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SEASONAL DEVELOPMENT OF THE PINE SAWYER BEETLE (*MONOCHAMUS GALLOPROVINCIALIS*) IN THE NORTH-EASTERN STEPPE OF UKRAINE

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Research of pine sawyer beetle (*Monochamus galloprovincialis*) seasonal development, the dates of revealing and duration of different stages and respective temperature conditions was carried out in 2012–2016 in the stands of Scots pine (*Pinus sylvestris* L.) of the six forest and forest & hunting enterprises in Kharkiv and Luhansk regions. Early, medium and late dates for renewal of larvae feeding after wintering, their pupation, adult emergency, egg-laying, larvae hatching were determined. Significant correlation was proved between the dates of larval feeding renewal and their pupation, as well as between the dates of stable transition of air temperature over 10°C and adult swarming beginning. All these phenomena have a tendency to shift to an earlier date. The necessity of pine wood debarking after summer felling and its exportation from forest no later than 10 days after felling is substantiated, taking into account the minimum duration of pine sawyer beetle eggs development.
K e y w o r d s: pine sawyer beetle (*Monochamus galloprovincialis*), seasonal development, sum of positive temperatures, dates of stable transition of air temperature over 5, 10 and 15°C.

Introduction. Pine sawyer beetle – *Monochamus galloprovincialis* (Olivier, 1795) ssp. *pistor* (Germar, 1818) – is the typical representative of longhorn beetles (Coleoptera: Cerambycidae) in pine forests of Ukraine (Martynov & Pisarenko 2003, Bartenev 2009, Arystova & Skrylnik 2012).

This pest colonizes mainly windfall and felled trees, which have enough nutritious and moist phloem with relatively low resistance to insect colonizing compared to living trees. However, at high population density, pine sawyer beetle colonizes living trees, which are weakened to varying degrees, and forms the foci of mass propagation in the stands with impaired stability (Valenta 2012).

Physiological damage of pine sawyer beetle is manifested in the ability to colonize living trees, to weaken them during maturation feeding and to transfer the pathogens (Skrylnik 2013). Particularly, pine sawyer beetle is a vector of pine wood nematode *Bursaphelenchus xylophilus* (Steiner & Buhrer, 1934) Nickle, 1970, which damages parenchyma cells of resin channels in pine and causes tree wilting and mortality (Braasch 2001). Because of it some countries have restricted timber import from the countries, where *Monochamus* sp. spread (Selikhovkin & Davydova 2003).

Pine sawyer beetle is also a technical pest because its larvae gnaw wide (over 7 mm) and deep (over 10 cm) galleries in the wood, which brings to its quality and value losses (Skrylnik 2013).

To prevent the living trees colonizing by pine sawyer beetle is possible only by creating conditions for stand stability increase (Bark and Wood Boring Insects 2004). To prevent the colonizing of windfall and felled trees by this pest is possible by in time exportation them from a forest, debarking or treatment with insecticides in optimal dates (Meshkova et al. 2011, Kochetova 2015). Such dates depend on peculiarities of pine sawyer beetle seasonal development, particularly on the period when it can colonize windfall and felled trees in the certain region.

Research of phenological peculiarities of pine stem pests in the Left-bank Forest-Steppe of Ukraine gave the possibility to include pine sawyer beetle into summer phenological group (Skrylnik 2011), moreover, adult swarming begins not earlier the date of stable transition of air temperature over 15ºC and is rather long.

It was evaluated by long-term data that the dates of stable transition of air temperature over 15ºC are registered on May, 9 (from April, 20 to May, 23 in different years) in the Steppe zone (meteorological station Luhansk), on May, 13 (from April, 23 to June, 3) in the Left-bank Forest-Steppe (meteorological station Kharkiv), and on May, 17 (from May, 7 to June, 6) in Novgorod-Siverske Polissya (meteorological station “Druzhba” (Meshkova et al. 2015). So the threat of

windfall and felled trees colonizing by pine sawyer beetle exists in more early dates in Steppe zone than in Forest-Steppe zone.

The aim of the research was to estimate the dates of pine sawyer beetle development, duration of different stages and respective temperature conditions in the North-Eastern Steppe of Ukraine.

Materials and Methods. Research was carried out in 2012–2016 in the stands of Scots pine (*Pinus sylvestris* L.) in the State Enterprises (SE) "Kremenske Forest & Hunting Economy" (FHE), SE "Stanychno-Luhanske FHE", SE "Novoaidarske FHE" and SE "Severodonetske FHE" of Luhansk region, in 2012–2015 in pine stands of SE "Kupyanske Forest Enterprise (FE)" and SE "Izyumske FE" of Kharkiv region.

Peculiarities of pine sawyer beetle seasonal development were studied both by direct registration the beetles during leaving colonized trees, pairing and colonizing of new trees or their segments, and inspection colonized stems and branches by dissection in different dates.

The date of the first appearance of a certain stage was considered as the earliest date from all findings in the region.

Data on daily air temperature were taken from Luhansk meteorological station (48° 35' N, 39° 20' E, Luhansk region) in 2012–2013 and Izyum meteorological station (49° 11' N, 37° 18' E, Kharkiv region) in 2014–2016. It was shown (Meshkova et al. 2015) that summer temperature for these meteorological stations has no significant differences.

The dates of phenological events for analysis were transformed to a number of days from January, 1.

The dates of stable temperature transition over 5, 10 i 15°C, as well as the sums of positive temperatures, have been calculated for different periods of pine sawyer beetle seasonal development using *MS Excel* applications (Meshkova 2009). Descriptive statistics and variation index (*V*, %) were calculated by standard approach (Atramentova and Utevskaya 2008) using *MS Excel*.

Results. Given the fact that pine sawyer beetle seasonal development like all poikilothermic organisms depends on temperature (Meshkova 2009), we have analyzed the key points of this process for the years of our research (2012–2016) and compared with respective mean dates and variation coefficients for 2000–2014 in this region (Meshkova et al. 2015).

Analysis of Table 1 shows that date of stable transition of air temperature over 5°C was the earliest (March, 14) in 2014, and the latest (March, 27) in 2012 and 2013. Mean date of this phenological event evaluated for last five years (March, 22) was 2 days earlier, than evaluated for 2000–2014, and variation coefficients for 2012–2016 was less than that for previous 15 years (7.1 and 8.8 %, respectively). Considering that the date of stable transition of air temperature over 5°C is close to the date of soil thawing and beginning of pine sap flowing (Yelagin 1976), it can be concluded that larvae development under the bark also begins earlier.

Table 1

Dates of stable transition of air temperature over 5, 10 and 15°C in the years of research (2012–2013 – meteorological station Luhansk, 2014–2016 – meteorological station Izyum)

Date of stable transition of air temperature over:	Year*					For 2012–2016		For 2000–2014**	
	2012	2013	2014	2015	2016	mean	*V*, %	mean	*V*, %
5°C	27.03 / 86	27.03 / 86	14.03 / 73	24.03 / 83	18.03 / 77	22.03 / 81	7.1	24.03 / 83	8.8
10°C	8.04 / 98	11.04 / 101	17.04 / 107	20.04 / 110	8.04 / 98	13.04 / 103	5.5	15.04 / 105	5.5
15°C	23.04 / 113	28.04 / 118	3.05 / 123	12.05 / 132	8.05 / 128	3.05 / 123	6.2	9.05 / 129	6.8

*Numerator – calendar date (dd.mm); denominator – days from 1.01.

**According to Meshkova et al. (2015).

Our research shows that in 2012–2016, pine sawyer beetle larvae resumed feeding under the bark after hibernation on April, 3–8, in average on April, 6 (Table 2). Air temperature at these dates

was 5.8–12.6°C (Table. 3), that is exceeded the threshold of pine sap flowing beginning (Yelagin 1976).

All years the larvae of pine sawyer beetle began feeding under the bark after hibernation later than air temperature exceeded 5°C, but not later than it exceeded 10°C (see. Table 1 and 2).

Table 2

Pine sawyer beetle phenology (2012–2016)

Phenological events and periods	Year					Mean	*V*, %
	2012	2013	2014	2015	2016		
*Dates of certain phenological events**							
Larvae feeding beginning under the bark after hibernation	3.04	5.04	7.04	7.04	8.04	6.04	2.1
Pupation	18.05	22.05	25.05	30.05	28.05	25.05	3.3
Adult emergence	5.06	10.06	13.06	17.06	9.06	11.06	2.8
Mass swarming	20.06	18.06	23.06	25.06	21.06	21.06	1.6
Oviposition	15.06	21.06	22.06	25.06	17.06	20.06	2.3
Larvae hatching	1.07	4.07	3.07	7.07	5.07	4.07	1.2
Period, days							
Pupae development	18	19	19	18	12	17.2	17.1
From adult emergence to oviposition	10	11	9	8	8	9.2	14.2
Egg development	16	13	11	12	18	14.0	20.8

*Calendar dates (dd.mm);

However, a reliable correlation between larvae feeding beginning and the dates of stable transition of air temperature over 5°C was not proved. This fact, as well as wide variation in dates of pupation (V = 3.3 %, see Table 2) and temperature at these dates (V = 6.5 %, see Table 3), are connected with the variation of larval instar during hibernation, xylem temperature and humidity (Skrylnik 2008).

Pine sawyer beetle larvae completed their development and pupated at the end of the 2nd – in the 3rd decade of May (see Table 2). Air temperature at the dates of pupation was from 15.8°C in 2015 to 26.1°C in 2014, average 20.6°C (Table. 3).

Table 3

Mean air temperature (°C) in different periods of pine sawyer beetle development (2012–2016)

Phenological events	Year					Mean	*V*, %
	2012	2013	2014	2015	2016		
Larvae feeding beginning under the bark after hibernation	7.2	12.6	7.9	5.8	7.2	8.1	32.0
Pupation	16.4	23.7	26.1	15.8	21.1	20.6	21.8
Adult emergence	23.2	21.2	15.9	22.9	24.6	21.6	15.7
Mass swarming	24.7	21.4	15.6	22.5	21.4	21.1	15.9
Oviposition	23.7	23.3	18.9	22.5	22.9	22.3	8.7
Larvae hatching	20.2	25.3	19.6	24.5	23.1	22.5	11.3

Sum of positive temperatures at the date of the first pupae appearance was from 849.5°C in 2012 to 1,002.7°C in 2014 (mean – 911.5°C) (see Table 4).

The dates of pupation correlated significantly (r = 0.92; P < 0.05) with the dates of the beginning of larvae feeding after hibernation.

Length of period between the date of stable air temperature transition over 10°C and the date of first pupae appearance (see Table 1, 2) was from 38 to 51 days in different years, and between the date of stable air temperature transition over 15°C and the date of first pupae appearance it was from 18 to 25 days. According to this, the dates of pine sawyer beetle development and optimal dates of felled wood exportation can be specified.

Sum of positive temperatures for pupae development (from pupation to adult emergence) varied less than a sum of positive temperatures for egg development or for the period from adult

emergence to oviposition (V = 9.8 %). The mean meaning of it was 380.7°C, the minimum (336.2°C) in 2012 and the maximum (413.7 °C) in 2014 (Table 4).

Table 4

Sum of positive temperatures (°C) on the date of certain phenological events beginning in pine sawyer beetle development or for different periods of its development (2012–2016)

Phenological events and periods	Year					Mean	V, %
	2012	2013	2014	2015	2016		
Sum of positive temperatures on the date of certain phenological event beginning, °C							
Larvae feeding beginning under the bark after hibernation	75.8	96.1	249.2	166.6	183.4	154.2	45.3
Pupation	849.5	873.2	1,002.7	926.7	905.4	911.5	6.5
Adult emergence	1,185.7	1,274.9	1,416.4	1,334.0	1,250.1	1,292.2	6.8
Mass swarming	1,552.4	1,477.8	1,591.4	1,507.1	1,414.6	1,508.7	4.5
Oviposition	1,437.9	1,541.4	1,575.8	1,507.1	1,456.2	1,503.7	3.8
Larvae hatching	1,757.5	1,845.8	1,777.9	1,769.4	1,720.7	1,774.3	2.6
Sum of positive temperatures for periods, °C							
Pupae development	336.2	401.7	413.7	407.3	344.7	380.7	9.8
From adult emergence to oviposition	252.2	266.5	159.4	173.1	206.1	211.5	22.3
Egg development	319.6	304.4	202.1	262.3	264.5	270.6	16.9

Pupae developed 12–19 days in different years (see Table 2). The sum of positive temperatures for pupae development was from 336.2°C in 2012 to 413.7°C in 2014, on the average 380.7°C (see Table 4).

By research in the Left-bank Forest-Steppe, the swarming of pine sawyer beetle was registered in May – June (Skrylnik 2011), in Central Europe in May (Bark and Wood Boring Insects 2004), in Baltic countries in July (Valenta 2012).

In the Steppe zone, by our research, beginning of pine sawyer beetle swarming have little variation over the years (V = 2.8 %). It begins at the end of the 1st – beginning of the 2nd decade of June (see Table 2). The air temperature was 15.9–24.6°C (average 21.63°C) in these dates (see Table 3). Correlation between the date of pupation and the date of adult emergence was high (r = 0.8) but not significant, which is connected with the short period of research.

The dates of flight beginning correlate significantly (r = 0.92; P < 0.05) with the dates of stable transition of air temperature over 10°C. This relation can be used for prediction the dates of felled wood colonization by this pest.

The mass flight of pine sawyer beetle began in different years in very close dates – from June, 18 to June, 25, in average on June, 21 (V = 1.6 %). Flight of this insect was registered up to the end of vegetation period, which is consistent with publications from other regions (Bark and Wood Boring Insects 2004, Skrylnik 2011, Valenta 2012).

After leaving the place of development pine sawyer beetle has maturation feeding on the tops of temporally weakened but viable trees, on thin branches in the crown, and thereby causes significant physiological damage (Fig. 1).

Only 8–11 days after emergence (see Table 2), after accumulation of 159.4–266.5°C positive temperatures (see Table 4), pine sawyer beetles mate and oviposit 1–3 eggs per one notch (browsed holes) on the stems of living, windfall and felled trees. Oviposition began the earliest on June 15, 2012, and the latest date was June 25, 2015 (in average, June 20). Mean air temperature during oviposition period was 18.9–23.7°C (V = 8.7 %) (see Table 3).

The first pine sawyer beetle larvae hatch in the 1st decade of July (July, 1–7, in average, on July, 4) (see Table 2). Eggs developed from 11 to 18 days in different years (in average 14 days). Sum of positive temperatures for their development was 202.1–319.6°C (in average 270.6°C) (see Table 4).

Obtained data show, that one must protect felled wood before larvae hatch and begin feeding. Taking into account the minimal duration of egg development, colonized felled wood must be

removed from the forest, debarked or treated not late than in 10 days (Meshkova et al. 2011, Kochetova 2015).

Fig. 1 – Maturation feeding of pine sawyer beetle on pine branch

After hatching, the larvae of pine sawyer beetle browsed the galleries under the bark, and closer to the winter moved to the xylem and hibernated there. Characteristic sawdust could be seen in the places of larvae relocation to the xylem (Fig. 2).

Fig. 2 – Characteristic sawdust in the places of pine sawyer beetle larvae development

At that time the galleries are rather wide and deep and can contain some pathogens, particularly blue-stain fungi (Fig. 3), which sharply decreases timber quality (Skrylnik 2013).

Studies from different regions show that pine sawyer beetle development can last one or more years (Bark and Wood Boring Insects 2004, Valenta 2012). It was shown (Skrylnik 2008) that in the Left-bank Forest-Steppe pine sawyer beetle develops for one year but in the drying logs larvae development slows down and resumes and completes the next year in conditions of increasing humidity. In such case the calendar dates of beetle swarming, oviposition, larvae hatch and pupation little depended on whether one-year or two-year generation of it developed.

Obtained data show, that immediate debarking of pine wood (which promotes its quick drying), and immediate exportation even pine sawyer beetle colonized wood and ensuring its drying can minimize the harmful effects of pine sawyer beetle activities.

Fig. 3 – Pine sawyer beetle larvae and blue-stain in the xylem of colonized pine

Conclusions

1. Pine sawyer beetle larvae resume feeding under the bark after hibernation on April, 3–8, pupate in the end of the 2nd beginning of the 3rd decade of May. Young beetles emerge in the 1st–2nd decades of June and browse the bark of young branches in pine crowns. For a period of adult emergence to oviposition 173.1–266.5°C and on egg development 270.6°C of positive temperatures accumulate. The larvae hatch in the first half of July, feed under the bark and move to the xylem at the end of vegetation period.

2. The dates of pupation of pine sawyer beetle larvae reliably correlate with the date of feeding beginning after hibernation, and the dates of flight beginning reliably correlate with the date of stable transition of temperature over 10°C. All these phenomena tend to shift at an earlier date.

3. Immediate debarking of pine wood after summer felling and exportation it from forest not later than 10 days after felling (taking into account the minimum duration of egg development) can minimize the harmful effects of pine sawyer beetle activities.

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СЕЗОННИЙ РОЗВИТОК ВУСАЧА ЧОРНОГО СОСНОВОГО У ПІВНІЧНО-СХІДНОМУ СТЕПУ УКРАЇНИ

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Дослідження сезонного розвитку вусача чорного соснового (*Monochamus galloprovincialis*), термінів виявлення, тривалості окремих стадій і відповідних температурних умов проведено у 2012–2016 рр. у насадженнях сосни звичайної (*Pinus sylvestris* L.) шести лісогосподарських і лісомисливських підприємств Харківської та Луганської областей. Визначено ранні, середні та пізні терміни відновлення живлення личинок після зимівлі, їхнього лялькування, вильоту жуків, відкладання ними яєць, вилуплення личинок. Доведено наявність достовірної кореляції між датами відновлення живлення личинок під корою та датами їхнього лялькування, а також між датами стійкого переходу температури повітря через 10°С та датами початку льоту імаго. Усі зазначені явища мають тенденцію до зсуву на більш ранні терміни. Обґрунтовано необхідність корування заготовленої влітку деревини сосни та вивезення її не пізніше ніж через 10 днів після рубки, зважаючи на мінімальну тривалість розвитку яєць цього шкідника.

Ключові слова: вусач чорний сосновий (*Monochamus galloprovincialis*), сезонний розвиток, сума додатних температур, дати стійкого переходу температури повітря через 5, 10 і 15°С.

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СЕЗОННОЕ РАЗВИТИЕ УСАЧА ЧЕРНОГО СОСНОВОГО В СЕВЕРО-ВОСТОЧНОЙ СТЕПИ УКРАИНЫ

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Исследования сезонного развития усача черного соснового (*Monochamus galloprovincialis*), сроков обнаружения, продолжительности отдельных стадий и соответствующих температурных условий проведены в 2012–2016 гг. в насаждениях сосны обыкновенной (*Pinus sylvestris* L.) шести лесохозяйственных и лесоохотничьих предприятий Харьковской и Луганской областей. Определены ранние, средние и поздние сроки возобновления питания личинок после зимовки, их окукливания, вылета жуков, откладки ими яиц, отрождения личинок. Доказано наличие достоверной корреляции между датами возобновления питания личинок под корой и датами их окукливания, а также между датами устойчивого перехода температуры воздуха через 10°С и датами начала лёта имаго. Все перечисленные явления имеют тенденцию смещаться на более ранние сроки. Обоснована необходимость окорки заготовленной летом древесины сосны и вывоза ее не позже чем через 10 дней после рубки, принимая во внимание минимальную продолжительность развития яиц этого вредителя.

К л ю ч е в ы е с л о в а : усач черный сосновый (*Monochamus galloprovincialis*), сезонное развитие, сумма положительных температур, даты устойчивого перехода температуры воздуха через 5, 10 и 15°С.

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