Aspects of the biology and ecology of *Ichneumon promissorius*, a true pupal parasitoid of *Helicoverpa* spp.

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Introduction.

Eggs, larvae and pupae of *Helicoverpa* (the new name for *Heliothis*) are attacked by a broad range of beneficial predators and parasitoids which help to reduce overall abundance by removing a proportion of the developing populations. Parasitoids which attack *Helicoverpa* larvae are generally well known and include the braconid wasp *Microplitis demolitor*, which parasitises small, 2nd instar larvae and immobilises them at the third or early 4th instar (small-medium) (Murray 1992) and several larval-pupal parasitoids, such as the wasps *Heteropelma scaposum, Netelia producta*, and various tachinid flies, which attack 3rd to 6th instar larvae, and emerge from large larvae or pupae.

There are, however, few parasitoids which specifically attack the pupal stage. This is perhaps understandable since pupae are not readily accessible, being in the soil. For the last few seasons we have been conducting a study of the biology, behaviour and field ecology of a true pupal parasitoid of *Helicoverpa* , the ichneumonid wasp, *Ichneumon promissorius*. The aim was to assess the impact of the wasp on pupal populations of *Helicoverpa* spp. and to assess the possibilities for mass rearing it as a biocontrol agent, particularly for management of overwintering pupae in cotton areas. Here we give a brief account of the biology of *I. promissorius* and provide a summary of the abundance of various parasitoids in *Helicoverpa* pupae collected in the Namoi/Gwydir area over the period 1987-1991.

Distribution and Host Range.

I. promissorius occurs naturally throughout much of eastern Australia but its distribution is not well described because pupae of noctuids have rarely been sampled systematically. As a result the significance of this parasitoid has also been underestimated. *I. promissorius* has been recorded from pupae of *Helicoverpa armigera* and *H.punctigera* in northern NSW, southern Qld, as well as from a range of other noctuid moths including the armyworms *Mythimna convecta, Persectania ewingii* and *Spodoptera exempta* . *I. promissorius* may well be a generalist pupal parasitoid of many noctuid species.

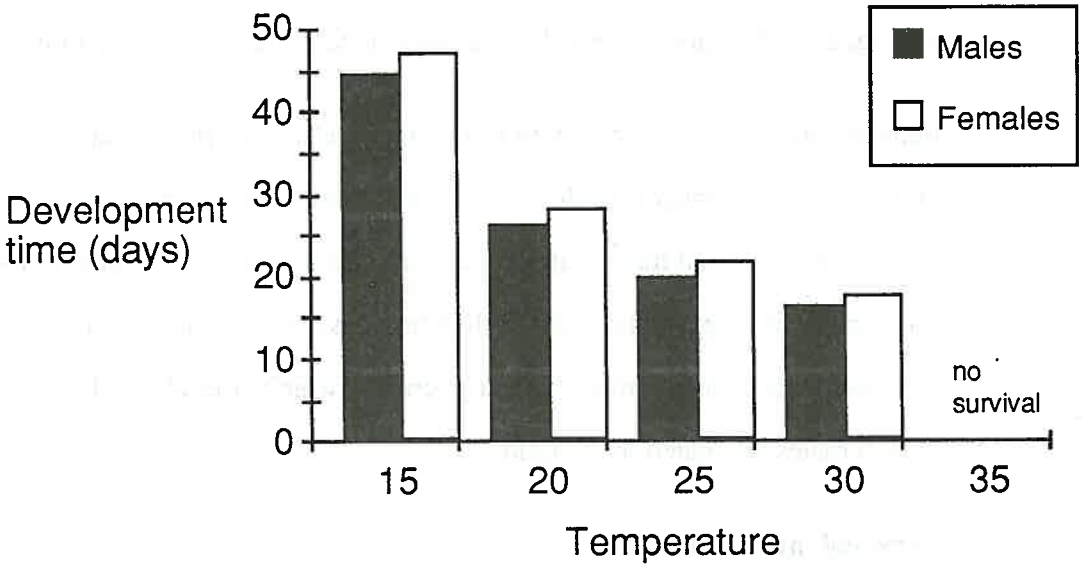
Basic Biology

I. promissorius is a solitary parasitoid; that is only one wasp is produced from each host. Even when several eggs are laid into a pupa only one larva survives to maturity. We have recovered *I. promissorius* only from pupae collected in the field, despite collecting many thousands of *Helicoverpa* larvae over the last 8 years. There are however, some odd records of *I. promissorius* as parasites of larvae (Room 1979). In the laboratory females readily parasitised *Helicoverpa* pupae, but totally ignored larva of all sizes. They showed no preference for pupae of particular ages and could successfully parasitise pupae up to about 10 days after pupation, the time when the moth is fully formed. They also showed no preference for *H. armigera* pupae over *H. punctigera* pupae.

Larval Development

Development of the immature stages is temperature dependent (Figure 1). At 15^{o} wasps took 45 days to develop, whereas at 30^{o} they take only 17 days. Immature *I. promissorius* did not survive at 35^{o}. Eggs may be deposited into any part of the *Helicoverpa* pupa although about two thirds were placed in the abdomen. At 25^{o} the eggs hatch in 1-2 days and the wasp larvae grows rapidly, often initiating feeding in the pupal abdomen and then proceeding to the anterior segments. Larvae reach full size in 10 days by which time they occupy much of the pupa, together with a pinkish mass of waste material which is packed into the posterior segments of the pupal case. The larva then metamorphoses into a wasp and emerges from the *Helicoverpa* pupal case by chewing a small exit hole from the head end of the pupa.

Figure 1. Development times (days) for male and female *Ichneumon promissorius* at a range of constant temperatures.



A *Helicoverpa* pupa contains sufficient nutrients for only one wasp larvae to complete development and wasp size is closely dependent on host size. In the laboratory we noted that *I. promissorius* did not avoid superparasitism (laying several eggs in a single host). While this may be a relatively rare event in the field given the low probability of two females finding the same pupa, we conducted an extensive series of studies to investigate the consequences of superparasitism and the consequent competition among wasp larvae which results. Whenever pupae were multiply parasitised over a short period the one surviving wasp was always a female. One larva usually assumed dominance by about 4 days, with the remaining larvae being consumed by the dominant one. The survivor of such competition was sometimes smaller than normal. Why females always win this competition is not known.

Adult Emergence and Mating

Males emerge about 2 days before females. As in many wasps, *I. promissorius* has an unusual sex determination mechanism, termed haplo-diploid sex determination. Males are produced from unfertilised eggs, while fertilised eggs become females. Thus unmated females will produce all male progeny, whereas mated females regulate fertilisation of each egg and may produce both male and female progeny. In the laboratory sex ratios averaged 50:50, though some females produced markedly skewed ratios.

Females are receptive for mating immediately after emergence and in the laboratory are quickly mated. Females produce a chemical stimulant which operates over a short range and initiates frenzied male searching activity during which they quickly locate the female. Since males emerge slightly earlier than females it is possible that in the field they stay in the emergence area and mate with any females which emerge locally. It is thus likely that most females are mated in the field.

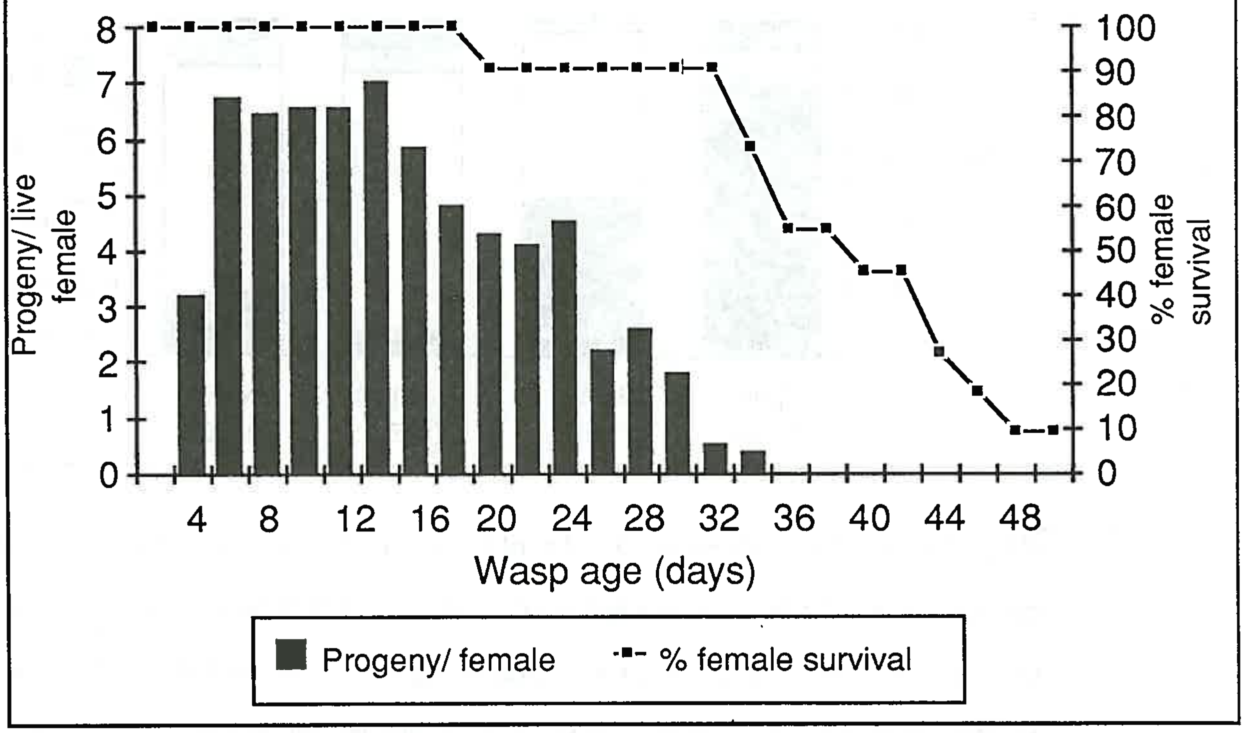
Survival and Fecundity

At 25^{o}, females lived an average of 40 days and produced eggs up to about 30 days of age. Survival declined rapidly once egg production had ceased (Figure 2). Fecundity peaked at about 6-7 progeny/ 2 days between 6 and 16 days of age. Lifetime fecundity averaged 74 progeny (range 47-103); that is each female may remove about 74 *Helicoverpa* pupae from beneath a cotton or other crop.

Host location.

One the most intriguing aspects of the behaviour of *I. promissorius* is how they locate their hosts. *Helicoverpa* pupae are of course in the soil, generally at depths of 5-10 cm. The females must locate and then reach the pupae. They have only a short ovipositor and must dig down to the pupa to parasitise it. We have demonstrated in the laboratory that females can locate pupae in soil, though not terribly successfully, but how they do it is not known. Observations of females searching over the soil surface, show that they move rapidly about, touching the ground with their antennae (antennating) and inspecting any cracks or other irregularities in the surface. Once they have located a pupal burrow they quickly dig through the cap and crawl down to parasitise the pupa. It appears they may detect the presence of pupae chemically, and we have demonstrated that chemical extracts from the pupal skin (cuticle) will stimulate females to oviposit.

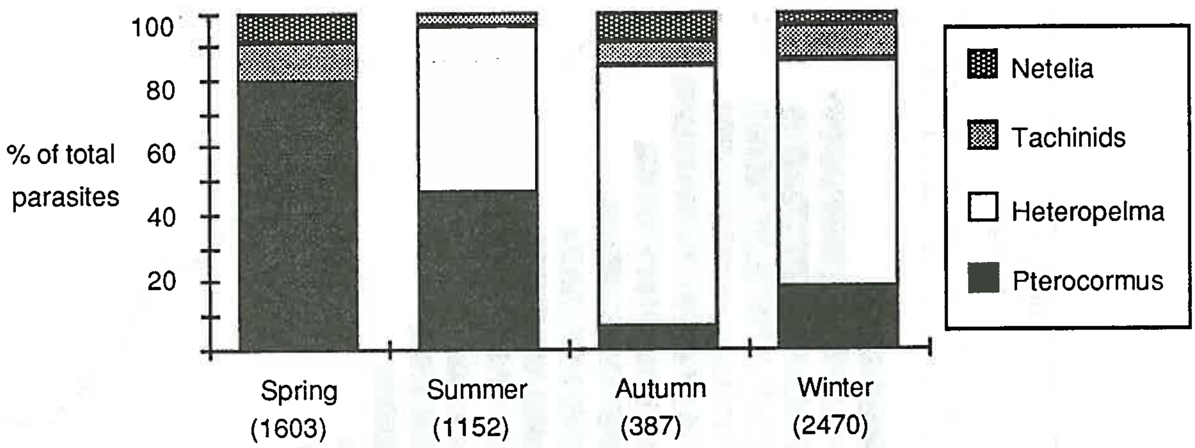
Figure 2. Age specific survival and fecundity at 25° of female *Ichneumon promissorius* offered an excess of *Helicoverpa* pupae.



Field Ecology

Levels of parasitism in different seasons. Samples of *Helicoverpa* pupae collected in spring, summer, autumn and winter from 1987-1992 showed average levels of parasitism of 7.4%, 7.9%, 20.7% and 16.2% respectively. Two parasitoids accounted for most of this: *I. promissorius* and *Heteropelma scaposum*. *Netelia producta* (Ichneumonidae) and a suite of tachinid flies together accounted for 20% or less of parasitism. *I.promissorius* was the dominant parasitoid emerging from pupae collected in spring (Figure 3), while *H. scaposum* dominated during summer, autumn and winter. The high level of *H. scaposum* in samples of overwintering pupae reflects parasitism of autumn populations of *Helicoverpa* larvae, whereas the proportion attacked by *I. promissorius* reflects activity during winter. Samples of pupae taken at intervals from the same field during winter/spring 1987 suggest that *I. promissorius* may be active during winter, indeed wasps could be seen searching over the soil surface during July/ August.

Figure 3. Composition of parasite complex emerging from pupae collected in different seasons of the year for the period 1987-1991. (total pupae collected in each season shown below season names)



Parasitism in different crops. Samples of *Helicoverpa* pupae collected under different crops revealed a highly variable species composition of parasitoids. Overall the parasitoid complex removed a substantial proportion of pupae (Figure 4), with levels of parasitism of 25% or more under Linseed, faba beans, sorghum and pigeon pea. *I. promissorius* was the major parasitoid recovered in spring crops such as chickpea, faba beans and linseed, but was rare or absent from autumn crops such as sunflower and pigeon pea and was recorded only 1 year in 5 in maize. *H. scaposum*, *Netelia producta* and the tachinids clearly have first access to *Helicoverpa* populations but the variable proportion of *I. promissorius* among crops is unlikely to reflect interference competition due to precedence since for most crops (except linseed and pigeon pea) only 10% or less of pupae produced parasitoids.

Figure 4 Levels of parasitism by all parasitoids in samples of pupae collected under different crops, 1987-1992. Total numbers of pupae sampled shown in parentheses.

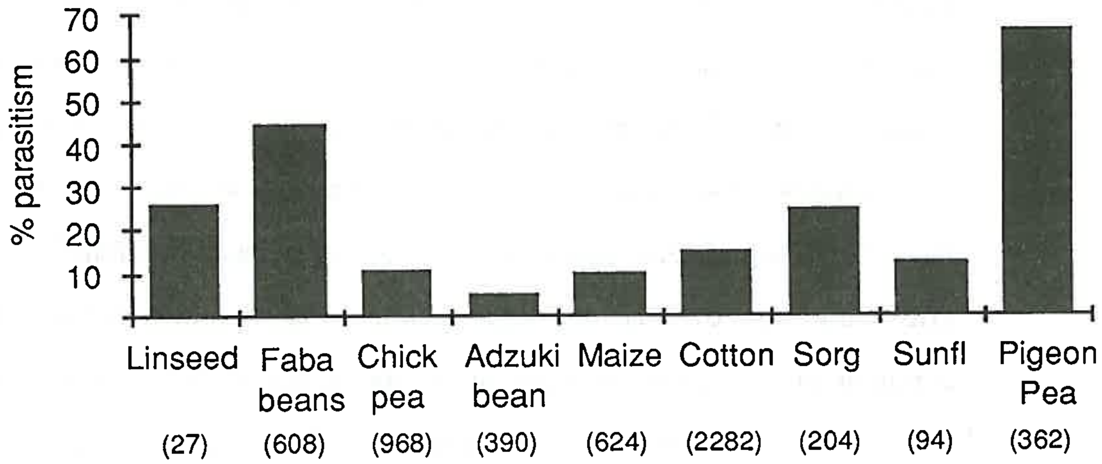
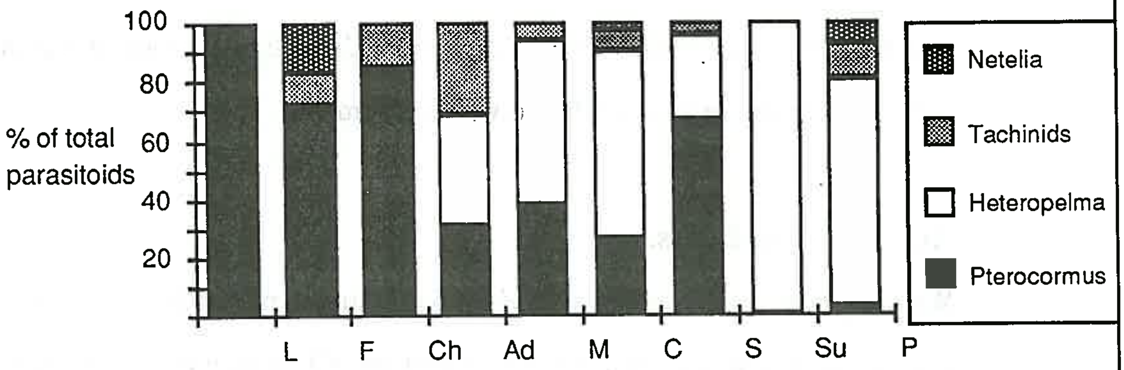


Figure 5. Species composition of parasitoids from samples of *Helicoverpa* pupae collected under different crops in the Namoi/ Gwydir, 1987-1992. Crops as in Figure 4.



Potential for Biological Control.

Parasitoids such as *Trichogramma* or *Microplitis* which attack eggs or larvae of *Helicoverpa* have received much attention as potential biocontrol agents. However, since Helicoverpa immatures suffer heavy mortality from climatic and other abiotic factors, these parasitoids must be extremely abundant in order to appreciably influence the overall abundance of Helicoverpa populations. A parasitoid such as *I. promissorius* which attacks *Helicoverpa* populations at the stage when they are naturally least abundant, may have a more significant impact on population size, since each female pupa parasitised effectively removes about 1000 eggs from the next generation. Since *I. promissorius* is common in spring any increase in its abundance at that time may well assist in management of the first spring generation of *Helicoverpa* on spring crops such as chickpea, faba bean and linseed (Figures 3 and 4). The species is easily reared in the laboratory provided a supply of *Helicoverpa* pupae is available. However, mass rearing in this way to boost the size of field populations would be prohibitively expensive. Without an artificial rearing medium for this parasitoid it appears unlikely that its potential as a biocontrol agent could be fulfilled. Such artificial diets are not yet available and may well be difficult to develop since endoparasitoids such as *I. promissorius* often rely on the host's biochemistry to drive their own development.

Acknowledgements.

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