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Tetrastichus howardi (Olliff) (Hymenoptera : Eulophidae), a hyperparasitoid of tachinid natural enemies of *Helicoverpa armigera* (Hübner) (Lepidoptera : Noctuidae) in India

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ABSTRACT : *Tetrastichus howardi* (Olliff) was found to be a hyperparasitoid of the tachinids *Goniophthalmus halli* (Mesnil) and *Senometopia* (= *Eucarcelia) illota* (Curran) parasitising *Helicoverpa armigera* (Hübner) pupae in pigeonpea fields in south India. Fifty nine per cent of *G. halli* and *S. illota* pupae were parasitized by *T. howardi* resulting in a hyperparasitism rate of 1.9 per cent. Unlike previous studies, *T. howardi* was not recorded as a primary parasitoid of *H. armigera* pupae. Rather than behaving as a pupal guild parasitoid, the data suggest that *T. howardi* wasps oviposit in the larval stage of the tachinid parasitoids while they are developing inside the *H. armigera* pupa. The fact that *T. howardi* was not found to be a primary parasitoid of *H. armigera* pupae, suggests that this species is able to distinguish between parasitised and unparasitised *H. armigera* pupae.

KEY WORDS : *Goniophthalmus halli, Helicoverpa armigera*, hyperparasitoid, pupal parasitoids, *Senometopia illota*, *Tetrastichus howardi*

The parasitoid *Tetrastichus howardi* (Olliff) (Hymenoptera : Eulophidae), is widely distributed across the Indian subcontinent, the Far East and parts of Australasia (Boucêk, 1988). It has previously been recorded under a number of synonyms (Kfir *et al*., 1993). In India, it is a common pupal parasitoid of several species of lepidopteran borers (Ayyar, 1927; Cherian and Subramanian, 1940),

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and attempts have been made to utilise it as a biological control agent against sugarcane borers in India (Rudriah and Sastry, 1959), and the spotted stem borer, *Chilo partellus* (Swinhoe) in South Africa (Kfir *et al*., 1993). It has also been reported as a hyperparasitoid on the pupae of several natural enemies including tachinid flies (Boucêk, 1988; Kfir *et al*., 1993). In India it has been suggested as a control agent for the uzi fly, *Exorista bombycis* (Louis), a serious pest of silkworm (*Bombyx mori* L.) larvae (Kishore *et al*., 1994).

This paper focuses on the role of *T. howardi* as a hyperparasitoid of tachinid parasitoids of *Helicoverpa armigera* (Hübner) pupae. The data presented here result from an intensive study on pupal diapause of *H. armigera*, the major lepidopteran pest of cotton, legumes and tomatoes in India (Reed and Pawar, 1982).

MATERIALS AND METHODS

Over 2300 *H. armigera* pupae were collected by excavating the top 10 cm of soil in pigeonpea fields on the ICRISAT research farm, Patancheru, Andhra Pradesh, India, harbouring heavy infestations of *H. armigera* larvae between mid October, 1995 and mid January, 1996. Only apparently healthy pupae were retained. Pupae were kept individually in 80 x 20 mm glass tubes with tight fitting cotton bungs and placed in one litre plastic boxes which were buried in the soil to a depth of 15 cm to keep the pupae in as near natural temperature conditions as possible. The boxes were checked for emergence of either the host or parasitoids 2-3 times every week. Parasitism and hyperparasitism were confirmed by observing emergence from the host pupa or parasitoid pupa, respectively. If parasitism was suspected to be the cause of death but no parasitoid emerged, the host was dissected to confirm the presence of a parasitoid and its identity ascertained.

In the laboratory an experiment was conducted to determine whether *T. howardi* could parasitise *H. armigera* larvae and pupae. Twenty five sixth instar larvae and 25 pupae (1-3 days old) were placed individually in 80 x 20 mm glass tubes. *Helicoverpa armigera* larvae were provided with chickpea based semi-synthetic artificial diet (Armes *et al*., 1992). At least twenty freshly emerged *T. howardi* adults (approx. 1:1 sex ratio) were placed in each tube fitted with a cotton bung, wetted each day with 10 per cent honey solution to provide food for the wasps. The wasps were left in the tubes until all had died which was between 48 and 96 h after the start of the experiment. In the tests with larvae, all wasps had died before host pupation. Parasitism of *H. armigera* larvae and pupae was confirmed by observing the emergence of progeny from the host. Laboratory temperature was maintained at 25 ± 2^{0}C, with natural photoperiod (approx. 12 h light : 12 h dark).

RESULTS AND DISCUSSION

From the field collections of *H. armigera* pupae, two tachinid larval - pupal parasitoids *viz.*, *Goniophthalmus halli* (Mesnil) and *Senometopia* (=*Eucarcelia*) *illota* (Curran) were recorded. For both species, parasitism frequencies were low (0.6 - 0.7%) (Table 1).*Tetrastichus howardi* adults emerged from 1.9 per cent of collected *H. armigera* pupae; all emerged from the pupae of *G. halli* and *S. illota*. There were no instances where *T. howardi* behaved as a primary parasitoid of *H. armigera* pupae. Hyperparasitism rates were very high, with 59 per cent of a combination of *G. halli* and *S. illota* pupae being parasitised by *T. howardi*.

Approximate numbers of *T. howardi* emerging from *G. halli* and *S. illota* pupae ranged from 40-80 with a 1:1 sex ratio. Durations from the time of host collection to either host or parasitoid emergence were similar for *H. armigera, G. halli* and *S. illota* (t-test, $P > 0.05$); *T. howardi* durations were significantly longer (t-test, $P < 0.01$) (Table 1).

In view of the fact that only live *H. armigera* pupae were retained from the field collections, and the pupae were immediately transferred to individual tubes with tight fitting plugs (thereby excluding entry of parasitoid wasps), it is evident that *T. howardi* must have stung the tachinid parasitoids during their early larval stage while in the live *H. armigera* host. This has very interesting implications with reference to the biology of this species and possibly other related species in the genus. From the literature it is generally assumed that *Tetrastichus* spp. are solely pupal guild parasitoids (Smith *et al.*, 1993), stinging either the host pupa (as a primary parasitoid), or the pupal stage of its tachinid parasitoid upon emergence from the host (as a hyperparasitoid). Our results suggest that under certain circumstances *T. howardi* can behave as a larval - pupal parasitoid, stinging the parasitoid larva and the resulting progeny emerging from the pupal stage of the parasitoid. Also from our results it appeared that *T. howardi* could differentiate between parasitised and unparasitised *H armigera* pupae, as it was

Table 1. Emergence and developmental periods of *H. armigera* pupae and its pupal parasitoids and hyperparasitoid

Species	Number	Time taken to emergence (days)			
		Range	Mean	±SD	Population (%)
H. armigera	2268	9-29	18.0	6.9	96.8
G halli	14	10-29	18.9	7.6	0.6
S. illota	17	12-26	18.7	4.8	0.7
T. howardi	45	13-32	21.9	5.6	1.9

only recorded as a hyperparasitoid in this study.

Under laboratory conditions we were unable to get *T. howardi* to parasitise either 6th instar larvae or pupae of *H. armigera*, contrary to the observations of Kfir *et al.* (1993) who routinely used one day old *H. armigera* pupae for laboratory rearing of *T. howardi*. Further, Okeyo-Owuor *et al.* (1991) reported that related *Tetrastichus* species readily parasitised pupae of other noctuids. Our laboratory results do, however, confirm the field data where no instances of *T. howardi* acting as a primary parasitoid of *H. armigera* was found, while high levels of hyperparasitism of the two tachinid fly species were observed.

On the basis of laboratory tests, Kfir *et al.* (1993) considered *T. howardi* to be a facultative hyperparasitoid, preferring to parasitise noctuid and pyralid pupae over parasitoid puparia. Cherian and Subramanian (1940) reported *T. howardi* (= *T. ayyari*) as a pupal parasitoid of *H. armigera* in south India. From our data it appears that *T. howardi* is predominantly a hyperparasitoid of tachinid parasitoids, rather than a primary parasitoid of *H. armigera*. This is consistent with Kishore *et al.* (1994) who considered *T. howardi* only to be hyperparasitoid of *E. bombycis* and did not report it acting as a primary parasitoid of *B. mori*. It has been suggested that host preference in *T. howardi* is dependent on previous oviposition experience and on the host species on which the adults had been reared (Kfir *et al.*, 1993). This may explain the inability of *T. howardi* to behave as a primary parasitoid in the laboratory. Further experimentation is needed to ascertain the biology of *T. howardi* and its status as a primary and/or hyperparasitoid under field conditions.

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