, 5, 6, 18, 19]. Less attention is paid to wind damage in pine forest [3, 10].

Stem insects cause physiological injury, when colonize viable trees, realize maturating feeding and vector the pathogens [11]. At high population density physiological pests become dangerous not only for weakened trees but also for healthy trees, which they weaken additionally during maturating feeding [1, 13, 16].

Other stem pests cause technical injury in living and felled trees [11]. Such insects colonize severely weakened, drying and dead trees, as well as felled and windbroken trees, which characterized previously by the I–II categories of sanitary condition (healthy and lightly weakened trees) [9, 11, 13]. Increase of population of technical pests promotes decomposition of dead wood in the forest, but brings to decrease of timber quality [14, 16].

Previously we have determined the species composition of stem insects in wind damaged pine stands in the northern east of Ukraine [10] and evaluated the injuriousness of these species. It was determined, that *Phaenops cyaneus* (Fabricius, 1775) (Coleoptera: Buprestidae), *Ips sexdentatus* (Boerner, 1767), *Ips acuminatus* (Gyllenhal, 1827), *Tomicus minor* (Hartig, 1834) and *Tomicus piniperda* (Linnaeus, 1758) (Coleoptera: Curculionidae: Scolytinae) were the main physiological pests, and *Monochamus galloprovincialis* (Olivier, 1795), *Hylotrupes bajulus*

[1] **Valentyna Lvivna MESHKOVA –** full member of Forestry Academy of Sciences of Ukraine, Doctor habil. (agricultural sciences), professor, Ukrainian Research Institute of Forestry & Forest Melioration named after G.M.Vysotsky. Ukraine, Kharkiv. Tel.: +38(057)707-80-71. E-mail: Valentynameshkova@gmail.com

[2] **Yuriy Yevgenovych SKRYLNYK –** researcher, Ukrainian Research Institute of Forestry & Forest Melioration named after G.M.Vysotsky. Ukraine, Kharkiv. Tel.: +38(057)707-80-27. E-mail: sklif83@mail.ru

[3] **Oleksandr Volodymyrovych TOVSTUKHA –** Deputy Chief of Sumy Regional Administration of Forest and Hunting Management. Ukraine, Sumy, Zasumska str. 12a. Tel. +38(067)540-17-70. E-mail: atovstukha@mail.ru

(Linnaeus, 1758), Acanthocinus aedilis (Linnaeus, 1758) (Coleoptera: Cerambycidae) were the main technical pests [12, 13, 16].

The aim of this research was the reasoning of priorities of sanitary felling in the wind damaged pine stands with a glance at species composition of stem pests, their phenology and peculiarities of substrate colonization.

Objects and methods. The investigations were carried out in 2006 – 2013 in the pine (*Pinus sylvestris* L.) stands of the State Enterprises of Sumy region ("Okhtyrs'ke Forest Economy", "Shostkyns'ke Forest Economy", "Sves'ke Forest Economy", "Seredyno-Buds'ke Forest Economy", "Yampils'ke Agroforest Economy"), Chernigiv region ("Novgorod-Sivers'ke Forest Economy") and Kharkiv region ("Gutyans'ke Forest Economy". Stem pests spread was assessed according to "Methodical recommendations ..." [7] for bent trees (with partly damaged roots), windthrown trees (totally or partly uprooted), trees with broken tops ("high stumps") and their broken crowns. Relative humidity of phloem was measured with needle hydrometer DT-129.

Results and discussion. The most of uprooted trees were colonized by *Acanthocinus aedilis* and *Tomicus minor* (45% each), somewhat less – *Tomicus piniperda* (40%), *Monochamus galloprovincialis* and *Phaenops cyaneus* (35% each) (Table 1).

Table 1

The part of trees, colonized by stem pests the next year after wind damage (colonization,%)

Insect species	Tree colonization,%		
	uprooted trees	wind broken trees	
		broken tops (crowns)	"high stumps"
1	2	3	4
Buprestridae			
Phaenops cyaneus (Fabricius, 1775)	35	10	65
Cerambycidae			
Acanthocinus aedilis (Linnaeus, 1758)	45	25	45
Arhopalus rusticus (Linnaeus, 1758)	0	0	30
Hylotrupes bajulus (Linnaeus, 1758)	0	0	30
Monochamus galloprovincialis (Olivier, 1795)	35	5	40
Pogonocherus fasciculatus (Degeer, 1775)	0	25	0
Rhagium inquisitor (Linnaeus, 1758)	0	0	25

End of Table 1

1	2	3	4
Curculionidae: Scolytinae			
Ips sexdentatus (Boerner, 1767)	10	0	25
Ips acuminatus (Gyllenhal, 1827)	15	15	0
Tomicus minor (Hartig, 1834)	45	30	15
Tomicus piniperda (Linnaeus, 1758)	40	0	25

Recently uprooted trees had green crowns, and their roots were partly in the soil. Such trees are always doomed to death, but are the most dangerous with a view to colonization by stem pests, because the rests of needles and roots provide the transportation of water in the stem and rather long-term humidity and vitality of phloem.

Broken tops (crowns) and "high stumps" had some peculiarities as the substrate for insect colonization. Broken tops were colonized mainly by insects, which are adapted to parts of stem and branches with thin bark. There were mainly *Tomicus minor* (30% trees), *Acanthocinus aedilis* and *Pogonocherus fasciculatus* (25% each), less *Ips acuminatus* (15%). The segments of branches with diameter over 19 cm were colonized by *Phaenops cyaneus* and *Tomicus minor* (10% each), *Monochamus galloprovincialis* (5% trees). In result of phloem drying these species often could not complete their development.

Both species diversity and substrate colonization were greater in "high stumps", which were colonized by stem pests, adopted to stem parts with thick and transitional bark. From physiological pests, *Phaenops cyaneus* dominated in this substrate (65% trees). The phloem kept the water for the longest time in the collar part of the stem, which gave the possibility to complete development for many wood destructors, particularly, *Arhopalus rusticus, Hylotrupes bajulus* and *Rhagium inquisitor* (see Table 1).

"High stumps" were suitable for colonization by majority of stem pests only in the first year after wind damage. At the same time, the larvae of longhorn beetles (Cerambycidae), which have colonized "high stumps" in the first year, prolonged their development in such substrate [14]. Broken off parts of stem and branches were colonized the same manner as the sections of felled trees of respective diameter, located on the ground surface [3, 6, 10].

Colonization of trees by stem insects depends on the terms of wind damage. In the years of our investigations the greatest wind storms in the region were registered in June-July. At the same time, the fall of single trees (particularly in wind damage stands and after selective sanitary felling) occurred mainly in winter. Species composition of insects and the level of trees colonization varied depending on the term of fall (Table 2).

Thereby, the trees, damaged by wind in summer (June-July) were not colonized by stem insects, which

swarmed before wind damage (*Acanthocinus aedilis, Pogonocherus fasciculatus, Tomicus minor, Tomicus piniperda*. Stem pests, which are able to colonize only drying and dead trees (*Arhopalus rusticus, Hylotrupes bajulus* and *Rhagium inquisitor*), also did not colonize the trees, damaged by wind, in the first year. Single cases of colonization by these insects were registered in the recently died trees, broken or uprooted by wind. In the year of summer wind storm the highest rate of colonization was characteristic for *Phaenops cyaneus* (40% of trees) and *Monochamus galloprovincialis* (35% of trees). The third and the forth place belong to *Ips sexdentatus* and *Ips acuminatus* (25% and 15% of trees), which colonized wind damaged trees in the second or sister broods (see Table 2).

Table 2

The terms of colonization of substrate by stem pests and the mean colonization of trees, damaged by wind in different months

Insect species	Terms of the start of colonization	Tree colonization,%			
		year of wind damage (n)		the next year after wind damage (n+1)	
		months of wind damage			
		June-July	January-March	June-July	January-March
Buprestridae					
Phaenops cyaneus	June	40.0	60.0	30.0	10.0
Cerambycidae					
Acanthocinus aedilis	end of April	0.0	75.0	40.0	30.0
Arhopalus rusticus	June	0.5	10.0	25.0	30.0
Hylotrupes bajulus	June	0.1	10.0	15.0	20.0
Monochamus galloprovincialis	June	35.0	80.0	50.0	60.0
Pogonocherus fasciculatus	May	0.0	30.0	10.0	0.0
Rhagium inquisitor	April	0.5	10.0	25.0	30.0
Curculionidae: Scolytinae					
*Ips sexdentatus**	May, end of June, August	25.0	45.0	10.0	10.0
*Ips acuminatus**	May, August	15.0	40.0	10.0	0.0
Tomicus minor	end of April	0.0	75.0	15.0	0.0
Tomicus piniperda	end of April	0.0	60.0	20.0	0.0

Note: second and sister broods

The next year the trees, damaged by wind in June-July of previous year, became sensitive for colonization by insects of spring phenological group – *Acanthocinus aedilis, Pogonocherus fasciculatus, Tomicus minor* and *Tomicus piniperda*. At the same time, the phloem of wind damaged trees has dried, and the substrate has lost the attractiveness for these insects (see Table 2).

The second year after wind storm, colonization of windthrown trees of previous year by *Arhopalus rusticus, Rhagium inquisitor* and *Hylotrupes bajulus* has increased to 25%, 25% and 15% respectively). Colonization of trees by *Phaenops cyaneus* on the second year after windstorm has decreased as compared with the first year (from 40% to 30%), and colonization of trees by *Monochamus galloprovincialis* has increased (from 35% to 50%). The last data is explained by the fact, that *Phaenops cyaneus* completes development for one year, and *Monochamus galloprovincialis* can prolong its development for several years in the case of substrate drying [14].

The trees, damaged by wind in winter, were attractive for stem insects of all phenological groups the same year (see Table 2). The greater was colonization of such trees by *Monochamus galloprovincialis* (80%), *Acanthocinus aedilis* and *Tomicus minor* (75% each), somewhat less by *Phaenops cyaneus* and *Tomicus piniperda* (60% each). Similarly to trees of summer wind damage, the trees of winter wind damage were not colonized by *Arhopalus rusticus, Hylotrupes bajulus* and *Rhagium inquisitor* in the first year.

The next year the trees, damaged by wind in winter of previous year, were not colonized by *Pogonocherus fasciculatus, Ips acuminatus* and *Tomicus sp.* New galleries of *Ips sexdentatus* and *Phaenops cyaneus* were revealed in 10% of uprooted trees, which partly preserved root connection with soil. Tree colonization by longhorn beetles, adopted to development in dead wood, as well as the species with prolonged development in drying substrate (*Monochamus galloprovincialis*) has somewhat increased (see Table 2).

The threat of dissemination of stem insects in surrounding stands is determined by colonization of recently died trees. Our research show, that in 2010 (the year of great wind storm in June) the part of colonized by *Tomicus sp.* recently died trees in the stands near wind damaged stands did not exceeded 2.5% of trees. In 2011 it reached 65%, and in 2012 was only 7.5%. Obtained data show, that the threat of spread of stem insects after wind damage in the region of our investigations exists only two years.

Galleries of stem insects were revealed mainly in the lower side of uprooted trees (stems). Signs of colonization, mother galleries and dry eggs of insects were often found in the upper side of these trees (stems). Obtained data on colonization are agreed with data on temperature and relative humidity of phloem in different parts of uprooted trees (Table 3).

Both temperature and relative humidity did not differ in the upper and lower sides of stem with thin bark (see Table 3). At the same time the temperature was significantly higher and relative humidity significantly

less on the upper side of uprooted trees ($p < 0.05$). It explains the higher population density of stem insects in the parts of uprooted trees with thick bark.

Table 3

Temperature and relative humidity of phloem in different parts of uprooted trees (stems) (June, 16, 2011, 11.00 a.m.)

Indices	Parts of stem	
	part with thin bark	part with thick bark
Temperature, °C		
– upper side of stem	29.7±3.2	30.0±3.3
– lower side of stem	29.0±2.6	24.0±2.6
Relative humidity of phloem,%		
– upper side of stem	41.0±5.6	32.0±4.6
– lower side of stem	40.0±4.7	45.0±6.1

Conclusions and generalization. In the pine stands of the northern east of Ukraine the severity of colonization by stem insects is different for windbroken and uprooted trees, which depends on different rate of phloem drying.

Species composition of stem insects and severity of colonization depends on the terms of wind damage. In the year of summer wind storm *Phaenops cyaneus* (40% of trees) and *Monochamus galloprovincialis* (35% of trees) were prevalent. *Ips sexdentatus* and *Ips acuminatus* colonized trees in the second and sister broods. *Monochamus galloprovincialis, Arhopalus rusticus, Rhagium inquisitor* and *Hylotrupes bajulus* colonized these trees the next year.

In the year of winter wind storm *Monochamus galloprovincialis* (80%), *Acanthocinus aedilis* and *Tomicus minor* (75% trees each), *Phaenops cyaneus* and *Tomicus piniperda* (60% trees each) colonize the trees. The next year new galleries of *Ips sexdentatus* and *Phaenops cyaneus* were revealed in 10% uprooted trees, which kept alive roots in the soil. Rate of colonization by longhorn beetles, adapted to dead wood, and by species with prolonged development (*Monochamus galloprovincialis*) somewhat increases.

Timely sanitary felling after windstorm is necessary to prevent distribution of stem insects and to decrease the losses of timber, but sometimes it is impossible to carry out such measures in the whole area. In connection with it:

– total sanitary felling must be carried out in the first turn in the isolated forest plots with obligatory removal, debarking or treatment of timber with insecticides;
– in the case, when all damaged trees can be removed from windstorm plot during one year, windbroken trees must be felled in the first turn;
– in the case, when all damaged trees cannot be removed from windstorm plot during one year, uprooted trees must be felled in the first turn;
– dead trees of previous years and windbroken trees, which do not belong to industrial timber and do not colonized by physiological stem pests, must be removed in the last turn.

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В.Л. Мєшкова, Ю.Є. Скрильник, О.В. Товстуха

СТОВБУРОВІ ШКІДНИКИ НА ДІЛЯНКАХ ВІТРОВАЛУ У СОСНОВИХ НАСАДЖЕННЯХ ТА ПРІОРИТЕТИ ПРИЗНАЧЕННЯ САНІТАРНИХ РУБОК

У соснових насадженнях північного сходу України видовий склад стовбурових комах та інтенсивність заселення залежать від термінів пошкодження вітром (літній або зимовий вітровал) і відрізняються для буреломних і вітровальних дерев, що пов'язане з різними темпами висихання лубу. Тому суцільні санітарні рубки мають бути проведені насамперед на ізольованих ділянках лісу з обов'язковим вивезенням, корування або обробкою інсектицидами деревини. У випадку, коли всі пошкоджені дерева можливо вилучити упродовж одного року, насамперед потрібно вилучати буреломні дерева. У випадку, коли всі пошкоджені вітром дерева неможливо вилучити упродовж одного року, передусім варто вилучати вітровальні дерева. Дерева старого сухостою та бурелом, які не є діловими та не заселюються фізіологічними стовбуровими шкідниками, можна вилучати в останню чергу.

Ключові слова: соснові насадження, пошкодження вітром, вітровальні дерева, буреломні дерева, стовбурові шкідники

В. Л. Мешкова, Ю. Е. Скрыльник, А. В. Товстуха

СТВОЛОВЫЕ ВРЕДИТЕЛИ НА УЧАСТКАХ ВЕТРОВАЛА В СОСНОВЫХ НАСАЖДЕНИЯХ И ПРИОРИТЕТЫ НАЗНАЧЕНИЯ САНИТАРНЫХ РУБОК

В сосновых насаждениях северо-востока Украины видовой состав стволовых насекомых и интенсивность заселения зависят от сроков повреждения ветром (летний или зимний ветровал) и отличаются для буреломных и ветровальных деревьев, что связано с разными темпами высыхания луба. Поэтому сплошные санитарные рубки должны проводиться в первую очередь на изолированных участках леса с обязательным вывозом удалением, окоркой или обработкой инсектицидами древесины. В случае, когда все поврежденные ветром деревья возможно удалить в течение одного года, в первую очередь следует вырубать буреломные деревья. В случае, когда все поврежденные ветром деревья невозможно удалить в течение одного года, в первую очередь следует вырубать ветровальные деревья. Деревья старого сухостоя и буреломные, которые не являются деловыми и не заселяются физиологическими стволовыми вредителями, следует вырубать в последнюю очередь.

Ключевые слова: сосновые насаждения, повреждение ветром, ветровальные деревья, буреломные деревья, стволовые вредители