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ORIGINAL PAPER

Effectiveness of pheromone traps for the European spruce bark beetle: a comparative study of four commercial products and two new models

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Abstract
Six types of pheromone traps were tested between 2012 and 2014 in the High Tatra Mountains, northern Slovakia. Traps were baited with lures for attracting the European spruce bark beetle (*Ips typographus* L.) (Coleoptera: Curculionidae, Scolytinae). Among the tested traps, four types are commercial products; Theysohn (T-trap), Ecotrap (E-trap), Lindgren funnel trap (L-trap), BEKA trap (B-trap) and two are our newly developed models; Funnel trap (P-trap) and Cross trap (K-trap). The traps were set up on ten selected sites and tested during three growing seasons (2012, 2013 and 2014). The newly developed models were compared to the commercially available models for trapping efficiency of target pest, easy to use and impact on non-target insect species. We found that the best commercially available model is the L-trap, however the bottom of L-trap is considered too shallow resulting in an accumulation of rainwater that increases the traps attractiveness for Silphids. In our experiment, the newly developed models; P-trap and K-trap performed better compared to commercially used models. P-trap caught 28% more *I. typographus* and K-trap caught 57% more beetles compared to T-trap in 2014. There are additional advantages of the newly developed traps such as easy handling, good rainwater drainage, higher collection container volume, and scale marking within the collection container. The results of this study have encouraged us to patent P-trap and K-trap as utility models.

Key words: pheromone traps; bark beetles; *Ips typographus;* lure; spruce forest

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1. Introduction

The European spruce bark beetle *Ips typographus* [L.] (Coleoptera: Curculionidae, Scolytinae) is considered as one of the most destructive insect in the forests of Europe (Økland et al. 2016), and only in Slovakia during 55 years (1960–2015) it has killed trees equaling about 34 million m^3 (Kunca et al. 2016). Commercially produced pheromone traps for monitoring and mass trapping of bark beetles and wood-boring insects have been used in forestry practice for more than 40 years; the Theysohn trap (black slot trap) is commonly used in Europe (Niemeyer et al. 1983), Lindgren funnel trap is used mainly in the USA and Canada (Lindgren 1983), Borregaard (1979 and 1980 models) drainpipe traps were used in Norway and Sweden (Regnander & Solbreck 1981), the BEKA model is also widely used in Scandinavia, and the Ecotrap was developed and is used mainly in Slovakia and the Czech Republic.

Development of these various types of pheromone traps peaked during the late 1970s and early 1980s after the secondary attractant pheromone compound was identified (Bakke 1976) and isolated from the *Ips typographus* L. (Bakke et al. 1977). During this period, many types of pheromone traps for capturing *I. typographus* were tested, most were not developed commercially. For example, Regnander & Solbreck (1981) tested different shapes and diameters of drainpipe traps, with and without a bottom funnel; Vité (1984) developed a flat funnel slot trap; Röchling, a commercially produced trap similar to T-trap was used in Germany but only for a few years (Richter & Kohnle 1984); Richert & Kohnle (1984) and Dubbel et al. (1985) tested various trap types as well as spatial installation and distribution of traps; Burzynski et al. (1981) tested and compared foil trap of its own production to commercially available drainpipe traps (both models); Egger et al. (1980) developed and tested several types of funnel and pipe traps; Klimetzek et al. (1979) tested window traps and drainpipe traps with different shapes and diameter; Adlung et al. (1979) tested window traps constructed from plexi-glass (50 × 60 cm) and used water as the killing agent. In general, water was used as the primary killing agent, particularly at the beginning of trap study and development (Novák 1981; Zumr 1982; Brutovský 1984). Between 1982 and 1986 more than 20 types and variants of pheromone traps were tried and tested in Slovakia (Brutovský 1990).

Since the intensive research and development of new pheromone traps, particularly in connection with *I. typographus* trapping was conducted between 1979 and 1985, no other pheromone traps that could efficiently replace widely commercially used traps have been developed. There are hundreds of thousands of pheromone traps, especially for *I. typographus*, used annually in Europe. For instance, about

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40 thousand traps in Slovakia (database of the Forest Protection Service, Banská Štiavnica), 35 thousand in Czech Republic (Knížek et al. 2016), 15–30 thousand in Romania (Nicolai Olenici, pers. comm.). This is a significant decline in the use of pheromone traps compared to the recent past. For instance, approximately 600 thousand drainpipe traps were used during the 1979–1981 bark beetle outbreak in Southern Norway (Bakke & Strand 1981; Bakke 1991). The use of pheromone traps in Slovakia culminated in 1995 when there were 93 thousand traps installed (Varínsky & Vakula 2014).

In recent years a number of countries have lost confidence in using pheromone traps for the purpose of mass-trapping. Currently, for example in Norway only around 500 pheromone traps (mostly BEKA) are used for monitoring purposes (Bjørn Økland, pers. comm.). In Switzerland in 2014, there were only about 1,000 traps (Beat Forster, pers. comm.), and in Sweden 150–200 traps (Åke Lindelöw, pers. comm.). Throughout Germany there are currently only a few thousand pheromones traps in use compared to about 160 thousand traps that were in use during the late 1980s (Niemeyer 1987). There is a decreasing tendency to use commercially available pheromone traps, but the risk of bark beetle outbreaks in forests is still increasing due to ongoing climate changes (Bentz & Jönson 2015), particularly the lack of precipitations and increase of drought episodes (Kolb et al. 2016).

The effectiveness of pheromone traps was analyzed by many authors. The number of the captured marked *I. typographus* imagines (recaptured imagines) differed by several authors with considerable variability. Zahradník et al. (1995) captured from 10.4% to 1.9% of marked beetles; Helland et al. (1984) from 7.3% to 10% in the radius of 500 m, however Anderbrant (1985) recaptured only 0.2% from radius of 30 m. Weslien & Lindelöw (1990) captured from 18 to 37%. Zumr (1990a, b) captured from 37.6 to 77% marked beetles and in another experiment from16 to 27% of marked beetles (Zumr 1992). Franklin et al. (2000) reported 7.0% (64 traps) of recaptured beetles and in second experiment only 2.3% (100 traps). This data are considerably inconsistent and it seems that the precise value of trap effectiveness is not known.

There is a long-standing gap in the development of new models of pheromone traps, probably due to decreasing trend of pheromones use in trapping of *I. typographus*. In our study, we were not focusing only on traps efficiency but also on other technical attributes related to its functionality. We extensively use pheromone traps for monitoring of *I. typographus* and other pest beetles. Based on our work and experience (e.g. Brutovský 1990, 1999; Galko et al. 2010, 2011; Gubka 2007) with pheromone traps, we decided to develop a trap with improved attributes of already existing traps. In principal, the newly developed traps must be tested, and compared with commercially available traps, mainly in terms of trapping efficiency of target pest, easy to use and impact on non-target insect species.

2. Material and methods

Study area. Tatranská Javorina (49°15'53.42"N; 20°8'28.40"E, area center) is situated in the eastern part of the High Tatra Mountains, western Carpathians, Slovakia. Sites are located at altitudes ranging from 1050 to 1150 m asl. The prevailing forest soils are cambisols and podzols and the bedrock is predominantly formed of granodiorit. The climate is characterised by low mean annual temperatures (around 4.0 °C), high precipitation (nearly 1,000 mm) and 140 days of snow cover (Vološčuk et al. 1994). The study area is dominated by Norway spruce (*Picea abies* [L.] Karst.) and the population density of *I. typographus* has remained at epidemic level for the entire study period (2012–2014). The beetle population levels are attributed to a series of severe windstorms that have damaged the spruce forest making it susceptible to bark beetle infestation. The climate during the last decade was characterized with under-average precipitation and over-average temperatures that form favorable conditions for bark beetle outbreaks. The beetle populations are further maintained by near non-managed areas due to forest conservation of the Tatra National Park.

Sites and pheromone traps. The trapping experiment was carried out during the growing seasons of three consecutive years (2012–2014). The experiment was conducted at ten different sites located on a clear-cut area within continuous spruce forest infested by *I. typographus*. Among the traps, four types were commercial products: Theysohn (T-trap), Ecotrap (E-trap), Lindgren funnel trap (L-trap) and BEKA trap (B-trap). Two types of traps are our newly developed models: cross trap (K-trap) (Fig. 1a) and Funnel trap (P-trap) (Fig. 1b). In 2012 four types of pheromone traps (models T, E, L, P) were installed at ten sites; in total 40 traps were installed. In 2013 and 2014 six types of pheromone traps (one of each model T, E, L, P, B, K) were installed at each of the ten sites; in total 60 traps were installed (Table 1). The trap types were all black in color and the position of traps varied each year (Table 2).

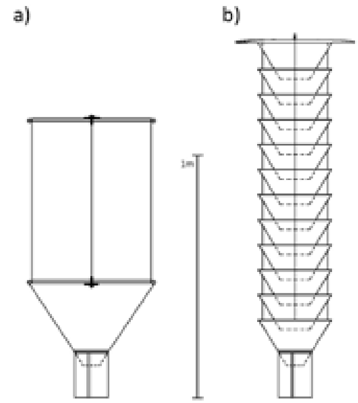
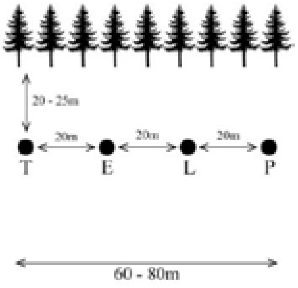
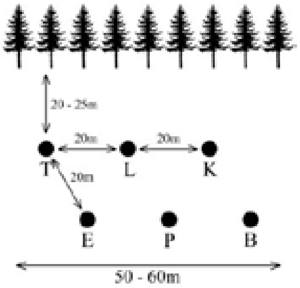
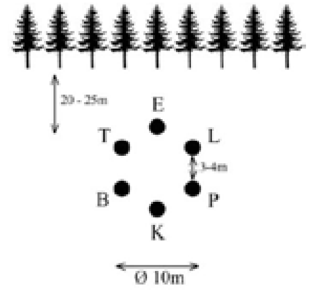


Fig. 1. Shape of the newly developed models of the pheromone traps (a) Cross trap (K-trap) and (b) Funnel trap (P-trap). Note: K-trap is made of durable foil with thickness of 1 mm (10 year warranty). The impact area was located between the upper and lower cross frame that is easy to fold into the lower funnel (also made of foil), thereby facilitating the transfer of multiple pieces. A folded model has a cylinder shape with diameter of collecting container. This model has no shelter. P-trap consists of plastic funnels, which are anchored on three wires. Damaged funnel can be easily replaced. The whole trap may be folded into one another and can be locked. Same collecting container is used in both models. The large capacity container has a scale for estimation of number of beetles catch. On the bottom side is a drain filter for rainfall water. For more see Table 1 and Table 3.

Table 1. Description of trap types.

Trap type	BEKA trap	Ecotrap	Cross trap	Lindgren funnel trap (12 unit)	Funnel trap	Theysohn trap
Image of the trap						
Abbreviation	B	E	K	L	P	T
Producer	NoveFella, Norway (not producing anymore)	Fytofarm, s. r. o., Bratislava, Slovakia	—	Contech Inc., Victoria, BC, Canada	—	Theysohn Vertriebs-GmbH, Salzgitter, Germany
Used in	Scandinavian countries	EU	Slovakia	USA, Canada, (EU)	Slovakia	EU
Shape	funnel	cross	cross	funnel	funnel	flat
Dimension [cm] (height × width × depth)	119 × 21 (10 funnels)	85 × 36 × 36	115 × 50 × 50	115 × 20 (roof 30) (12 funnels)	145 × 30 (roof 46) (12 funnels)	57 × 49 × 6 (roof 13)
Impact area [dm^2]	56.2	45.4	134	39.6	95.3	40.5
Volume of collecting container [l]	1.3	0.5	1.5	0.65	1.5	1.5
Max. possible catch of *I. typographus*	52,000	20,000	60,000	26,000	60,000	60,000
Area of bottom part of collecting container [dm^2]	1.27	0.15	1.13	0.79	1.13	2.70
Drain water from collecting container	hole in the middle of collecting container	mesh over the whole bottom part	mesh over the whole bottom part	one small mesh hole	mesh over the whole bottom part	three small mesh holes
Number of trap components	25	8	4	50	17	3
Possible variants	no	trio configuration	under development	4, 8, 12, 16 funnels	under development	trio configuration
Need of holder frame	no	yes	yes	yes	yes	yes

Table 2. Design of the three year experiment.

Year	2012	2013	2014
Placing of the traps on site			
Design	Traps in line – position were changed every week. Traps were spaced randomly at each site.	Traps in two lines – position of traps were not changed during the season. Traps were spaced randomly at each site.	Traps in the circle – position of traps were not changed during the season. Traps were spaced randomly at each site.
Trap on site (total in year)	4 (40)	6 (60)	6 (60)
Used dispensers (producer)	Pheroprax A (Basf SE, Ludwigshafen, Germany)	IT-Ecolure Tubus Mega (Fytofarm, s. r. o., Bratislava, Slovakia)	Pheroprax A (Basf SE, Ludwigshafen, Germany)
Replacement of the dispensers	4× (each 4 weeks)	1× (whole season duration)	4× (each 4 weeks)
Total number of samples	800 (4 × 10 × 20)	1200 (6 × 10 × 20)	1200 (6 × 10 × 20)

All traps were baited with the same dispenser type; in 2012 and 2014 with Pheroprax A (Basf SE, Ludwigshafen, Germany), and in 2013 with IT-Ecolure Tubus Mega (Fytofarm, s. r. o., Slovakia). The pheromone traps were emptied weekly during the flying period of *I. typographus*. Dispensers were placed in the lower half of each trap. New dispensers were added each month for Pheroprax A (during 2012 and 2014). The old dispensers remained within the traps. In addition to trap emptying, the weeds around the traps were trampled to prevent any bias in trap exposure and stand checks were conducted to ensure the trap components were properly installed and were not damaged.

Sampling procedure. Annually, 200 catch samples from each trap type (20 weeks × 10 sites) were collected. In total 3200 samples were collected for the entire period of the experiment (Table 2). Samples were collected into the Zip-Loc bags. Samples were stored at a temperature of –18 °C until processing. Samples were then defrosted, dried, cleaned and species determined. Imagines of *I. typographus* were measured in graduated cylinder in a ratio of 1 ml: 40 Imagines according to Slovakian standard (STN No. 48 2711, 2012). Samples at low numbers (< 100) were counted. Determination of insects was carried out in the laboratories of the Forest Protection Service in Banská Štiavnica (National Forest Centre, Forest Research Insitute Zvolen).

Statistical analyses. Statistical analyses were performed using Statistica 10 (StatSoft Inc., Oklahoma, USA). The differences between trap captures were analyzed with Kruskal-Wallis non-parametric analysis of variance followed by post-hoc Dunn's test for multiple comparisons.

3. Results

3.1. Comparison and description of efficacy to target pests

In total approximately 3 million imagines of *I. typographus* were captured (1.6 m in 2012, 0.6 m in 2013, and 0.8 m in 2014). Theysohn (T-trap) was chosen as a benchmark or standard (100%) of the mean catch for the entire experiment as it is most frequently used in Europe.

There were no significant differences in numbers of *I. typographus* captured between the trap types. Differences between years were not analyzed due to different design of experiment (different trap layout; dispenser; weather conditions etc.).

In 2012 the T-trap captured almost the same number of beetles as the E-trap (Fig. 2a). First developed trap, P-trap captured 29% and L-trap captured 42% more beetles compared to T-trap (Fig. 2a).

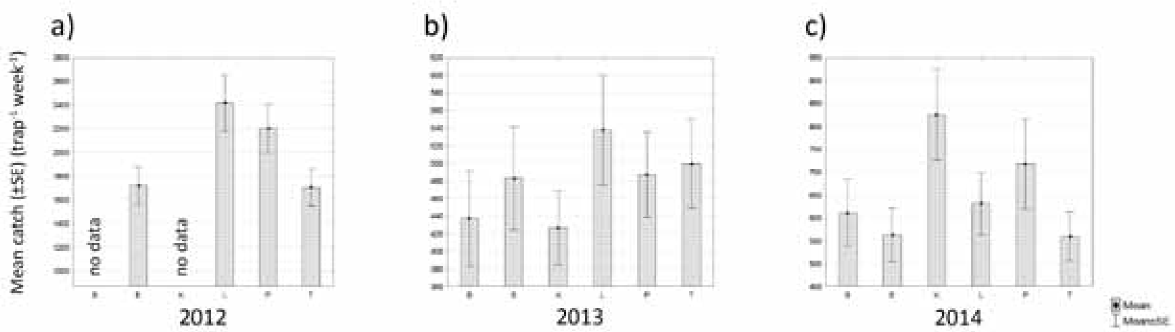


Fig. 2. Mean catch (±SE) of *I. typographus* according to tested pheromone trap models during the study.

In 2013, the total combined trap captures were approximately four times lower than in 2012. This was probably caused by colder weather and the major reason was the exchange trap design and pheromone dispenser. Instead of Pheroprax A we used all season dispenser IT-Ecolure Mega Tubus. Although this dispenser attracted beetles throughout the entire flying period of *I. typographus*, its efficiency was much lower, due to lower amount of evaporated pheromone compound (unpub. data). In 2013, we used a different layout of traps across all study sites (Table 2) and we tested an additional two trap types: B-trap and the second of our developed traps, K-trap. Again the L-trap captured the highest values (8% higher than the standard T-trap). Traps T, P and E caught around the same number of beetles. The lowest average catch was recorded in the K-trap (17% less compare to T-trap) and in the B-trap (14% less compare to the T-trap) (Fig. 2b).

In 2014, traps were installed in a circle shape (10 m diameter) at each site (Table 2) and the pheromone dispenser, Pheroprax A, was used as in 2012. There was no statistically significant difference between the pheromone traps, but our results showed that the highest beetle catches were recorded in both our prototype traps (P-trap 28% and K-trap 57% higher than T-trap) (Fig. 2c). As in the previous years, the highest beetle catches from commercially sold traps were recorded in the L-trap (13% higher than T-trap type). Again, T-trap and E-trap caught around the same number of beetles.

Six-toothed spruce bark beetle (*Pityogenes chalcographus*) was also partly attracted by the used pheromone dispensers. In total we recorded 50.6 thousand imagines of this species. In 2012 and 2013 the highest number of beetles were recorded in the T-trap. This difference was statistically significant compared to all other tested traps (Fig. 3a, b). There were no statistically significant differences between other commercially sold traps. Both of our developed models trapped only low numbers of *P. chalcographus*. This was caused by the size of mesh holes that allow water to drain out from the collecting container. Mesh holes were designed to detain *I. typographus* beetles which are several times larger than *P. chalcographus*, allowing smaller beetles to escape. In 2014, we used mesh with smaller holes, which is reflected in the increased efficiency with the K-trap capturing on average 33% more beetles than in previous years compared to the most effective standard T-trap (Fig. 3b).

3.2. Catches of non-target insect species

Although there were significant differences in trap captures of non-target species, we are not reporting them because of a low number of captured insects.

During the study period we captured 1,007 pcs of Cleridae beetles, what is generally undesirable. All the specimens were of *Thanasimus* sp. For the entire period of the experiment the T-trap captured the lowest number of Clerids compare to the E, K, L and P-traps. Lower catches were also recorded in the B-trap. Although the results significantly differed between the trap types each year (Fig. 4a, b, c) we cannot clearly determine which of the tested traps can be considered as 'worse' in catches of the non-target insect. The E-trap captured relatively high number of Clerids (highest number in 2013) even when the selection mesh was present (Fig. 4b).
We also recorded the abundance of Silphids caught in the traps, which is another unwanted ecological impact. This is caused by the poor drainage of rainwater with the smell of wet decomposed bark beetles in the collection containers attracting Silphids. In total, we recorded 587 imagines predominantly, *Nicrophorus vespillo*. In 2012 E-trap and L-trap captured significantly higher numbers of Silphids compare to the P-trap and T-trap (Fig. 5a). In subsequent years of experiment, we changed the drainage mesh in the E-trap and the number of captured Silphids significantly decreased (Fig. 5b, c). In 2013 and 2014 the B-trap captured most of the Silphids compared to all other traps. The advantage of our prototypes (P and K) is the excellent drainage of rainwater, which was reflected in the lowest number of trapped Silphids during all years (Fig. 5a, b, c).

3.3. Practical comparison of tested pheromone traps

The main advantages and weakness of the tested pheromone traps for our experiment under Slovak conditions are described in Table 3. Based on the results, our newly developed models have been patented in the Slovak Republic; Funnel pheromone trap of bark and/or wood boring insects (P-trap) (utility model No. 7170) and 'Cross pheromone trap of bark and/or wood boring insects' (K-trap) (utility model No. 7169).

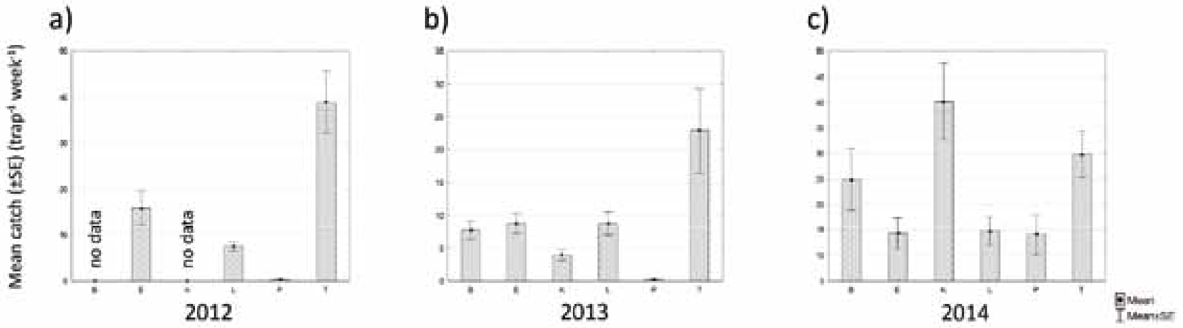


Fig. 3. Mean catch (±SE) of *P. chalcographus* according to tested pheromone trap models during the study.

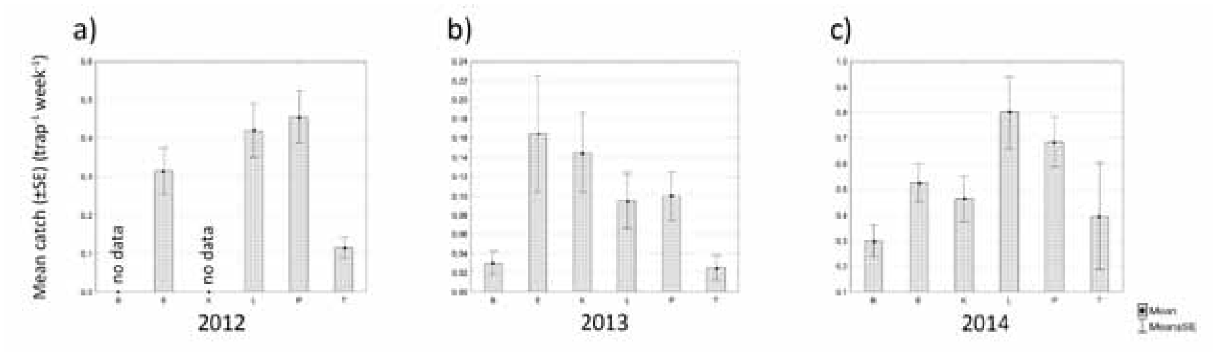


Fig. 4. Mean catch (±SE) of Clerids according to tested pheromone trap models during the study.

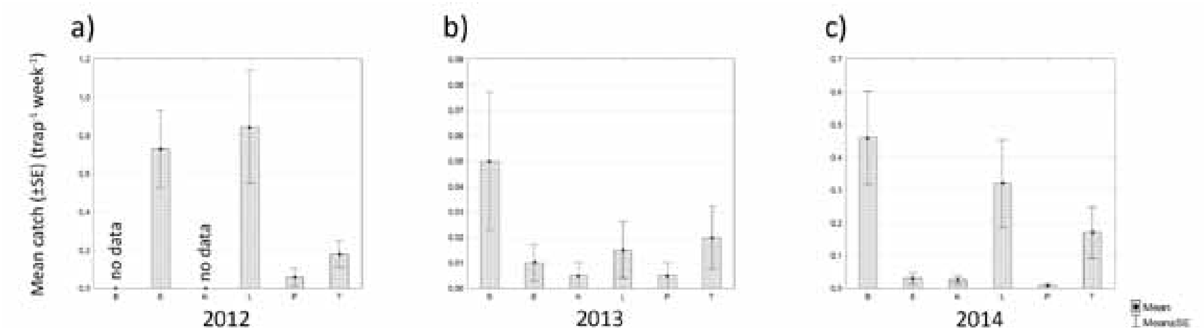


Fig. 5. Mean catch (±SE) of Siplhids according to tested pheromone trap models during the study.

4. Discussion

4.1. Comparison of trap advantages and disadvantages

Spruce bark beetles are a major forest pest agent in central Europe (Kunca et al. 2015). Pheromone traps are one tool available for integrated pest management to monitor and control beetle populations. There are few papers regarding the effectiveness of *I. typographus* pheromone traps. Brutovský (1999) compared pheromone traps T-type and E-type as the most frequent used pheromone traps in Slovak forests and concluded that T-trap is more effective than E-trap. However, Gubka (2007) found the differences between T-trap and E-trap were not statistically significant. L-trap, common in North America, was tested for the first time in the High Tatras, Slovakia, and its effectiveness was compared with T-trap (Galko 2010). L-trap was 20% more effective than T-trap, but due to high variability in beetle catches this result was non-significant. Galko (2011) expanded the experiment to Poľana Mountains, central Slovakia and compared three pheromone traps (L, T and E). The results were the same, with L-trap considered more effective by 20 to 30%. These results triggered a new effort to explore the potential of L-trap as a new product for improving integrated pest management in central Europe.

Brutovský (1984, 1990) summarized his experiences with pheromone traps originating from experiments performed in the1970s and 1980s and defined the optimal characteristics of the pheromone traps concluding that they should contain a barrier with optimal dimensions of impact surface and a collection container with good drainage of rain water with a selection net preventing the target pest from escaping. Our developed models were designed with respect of those conditions making them more competitive than other pheromone traps under Slovak conditions. It is worth mentioning that the collection container on our prototypes is marked with a volume scale to be (*I. typographus* in 1 ml/40pc, *P. chalcographus* in 1 ml/600pc) able to estimate the number of caught beetles directly from the container without further processing.

Since L-trap worked very well in the preliminary experiments with *I. typographus* catches (Galko et al. 2010, 2011) by implementing Brutovsky's recommendations (1984, 1990) characteristics such as easy to use of handling and the number of beetles captured could easily be improved. The major disadvantage of the L-trap was the collection container that, due to very small aperture, is unable to drain rain water efficiently. If the rain water remains stagnant, the beetles in the container quickly decompose (Kretschmer 1990) and attracts Silphids that feed on the decomposing beetles. Ultimately, it is difficult to measure the amount of beetles caught and the decomposing smell contains 1-hexanol and verbenone that masks the pheromones and repels the beetles from the trap (Zhang at al. 2003).

A high abundance of Silphids were found in B-trap (Fig. 5c) meaning the beetles caught were in a state of decomposition. The problems associated with drainage of rain water have been addressed in the new prototype traps P and K which resulted in lower catches of Silphids (Fig. 5a, b, c) and also better handling within the collection container.

Table 3. List of main advantages and weaknesses of tested pheromone traps.

Characteristics	Trap type (abbreviation)					
	BEKA Trap (B)	Ecotrap (E)	Cross trap (K)	Lindgren funnel trap (L)	Funnel trap (P)	Theysohn (T)
Advantages	– no need for frame – high volume of collecting container	– cross shape – price – transparent collecting container	– effectiveness – large impact surface – high volume of collecting container – drainage of rain water – scale on the collecting container – storability – operating life – cross shape – low non-target insect catches	– effectiveness – handing – storability – possibility of wet option of catching	– effectiveness – handing – high volume of collecting container – drainage of rain water – scale on the collecting container – low non-target insect catches	– weight – higher volume of the collecting container – handling – selection – operating life
Weaknesses	– effective impact surface is very low, often in the weeds – operating life – handling – storability – drainage of rain water – price	– low volume collecting container – drainage of rain water – handling – operating life	– handling	– drainage of rain water – no selectivity – price	– dimensions	– panel shape – storability

In the first year (2012) of experiments pheromone Pheroprax A was used (Fig. 2a) and in the second year (2013) we switched to pheromone IT-Ecolure Mega Tubus (Fig. 2b). As 2013 results show the pheromone was less effective than in 2012, Pheroprax A was used in the third year (2014) (Fig. 2c) again. Zahradník & Zahradníková (2014) reported that Pheroprax A has a good efficiency, but the evaporation was inconsistent for the whole period (10 – 14 weeks) declared by producer. Therefore, we were changing this type of pheromone dispensers every 4 weeks (Table 2). Nakládal & Sova (2010) and Nakládal et al. (2013) compared pheromones IT-Ecolure Mega Tubus with IT-Ecolure and they found out that IT-Ecolure captured statistically more beetles than IT-Ecolure Mega Tubus. Unfortunately, we did not choose the best pheromone type (IT-Ecolure Mega Tubus) for our experiments in the second year and also the placing of the traps was probably not well designed in two lines (Table 2). In 2014, the design of the pheromone traps spatial distribution was modified. Each group was arranged in a circle with a diameter of 10 m. Each trap had a pheromone and thus a cloud of evaporated pheromone was concentrated around the circle of traps. It is assumed that the beetles were attracted by the cumulative cloud that was emitted from the cluster of traps. Beetles flying in or near to the traps would be attracted to the trap barriers. Thus, there is a trend that traps with larger barrier surfaces are more effective in beetle catches than traps with smaller barrier surfaces (Fig. 2c).

As for the color of traps, Dubbel et al. (1985) found no significant difference in bark beetles catches in the case of clear, black, green, grey and red brown traps. However, catches of bark beetles into white traps were significantly lower, moreover, many beneficial Hymenoptera were attracted to the white traps compared to traps of other colors. On the other hand, Schönherr (1976) reported, that *I. typographus* preferred dark colored traps when approaching a pheromone source of attraction. This is why all the traps used in our experiments (including the newly developed models) were black.

Recent studies of pheromone traps published in the Czech Republic (Lubojacký & Holuša 2011) compared T-trap with tripod trap logs and showed that T-traps caught approximately one-third more beetles than the tripods. Zahradník & Zahradníková (2015) compared the efficacy of the traditional set-up of pheromone traps (distance 20 m between traps) and a new arrangement where the traps were placed in the middle of a stocking area with no space between each trap. The results showed that the new organization of pheromone traps is more effective than the traditional set-up and can provide a better tool for active forest protection in managing outbreaks of *I. typographus*.

In addition to pest control, there remains scope for traps to be used for additional methods of forest protection. One popular biological controls against bark beetles is the use of entomopathogenic fungi in combination with pheromone traps (Vakula et al. 2012; Grodzki & Kosibowics 2015). An adjusted trap container can be used as the source of powdery biopreparation. As such, this combination could be called a biotechnical or biological method to monitor and control bark beetles. These last examples clearly suggest that there is scope for a future trend of traps development into a new and improved trapping systems.

4.2. Mass trapping versus monitoring

Niemeyer (1987) presented traps as a part of a complex system and at a particular density e.g. 0.5 – 1.0 traps per ha. Later, Niemeyer (1997) specified that only a correctly applied integrated system of bark beetle control is able to reduce infestation of living spruce by 70 – 100% compared to overall tree mortality when the system operates without pheromone traps. However, nowadays only a few countries use pheromone traps with the intention to achieve mass-trapping and/or a reduction in pest infestation. Most countries use them for monitoring purpose only. We propose that the possibly way to change management attitudes is to develop a user- and environmentally-friendly, cheap but effective trap. Yet there is still scope to develop a new pheromone lure type. In forestry practice, for example, Pheroprax A lure has been using for decades in the same compound. Thus, there is a long-term absence in development of a pest lure attractive to harmful pests and is required to shift pheromone traps usages from only monitoring to mass-trapping again.

Finally, we would like to point out that pheromone traps are a good tool within an integrated pest management concept. However, applying them either incorrectly or without other essential methods of forest protection (i.e. sanitary felling, a frequent searching for new infestations, using trap trees etc.), they might perform ineffectively (Niemeyer 1997).

We suppose that the use of pheromone traps still has its importance. Even though we haven't found any statistically significant differences between trap types we believe that our results can help to improve further research in this topic. Each captured imago of *I. typographus* decreasing the risk of further proliferation and relieves beetle attacks on forest edges. The results of Faccoli & Stergluc (2008) support the hypothesis that intensive trapping performed at stand level may be useful for protecting forests against *I. typographus*, locally reducing population density and tree mortality.

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