Control of the chalcid wasp *Pteromalus apum* Retzius, a parasite of *Megachile rotundata* (Fabr.) (Hymenoptera, Pteromalidae & Apidae)

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The alfalfa leafcutting bee *Megachile rotundata* (Fabr.) is parasitized by the chalcid wasp *Pteromalus apum* (Retzius) in Europe. A brief description of the wasp is given, and the emergence period of adults, the number of parasites/host and sex ratios are treated. The effect of the insecticide dichlorvos on bees and wasps has been studied during the incubation period of the bees. A procedure for an effective control of parasitic wasps and predators with dichlorvos without harm to the bees is proposed.

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The alfalfa leafcutting bee (*Megachile rotundata* (Fabr.)) is believed to have been accidentally introduced into North America from Eurasia in the first half of this century (Stephen, 1962), but is now the most commonly used pollinator of alfalfa seed fields in North America (Parker, 1980), and alfalfa seed yields have been greatly increased after colonization of this bee in artificial hives in Canada (Hobbs, 1968; Peck, 1969). During recent years these bees have been propagated and exported from Canada to countries in other parts of the world. As several Chalcidoid wasps are known to parasitize the bees under Canadian conditions (Eves et al., 1980; Hobbs & Krunic, 1971), these shipments of leafcutting bees could result in the introduction of some of the parasites into new areas (Parker, 1982).

The most common chalcidoid wasp parasite associated with the alfalfa leafcutting bee in the USA and western Canada is *Pteromalus apum* Retzius (1783) (synonyms *P. venustus* Walker, 1835; *P. planiscuta* Thomson, 1878). According to Boucek & Graham (1978), *P. apum* is the only species of the genus *Pteromalus* which is parasitic in the nests of megachiline bees. The wasp was accidentally introduced from Europe and probably arrived in Canada with the bee (Richards, 1984). Because of its high reproductive capacity and short emergence time (Eves et al., 1980), this parasite has the potential to cause severe economic losses.

The wasp is associated with solitary bees and seems a very common parasite of indigenous leafcutting bees nesting in buildings in Denmark. Nests with alfalfa leafcutting bees placed on or close to sheds or houses are therefore always heavily infected with this parasite, and without control the whole population of leafcutting bees is destroyed.

The aim of the present experiments was to investigate the possibility of destroying the emerging wasps during incubation of the bees before the bees were released in the field. The experiments were conducted in 1983 and 1984.

Material

The bees were originally imported from Montana, USA, and Beaverlodge, Alberta, Canada, in 1979-1981. Some of the wasps may have been present in the imported cocoons.

Methods

The fully grown larvae of *Megachile rotundata* spend the winter in their cocoons. The cocoons used in the experiment were removed from wooden grooved nesting boards during the winter and kept at 6-8°C until June 1st. A room was then equipped for incubation of the bees at 30°C. The appropriate humidity was ensured by sprinkling with water.

On the ninth day of incubation a Shell Vapona Strip was hung up in the incubation room to kill the adult *Pteromalus apum* as soon as they emerged from the bee-cocoons. The active ingredient in the strip is 18.6% dichlorvos (0.0 - dimethyl - 2.2 - dichlorvinylphosphate). Normal concentration is 3.5 g Vapona Strip per m^3. In this experiment only 2.1 g per m^3 was used unless otherwise stated. 343,000 cocoons were incubated and exposed to Vapona Strips in 1983 and approximately 650,000 in 1984. A. UNIKUM insect-attracting device with a Phillips HPW (E/70/2) 125 watt bolb was used to attract the wasp away from the cocoons in 1984.

Before the cocoons were exposed to the effect of dichlorvos from a Vapona Strip, 100 cocoons were selected at random and exposed to dichlorvos for 7 days and examined for mortality. All 100 bees emerged except one which was found dead in an imcomplete cocoon. Several similar tests were made, and in no cases the bees were harmed or killed by the insecticide as long as they were inside the cocoons.

The Vapona Strip hung on the 9th day of incubation was left until a few small males of *M. rotundata* (the first sex to emerge) were killed. A few parasites and predators other than *P. apum* were also destroyed at the same time. In order to ensure adequate exposure of the emerging wasps to the insecticide, the incubation trays were left open.

Each year all cocoons were divided into samples for rearing in incubation trays, and 400 cocoons from each sample were randomly selected and examined by x-radiography using the method of Stephen & Undurragd (1976).

In order to determine how far the wasps were able to crawl before they were killed by the insecticide, a polyethylene tray 300 cm. long and 50 cm wide was placed in the incubating room in 1983. Daily records were made of the number of emerged wasps and their position on the tray (Farkas & Szalay, 1982). A plexiglass box (0.9 m^3) in which temperature, humidity and light intensity could be controlled was used to determine the death rate of bees and wasps at three concentrations of dichlorvos: 3.2 g per m^3 (prescribed dose), 6.4 g per m^3 and 12.8 g per m^3.

Description of *Pteromalus apum* Retzius

The wasp differens in colour and size from the description by Eves et al. 1980 as follows. Females are black with a dark brown to metallic blue-green colouration. Males are similarly coloured except on the head and thorax where they are more metallic green. Both sexes have dark brown legs.

Length, of 25 adults of each sex and 25 mature larvae, means and rages

Females	3.14 mm (2.6-3.7 mm)
Males	2.9 mm (2.6-3.9 mm)
Mature larvae	2.4 mm (1.6-2.7 mm)

Results

Emergence

The adult parasites started to emerge on the 9th and 10th days of incubation at 30°C and continued to emerge over a period of 5 to 6 days. At 25°C the emergence period was 11 days. Peak emergence occurred on the 3rd or 4 th day and after the 6th. day more than 92% of all the parasites had emerged (Fig. 1).

Generations

The overwintered wasps were reared at different temperatures for successive generations (Table 1). at 30°C the wasps went through three successive generations before entering diapause while at 20° and 25°C only two generations could be reared before dia-

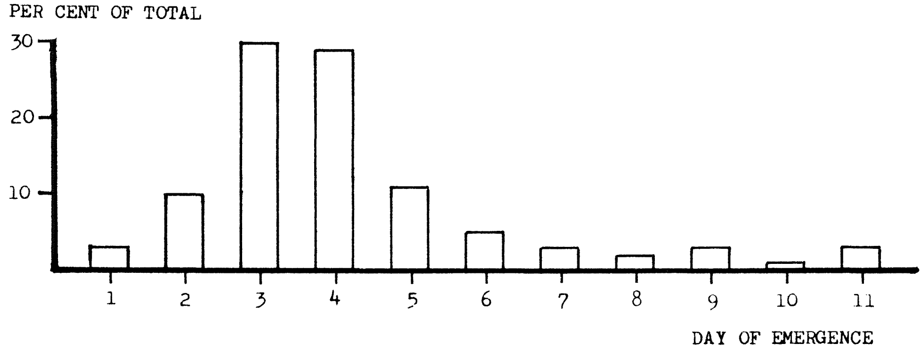

Fig. 1. Percentage of *Pteromalus apum* emerging on successive days following the emergence of the first wasp. Based on 339 males and females incubated at 25°C.

Fig. 1 Den procentvise fordeling af klækkede Pteromalus apum *i forhold til det først klækkede individ. Baseret på 339 hanner og hunner ved inkubation på 25°C.*

pause occurred. Further generations of the wasps could not be obtained until the diapause was broken by subjecting the mature larvae to low temperatures (3-5°C) for three months.

The emergence period was about 15 days for the first two generations reared at 30°C. In the third generation at this temperature only very few wasps emerged, and they emerged on average after 31 days. At lower temperatures the incubation period was correspondingly longer and took 36 days at 20°C compared with 20 and 26 days for first and second generations reared at 25°C (Table 1).

Number of generation	Number of days to emergence at: 20°C	25°C	30°C
1.	36	20	15
2.	–	26	16
3.	–	–	31

Table 1. Number of days to emergence of successive generations of *Pteromalus apum* at different temperatures before entering diapause.

Tabel 1. Antal dage inden klækning for tre successive generationer af Pteromalus apum *ved forskellige temperaturer inden diapausens indtræden.*

Oviposition

Shortly after emergence from the cocoon females start to search for a new host (Richards, 1984). On contacting the host she drums it with the antennae and selects an oviposition site on the cell and inserts the ovipositor (Fig. 2).

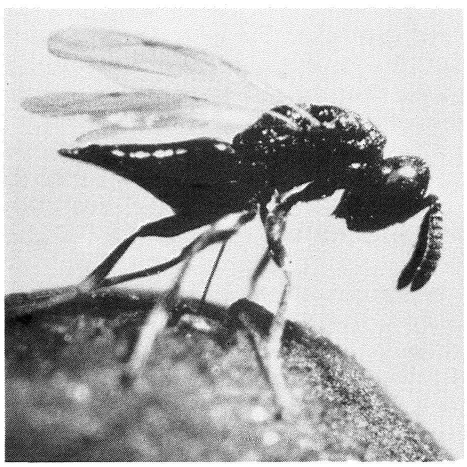

Fig. 2. Egglaying *Pteromalus apum.*

Fig. 2. Æglæggende Pteromalus apum.

Number of parasites/host and sex ratio

All adult wasps emerged through a single 1 mm hole chewed in the side of the bee cell. The males emerged first and mated with the females as soon as they emerged from the cocoons. Estimates of the number of wasps per host and sex retio, based on 61 bee cells, are shown in Table 2. A total of 1,100 wasps were reared, giving an average of 18 per cell. Most of the host cells contained both male and female wasps, although some cells contained only one sex. In general a greater number of females than males emerged, and an overall sex ratio of 1:1.26 males to females was found.

Sex	Number of wasps per cocoon	Average	Range
♂	485	8	0-35
♀	615	10	0-32
Total	1.100	18	6-52

Table 2. Number of *Pteromalus apum* emerged from 61 *Megachile rotundata* cocoons.

Tabel 2. Antal Pteromalus apum *klækket fra 61* Megachile rotundata *kokoner.*

Effect of dichlorvos

The effect of the insecticide dichlorvos on bees and wasps was studied using three different dose rates (Table 3). The first wasps died after 38, 18 and 10 minutes exposure to normal (1x), 2x and 4x normal concentrations of dichlorvos, respectively.

At the normal concentration it took approximately 42 minutes before all of the wasps were dead, and this extinction time was halved for each doubling of the concentration.

When exposed to dichlorvos most bees died more quickly than the wasps; at the normal concentration of dichlorvos the bees died within half an hour after emergence. There were no detrimental effects on unemerged bees even when the cocoons were exposed for 7 days at the normal concentration. The intact cocoons effectively protected the developing pupae of *M. rotundata* against the concentrations of dichlorvos used in these experiments.

The distance the wasps were able to crawl before they died was recorded using the polyethylene tray and the results are shown in Fig. 3. Over twenty percent were able to move more than 3 m, before they died of exposure to the insecticide. The adult wasps are attracted to light, but not all adults were attracted, which indicates that white light is not attractive to the wasps.

The UV-light used in 1984 appeared to be more attractive and effectively caused the wasps to leave the bee cells very soon after emergence. The method removed the wasps effectively and they were killed by the insecticide before the females could lay eggs in the inparasitized cocoons in the incubation trays.

Concentration	normal	2x	4x
No of wasps	10	10	10
First wasps dead after	38 min.	18 min.	10 min.
All dead after	41.6 m.	22.2 m.	11.2 m.
No of bees	6	–	5
First bees dead after	28 min.	–	5 min.
All dead after	34 min.	–	13 min.

Table 3. Survival time of *Pteromalus apum* and *Megachile rotundata* after exposure to different concentrations of Vapona.

Tabel 3. overlevelsestid for Pteromalus apum *og* Megachile rotundata *efter påvirkning af forskellige koncentrationer af Vapona.*

Discussion

Various control procedures have been implemented in the USA and Canada to control chalcidid wasps and to remove them from the *M. rotundata* cells during the incubation period (Hobbs, 1968; Johansen & Eves, 1969; Eves, 1970; Hobbs & Krunic, 1971; Waters, 1971; Brindley, 1976; Parker, 1980; Hill et al., 1984).

Pteromalus apum was probably introduced into Denmark with importation of *M. rotundata* cocoons in 1979-1981 (Holm, 1982), but it also parasitizes indigenous leafcutting bees in Denmark, and it is therefore important to control this parasite in the populations of leafcutting bees used for pollination of crops (Holm, 1983). The female wasps are able to lay eggs inside a new cocoon within four hours from emergence (Richards, personal communication). The results obtained show that normal concentrations of dichlorvos can be used to exterminate the emerged female wasps before they are able to parasitize other cocoons and thereby produce the second generation which would normally emerge under field

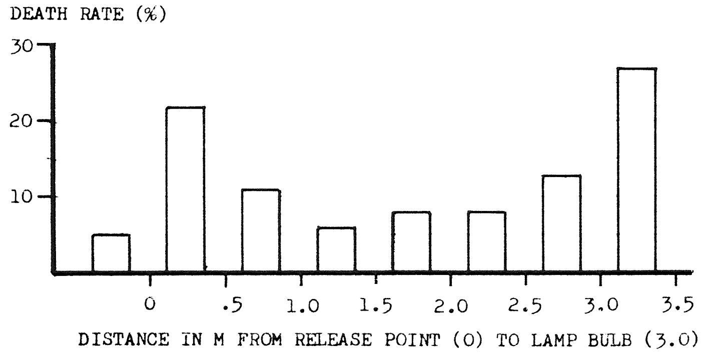

Fig. 3. Effect of dichlorvos on death rate of 164 males and 111 females of *Pteromalus apum* at different distances from the release point (0).

Fig. 3. Den relative effekt af dichlorvos på dødeligheden af 164 hanner og 111 hunner af Pteromalus apum *i forhold til klækningsstedet (0).*

conditions and cause great damage to the next generation of bees.

Dichlorvos is effective in controlling insect parasites and predators of *Megachile rotundata* because these normally emerge before the bees emerge from their cocoons. *M. rotundata* requires a longer incubation period for emergence as an adult (Holm & Skou, 1972) than do the indigenous Danish species of parasites and predators. The indigenous parasitic bee *Coelioxys inermis* Kirby, which is occasionally found in *M. rotundata* nests in Denmark, was effectively destroyed by use of dichlorvos.

Conclusions

The use of Vapona Strips with dichlorvos together with UV-light to attract the wasps away from the cocoons of leafcutting bees ensures an effective control of parasitic wasps and predators, and if used with care does not cause bee mortality.

Proposed control procedure: Insecticide vapour strips should be used with great care because excessive concentrations and/or prolonged exposure periods may cause mortality among the bees. The vapour strips should be placed 15-20 cm from the ceiling on the 9th day of incubation af 30°C and left in the room for 5-6 days or until all parasites and predators have emerged. The concentration of the insecticide must be sufficient to destroy the wasps soon after they have emerged, but should not exceed the recommended concentration.

The fumes from the strips adhere readily to wooden incubation thrays and other surfaces, and losses of emerging bees may occur as the vapours are released. To prevent subsequent losses after the treatment with dichlorvos it is recommended that the bees be transferred to uncontaminated trays in which they can be transported to the hives and released.

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Sammendrag

Kontrol af Chalcididen *Pteromalus apum* Retzius, en parasit på bladskærebien *Megachile rotundata* (Fabr.) (Hymenoptera, Pteromalidae & Apidae).

Lucernebladskærebien (*Megachile rotundata* Fabr.) udnyttes kommercielt til bestøvning af lucerne i USA og Canada, og den blev indført i Danmark i 1981 med henblik på bestøvning af lucerne og kløver m.v. Bierne angribes af snyltehvepsen *Pteromalus apum* Retzius, der kan destruere hele populationen af bier, hvis der ikke gennemføres en effektiv bekæmpelse af snylteren. Denne afhandling omhandler en metode til at destruere snyltehvepsene under inkubationsperioden af bierne, før de udsættes i fromarkerne.

Snyltehvepsen *Pteromalus apum* er 2,6 til 3,2

mm. Hunnerne har sortbrun til metal-grøn farve; hannerne er tilsvarende farvet undtagen på hovedet og brystet, hvor de er mere metalgrønne. Straks efter klækning og parring opsøger hunnen en kokon med en bilarve eller puppe. Hun indfører læggebrodden igennem bladcellen og kokonen og lægger æggene på bilarven (Fig. 2).

Snyltehvepsene klækkes fra kokonerne fra den 9. til den 15. dag ved en inkubationstemperatur på 30°C. Ved lavere temperaturer foregår klækningen over en længere periode (Fig. 1). Ved klækning af overvintrede snyltelarver udvikles ved 3o°C tre successive generationer, før diapause indtræder (Tabel 1). Gennemsnitligt klækkes der 18 snyltehvepse pr. parasitiseret kokon i forholdet 1 han til 1,26 hunner (Tabel 2).

Snyltehvepsene dræbtes med Shell Vapona Strip (18,6% dichlorvos), der opsattes på den 9. dag, og indtil alle snyltehvepsene var klækket af kokonerne. Ved normal koncentration (104 g Vapona Strip pr. 30 m^3 rum) døde snyltehvepsene gennemsnitligt efter 41,6 minutter. Ved stigende koncentration af dichlorvos reduceredes tiden forholdsvis (Tabel 3). Distancen, snyltehvepsene bevægede sig inden 3 m, før de døde, fremgår af Figur 3.

Resultaterne viser, at det er muligt ved brug af normal koncentration af dichlorvos at dræbe alle snyltehvepsene, før de er i stand til at producere en ny generation, og uden at det skader bierne.

Ved en inkubationstemperatur på 3o°C placeres Vapona Strip 15-20 cm. fra loftet på den 9. dag, eller når de første snyltere klækkes. Da dichlorvos trænger ind i træet i klækningskasserne, anbefales det at overføre kokonerne til en anden kasse straks efter behandlingens afslutning, før bierne klækkes.

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