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EVALUATION OF PHEROMONE TRAPS FOR BARK BEETLES AND THEIR PREDATORS IN PINE FORESTS IN THE KHARKIV REGION

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Species composition, abundance, and seasonal dynamics of bark beetles and their predators were investigated in different pheromone trap-blade combinations in Scots pine stand in the Kharkiv region. Three types of traps (A – Funnel; B – Theyson; C – Crosstrap® mini) and pheromones of *I. acuminatus* and *I. sexdentatus* (produced by the Spanish company Sanidad agricola econex s.l.) were tested. Five bark beetle species (Curculionidae: Scolytinae), five longhorn beetles (Cerambycidae), five predator species from Histeridae, Cleridae, Nitidulidae, Monotomidae, and Tenebrionidae, as well as several representatives of Staphylinidae, Carabidae, and Elateridae were captured in traps with pheromones of *Ips acuminatus* and *I. sexdentatus*. Target species – *Ips acuminatus* and *I. sexdentatus* accounted for 51% and 31% of all captured beetles, respectively. Their abundance, seasonal dynamics, and proportion depended on the trap type, pheromone, and blade. The highest number of *I. acuminatus* beetles was captured in Crosstrap® mini traps (C type), that of *I. sexdentatus* – in Theyson traps (type B). An increase in dispenser number provides more captures of *I. acuminatus* and has no significant influence on captures of *I. sexdentatus.* Abundance of *Th. formicarius* was the lowest in trap B (Theyson), and the highest in trap C (Crosstrap® mini). The number of *Th. formicarius* individuals in traps A and C with the pheromone of *I. acuminatus* was higher than in the traps with the pheromone of *I. sexdentatus.* Differences in the captured *Th. formicarius* beetles in the traps with more dispensers with the pheromone of *I. acuminatus* are significant and in the traps with the pheromone of *I. sexdentatus* nonsignificant.
Key words: *Ips acuminatus*, *I. sexdentatus, Thanasimus formicarius*, non-target species, seasonal dynamics, dispenser.

Introduction. The pine stands of many regions have been affected by outbreaks of bark beetles with the dominance of *Ips acuminatus* (Gyllenhal, 1827) and *Ips sexdentatus* (Börner, 1776) (Colombari et al. 2013, Liška et al. 2021, Meshkova 2021, Lantschner & Corley 2023). As the foci of these insect species collapsed, the abundance of *Tomicus piniperda* (Linnaeus, 1758) and *T. minor* (Hartig, 1834) increased (Andreeva et al. 2019). In 2019–2022, we studied the distribution of predatory Coleoptera in the foci of bark beetles in the Sumy and Kharkiv regions by assessing under the bark and capturing insects in window traps (Vorobei 2022). The results indicated the dependence of the species composition and number of predators on the environmental conditions of the stands and the method of assessing.

In many countries, pheromone traps are produced and used to monitor and suppress native and alien bark beetles (Faccoli et al. 2020, Knížek et al. 2022, Miller & Asaro 2023, Erdoğan 2024). The effectiveness of their use depends on trap design, shape, size, color, position, and deployment timing. In Ukraine, pheromone traps for catching bark beetles are not produced. In past years, individual forestry enterprises used pheromone traps produced in different countries; however, the results were not analyzed and published. The effectiveness of different trap designs and the number of lures for pine bark beetles have not been previously studied in Ukraine.

In 2023, within the framework of the FAO project TCP/RER/3801, State Specialized Forest Protection Enterprise "Kharkivlisozahyst" received three types of pheromone traps produced by the Spanish company Sanidad agricola econex s.l. and pheromones intended for the capture of *I. acuminatus* and *I. sexdentatus*.

The study aimed to compare the species composition and abundance of both bark beetles and their predators by captures in the different pheromone trap-lure combinations.

Materials and Methods. The research was carried out in June – August 2023 in pure mature pine stands in compartment 80 subcompartment 4 of the Vasishcheve subunit (State Specialized Enterprise "Forests of Ukraine", Branch "Zhovtneve Forestry"). Three types of pheromone traps were placed randomly in six locations of a homogeneous stand, the distance between which was about 50 meters. Type A traps (Funnel) contain 8 funnels (Fig. 1), Type B traps are Theyson (Fig. 2), and type C traps are Crosstrap® mini (Fig. 3). Depending on the experimental design, the traps contained blades with pheromones of *Ips acuminatus* or *Ips sexdentatus*. Blades for *I. acuminatus* contained 2 and 3 dispensers (commercial names 4C and 5C, respectively), and blades for *I. sexdentatus* contained 3 and 4 dispensers (commercial names 4C and 5C, respectively). In control treatments, respective traps (A, B, and C) were left empty (without blades). Trapping experiments were carried out from 20 June through 8 August 2023.

Fig. 1 – Type A trap (Funnel)

Fig. 2 – Type B trap (Theyson)

Fig. 3 – Type C trap (Crosstrap® mini)

Trapped insects were collected every 7 days, dried, and sorted. Bark beetles, longhorn beetles, and predators were identified at the species level, and some other insect groups at the family level at least.

To compare the beetle abundance in different types of traps and blades, the χ^2 test was used (Atramentova & Utevskaya 2008).

Results and Discussion. A total of 5,848 beetles were captured by all traps from 20 June through 8 August 2023.

Five bark beetle species (Coleoptera: Curculionidae: Scolytinae), particularly *I. acuminatus*, *I. sexdentatus*, *T. piniperda*, *T. minor*, and *Pityogenes chalcographus* (Linnaeus, 1761) were captured. The first two species whose pheromones were used in traps were the most abundant and accounted for 51 and 31% of all captured beetles, respectively (Fig. 4).

Predators of bark beetles in traps included *Platysoma elongatum* (Leach, 1817) (Histeridae), *Thanasimus formicarius* (Linnaeus 1758) (Cleridae), *Glischrochilus quadripunctatus* (Linnaeus 1758) (Nitidulidae), *Rhizophagus depressus* (Fabricius, 1792) (Monotomidae), and *Corticeus pini* (Panzer, 1799) (Tenebrionidae) (Fig. 5). Three most abundant species (*Th. formicarius*, *G. quadripunctatus*, and *C. pini*) were considered in further analysis.

Longhorn beetles included five species: *Stenurella melanura* (Linnaeus, 1758), *Arhopalus rusticus* (Linnaeus, 1758), *Asemum striatum* Linnaeus, 1758, *Molorchus minor* (Linnaeus, 1758), and *Acanthocinus griseus* (Fabricius, 1793). Staphylinidae, Carabidae, and Elateridae represented other non-target beetles in pheromone traps.

Both *I. acuminatus* and *I. sexdentatus* were caught in the traps with each species' pheromones. Control traps without pheromones were mainly empty or contained single specimens of non-target species (mainly Elateridae or Staphylinidae).

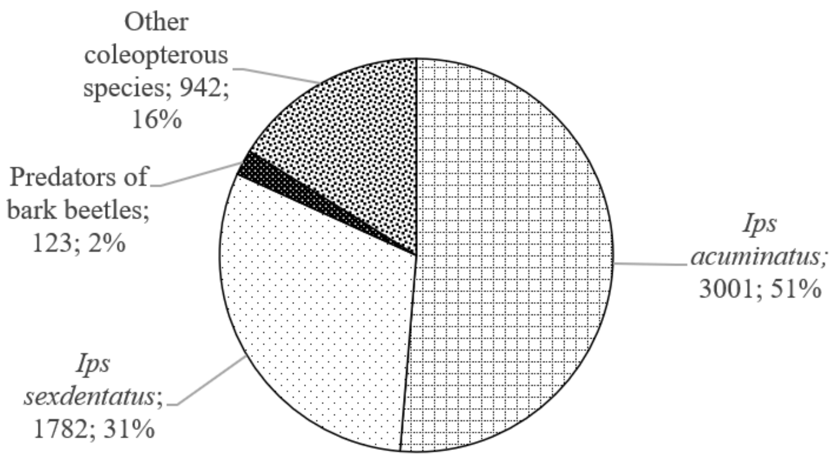

Fig. 4 – Proportion of target bark beetle species, their predators, and other coleopterous species in the traps (pooled from all traps; number; the proportion of predator specimens, %)

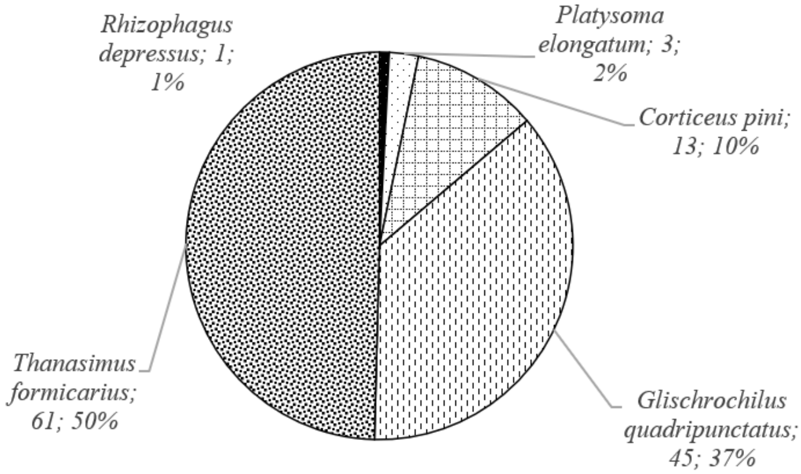

Fig. 5 – Proportion of bark beetles' predators in the traps (pooled from all traps; number; proportion of predator specimens, %)

The number of target bark beetles (*I. acuminatus* and *I. sexdentatus*) and their proportion in the traps depended on the sampling date (Figs. 6–11).

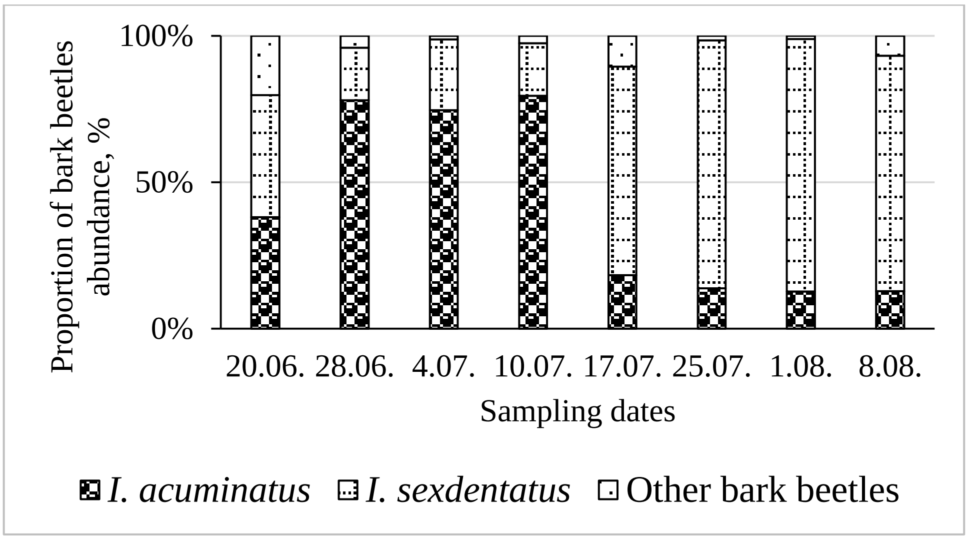

Fig. 6 – The proportion of bark beetle species in traps from 20 June through 8 August 2023 (pooled from all trap-blade combinations)

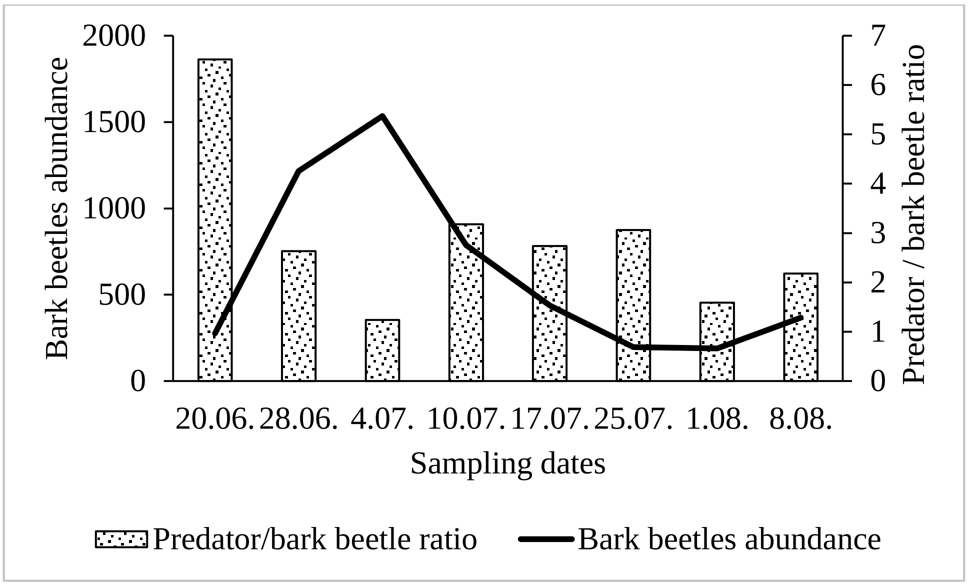

Fig. 7 – Dynamics of abundance of all bark beetles and predator/bark beetles ratio in traps (pooled from all trap-blade combinations)

Thus, on 20 June, various species of bark beetles were captured in the traps, and the proportions of *I. acuminatus* and *I. sexdentatus* were approximately equal. At this time, the offspring of the wintering beetles emerged. From 28 June to 10 July, *I. acuminatus* predominated among the bark beetles in the traps with a proportion of almost 80 %. The proportion of *I. sexdentatus* was about 20 %, and other species comprised only 1–4 %.

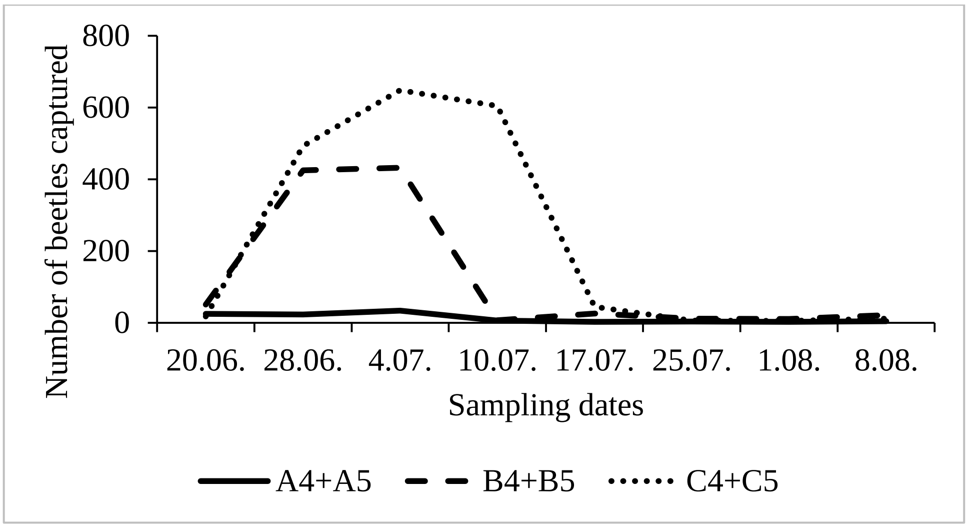

Fig. 8 – Number of *I. acuminatus* captured by pheromone of *I. acuminatus* in different trap types (A – Funnel; B – Theyson; C – Crosstrap® mini) from 20 June through 8 August 2023 (A4, B4, C4 – blades with the lowest number of dispensers, A5, B5, C5 – blades with the highest number of dispensers)

Since 17 July, the ratio of bark beetle species has changed dramatically. The proportion of *I. acuminatus* decreased to about 12%, while that of *I. sexdentatus* increased to 70–80%. The low abundance of the second generation was associated with the collapse of the outbreak of this species. Simultaneously, *I. sexdentatus* which usually inhabits severely weakened trees, exhibited relatively high abundance in the main and sister generations, as confirmed by catches in pheromone traps (Figs. 10, 11).

The total number of captured bark beetles of various species increased from 20 June to 4 July, then gradually decreased with a slight increase from 1 August to 8 August (Fig. 7). The latter is associated with the emergence of the second generation of *I. sexdentatus*. The rather low number of bark beetles captured at the end of the season may also be associated with a decrease in pheromone effectiveness.

Captures of predatory beetles in pheromone traps also varied throughout the season. The predator-to-prey ratio is typically very variable in different regions and foci (Warzee et al. 2006, Wermelingeret al. 2021, Meshkova et al. 2022). According to our data, the average ratio in pheromone traps was 2.5 for the season. The highest number of predators was observed in the captures on 20 June. As the number of bark beetles in traps increased, the number of predators increased more slowly, but the predator-to-prey ratio also decreased on 4 July, reaching only 1.2 at the maximum number of bark beetles. Subsequently, the predator-to-prey ratio increased to 3.1–3.2.

The number of bark beetles in pheromone traps depended on the type of trap, pheromone, and blade (Figs. 8–11). Analysis of *I. acuminatus* dynamics using pooled data on blade types from each trap type shows, that the highest number of this species and the longest period of the high number were observed in the traps of type C (see Fig. 8). The number of *I. acuminatus* in the traps of type B was already lower compared to type C trap since 28 June onwards; on 4 July it was 1.5 times lower, on 17 July it was 1.7 times lower. In the type A trap, the highest number of *I. acuminatus* was 34 individuals, and after 10 July did not exceed 2–4 individuals.

The highest number of *I. acuminatus* beetles was captured in Crosstrap® mini traps (C type).

Significant differences were confirmed (χ^2 = 52.99, $P < 0.01$) in the distribution of *I. acuminatus* beetles among the traps of A, B, and C type.

Analysis of *I. acuminatus* dynamics by pooled data on trap types depending on blade type shows, that a greater number of dispensers results in more captures (Fig. 9). Significant differences in the captured *I. acuminatus* beetles in the traps with more dispensers were confirmed (χ^2 = 31.85, $P < 0.01$).

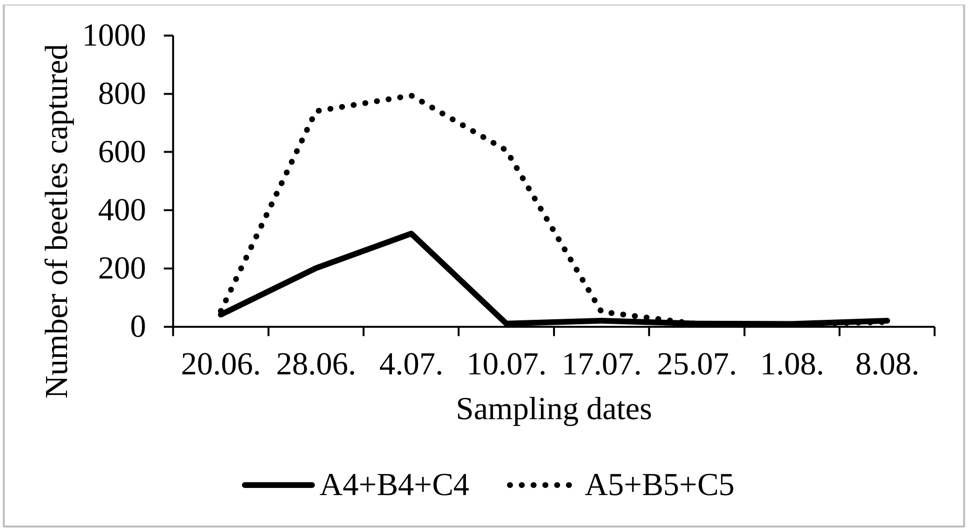

Fig. 9 – Number of *I. acuminatus* captured by pheromone of *I. acuminatus* in traps with different blade types from 20 June through 8 August 2023 (A4, B4, C4 – blades with the lowest number of dispensers, A5, B5, C5 – blades with the highest number of dispensers)

Analysis of *I. sexdentatus* dynamics using pooled data on blade types from each trap type shows three periods of a high number of this species in the traps of type B with a maximum on 4 July. In the traps of type C, two peaks of *I. sexdentatus* abundance were observed (4 July and 8 August). On both dates, the numbers of *I. sexdentatus* beetles in the traps of type A were lower than in traps B and C. In traps of type A, slight fluctuations in the number of beetles were observed at the end of June and the beginning of July, when the maximum numbers of individuals were captured in traps of types B and C. At the same time, in type A traps, the maximum of beetles caught on 17 July coincided with the second maximum in type B traps (see Fig. 10).

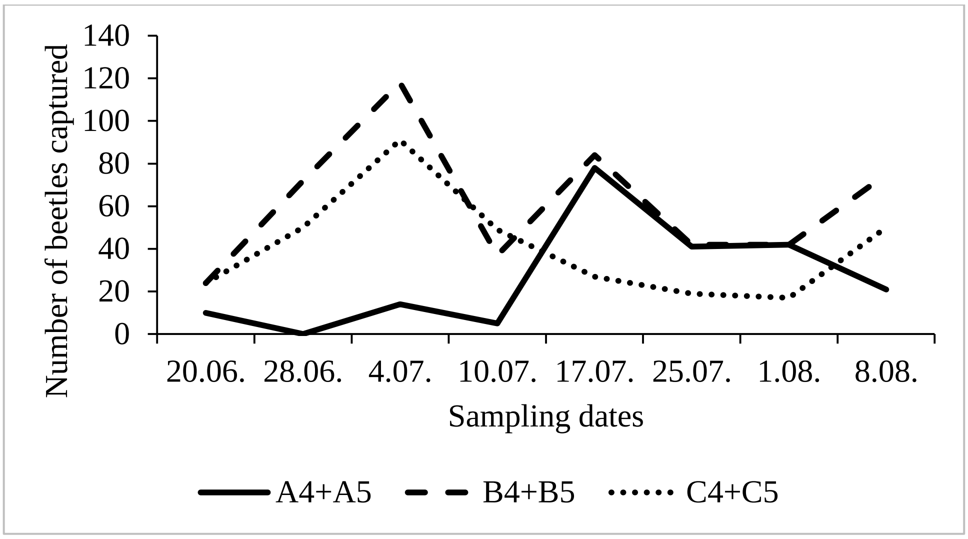

Fig. 10 – Number of *I. sexdentatus* captures by pheromone of *I. sexdentatus* in different trap types (A – Funnel; B – Theyson; C – Crosstrap® mini) from 20 June through 8 August 2023 ((A4, B4, C4 – blades with lowest number of dispensers, A5, B5, C5 – blades with highest number of dispensers)

In the total abundance of *I. sexdentatus* beetles captured in traps containing the pheromone of this species, significant differences in the captured *I. sexdentatus* beetles in the traps of A, B, and C type were confirmed ($\chi^2 = 11.41$, $P < 0.01$).

Unlike *I. acuminatus*, the dynamics of *I. sexdentatus* in traps with different numbers of dispensers showed no significant differences ($\chi^2 = 0.11$, $P > 0.1$) (Fig. 11).

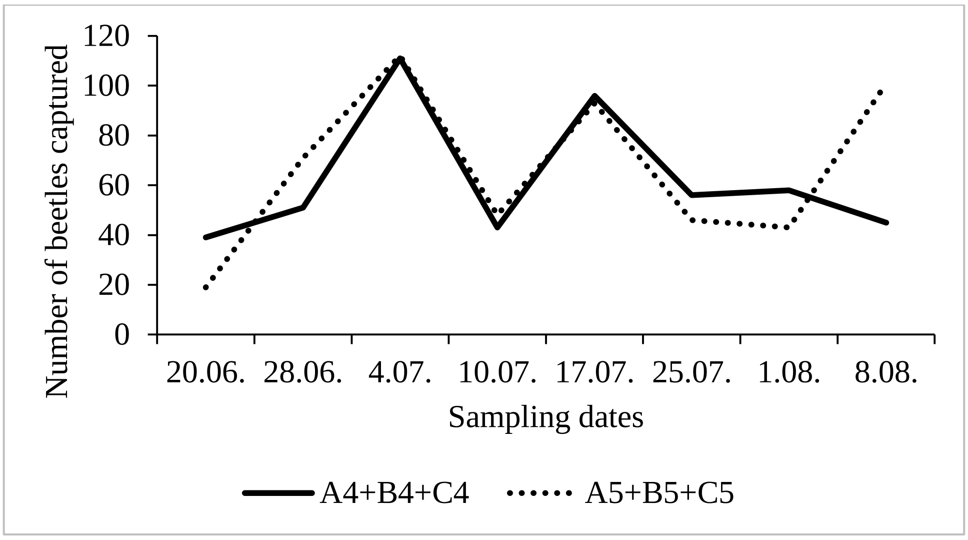

Fig. 11 – Number of *I. sexdentatus* captured by pheromone of *I. sexdentatus* in traps with different blade types from 20 June through 8 August 2023 (A4, B4, C4 – blades with the lowest number of dispensers, A5, B5, C5 – blades with the highest number of dispensers)

In the total number of *I. sexdentatus* beetles captured in traps containing the pheromone of this species, traps with a smaller number of dispensers accounted for 48.4% of individuals, and those with a larger number accounted for 51.6% of individuals.

Overall, the number of *Th. formicarius* was the lowest in trap B (Theyson) and the highest in trap C (Crosstrap® mini). The number of *Th. formicarius* captured in traps A and C with the pheromone of *I. acuminatus* was higher than in traps with the pheromone of *I. sexdentatus* ($\chi^2 = 21.9$, $P < 0.01$) (Fig. 12).

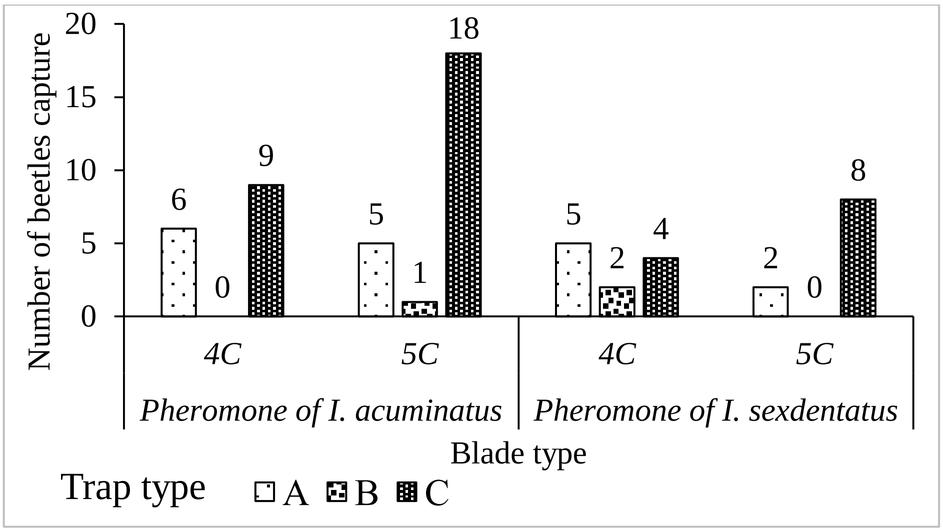

Fig. 12 – Number of *Th. formicarius* beetles capture in pheromone traps from 20 June through 8 August 2023 (Trap types: A – Funnel; B – Theyson; C – Crosstrap® mini; 4C and 5C – blades with the lowest and the highest numbers of dispensers, respectively)

Significant differences were confirmed for *Th. formicarius* beetles in traps of A, B, and C type both with the pheromone of *I. acuminatus* (χ^2 = 67.79, P < 0.01) and with the pheromone of *I. sexdentatus* (χ^2 = 33.88, P < 0.01).

Significant differences were also confirmed for *Th. formicarius* beetles in the traps with more dispensers with the pheromone of *I. acuminatus* (χ^2 =5.29, P<0.05) and nonsignificant ones in the case of the pheromone of *I. sexdentatus* (χ^2 = 0.23, P > 0.1).

Insects of other detected species were found singly in traps and were not subject to statistical analysis.

Conclusions. Five bark beetle species (Curculionidae: Scolytinae), five longhorn beetles (Cerambycidae), five predator species from Histeridae, Cleridae, Nitidulidae, Monotomidae, and Tenebrionidae, as well as several species of Staphylinidae, Carabidae, and Elateridae were captured in traps of three types (A – Funnel; B – Theyson; C – Crosstrap® mini) with pheromones of *Ips acuminatus* and *I. sexdentatus*.

Target species – *Ips acuminatus* and *I. sexdentatus* – accounted for 51% and 31% of all captured beetles, respectively. Their number, seasonal dynamics, and proportion depended on the trap type, pheromone, and blade. The highest number of *I. acuminatus* beetles was captured in Crosstrap® mini traps (C type), that of *I. sexdentatus* was found in Theyson traps (type B). An increase in dispenser number provides more captures of *I. acuminatus* and has no significant influence on captures of *I. sexdentatus.*

The number of *Th. formicarius* was the lowest in trap B (Theyson) and the highest in trap C (Crosstrap® mini). The number of *Th. formicarius* captured in traps A and C with the pheromone of *I. acuminatus* was higher than in the traps with the pheromone of *I. sexdentatus.* Differences in the captured *Th. formicarius* beetles in the traps with more dispensers with the pheromone of *I. acuminatus* are significant, whereas in the traps with the pheromone of *I. sexdentatus* they are nonsignificant.

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ОЦІНЮВАННЯ ФЕРОМОННИХ ПАСТОК ДЛЯ МОНІТОРИНГУ КОРОЇДІВ ТА ЇХНІХ ХИЖАКІВ У СОСНОВИХ НАСАДЖЕННЯХ ХАРКІВСЬКОЇ ОБЛАСТІ

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У насадженнях *Pinus sylvestris* L. Харківської області досліджували видовий склад, чисельність і сезонну динаміку короїдів та їхніх хижаків у дослідах із різним поєднанням феромонних пасток і диспенсерів. Тестували три типи пасток і феромони *Ips acuminatus* та *I. sexdentatus* (виробник – іспанська компанія Sanidad agricola econex s.l.). У пастках трьох типів (A – тунельні; B – Тайсона; C – Кростреп®міні) з феромонами *Ips acuminatus* and *I. sexdentatus* виловлено п’ять видів короїдів (Curculionidae: Scolytinae), п’ять видів вусачів (Cerambycidae), п’ять видів хижих комах із родин Histeridae, Cleridae, Nitidulidae, Monotomidae та Tenebrionidae, а також представників родин Staphylinidae, Carabidae та Elateridae. Цільові види – *I. acuminatus* та *I. sexdentatus* становили 51 і 31 % усіх виловлених жуків відповідно. Їхні чисельність, сезонна динаміка та участь у видовому складі залежали від типів пастки, феромону та диспансерів. Найбільшу кількість жуків *I. acuminatus* виловлено у пастки Crosstrap® mini traps (тип C), а *I. sexdentatus* – у пастки Theyson (тип B). За збільшення кількості диспенсерів виловлено більшу кількість *I. acuminatus*, але це не мало значущого впливу на виловлену кількість *I. sexdentatus.*Чисельність виловлених жуків *Th. formicarius* була найменшою у пастках типу B (Theyson), а найбільшою – у пастках типу C (Crosstrap® mini). Чисельність виловлених жуків *Th. formicarius* у пастках A і C з феромоном *I. acuminatus* була більшою, ніж у пастках із феромоном *I. sexdentatus.* Різниці цього показника за більшої кількості диспенсерів із феромоном *I. acuminatus* є значущими, а з феромоном *I. sexdentatus* – незначущими.

К л ю ч о в і с л о в а: *Ips acuminatus, I. sexdentatus, Thanasimus formicarius*, нецільові види, сезонна динаміка, диспенсер.

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