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BIOLOGY OF MULTIVOLTINE BARK BEETLES SPECIES (COLEOPTERA: SCOLYTINAE) IN THE NORTH-EASTERN STEPPE OF THE UKRAINE

Meshkova V. L., Kochetova A. I., Zinchenko O. V., Skrylnik Yu. Ye. Biology of multivoltine bark beetles species (Coleoptera: Scolytinae) in the North-Eastern Steppe of the Ukraine. *Biological peculiarities, seasonal development and seasonal population dynamics of three multivoltine bark beetles — Ips sexdentatus (Boerner, 1767), I. acuminatus (Gyllenhal, 1827) and Orthotomicus proximus (Eichhoff, 1867) in the stands of Scots pine (Pinus sylvestris L.) in the North-Eastern Steppe of the Ukraine have been studied. Investigated species have two basic generations and additional sister brood, which development overlaps. Fresh nuptial chambers can be found from the beginning of vegetation up to beginning of August. Number of adults is the highest at the end of April — on the beginning of May. I. sexdentatus prefers to colonize the lowest part of stem with rough bark, I. acuminatus colonizes the upper part of stem with thin bark, and Orthotomicus proximus colonizes the middle part of stem with transitional bark. Mean duration of development and respective sums of positive temperatures for individual generations of Ips sexdentatus have been evaluated …….. 16 Ref.*
Key words: *Ips sexdentatus, I. acuminatus, Orthotomicus proximus*, biology, seasonal development, seasonal population dynamics.

Мєшкова В. Л., Кочетова А. І., Зінченко О. В., Скрильник Ю. Є. Біологія полівольтинних видів короїдів (Coleoptera: Scolytinae) у Північно-Східному Степу України. *Досліджено біологічні особливості, сезонний розвиток і сезонну динаміку популяцій трьох полівольтинних видів короїдів — Ips sexdentatus (Boerner, 1767), I. acuminatus (Gyllenhal, 1827) та Orthotomicus proximus (Eichhoff, 1867) у насадженнях сосни звичайної (Pinus sylvestris L.) у Північно-Східному Степу України. Досліджені види характеризуються наявністю двох основних і додаткових сестринських поколінь, розвиток яких перекривається. Свіжі поселення можливо виявити з початку вегетаційного періоду і до початку серпня. Чисельність жуків є максимальною наприкінці квітня – на початку травня. Шестизубчастий короїд надає перевагу нижній частині стовбура із грубою корою, верхівковий — верхній частині стовбура з тонкою корою, а сушняковий — середній частині стовбура з перехідною корою. Розраховано середню тривалість розвитку окремих поколінь шестизубчастого короїда та відповідні суми додатних температур……..16 назв.*
Ключові слова: короїд шестизубчастий (Ips sexdentatus), короїд верхівковий (I. acuminatus), короїд сушняковий (Orthotomicus proximus), біологія, сезонний розвиток, сезонна динаміка популяції.

Мешкова В. Л., Кочетова А. И., Зинченко О. В., Скрыльник Ю. Е. Биология поливольтинных видов короедов (Coleoptera: Scolytinae) в Северо-Восточной Степи Украины. *Исследованы биологические особенности, сезонное развитие и сезонная динамика популяций трех поливольтинных короедов — Ips sexdentatus (Boerner, 1767), I. acuminatus (Gyllenhal, 1827) и Orthotomicus proximus (Eichhoff, 1867) в насаждениях сосны обыкновенной (Pinus sylvestris L.) в Северо-Восточной Степи Украины. Исследованные виды характеризуются наличием двух основных и дополнительных сестринских поколений, развитие которых перекрывается.*

Свежие поселения можно обнаружить с начала вегетационного периода и до начала августа. Численность жуков является наибольшей в конце апреля – в начале мая. Шестизубчатый короед предпочитает заселять нижнюю часть ствола с грубой корой, вершинный — верхнюю часть ствола с тонкой корой, а валежный — среднюю часть ствола с переходной корой. Рассчитана средняя продолжительность развития отдельных поколений шестизубчатого короеда и соответствующие суммы положительных температур……16 назв.
Ключевые слова: короед шестизубчатый (*Ips sexdentatus*), короед вершинный (*I. acuminatus*), короед валежный (*Orthotomicus proximus*), биология, сезонное развитие, сезонная динамика популяции.

Introduction. Recently, due to global climate change and anthropogenic pressure health condition of pine forests has been worsened [11]. Such situation is especially dangerous for Ukraine, where Scots pine (*Pinus sylvestris* L.) is the main forest forming species in the forest stands of over 30 % forest fund area and grows mainly in the pure plantations [4].

Deterioration of pine forest health condition is favorable for bark beetles outbreaks, because abundance of these insects depends on volume of available substrate for colonization, particularly severely weakened, wind disturbed and felled trees, and wood debris [3, 7]. At rather high population density bark beetles can colonize even healthy looking trees, although many specimens of beetles become killed when attempting to do it [12].

Physiological injuriousness of bark beetles consists in their ability to colonize living trees, to damage them during maturation feeding and to vector the pathogens, which accelerate tree mortality. Technical injuriousness of bark beetles, which is connected with browsing the galleries, is relatively small, because these galleries are under the bark. However penetration of pathogenic fungi and other organisms with these insects causes the worsening of wood quality and decrease of its value [9, 16].

General injuriousness of bark beetles increases, if they develop in several generations per year, because the risk of tree and harvested wood colonization is rather high during the most part of vegetation period [9, 12]. In the pine forests of the Left-bank Ukraine two multivoltine bark beetle species – *Ips sexdentatus* (Boerner, 1767) and *I. acuminatus* (Gyllenhal, 1827) are the most spread [10]. In the North-Eastern Steppe of the Ukraine one more multivoltine bark beetle species, *Orthotomicus proximus* (Eichhoff, 1867) is abundant [1].

Effective measures to reduce economic losses in the foci of bark beetles are timely removal of harvested wood or its debarking or treatment with insecticide, as well as detecting and felling of colonized trees before emergence of new bark beetles generation [12].

Despite the large number of publications regarding multivoltine bark beetles, the research cover mainly their species composition and biology of certain species [1, 8, 13, 14], whereas little attention is paid to their seasonal development and seasonal population dynamics [10, 12, 15], especially in the Steppe zone of Ukraine [3, 7].

The aim of our research was to reveal the peculiarities of seasonal development and seasonal population dynamics of multivoltine bark beetles in the North-Eastern Steppe of the 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 bark beetles seasonal development were studied both by direct registration the beetles during leaving colonized trees, pairing and colonizing of new trees or their segments, and by inspection colonized stems and branches by their dissection in different dates [5].

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

Population density of bark beetles in different survey dates was assessed by stem sections inspection. The data were transferred to the standard segment with surface area 10 dm^2 (50 cm long with 20 cm circumference).

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 [7], that summer temperature for these meteorological stations had not significant differences.

The dates of phenological events for analysis were transformed to number of days from January, 1. The sums of positive temperatures have been calculated for different periods of bark beetle seasonal development [6] using MS Excel applications. Descriptive statistics was calculated by standard approach [2] also using MS Excel.

Results. *Ips sexdentatus* actively colonizes wind broken and wind excavated trees, trap trees, harvested wood, wood debris, much less – standing weakened trees in the region of our investigation. This is consistent with publications [3, 14], according to which the pest colonizes only those living trees, which were weakened by fire, root rot or have been already colonized in the upper part of stem by more aggressive stem pests.

I. sexdentatus hibernates as adult in the galleries, which it browses near place of its development, or in special (so called "minir") galleries under the bark of trees, fresh pine stumps or in the forest litter. After different sources [3, 7, 10], the first adults of *I. sexdentatus* can be seen from the beginning of May up to the end of June. After our research, the first adults were revealed simultaneously with *Tomicus minor* (Hartig, 1834) – in the 2nd – the 3rd decades of April (Table 1).

1. Phenology of *Ips sexdentatus* (2012–2016)

Phenological events and periods	Years					Mean
	2012	2013	2014	2015	2016	
*Dates of certain phenological events**						
Adult emergence after hibernation	14.04	15.04	23.04	24.04	13.04	18.04
Tree colonization by the 1st generation	20.04	21.04	27.04	29.04	19.04	23.04
Tree colonization by sister brood	19.05	15.05	19.05	23.05	13.05	19.05
Tree colonization by the 2nd generation	8.07	11.07	17.07	15.07	7.07	12.07
Emergence of the 2nd generation offspring	26.09	18.09	25.09	27.09	21.09	23.09
Period, days						
Between tree colonization by the 1st and sister broods	30	25	22	24	26	25
Between tree colonization by the 2nd and the 1st generations	80	81	81	77	80	80
Between tree colonization by the 2nd generation and emergence of its offspring	80	70	61	73	82	73

Notes: * calendar dates (dd.mm)

The beetles carried out maturation feeding near larvae galleries in the places of their development, and moved to other trees at high population density, where browsed "minir" galleries. The beetles colonized the trees or wood a few days after leaving the places of hibernation or development. Little piles of sawdust is the main sign of tree colonization, it is especially well visible on lying trees.

In connection with the presence of two main generations and sister broods, that were overlapped, i *I. sexdentatus* adults can be found throughout almost the entire period from the end of April to the end of August.

I. sexdentatus is polygamic species. During tree colonization a male browses rather large nuptial chamber (width about 2 cm), from which the females build maternal galleries. There is usually one male and 3–6 females in one family; therefore several maternal galleries are browsed from nuptial chamber. One of them is directed to the crown and other to the soil.

Female browses several ventilation holes along the maternal gallery. As it browses the gallery, it lays the eggs in the niches. The first larvae of *I. sexdentatus* were found 10 days after tree colonizing, and the first pupae — in the middle of June. The dates of larvae development vary even in the progeny of one female, because it browses the maternal gallery within a few days, and temperature varies considerably within the stem.

larvae galleries are relatively short (2–5 cm), directed at right angles to the maternal gallery, winding, well separated from each other. They are located at the both sides of each maternal gallery and ended with pupal chambers. All galleries are located in the bark and almost do not touch the sapwood.

I. sexdentatus beetles, which have hibernated, after oviposition carried out maturation feeding and then mated and oviposited, initiating the sister brood (see. Table 1). Galleries of sister brood were found on May 13 in 2016, on May 19 in 2012 and 2014, and on May 23 in 2015, that is after 24–30 days (in average 25 days) after tree colonizing by the beetles after hibernation.

Air temperature at the dates of adult emergence after hibernation was from 12.7°C in 2013 to 18.0°C in 2014, average 15.3 °C (Table. 2). During tree colonization by the 1st generation air temperature amounted from 16.3 °C in 2014 to 21.8 °C in 2012, average 18.8 °C. Tree colonization by sister brood occurred at air temperature over 20 °C in almost all years of research, and tree colonization by the 2nd generation occurred in average at 22.3 °C, but in 2015 and 2016 the temperature was below 20 °C. Emergence of the 2nd generation offspring occurred at 10 and 11 °C in 2014 and 2016, and was above 20 °C only in 2015. Therefore some part of beetles did not leave the place of development and stayed there for hibernation.

2. Mean air temperature (°C) in different periods of *Ips sexdentatus* development (2012–2016)

Phenological events	Years					Mean
	2012	2013	2014	2015	2016	
Adult emergence after hibernation	13.5	12.7	18.0	14.3	17.8	15.3
Tree colonization by the 1st generation	21.8	18.6	16.3	18.1	19.4	18.8
Tree colonization by sister brood	23.7	22.5	27.1	23.9	18.3	23.1
Tree colonization by the 2nd generation	25.4	23.4	25.8	17.8	19.0	22.3
Emergence of the 2nd generation offspring	15.8	17.8	10.0	21.2	11.0	15.2

Sum of positive temperatures at the time of starting the sister brood of I. sexdentatus amounted 714.8–873.2 °C (in average 797.9 °C) (Table 3).

Adults of *I. sexdentatus* 2nd generation, which are the offspring of hibernated beetles, emerge from the end of June to the beginning of July. Very often young beetles leave the tree for several individuals through each exit hole, which complicated the calculation the offspring of one family.

The first generation of *I. sexdentatus* develops 80 days in average, in different years from 77 (2015) to 81 days (2013 and 2014) (see Table 1). For period of this generation development 1446.1–1745.4 °C (in average 1599.7 °C) of positive temperatures is accumulated (see Table 3).

The first tree colonization by the adults of the 2nd generation of *I. sexdentatus* were found on July, 7–17. Young beetles of the 2nd generation were found in the 2nd–3rd decades of September at 10–17.8 °C (in average 15.2 °C) (see Table 1, 3).

3. Sum of positive temperatures (°C) on the date of certain phenological events in *Ips sexdentatus* development or for different periods of its development (2012–2016)

Phenological events and periods	Years					Mean
	2012	2013	2014	2015	2016	
Sum of positive temperatures on the date of certain phenological event beginning, °C						
Adult emergence after hibernation	185.6	180.0	429.9	316.8	333.0	289.1
Tree colonization by the 1st generation	278.0	269.6	482.3	404.2	427.1	372.2
Tree colonization by sister brood	873.2	714.8	855.5	779.0	766.8	797.9
Tree colonization by the 2nd generation	1957.6	2015.0	2085.5	1928.3	1873.2	1971.9
Emergence of the 2nd generation offspring	3641.3	3369.3	3548.9	3526.6	3494.3	3516.1
Sum of positive temperatures for periods, °C						
Between tree colonization by the 1st and sister broods	595.2	445.2	373.2	374.8	339.7	425.6
Between tree colonization by the 2nd and the 1st generations	1679.6	1745.4	1603.2	1524.1	1446.1	1599.7
Between tree colonization by the 2nd generation and emergence of its offspring	1683.7	1354.3	1463.4	1598.3	1621.1	1544.2

Development of the 2nd generation of *I. sexdentatus* lasted from 61 to 82 days (in average 73 days), and the sum of positive temperatures for this period amounted 1354.3–1683.7 °C (in average 1544.2 °C).

Since the last-generation beetles of *I. sexdentatus* develop at the end of vegetation period, in a few days until a stable temperature decrease through 10 °C, these beetles do not leave the places of development, and hibernated there.

Ips acuminatus. Unlike *I. sexdentatus*, another bark beetle, *I. acuminatus* colonizes mainly the parts of stems with thin bark and branches [8]. Therefore its seasonal development is impossible to study in living trees. In the felled trees *I. acuminatus* colonized mainly the parts of stem with diameter up to 10 cm, which quickly dried up. Therefore it was not impossible to determine exact dates of certain stages development, and we can demonstrate only the scheme of seasonal dynamics of *I. acuminatus* seasonal development on the base of five-year data on trap trees colonization (Fig. 1).

Seasonal development of *I. acuminatus* in the region of our research was very similar to that of *I. sexdentatus*. The beetles carried out maturation feeding in the galleries after hibernation and then leave the trees and colonize another available trees or harvested wood from the 2nd decade of April up to the end of May with the maximum in the 3rd decade of April.

The beetles, which hibernated, repeatedly oviposit from the end of April up to the end of June with the maximum in the 2nd–3rd decades of May. Sister brood of *I. acuminatus* develops from these eggs (maximum of freshly colonized trees in the middle of July).

The beetles of the 2nd generation emerge from the end of August up to the middle of October. It is possible to reveal the beetles of *I. acuminatus* (see Fig. 1) as well as its larvae under the bark during the whole vegetation period.

Orthotomicus proximus colonizes mainly felled trees and wood debris, and more seldom the tops of drying trees. However sometimes we found its galleries in the living pines. *O. proximus* colonizes the trees mainly in the middle part of stem with transitional bark, but sometimes its galleries can be detected in the parts of stem with thin and rough bark.

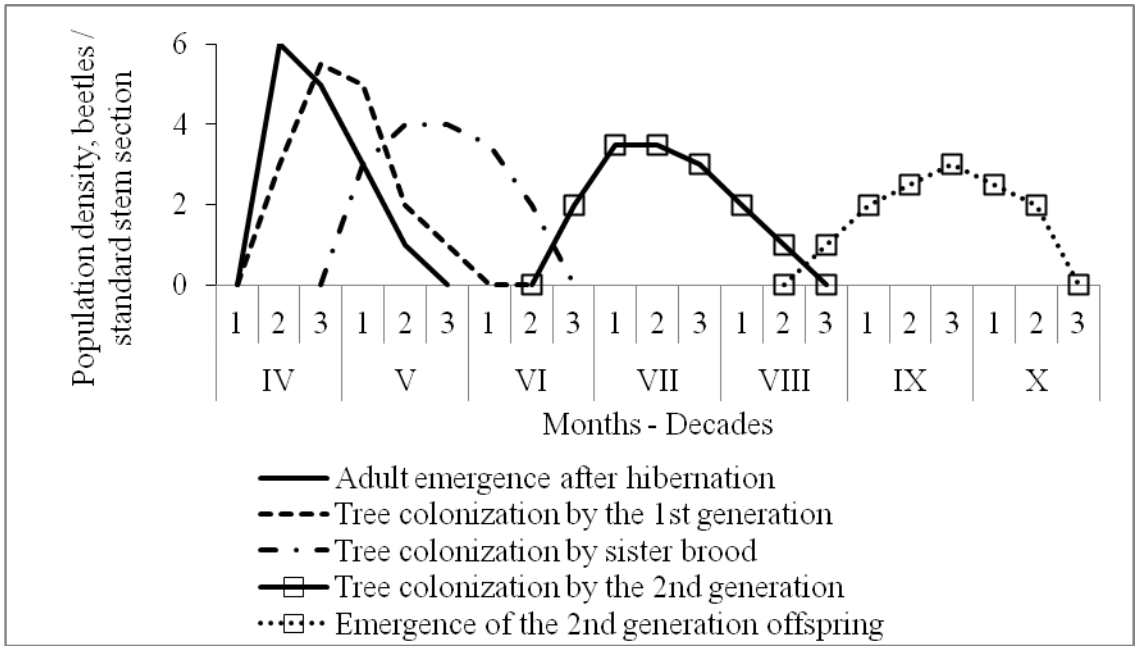

Fig. 1. Seasonal dynamics of harvested pine trees colonizing by *I. acuminatus* (standard stem section surface = 10 dm^2, average for 2012–2016)

Beetles of *O. proximus* (Fig. 2) hibernate under the bark of pine stumps or in undamaged parts of trees, where they developed. Entrance holes of "winter" galleries are confined to sracks and bark damage, the galleries have irregular shape and somewhat buried in sapwood. Certain part of population hibernates in the forest litter.

O. proximus beetles carried out maturation feeding under the bark in the galleries, which are browsed in different directions. The place of O. proximus development includes triangle nuptial chamber, 2–3 undulate maternal galleries length less than 10 cm and width 2 mm (Fig. 3). Long larval galleries are located dense and often interwined. Mother galleries can touch the sapwood, and larval galleries are under the bark. Pupal chamber are located in the outer layer of sapwood.

Fig. 2. *Orthotomicus proximus* colonizes tree (May, 2014)

Fig. 3. Galleries of *Orthotomicus proximus* (June, 2014)

Seasonal development of *O. proximus* in the region of our research was similar to those of *I. sexdentatus* and *I. acuminatus*. Maximal abundance of *O. proximus* beetles colonizing trap trees was assessed in the 2nd half of April up to the 1st half of May (Fig. 4).

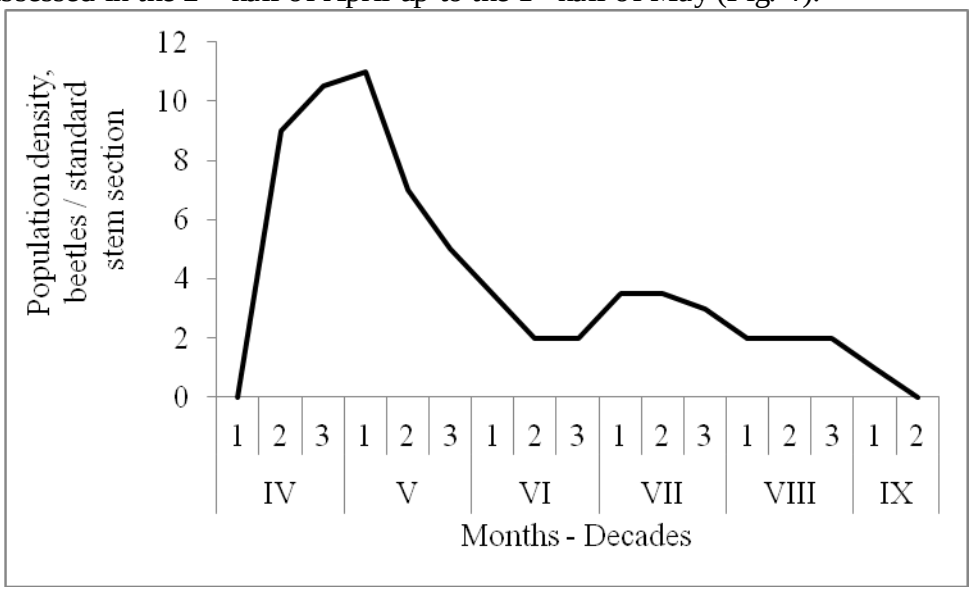

Fig. 4. Seasonal dynamics of *Orthotomicus proximus* population density (standard stem section surface = 10 dm^2, average for 2012–2016)

In May the beetles of *O. proximus*, which hibernated, oviposited for the second time, starting a sister generation. The offspring of beetles, which have oviposited soon after hibernation, completed their development at the end of June. These beetles colonized trees in July, and their progeny emerged in September. As the development of generations overlapped, new nuptial chambers could be found from the beginning of May to the beginning of August, and the larvae were found from the second half of May to the end of August.

Like other analyzed bark beetles, *O. proximus* vectors the blue-stain fungi during maturation feeding and tree colonizing, which enhances its injuriousness.

Conclusions. 1. *Ips sexdentatus* (Boerner, 1767), *I. acuminatus* (Gyllenhal, 1827) and *Orthotomicus proximus* (Eichhoff, 1867) in the stands of Scots pine (*Pinus sylvestris* L.) in the North-Eastern Steppe of the Ukraine have two basic generations and additional sister brood, which development overlaps. Fresh nuptial chambers can be found from the beginning of vegetation and by the beginning of August. Number of adults is the highest at the end of April – on the beginning of May.

2. *Ips sexdentatus* prefers to colonize the lowest part of stem with rough bark, *I. acuminatus* colonizes the upper part of stem with thin bark, and *Orthotomicus proximus* colonizes the middle part of stem with transitional bark.

3. *Ips sexdentatus* leaves the place of hibernation in the second–third decades of April. The beetles lay eggs twice at intervals of 24–30 days. Beetles of the first generation develop 80 days in average (1446.1–1745.4 °C of positive temperatures), of the second generation develop 61–82 days (1354.3–1683.7 °C).

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