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Evaluation of the efficacy duration of different types of pheromone dispensers to lure *Ips typographus* (L.) (Coleoptera: Curculionidae: Scolytinae)

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ABSTRACT: We present the results of testing 10 pheromone dispensers used to lure the spruce bark beetle – *Ips typographus* (Linnaeus, 1758). A comparison was made between both their efficacy and also the decrease in their efficacy after application. Dispensers Pheagr IT and IT Ecolure Tubus are effective throughout the whole flight activity of *I. typographus*; the efficacy of IT Pheagr Extra was partly similar. The others are effective for a declared period of efficacy, with the exception of dispenser Pheroprax A, which initially had a very good level of catches, but soon subsided, and the efficacy did not reach either the time or the efficacy of all the declared shelf-life. Overall, the most effective dispenser was IT Ecolure Mega and dispensers IT Ecolure Tubus and FeSex Typo showed a similar efficacy. Completely unsuitable for the trapping of *I. typographus* were found to be combined dispensers PCHIT Etokap and PCIT Ecolure.

Keywords: forest protection; spruce bark beetle; efficacy; trapping

Pheromones have been used in forest protection against the spruce bark beetle *I. typographus* for more than 30 years. In the Czech Republic there are 15 kinds of dispensers registered at the present time and around another 10 kinds were used in the last years from the production of the Czech Republic, Slovakia, Germany and Austria. Two of these dispensers have a combined effect on two species of bark beetles – *I. typographus* and *Pityogenes chalcographus* (Linnaeus, 1761). The pheromone dispensers have different effective substances, different volumes and different ratios between these substances. Of particular importance is how the pheromone substances are evaporated. Two basic types of dispenser were used. The first one evaporates pheromones by means of a wick and the second dispenser releases pheromones through the permeable sides. All of these factors influence the length of efficacy after application into pheromone traps which can range between 5 to 14 weeks according to data from the dispenser producers. Biological testing in our reference laboratory is normally carried out for 8 weeks. The intention of this paper is to establish (*i*) the relative efficacy of pheromone dispensers currently in use in the Czech Republic and (*ii*) the length of efficacy because of its possible impact on the beetles' flight curve.

Although catches in pheromone traps have commonly been used in compiling the flight curve of this pest, their influencing due to a reduction in the efficacy of the dispenser during the whole period of use (without regard to a reduction in the amount of the substance) has never been taken into consideration. Attention has always been focused only on the maximum amount of catches for a predetermined trapping period.

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MATERIAL AND METHODS

The experiments were conducted in the Višňová forest district (Dobříš forest enterprise, Forests of the Czech Republic) between May–August 2008 and April–September 2009. In 2008, only commercially available registered pheromone dispensers were used, including two combined pheromone dispensers. The following wicked dispensers were used: IT Ecolure Extra, IT Ecolure Mega, IT Ecolure Tubus, PCHIT Etokap, PCIT Ecolure, and dispensers with a permeable side included: FeSex Typo, Pheagr IT, Pheagr IT Extra, Pheagr IT Forte, Pheroprax A. In 2009 were used only FeSex Typo, IT Ecolure Tubus, Pheagr IT, Pheagr IT Extra because their flight curves had no statistically significant differences (except of FeSex Typo, which was very often used in practice). Basic data on the pheromone dispensers used is available in Table 1. The conditions of independence on the manufacturers of pheromone dispensers when they were bought from different distributors were observed. All of the dispensers were used in the year of their manufacture.

Theysohn pheromone traps were installed along the stand edge with a safety distance of 10–15 m from the stand edge. The distance between the pheromone traps was approximately 15–20 m. In 2008, there were 66 pheromone traps arranged as follows: two variants (exchanged and unexchanged) of the 10 types of pheromone dispenser mentioned above plus two fake (untreated) control traps (one for exchanged, the other for unexchanged variant) and this was then repeated three times. The arrangement in 2009 was the same as in 2008, but with only 4 types of pheromone dispenser with 5 replications included in the test. In each replication, a double of the amount of each type of pheromone dispenser was used. The first variant was exchanged dispenser, the second one was unexchanged dispenser. The same type of pheromone dispenser was used in adjacent traps. Every odd numbered pheromone dispenser was left for the whole season without being exchanged, while every even numbered pheromone dispenser was exchanged every four weeks. In 2008, the even numbered dispensers were exchanged three times and in 2009 they were exchanged four times. After counting the beetles in each trap, a decrease of the pheromone dispenser efficacy during the time was evaluated. All beetles were counted each week and measured in a graduated cylinder with 1 ml considered to be equal to 35 beetles. Beetles captured in small numbers were counted individually. The trap catches were statistically evaluated for each type of pheromone dispenser by paired test with the use of Student's *t*-test. When it holds good that $P < \alpha = 0.05$, the H_0 for equality of both means is rejected. The QC.Expert statistical programme was used for the analysis. The efficacy of a single pheromone dispenser in percent was determined by com-

Table 1. Basic data on pheromone dispensers

Pheromone dispenser	Time of efficacy	Type	Composition	Producer
FeSex Typo	10	2	ipsdienol (0.3–0.4%) (S)-cis-verbenol (3.2–4.5%)	Karel Ubik-U-SPEKTRUM (CZ)
IT Ecolure Extra	8–10	1	(S)-cis-verbenol (1.6%)	FYTOFARM Group s.r.o. (CZ)
IT Ecolure Mega	21	1	(S)-cis-verbenol (3%)	FYTOFARM Group s.r.o. (CZ)
IT Ecolure Tubus	8–10	1	(S)-cis-verbenol (3%)	FYTOFARM Group s.r.o. (CZ)
Pheagr IT	6	2	(S)-cis-verbenol (3.9–4.3%)	SciTech s.r.o. (CZ)
Pheagr IT Extra	8–10	2	(+/-)ipsdienol (4 g·kg^{-1}) (S)-cis-verbenol (42 g·kg^{-1})	SciTech s.r.o. (CZ)
Pheagr IT Forte	8–10	2	(S)-cis-verbenol (42 g·kg^{-1})	SciTech s.r.o. (CZ)
Pheroprax A	10–14	2	ipsdienol (3.56 g·kg^{-1}) (S)-cis-verbenol (35.59 g·kg^{-1})	BASF AG (GE)
PCHIT Etokap	5–6	1	(S)-cis-verbenol (3.2%) 2-methoxypropan-2-ol (96%)	Chemika a.s. (SK)
PCIT Ecolure	7–8	1	(S)-cis-verbenol (3.2%) chalcogran (1.5%)	CHEMINA s.r.o. (SK)

Type 1– evaporation by means of wick; 2 – evaporation through permeable side

parison with the efficacy of unexchanged Pheagr IT (100%) using the rule of three.

RESULTS

Primary evaluation

From the 2008 results, it is possible to divide the pheromone dispensers into 3 groups according to changes in their efficacy during *I. typographus* flight activity (Fig. 1):

- Pheromone dispensers with unchanged efficacy during the whole flight activity of *I. typographus*: IT Ecolure Tubus, Pheagr IT, Pheagr IT Extra.
- Pheromone dispensers with slightly decreased efficacy in the second part of the flight activity: FeSex Typo, IT Ecolure Mega, Pheagr IT Forte, PCHIT Etokap.
- Pheromone dispensers with low efficacy in the second part of the flight activity: IT Ecolure Extra, Pheroprax A, PCIT Ecolure.

Pheromone dispensers belonging to the first group did not show a significant difference in efficacy during the whole flight activity.

Pheromone dispensers belonging to the second group had a significantly decreased efficacy after 8 weeks when unexchanged.

The third group showed a decrease in efficacy after 6 weeks (Pheroprax A, IT Ecolure Extra) and the same after 8 weeks (PCIT Ecolure), with almost no beetles being trapped.

In 2008, the highest number of trapped beetles was found in the pheromone dispenser IT Ecolure Mega in the unexchanged dispenser variant (Fig. 2) and in the pheromone dispenser Pheroprax A in the exchanged dispenser variant. This pheromone dispenser showed a high efficacy immediately after application. The lowest amounts of trapped beetles were found for the combined pheromone dispensers for *I. typographus* and *P. chalcographus* – PCHIT Etokap and PCIT Ecolure, which appeared to be totally ineffective to lure *I. typographus*. The other pheromone dispensers reached similar efficacy during the first 8 weeks and also during the whole flight activity of *I. typographus*.

Experiments were continued in 2009 with only four types of pheromone dispensers (Fig. 3). These dispensers were chosen on the basis of the stability of trap catches in 2008. The pheromone dispensers IT Ecolure Tubus and Pheagr IT had similar results for both the exchanged and unexchanged variants. The pheromone dispensers Pheagr IT Extra and FeSex Typo showed slightly decreased efficacy when unexchanged during the whole period of flight activity. The efficacy of FeSex Typo dispensers decreased after 8 weeks, Pheagr IT Extra showed significant activity almost immediately after the application.

The highest trap catches were reached by the pheromone dispenser FeSex Typo of both variants, both exchanged and unexchanged during the whole season. The other pheromone dispensers had lower trap catches.

Statistics

In 2008, the differences between the IT Ecolure Tubus, Pheagr IT and Pheagr IT Extra pheromone dispensers were not statistically significant. This agrees with the first group from the primary evaluation. In the remaining cases, there were statistically significant differences between the exchanged and unexchanged variants in the second and the third primarily evaluated group. This leaves two groups after statistical evaluation: (1) pheromone dispensers with statistically insignificant differences between the exchanged and unexchanged variants (IT Ecolure Tubus, Pheagr IT and Pheagr IT Extra) and (2) pheromone dispensers with statistically significant differences between the exchanged and unexchanged variants (FeSex Typo, IT Ecolure Mega, Pheagr IT Forte, PCHIT Etokap, IT Ecolure Extra, Pheroprax A, PCIT Ecolure). In the second group, differences vary according to the primary evaluation.

For 2009, statistically insignificant differences between the exchanged and unexchanged pheromone dispensers were found in the case of Pheagr IT. IT Ecolure Tubus, Pheagr IT Extra and FeSex Typo showed statistically significant differences between the exchanged and unexchanged pheromone dispensers, while the value for IT Ecolure Tubus was close to a statistically insignificant difference.

Biological efficacy

The standard preparation was defined as pheromone dispenser Pheagr IT (unexchanged) because of its widespread use and for having the shortest efficacy period, as given by the producer. The percentages for the total efficacy evaluation are provided in Table 2.

Since it is more usual to exchange the pheromone dispensers during the whole flight activity of the spruce bark beetle, it is better to use the total per cent efficacy evaluation results from Table 2, where catches are summarized after 8 weeks, which is the declared length of efficacy for most pheromone dispensers (excluding IT Ecolure Mega and Pheroprax A, which have a longer declared efficacy period, and

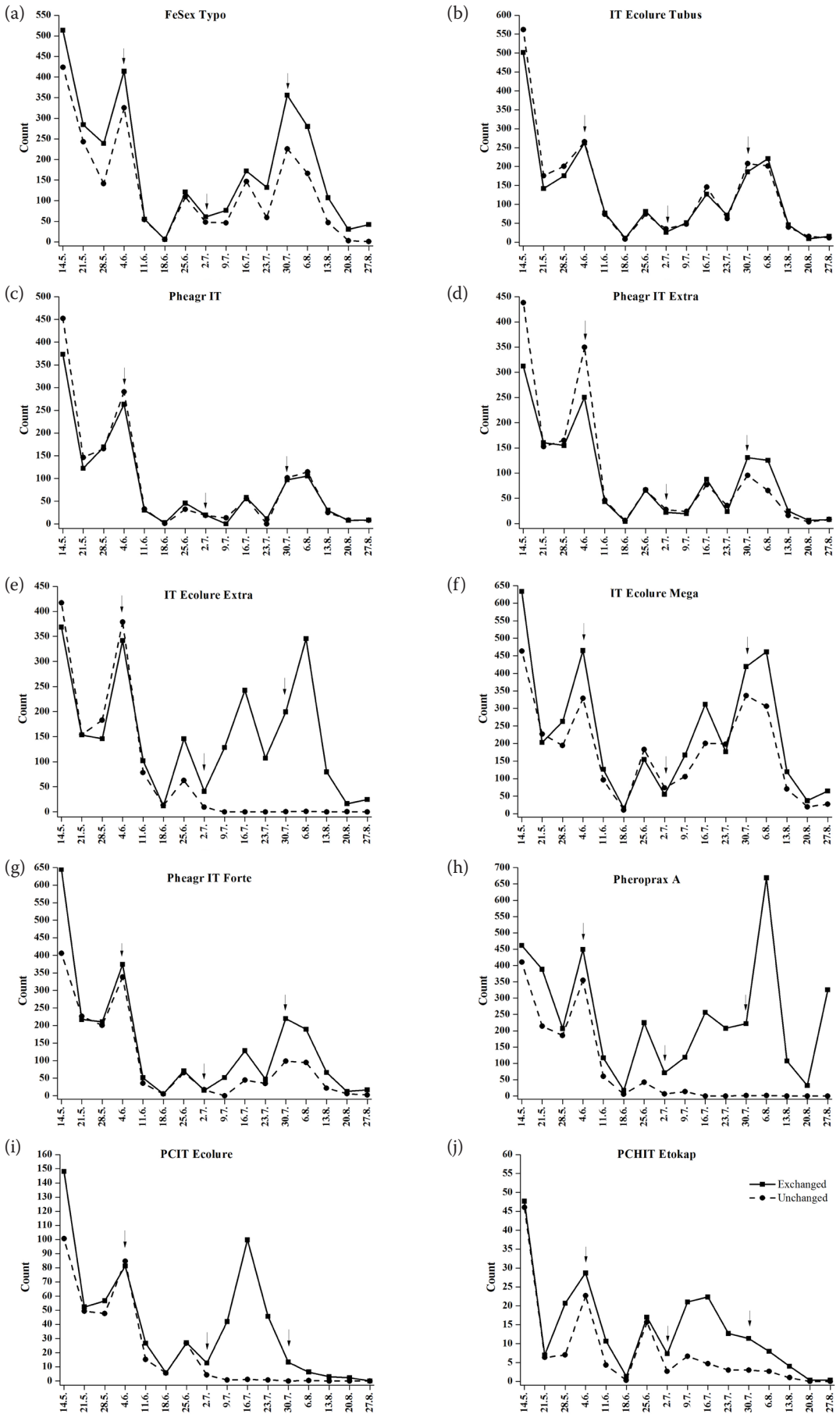

Fig. 1. Comparison of trap catches of exchanged and unexchanged pheromone dispensers in 2008

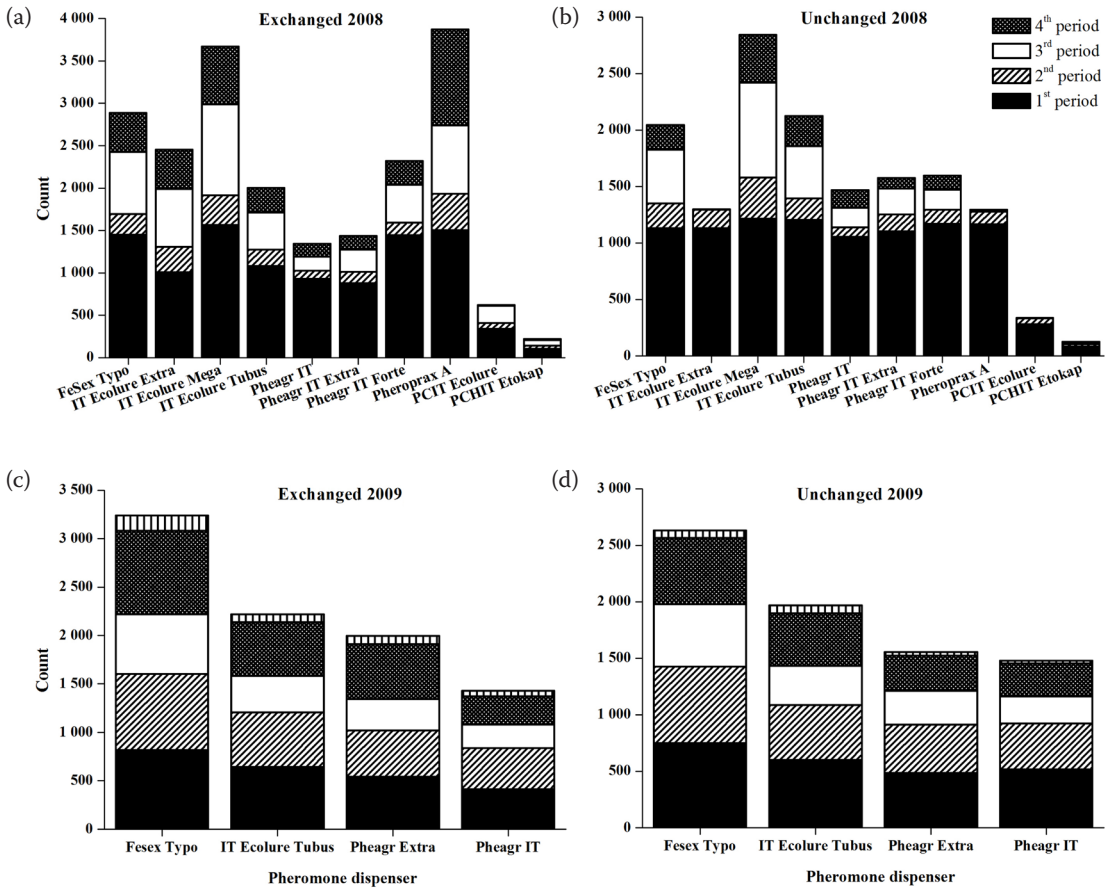

Fig. 2. Comparison of total trap catches in 2008 and 2009

it is therefore better to use Table 3, where results are shown after 16 weeks, which is closer to the declared length of efficacy).

Over the standard 8-week period in 2008, the most effective pheromone dispenser was found to be IT Ecolure Mega (Table 3). The pheromone dispenser

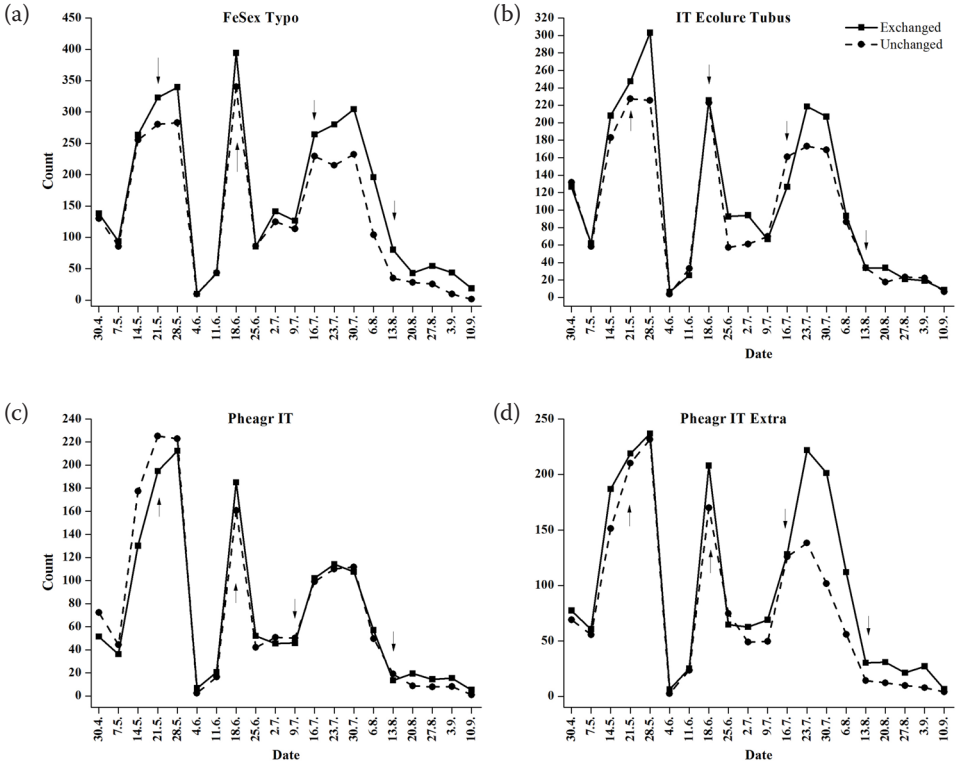

Fig. 3. Comparison of trap catches of exchanged and unexchanged pheromone dispensers in 2009

Table 2. Total percent efficacy of tested pheromone dispensers (in %) (exchanged every four weeks and unexchanged)

Pheromone dispenser	2008		2009	
	unchanged	exchanged	unchanged	exchanged
Over the whole season				
FeSex Typo	139	197	178	219
IT Ecolure Extra	89	167	–	–
IT Ecolure Mega	194	250	–	–
IT Ecolure Tubus	145	137	138	150
Pheagr IT	100	92	100	97
Pheagr IT Extra	107	98	105	135
Pheagr IT Forte	109	159	–	–
Pheroprax A	89	264	–	–
PCHIT Etokap	9	15	–	–
PCIT Ecolure	23	42	–	–
Over 8 weeks				
FeSex Typo	118	148	155	174
IT Ecolure Extra	114	115	–	–
IT Ecolure Mega	138	168	–	–
IT Ecolure Tubus	122	112	126	131
Pheagr IT	100	90	100	91
Pheagr IT Extra	110	89	99	111
Pheagr IT Forte	114	140	–	–
Pheroprax A	112	170	–	–
PCHIT Etokap	9	12	–	–
PCIT Ecolure	29	36	–	–

IT Ecolure Tubus was found to be slightly above-average (more than 20% above the standard Pheagr IT). In 2009, the pheromone dispensers FeSex Typo and IT Ecolure Tubus were evaluated as being above-average. If we extend the effective period onto the entire flight activity of the spruce bark beetle (approx. 16 weeks), then the FeSex Typo, IT Ecolure Mega and IT Ecolure Tubus pheromone dispensers appear to be above-average in 2008 and in 2009 the FeSex Typo and IT Ecolure Tubus pheromone dispensers appear to show above-average efficacy (Table 2).

Table 3. Results of Pair-test–exchanged and unchanged pheromone dispensers on the significance level α = 0.05

Pheromone dispenser	2008	2009
FeSex Typo	0.00007	0.00003
IT Ecolure Extra-	0.01000	–
IT Ecolure Mega	0.00300	–
IT Ecolure Tubus	0.07300	0.01600
Pheagr IT	0.09300	0.24100
Pheagr IT Extra	0.22700	0.00100
Pheagr IT Forte	0.00600	–
Pheroprax A	0.00060	–
PCHIT Etokap	0.00030	–
PCIT Ecolure	0.01000	–

Percentage comparison show a very low efficacy of combined pheromone dispensers to lure *I. typographus* and *P. chalcographus*.

Table 4 shows a comparison of declared efficacy length and efficacy discovered in our experiments.

DISCUSSION

The efficacy periods are provided by the suppliers as a range of weeks because the efficacy can be influenced by a number of different circumstances, particularly air temperature. We presumed that there were no negative impacts on pheromone dispensers during storage.

The testing of pheromone dispensers is not often mentioned in the literature, and when it is mentioned,

Table 4. Comparison of the time of efficacy declared by the producer and observed in our experiments

Pheromone dispenser	Time of efficacy	
	state by producer	approximate discovered
FeSex Typo	10	8–10 (12)
IT Ecolure Extra	8–10	6–8
IT Ecolure Mega	21	8–16
IT Ecolure Tubus	8–10	16 (20)
Pheagr IT	6	16 (20)
Pheagr IT Extra	8–10	11–16 (20)
Pheagr IT Forte	8–10	8
Pheroprax A	10–14	6
PCHIT Etokap	5–6	7–8
PCIT Ecolure	7–8	8

it is usually in professional rather than in scientific literature. In addition, it is significantly influenced by the period when testing was carried out because of the changing spectrum of registered pheromone dispensers, which is especially the case in the Czech Republic and Slovakia (over the last 30 years, nearly 40 pheromone dispenser types have been used and tested). This issue was dealt with by Novák (1984) during the early use of dispensers in the Czech Republic and by Brutovský (1980) in the Slovak Republic. Based on the results of Novák (1982), the Pheroprax pheromone dispenser was used as the standard for testing and this has continued until the present. In the 90's, the range of dispensers used was much wider and some of them are still used at present or served at the development of new dispensers, e.g. Zahradník et al. (1990), and Brutovský (1996). Some pheromone dispensers used at that time are still used today, some of them merely formed a part of the development of dispensers, and some of them were used only shortly. Furthermore, some results were very inconsistent which could be caused by the non-uniform testing methodology. However, there is no overall comparison of the pheromone dispensers currently used in the region of Central Europe. Tests of pheromone dispensers were also conducted abroad, but these tests were usually aimed at the evaluation of one pheromone dispenser, usually at the beginning of its use (e.g. Donaubauer et al. 1979; Egger 1987). Vaupel (1991) compares a new pheromone dispenser Pheroprax A with Pheroprax. At the beginning, attention was focused more on optimizing the whole catching system, including the pheromone traps (Vaupel et al. 1986), because there were only a few types of pheromone dispensers which differed little, for example Pheroprax (e.g. Zumr 1982; Vaupel et al. 1986), Typolur (Vité 1978; Klimetzek et al. 1979; Zumr 1982), Ipslure (Zumr 1981) or IT Etokap in various modifications (e.g. Novák 1982). The gradual decrease in the efficacy of pheromone dispensers has not been studied yet. Only Lie (1984) pointed to a decrease in the amount of individual evaporating active substances of the Pheroprax dispenser and found a decrease in efficacy by about 45% after 2 to 4 weeks, and about 60% after 6 to 8 weeks. Based on this finding, he recommends exchanging the pheromone dispenser after 8-week exposure. Nevertheless, the pheromone dispensers are commonly used for determining the flight activity of spruce bark beetles regardless of the impact of decreased efficacy, which may in turn affect the flight activity curve. Our experiments show that when dispensers are exchanged within the specified 8 weeks, no such a substantial decrease occurs and there is no effect on the flight curve.

CONCLUSIONS

It is possible to interpret obtained results from different points of view:

– **Effect on flight curve**. No negative effect – Pheagr IT and IT Ecolure Tubus pheromone dispensers showed unchanged efficacy during the whole flight activity of *I. typographus*, making it ineffective and uneconomic to exchange those pheromone dispensers.
  Negative effect – there were variations in the results for Pheagr IT Extra.
  The remaining pheromone dispensers had statistically significantly lower trap catches when only one dispenser was used during the whole flight activity of *I. typogaphus*.
– **Efficacy**. IT Ecolure Mega (unexchanged variant) was the most effective pheromone dispenser and the IT Ecolure Tubus and FeSex Typo (unexchanged variant) were slightly above standard and equivalent to the results for the IT Ecolure Mega dispenser.
  The declared extended efficacy of IT Ecolure Mega is based on its highest efficacy; in the case of Pheroprax A (another pheromone dispenser with declared extended efficacy) the results did not show that the efficacy of the Pheroprax A dispenser was much lower than declared.
  With the remainder of the pheromone dispensers, it is possible to claim that there is no efficacy

decrease of pheromone dispensers over 8 weeks. When the dispensers were exchanged every 4 weeks, the most effective were found to be Pheroprax A and IT Ecolure Mega.

The PCHIT Etokap and PCIT Ecolure pheromone dispensers were completely ineffective at the combined luring of *I. typographus* and *P. chalcographus*.

According to the results, we believe that it is not possible to define the most effective pheromone dispenser and that there should be a larger measuring range. It is possible to choose the most appropriate pheromone dispenser according to the purpose of usage (necessity of exchange, maximal trap catch, monitoring, control, etc.). Regarding all results mentioned in this paper, it is necessary to base the choice of pheromone dispenser on preferred criteria. Further research could help increase the rational and effective usage of pheromone dispensers, especially in helping to make savings. However, our results can help to better understand the effective usage of pheromone dispensers, including their more economical use, although it is very important to be aware of the intended purpose for the pheromone dispensers. We plan to conduct further experiments in order to better assist users in deciding which pheromone dispenser to use.

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