On the specific attraction of the males of the six-toothed spruce bark beetle, *Pityogenes chalcographus* (L.) to a mixture of synthetic pheromones of the eight-toothed spruce bark beetle, *Ips typographus* (L.) (Coleoptera, Scolytidae)

G. Benz, P. Bovey and P. Junod

Department of Entomology and Department of Forest and Wood Sciences, Swiss Federal Institute of Technology, CH-8092 Zürich (Switzerland), 12 June 1985

Summary. Traps containing a mixture of attractants for *Ips typographus* also caught other species of bark beetles. The numbers of *Pityogenes chalcographus, Pityogenes conjunctus,* and *Trypodendron lineatum* were too high to be interpreted as accidental captures. The males of the polygamous *P. chalcographus* were specifically attracted, indicating that the *I. typographus* pheromone or one of its components acts as a kairomone and primary attractant for the pioneering males of *P. chalcographus.*

Key words. Attraction; bark beetles; *Ips typographus;* kairomone; *Pityogenes chalcographus;* population aggregation pheromone; *Trypodendron lineatum.*

Colonization of host trees by bark beetles has been divided into four phases: dispersal, selection, concentration, and establishment[1]. Dispersal begins with the emergence of the beetles from brood trees or overwintering sites in the ground and ends with a response to host stimuli and/or attractive pheromones, initiating the selection of a suitable host. This second phase ends with the landing on the tree and sustained feeding in the bark. The pioneering beetles are females in the case of the so-called monogamous bark beetles, but males in the case of the polygamous bark beetles. They initiate the concentration phase by emitting their specific population aggregation pheromone, which attracts both males and females and thus concentrates the population on one or a few suitable host trees.

The polygamous bark beetles, *Ips typographus* (L.) and *Pityogenes chalcographus* (L.), swarm twice a year at about the same time[2]. Both infest mainly wind-blown, water-stressed, diseased or otherwise weakened spruce trees (*Picea* spp., mainly Norway spruce, *Picea abies*). It is generally thought that such trees produce primary attractants that are missing or less concentrated in healthy spruce. These substances attract the pioneering males to suitable trees where each of them bores a hole into the bark and enlarges it to a nuptial chamber. By eating some of the bark the males take up oleoresin containing monoterpenes which are oxidized to one or several substances and excreted with the frass. These substances function as the specific secondary attractants for both males and females of their species[3]. In the case of *I. typographus* the main aggregation pheromone components are 2-methyl-3-buten-2-ol and (S)-*cis*-verbenol[4,5]. They are first excreted, whereas ipsdienol, another substance produced by the male beetle[6], is excreted after the nuptial chamber has been excavated and 2–3 females have entered the gallery[7]. The main component of the population aggregation pheromone of *P. chalcographus* is 2-ethyl-1,6-dioxaspiro(4,4) nonane[8].

European forest entomologists consider *P. chalcographus* a typical 'companion' of *I. typographus.* But while the much larger *I. typographus* prefers the thicker bark of the lower two thirds of the stems of more than 50-year-old spruce, *P. chalcographus* prefers young spruce trees and/or the crown region, i.e. the upper third of the stems and the large branches of older trees, where the bark is comparatively thin. Altogether the ecological niches of the two species are well separated.

In 1972 Švihra reported that other beetles attacking spruce had been found in a trap, baited with infested logs and additional oleoresin, designed for trapping *I. typographus* in Slovakia[9]. Besides about 4000 individuals of this species, he caught more than 100 individuals each of the bark beetles *Ips amitinus* (Eichh.) and *P. chalcographus* as well as 50–100 individuals each of *Cryphalus abietis* (Ratz.) and *Polygraphus poligraphus* (L.). However, since the trap emitted both primary and secondary attractants, it could not be determined which type was actually attractive. Concerning *I. amitinus* our findings have meanwhile made clear that this species is not attracted by the secondary attractant of *I. typographus* (see below).

In the course of field work for the diploma thesis of one of us (P.J.) 18 slit traps of the Theyson type were installed in spring 1984 in the forests of the community of Buttes, Val-de-Travers, Switzerland, consisting of mixed stands of mainly Norway spruce (39%), silver fir (35%), and beech (25%)[10]. Each trap was furnished with a Pheroprax® bag containing verbenol, methylbutenol, and ipsdienol for the specific attraction of *I. typographus*[11].

The traps were placed at different altitudes from 830 to 1220 m above sea level within the stands, between two beech or fir trees, if possible at a distance of 10 m or more from the next spruce tree. Between 19 April and 17 May the traps were emptied four times and the trapped beetles separated and counted according

Table 1. Bark beetles of different species caught in traps at four different dates in 1984

Subfamily and species	27 April	12 May	15 May	17 May	Total
Ipinae					
Cryphalus abietis (Ratz.)	14	8	2	8	32
Cryphalus piceae (Ratz.)	–	4	–	–	4
Crypturgus cinereus (Herbst)	–	–	–	2	2
Crypturgus pusillus (Gyll.)	–	–	–	8	8
Dryocoetes autographus (Ratz.)	–	11	19	9	39
Ernoporus fagi (F.)	–	–	–	1	1
Ips typographus (L.)	1160	6170	5700	8000	*21,030*
Pityogenes chalcographus (L.)	48	32	263	513	*856*
Trypodendron lineatum (Ol.)	140	500	64	64	*768*
Hylesinae					
Hylastes ater (Paykull)	–	2	–	–	2
Hylastes cunicularius Erichs.	–	3	111	86	*200*
Hylurgops palliatus Gyll.	50	77	1	–	*128*
Phthorophloeus spinulosus Rey	–	–	–	1	1
Non-scolytide beetles	–	1	–	27	28

to species (table 1). Three species were sexed (table 2). The number of *I. typographus* was estimated by a volumetric method: 5 ml contain about 200 beetles.

A further Pheroprax® baited trap was exposed from 1 July to 31 August 1985, at the fringe of a mixed stand of larch and cembran pine in Pontresina (Switzerland) at 1810 m above sea level. Many of the cembran pines in this stand were attacked by *I. amitinus*, *Pityogenes conjunctus* (Reitter), and other bark beetles. Within 8 weeks the trap caught one *I. amitinus*, one *Hylaster ater* (Paykull), and 397 *P. conjunctus* (75 males and 322 females; sex ratio 0.23).

Table 1 shows that, besides about 21000 individuals of *I. typographus*, 2000 bark beetles belonging to 12 other species were captured within 4 weeks in Buttes. Six of these species were represented by only 1–8 individuals and may thus be regarded as probably caught by accident. The same may be true for *C. abietis* and *Dryocoetes autographus* (Ratz.) represented by respectively 32 and 39 individuals. Since, unfortunately, no empty control traps had been exposed, the question of whether or not these figures should be interpreted as a sign of some attractiveness of the traps for these species remains open. The fact that within 8 weeks the trap in Pontresina captured only one individual of *I. amitinus* accidentally, in a forest where large numbers of this species existed, might speak in favor of the attraction hypothesis. On the other hand, the numbers of *P. chalcographus* and *Trypodendron lineatum* (Ol.), *Hylastes cunicularius* Erichs, *Hylurgops palliatus* Gyll., and *P. conjunctus* seem to be higher than would be expected from accidental trapping of free flying beetles. This is especially true for *P. chalcographus*, of which almost only males had been trapped (table 2).

The male/female sex ratio of the captured *P. chalcographus* was 44, i.e. very different from the natural sex ratio of about one in this species[12]. The 837 captured males may therefore be regarded as a result of specific attraction and the 19 females (2.3% of the female population) as accidental captures. This ratio of accidental captures speaks also in favor of the non-accidental trapping of the other species mentioned above.

A positive response of other bark beetle species to the *I. typographus* pheromone (ITP) may be to their advantage, since it directs the pioneering individuals to suitable host trees only partly exploited by *I. typographus*. *P. chalcographus* infests the parts with thin bark spared by *I. typographus*. Our results therefore suggest that ITP or one of its components acts as a kairomone for the pioneering males of *P. chalcographus*, similar to the primary host attractants. Not until the concentration phase, when the pioneering males have selected their host and constructed the nuptial chamber, do they emit the specific pheromone attracting the females and other males.

It is interesting that the related *P. conjunctus* is also attracted by the ITP or one of its components. However, in this case 4.3 times more females than males were captured, indicating that both sexes were attracted. Whether or not the sex ratio found in the captured individuals corresponds to that of the natural flying population of *P. conjunctus* is not known. Since it is a polygamous species where each male in its gallery is joined by 3–5 females a preponderance of females is possible. At any rate the ITP mixture or part of it seems to correspond with or substitute for the natural aggregation pheromone of *P. conjunctus*. However, in this typical alpine species of the cembran pine little or no overlapping with *I. typographus* should occur and no kairomonal activity can be expected.

As mentioned before, in the monogamous species *H. cunicularius*, *T. lineatum*, and others the females are the pioneering sex primarily attracted by the host plant. If the ITP could substitute for the primary attractant, as suggested for *P. chalcographus*, a dominance of females would be expected in the traps. However, only *H. cunicularius* showed a sex ratio of 0.5, whereas the ratio for *T. lineatum* was 1.5, indicating a dominance of males in the latter species (table 2). It is thus possible that ITP or part of it attracts the pioneering females of *H. cunicularius* as it attracts the males of *P. chalcographus*. The relatively high number of males attracted would then indicate that either the attractant was less sex specific for *H. cunicularius* or the specifically attracted pioneering females emitted their population aggregation pheromone already during the selection phase and consequently attracted males. Such early pheromone production has been demonstrated in *T. lineatum*[13,14] and males have been observed to follow searching females on the bark of trees before they began to bore their galleries[15].

Concerning *T. lineatum* we suppose that both sexes are attracted by ITP, as suggested for *P. conjunctus*. However, whereas in the latter species the ITP mixture or part of it might correspond with the aggregation pheromone of the species, this is not the case in *T. lineatum* where the aggregation pheromone is known to be lineatin[16]. Therefore, the ITP mixture or part of it may only act as a substitute for the specific secondary stimulus of *T. lineatum* or else another explanation must be looked for. The hypotheses put forward for *H. cunicularius* may be applied to *T. lineatum* as well.

As a rule the monogamous *T. lineatum*, *H. cunicularius*, and *H. palliatus* attack dying spruce trees only. However, of the five main species captured in Buttes the polygamous *I. typographus* and *P. chalcographus* are the only ones which kill trees. Being attracted to trees already infested by one of these tree killers may therefore be profitable to the three monogamous species. Even if a tree is attacked simultaneously by *I. typographus* and *P. chalcographus* the monogamous species may find sufficient uninfested space for their broods. This is especially true for the fungus breeding *T. lineatum*, which constructs its brood galleries in the xylem.

Table 2. Sex ratio of *Pityogenes chalcographus*, *Trypodendron lineatum*, and *Hylastes cunicularius* captured at different dates in traps with *Ips typographus* attractant mixture. Number of non-sexed beetles in brackets

Date	*P. chalcographus*		*T. lineatum*		*H. cunicularius*	
	♂	♀	♂	♀	♂	♀
27 April	47	1	88	52	0	0
12 May	31	1	(500)		(3)	
15 May	255	8	40	24	33	78
17 May	504	9	12	16	36	50
Total	837	19	140	92	69	128
♂:♀	44.0		1.5		0.5	

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