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ORIGINAL PAPER

Comparison of *Ips duplicatus* (Sahlb.) infestation of insecticide sprayed and injected standing trap trees

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ABSTRACT

At present, *I. duplicatus* (Sahlb.) creates extensive outbreaks in the Czech Republic. Established methods used to protect against *Ips typographus* (L.) and check its spread, are not effective against *Ips duplicatus*.

The aim of the survey was to verify the possibility of protecting forest against *I. duplicatus* by using chemical treatment or by injecting protected standing spruce trap trees.

Thirty-four trees inside an area with an outbreak of *I. duplicatus* (East Czech Republic) were randomly chosen in a stand of spruce. The stems of 10 spruces (*i*) were treated with alfa-cypermethrin insecticide up to a height of 4 m and a device for collecting dead bark beetles was attached to these trap trees. Eight spruces (*ii*) were injected with imidacloprid (1% solution), and the rest of the trees (*iii*) were used as a control. Pheromone lures were applied on these trees, with two items on every type of trap tree. Five naturally infested trees *I. duplicatus* located outside the area of influence of the pheromone lure were included in the analysis (*iv*). Infestation of the spruce trees was calculated from the density of entry holes on the stem (*i, iii, iv*) or the number of collected dead bark beetles (*ii*).

Naturally attacked trees had the highest density of entry holes. Standing trap trees treated with alpha-cypermethrin had a lower infestation density than injected trees. The pheromone lure attracted *I. duplicatus* to the bottom of the stem, away from the naturally infested crown section.

Treatment with insecticide to a height of 4 m was insufficient, because varying infestation rates of standing trap trees ranged from thousands to just a few individuals of bark beetle adults. These standing trap trees were also infested in the treated section. The dispersion of the infested trees within the group was uneven. Injection by imidacloprid had a low efficacy in protecting trees against development of a new generation of bark beetle.

KEY WORDS

alpha-cypermethrin, imidacloprid, *Ips typographus*, standing trap trees

Introduction

The Czech Republic has been suffering from heavy mass outbreaks of bark beetles in spruce stands for several years. The volume of incidental felling due to bark beetle attacks continues to increase (2015 – 2.31 mil. m^3, 2016 – 4.42 mil. m^3, 2017 – 5.85 mil. m^3, 2018 – 13.06 mil. m^3, 2019 – 22.78 mil. m^3, 2020 – 26.24 mil. m^3) (Anonym, 2021). Seventy-six thousand pheromone-

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baited traps and approximately 660 thousand m^3 of trap trees were used for protection against and monitoring of bark beetles in 2017. The standard situation regarding the occurrence of bark beetle on Norway spruce represents a volume of salvage felling of <0.2 $m^3 \cdot ha^{-1}$ (Decree No. 101/1997 Sb.), whereas this volume reached 4 $m^3 \cdot ha^{-1}$ in the Czech Republic in 2017 (Anonym, 2021). The most serious situation persists in the north-east of the country, in the Moravian-Silesian Region (2017 – 2.083 mil. m^3, *i.e.* approximately 39% of all trees felled in the country due to bark beetle infestation) where our research was conducted. *Ips typographus* (L.), *Ips amitinus* (Eichh.) and *Pityogenes chalcographus* (L.) are the cause of a total of 75% of bark beetle infested spruce wood, and *Ips duplicatus* (Sahlb.) causes the remaining 25% (Anonym, 2019).

I. duplicatus is a native species from Scandinavia and the Siberian taiga (Wood and Bright, 1992; Pfeffer, 1995). It is considered an invasive insect species in Central and North-East Europe (Zúbrik *et al.*, 2006; Vakula *et al.*, 2007). The European and Mediterranean Plant Protection Organization listed *I. duplicatus* as a quarantine organism (Smith *et al.*, 1996). *I. duplicatus* was rare in the Czech Republic from the 1960s to the 1980s and the first outbreak was recorded after in 1990s (Zahradník, 2014). In Central and North-east Europe *I. duplicatus* infests stands of Norway spruce *Picea abies* (L.) Karst. aged above 40 years, growing on non-native sites (Knížek and Zahradník, 1996; Stanovský, 2002; Grodzki, 2003; Hrubík, 2007; Olenici *et al.*, 2009, 2011; Duduman *et al.*, 2011; Zahradník, 2014). If *I. duplicatus* occurs together with *I. typographus*, it inhabits the stem within the crown (Zahradník, 2014). *I. duplicatus* prefers trees in a stand and infestation is dispersed throughout the forest (Lubojacký and Holuša, 2013). The reason for the disastrous spread of *I. duplicatus* in Central Europe is the extensive cultivation of spruce, climate change (Holuša *et al.*, 2010) and transportation of untreated, infested timber.

The early detection of infested trees is effective as prevention against bark beetle in general. The strategy consists of the timely identification of trees infested by *I. duplicatus,* which is difficult because the pest colonizes the stem within the crown. Sawdust, a phenomenon accompanying the presence of bark beetles, is missing at the base of the stem of the infested tree, because it is blown away by the wind. Noticeable changes in the colour of needles and falling bark usually only occur after the pest has left the tree (Grodzki, 1997; Lubojacky and Holuša, 2013).

Although a sporadic occurrence of the beetle was observed on the lying trap trees (Liška and Lubojacký, 2015), most authors claim that lying wood is not attractive and is a useless protective measure (Schnaider and Sierpiński, 1955; Grodzki, 1997; Knížek, 1998; Šotola *et al.*, 2021). These facts emphasize the need for alternative, efficient protective measures as a solution.

According to Zahradník (2014), use of baited standing trap trees is an option, but may not always be effective against *I. duplicatus*. Felled, treated (insecticide sprayed) trap trees have some advantages, with unlimited trapping capacity, high efficacy, and a shorter safety distance from a stand (Blaženec *et al.*, 2015). Lubojacký and Holuša (2014) also point out that debarking or other sanitation measures and regular checks are not needed.

The introduction of some dangerous insect pests into the USA, such as *Adelges tsugae* (Annand), *Anoplophora glabripennis* (Motschulsky) and *Agrilus planipennis* (Fairmaire), initiated interest in tree injection (McClure, 1992; Doccola *et al.*, 2007; Smitley *et al.*, 2010). Development of this method made it an alternative to application of chemical surface treatment. Tree injections have some advantages, such as the efficient use of chemicals, reduced environmental exposure or are useful when foliar or soil application is ineffective or difficult (Stipes, 1988; Sanchez-Zamora and Fernandez-Escobar, 2004). Employing tree injection methods resolves these issues; the chemicals are distributed by the vascular system into the canopy for systemic activity. Systemic injections are used to effectively control borers feeding under the bark, where active ingredients sprayed onto the surface of trees may not penetrate in biologically active concentrations (Doccola and Wild, 2012).

Imidacloprid, which was used in our study, is a chloronicotinyl (neonicotinoid) chemical with a water solubility of 0.51 $g{\cdot}l^{-1}$ (Yen *et al.*, 2000). Imidacloprid shows translaminar and systemic activity in plants (Buchholz and Nauen, 2002) and controls sucking insects such as adelgids, aphids, thrips, whiteflies, and some beetles, including Cerambycids. Tree injection is used when trees are at risk of attack by destructive or persistent pests. It can be put to good use in tall trees. Tree injection is a method of delivering specific toxicants to the harmful pest and minimising unintentional exposure and is also an alternative method for applying systemic insecticides for the protection of trees (Doccola and Wild, 2012).

The aim of our study was to determine the attractiveness or effectiveness of three types of standing trap tree in relation to *I. duplicatus*, under the influence of a synthetic pheromone, and to compare treated, untreated and injected standing trap trees to naturally infested spruce trees outside the range of influence of the *I. duplicatus* pheromone.

We hypothesize that insecticide treated or injected standing trap trees can be useful as a protective measure against *I. duplicatus*, because the bark beetles infested naturally standing trees. Injected standing trap trees can be successful if the development of a new generation of bark beetles is stopped by imidacloprid injections.

Material and methods

Research was situated within an *I. typographus* (IT) outbreak area (Fig. 1), which also had a high population density of *I. duplicatus* (ID). The survey was conducted in the Bílčice location (49.8499631 N, 17.5846747 E, Norway spruce monoculture, canopy 0.8, age 60 years, 610 m a.s.l.) (Fig. 2). The experiment was executed on a group of Norway spruce trees extending into a clearing from the tract of forest, where 34 trees were selected on an area of about 0.1 ha (Fig. 2, Table 1).

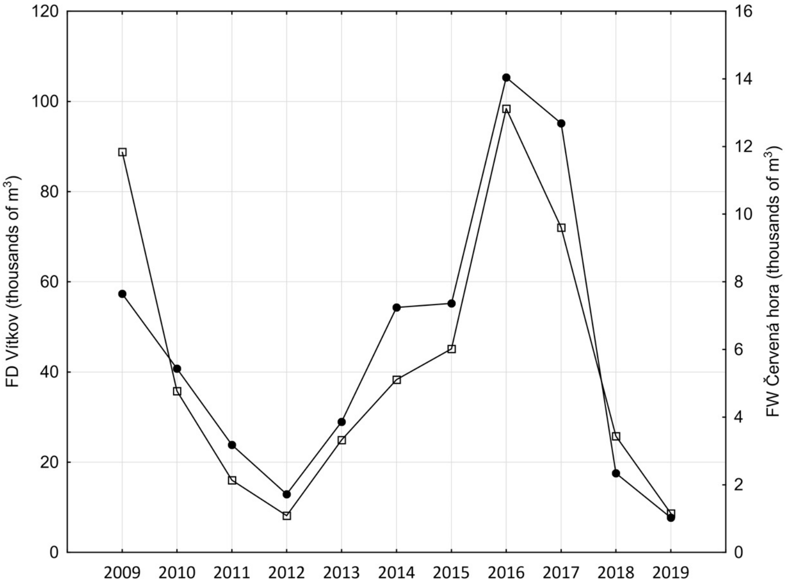

Fig. 1.

Volume of salvage basis in the Vítkov Forest District (Empty squares, left axis), forest ward of Červená hora (Full point, right axis) (volume of bark beetles timber from 1st August to 31st March)

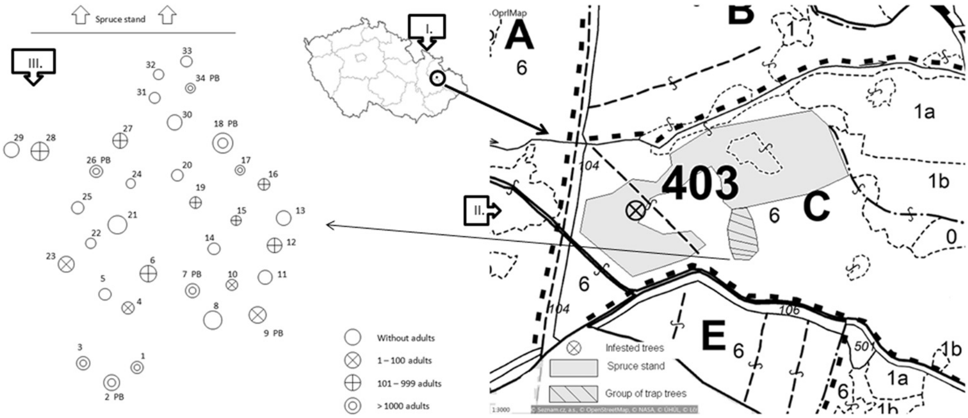

Fig. 2.

Study plot in the eastern Czech Republic (I), locations of set traps in the map of stands with marking of study forest stand (II) and distribution of trap trees in study plot (III) (see Table 1)

Table 1.

Numbers of protective measures from study plot

Protective measure	Without lure	Baited
Treated standing trap trees	3, 4, 6, 10, 12, 15, 19, 23	9, 26
Injected standing trap trees	5, 11, 13, 20, 22, 27	2, 34
Control standing trap trees	1, 8, 14, 16, 17, 21, 24, 25, 28, 29, 30, 31, 32, 33	7, 18

Six randomly selected Norway spruce trees lured with ID Ecolure (25 April 2017, ID Ecolure, Fytofarm group, s.r.o., active substance Ipsdienol 1,6%) (Zahradníková and Zahradník, 2016), were distributed evenly throughout a group of 34 standing trees (Fig. 2, Table 1). Ten standing trap trees in this group were treated (two of them were also baited with the pheromone lure – TR), eight standing trap trees were injected (two of them were baited with the pheromone lure – INJ) and the remaining 16 trees were used as a control (two of them baited with the pheromone lure – CON) (Fig. 2, Table 1). All three types of standing trap tree were always situated near a baited trap tree (one type was baited and other two types were near of this type of trap tree). The Vaztak Active insecticide (Agrospol Czech, s.r.o.; active substance: 1% solution, alpha-cypermethrin 50 $g \cdot l^{-1}$; application to 5 $l \cdot m^{-3}$ of infested wood) (Zahradníková, Zahradník, 2016) was applied to the stems of TR using a motorized backpack mist blower (Solo) up to a height of 4 m on 24 April 2017. A control funnel extending 36 cm past the stem diameter was simultaneously installed at a height of 1.3 m to collect any fallen dead beetles. The upper part of the funnel was covered with wire mesh to prevent access to birds. As there was no risk of dead adults releasing an anti-aggregation pheromone, their numbers were counted only once (10 June 2017).

Eight trap trees were injected with a 1% solution of imidacloprid at the same time as treatment of the TR. Injection was performed by QUIK-jet kit (Arborjet Inc., Woburn, USA). The necessary volume of imidacloprid solution was calculated based on the stem diameter at breast height for every INJ individually. The required volume of solution was calculated as 1 cm of diameter requiring 1 ml of solution. We used $^{3}/_{8}$' arborplugs. Around 5 ml of solution was applied to every 10 cm deep drilled hole.

A larger group of Norway spruce trees, which were naturally infested by bark beetle, especially by *I. duplicatus* (NIT), were situated outside the range of influence of the pheromones (at a distance >100 m). Five infested trees were analysed (Fig. 2).

All the trap trees were felled in the first half of June after the end of spring swarming. Bark was removed from upper side the stem to reveal a 0.1 m wide, continuous band of phloem. The bark beetle species were subsequently determined based on the gallery pattern or presence of beetles, over continuous meter-long sections. The incidence rate in each section was expressed as the number of entry holes per dm^2 (eh/dm^2), the number of maternal galleries per entry hole (g/eh) and the length of the maternal galleries per dm^2 (cm/dm^2).

In addition to evaluation of the effect of the pheromone-lure group of spruce trees, we used the same methodology to evaluate natural infestation of five spruce trees by bark beetles.

We compared all the types of trap tree and naturally infested trees on the basis of the numbers of adults on 1 dm^2 (na/dm^2). The adult density on NIT, INJ and CON was calculated using data from debarking: na ($adults/dm^2$)=neh ($males/dm^2$)+ng ($females/dm^2$).

We used the number of captured adults and data from debarking to calculate the number of na/dm^2 on TR. The treated part of the trap tree, characterized by the typical bark surface and the number of killed bark beetles (from the control funnel), could be used to calculate the infestation density (na/dm^2). The infested part of the TR, over the treated section, was debarked and the number of adults was calculated using the same method as for the other analysed trees.

The respective types (TR, INJ, CON, NIT) were compared in regard to the density of individual bark beetle species, by using analysis of variance. We used the number of bark beetles trapped on the inspected trees with respect to the infested part of the stem (meaning the number of entry holes and maternal galleries). The surface area of the individual stem sections was calculated as the surface area of a conical frustum.

We used analysis of variance (Statistica 12, StatSoft) to compare all the types of the trap trees and NIT. In this analysis we used the number of $adults/dm^2$ to show the difference between different types of trap tree.

Results

Of the four compared types (treated, injected and control trap trees in the group under the influence of pheromones, and naturally infested trees) the highest numbers of entry holes were observed on NIT (ID 1.3 eh/dm^2 and IT 0.2 eh/dm^2) (Fig. 3A). TR had a higher frequency of bark beetles above the treated part of the stem (ID 0.9 eh/dm^2 and IT 0.2 eh/dm^2) (Fig. 3B). INJ (ID 0.4 eh/dm^2, IT 0.1 eh/dm^2) (Fig. 3D) and CON (ID 0.3 eh/dm^2, IT 0.1 eh/dm^2) showed the lowest infestation rate (Fig. 3C).

Analysis of the presence of ID and IT in 924 inspected one-meter long sections showed a decrease in the frequency of NIT>CON>INJ>TR infestation by ID (98.2–17.4–14.8–13.7%) and a lower incidence of IT (71.9–7.8–7.4–8.5%).

The higher number of adults was also defined by the number of maternal galleries per entry hole in ID (2.46 g/eh in NIT and 1.87–2.54 g/eh in the standing trap trees). Three-arm gallery patterns were more frequent in ID then in IT.

The average density of maternal galleries in all infested trap trees was 6.87 cm/dm^2 (ID) and 2.28 cm/dm^2 (IT) and was higher on naturally infested trees at 15.19 cm/dm^2 (ID) and 3.34 cm/dm^2 (IT).

Despite the applied pheromone baits, the standing treated trap trees were not infested uniformly, and the number of captured beetles differed considerably (ID 36 – 9,970 pcs, average – 1,403 pcs, median – 158 pcs; IT 4 – 999 pcs, average – 178 pcs, median – 18 pcs).

The Kruskal-Wallis test demonstrated significant differences in the numbers of ID [H (3, N=561)=120.7412; p=0.0000] (Fig. 4A), with NIT showing a higher frequency than the three

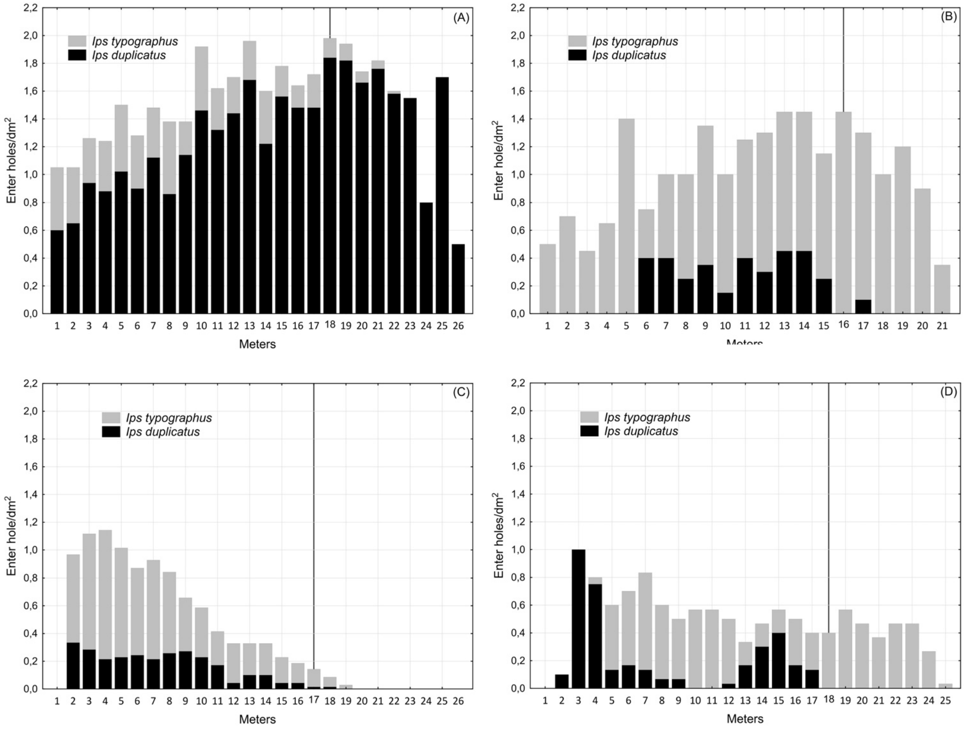

Fig. 3.

Mean abundance of bark beetles along Norway spruce stem in the bark beetle focus (A), on the standing treated trap trees (B), on the standing control trap trees (C), on the injected standing trap trees (D), (crown setting is marked with a solid line)

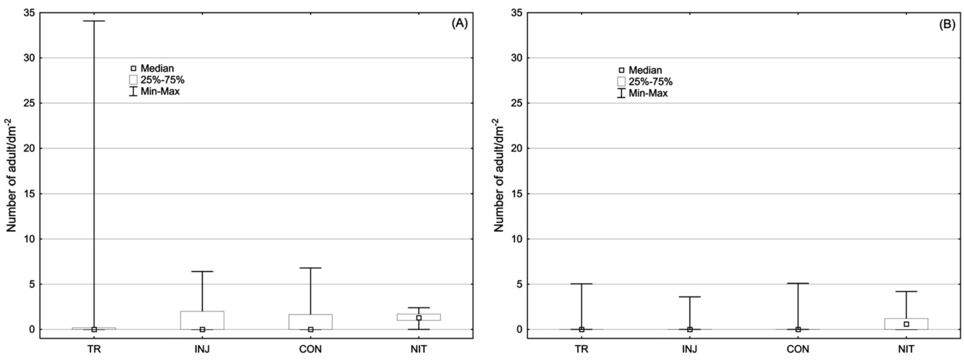

Fig. 4.

Number of Ips duplicatus (A), *Ips typographus* (B) beetles on trees (TR – treated standing trap trees, INJ – injected standing trap trees, CON – control standing trap trees, NIT – naturally infested trees)

remaining type (Dunn's test $p<0.0257$). Lowest frequency was determined on TR and was significantly lower than on other trap trees. The unusual maximum ID on TR (almost 35 na/dm^2) is reflected in the high number of killed beetles (Fig. 4A). The established numbers of IT imagines [H (3, N=561) =112.3462; $p=0.0000$] (Fig. 4B) show that NIT exhibited an incidence higher than TR, INJ and CON (Dunn's test $p<0.0000$).

Discussion

The advantages of standing trap trees are confirmed only partially. In practice, the insecticide mixture can only be applied to them on the lower part of the stem, up to a height of 4-6 m (application from the ground). Although we collected up to 10 thousand adult *I. duplicatus* on the treated sections of standing trap trees, efficacy was limited by the fact that the untreated stem section was also infested. The tree subsequently died and necessary sanitation measures were subsequently required. Although the number of beetles (*I. duplicatus* and *I. typographus*) was distinctly lower above the treated part of the trap tree, the trap tree's effectiveness was limited because of the different aetiology of *I. duplicatus*. If the *I. duplicatus* pheromone is applied at a height of 2 m above the ground, with simultaneous stem treatment up to a height of 4 m, infestation and subsequent dieback of the trap tree may occur. *I. duplicatus* prefers the middle and upper stem parts (Zahradník, 2014), which were not treated with the insecticide mixture. The difference in the bionomy of the two mentioned species calls for the application of the insecticide mixture higher up the stem than when applied against *I. typographus*. The effective height of treatment for *I. typographus* was 5-6 m (Raty *et al.*, 1995; Juha and Turčáni, 2008). Juha and Turčáni (2008) observed that infestation by *I. typographus* was 50% more concentrated within an area of ±1.5 m round the pheromone bait. Despite pheromone application, the presence of *I. duplicatus* was observed across practically the whole tree profile (Fig. 3).

Trap trees can die in the event of intensive infestation, low quality coverage by insecticide mixture or degradation of the treatment. This means that the advantages of standing treated trap trees are substantially limited. Švestka (1990) informs that treatment with the insecticide mixture can kill up to 100% of the infesting bark beetles (*I. typographus*), if the insecticide is applied on the trap trees just before the bark beetles begin to swarm. Stems treated with the insecticide mixture and baited with pheromone were infested by more bark beetles than the classic trap trees without any treatment (Zahradník and Kapitola, 1993). In our case, two trap trees (20% of the treated trap trees) were infested in the treated section of the stem, but both had the highest number of captured bark beetles.

Luring is essential for capturing *I. duplicatus* but is not necessarily effective every time (Zahradník, 2014). The pheromone bait also attracts beetles to adjacent trees, this effect cannot be mitigated, and bark beetles also infest nearby standing trees. In the surveyed group of 34 trees (6 pheromone baits were placed), 18.4% trees suffered from severe infestation (>1,000 adult ID on the trap tree) and 31.6% trees suffered a mild infestation (<1,000 adults), the remaining trap trees showed no presence of adults. The severely infested trees were concentrated around the pheromone baits. Standing treated trap trees can survive a bark beetle infestation only at low frequencies.

Švestka *et al.* (1998) mention the problematic detection of spruce infested by *I. duplicatus* in the absence of an infestation of the lower stem by *I. typographus*. If the lower part of the stem is treated, we are not able to recognize an infestation of the upper part of the trap tree in time. Knížek and Holuša (2007) admit that if a tree is infested by *I. duplicatus*, the crown only becomes rust coloured after some time and a new generation of beetles can be of an age where they are just about to leave the tree or have even already left the spruce tree. This means that sanitation measures must take place preventively, in line with the expected completion of development of the generation. The unlimited capture capacity of treated trap trees was also refuted (Blaženec *et al.*, 2015).

Infestation of the higher stem parts of treated trap trees contradicts the advantage of unnecessary sanitation (Lubojacky and Holuša, 2014). The placement of pheromone bait for luring *I. duplicatus* on the base part of the stem makes this species partially gather within the natural habitat area of *I. typographus*. Our survey showed that *I. duplicatus* and *I. typographus* can invade the same stem sections within a competitive area, in contrast to *I. amitinus*, which does not share the same space as *I. typographus* (Kula and Ząbecki, 2002).

Representation of the two monitored bark beetle species within the stem profile of naturally infested trees (tree age >70 years) indicates that *I. typographus* mainly colonises the spruce stem below the crown and *I. duplicatus* prefers the stem section within the tree crown during natural infestation. Because the stems of younger trees (<70 years) have smooth and thin bark and a low density of infestation by *I. typographus* below the crown, they can be attacked by *I. duplicatus*. Grodzki (2012) describes two types of infestation: a southern type (Czech Republic and Polish region of Silesia) where *I. duplicatus* infests the entire stem (from the base to the crown), and a northern type where only the stem in the crown is colonised. Our trap trees with pheromone bait (70 years) showed that infestation by *I. duplicatus* was concentrated in the lower parts of the stem which resembles the northern type of infestation. But is a result of presence of lure. Naturally infested trees were colonized by *I. duplicatus* in the lower part of the stem; this is apparent in the high density of this species of bark beetle (Fig. 3A). Control standing trap trees were colonized mainly in the lower section because of the influence of the pheromone lure (Fig. 3C).

In our case, injection did not protect trees against bark beetle infestation. Some authors refer to pest prevention applied more than once a year (Grosman *et al.*, 2002, 2009; Smitley *et al.*, 2010). But these authors used a different insecticide (emamectin benzoate). We applied imidacloprid about 2-3 weeks before swarming. The insecticide's low effectiveness against bark beetles is related to the insufficient time for its distribution throughout the bast. This can be a problem with this agent, because imidacloprid residues were not observed 7-9 weeks after application (Morse *et al.*, 2008).

Conclusions

The naturally infested trees had a higher ID than IT density, thus confirming the plan to situate the research site in an ID outbreak area.

The frequency of ID on the stems of standing trees had a declining trend NIT>CON=INJ>TR.

On TR, a serious bark beetle infestation was recorded not only on the treated part of the stem, but also on the stem above the treated section (>4 m) IT>ID, and was the cause of tree deaths. Standing treated trap trees with pheromone applied at the stem base, allow the capture of ID imagines, whose natural habitat is the stem within the crown. Increased bark beetle population density and simultaneous infestation by ID and IT was observed on the untreated stem. If the stem is treated with an insecticide only up to a height of 4 m, the TR is ineffective and therefore cannot be used in forestry practice.

In accordance with the hypothesis, bark beetle infestation (IT>ID) was confirmed on both CON and INJ, but was lower than on TR. After applying the pheromone to a standing tree (trap), the surrounding trees must also be checked.

The density of maternal galleries was higher on NIT than on CON, INJ and TR. One reason for ID>IT is because ID has a higher incidence of three-arm galleries compared to IT, which has a higher incidence of two-arm galleries.

INJ did not show any effect on ID and IT development by injection of a 1% imidacloprid solution, as the length of maternal galleries did not differ between CON, INJ and the untreated part of TR.

Authors' contribution

V.Š. – the research concept, field, laboratory and statistical analysis, manuscript preparation; E.K. – manuscript preparation and corrections.

Conflicts of interest

The authors declare no potential conflicts of interest.

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STRESZCZENIE

Porównanie zasiedlenia przez kornika zrosłozębnego *Ips duplicatus* (Sahlb.) stojących drzew pułapkowych opryskanych insektycydem oraz poddanych iniekcjom do pnia

Kornik zrosłozębny *I. duplicatus* (Sahlb.) to gatunek występujący gradacyjnie na znacznych obszarach Republiki Czeskiej. Istniejące metody stosowane w celu ochrony drzewostanów przed kornikiem drukarzem *Ips typographus* (L.) nie są skuteczne w odniesieniu do *I. duplicatus*.

Celem badań było określenie atrakcyjności lub skuteczności trzech rodzajów stojących drzew pułapkowych wobec chrząszczy *I. duplicatus* przywabianych przez syntetyczny feromon. Porównywano drzewa pułapkowe opryskane insektycydem, nieopryskane oraz poddane iniekcjom do pnia ze świerkami znajdującymi się poza zasięgiem oddziaływania feromonu *I. duplicatus*, zaatakowanymi przez korniki w sposób naturalny.

Badania zlokalizowano na obszarze objętym gradacją *I. typographus* w Obrębie Leśnym Vítkov (ryc. 1), będącym jednocześnie rejonem licznego występowania *I. duplicatus*. Sześć losowo wybranych świerków pospolitych z dyspenserami ID Ecolure rozmieszczono równomiernie w grupie 34 drzew stojących (ryc. 2). Dziesięć stojących drzew pułapkowych w tej grupie było opryskanych do wysokości 4 m preparatem Vaztak zawierającym 1% alfa-cypermetryny (TR), na ośmiu stojących drzewach pułapkowych wykonano iniekcje do pnia preparatem zawierającym 1% imidakloprydu (INJ), a pozostałe 16 drzew stanowiło grupę kontrolną (CON) (ryc. 2, tab. 1). Obserwowano także grupę świerków znajdujących się poza zasięgiem oddziaływania feromonów (w odległości >100 m), które zostały w naturalny sposób zaatakowane przez korniki, zwłaszcza przez *I. duplicatus* (NIT) (ryc. 2). Do obliczenia liczby osobników na 1 dm^2 użyto liczby stwierdzonych podczas korowania imagines i/lub żerowisk.

Pomimo zastosowanych feromonów opryskane stojące drzewa pułapkowe nie zostały zaatakowane w jednakowym stopniu (ryc. 3), a liczby stwierdzonych imagines różniły się znacząco (*I. duplicatus*: 36-9970 szt., średnia 1403 szt., mediana 158 szt.; *I. typographus*: 4-999 szt., średnia 178 szt., mediana 18 szt.). Liczba chrząszczy *I. duplicatus* na strzałach drzew stojących w poszczególnych wariantach wykazywała tendencję spadkową w układzie NIT>CON>INJ>TR (ryc. 4).

W wariancie TR intensywne zasiedlenie przez korniki, będące przyczyną zamarcia drzew, zostało stwierdzone nie tylko na opryskanej części pnia, ale także ponad nią (>4 m). Umieszczenie feromonu *I. duplicatus* w części odziomkowej opryskanych stojących drzew pułapkowych pozwala na przywabienie do opryskanej strefy imagines tego gatunku, naturalnie zasiedlającego strefę strzały w obrębie korony drzewa. Na drzewach nieopryskanych zaobserwowano większe zagęszczenie populacji obu gatunków korników, zasiedlających je równocześnie. Jeżeli oprysk

insektycydem wykonano tylko do wysokości 4 m, metoda zastosowana w wariancie TR jest nieskuteczna i dlatego nie nadaje się do stosowania w praktyce leśnej.

Zgodnie z hipotezą zasiedlenie przez korniki (IT>ID) zostało potwierdzone zarówno na drzewach w wariancie CON, jak i INJ, ale było ono słabsze niż w wariancie TR. Po umieszczeniu feromonu na stojącym drzewie pułapkowym należy objąć kontrolą także otaczające je drzewa.

W wariancie INJ nie stwierdzono żadnego działania wstrzykniętego do pni drzew imidakloprydu, ponieważ długość chodników macierzystych obu gatunków korników nie różniła się między wariantami CON i INJ oraz nieopryskaną częścią pni w wariancie TR. Drzewa pułapkowe nie okazały się skuteczne, w związku z czym nie są przydatne w praktyce leśnej.