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Effect of temperature and host species on parasitism, development time and sex ratio of the egg parasitoid *Trichogrammatoidea lutea* Girault (Hymenoptera: Trichogrammatidae)

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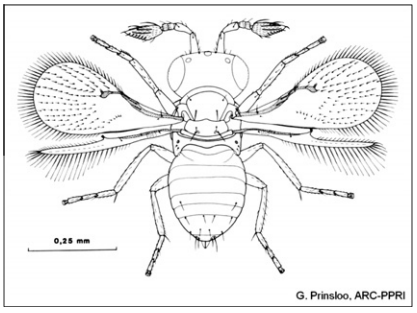
HIGHLIGHTS

- Parasitism was highest on eggs of *Helicoverpa armigera* and *Cadra cautella*.
- Number of progeny of *T. lutea* per parasitized host egg was highest on *H. armigera*.
- Number of progeny and sex ratio of *T. lutea* depended on host egg size and shape.
- Development of *T. lutea* was fastest on *H. armigera* and slowest on *Chilo partellus*.
- *T. lutea* can be mass-reared on eggs of *H. armigera* and *C. cautella*.

GRAPHICAL ABSTRACT



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ABSTRACT

The developmental biology of *Trichogrammatoidea lutea* Girault (Hymenoptera: Trichogrammatidae) was studied at six constant temperatures (18, 21, 24, 27, 30 and 35 °C) on eggs of three lepidopteran host species: *Helicoverpa armigera* (Hübner) (Noctuidae), *Chilo partellus* (Swinhoe) (Crambidae) and *Cadra cautella* (Walker) (Pyralidae). *T. lutea* did not complete development at 35 °C on any of the three host species. Parasitism levels were highest on *H. armigera* at 27 °C (58%), *C. cautella* at 27 and 30 °C (31% and 28%) and *C. partellus* between 24 and 30 °C (13–17%). Realized progeny of *T. lutea* per parasitized host egg was influenced by host size. The number of progeny of *T. lutea* per parasitized host egg was highest on *H. armigera*, followed by *C. partellus* and lowest on *C. cautella*. The sex ratio was female biased on *C. partellus*, female biased on *C. cautella* with the exception of 21 °C and close to 1:1 on *H. armigera*. The rate of development from egg to pupa and egg to adult was fastest on *H. armigera* and slowest on *C. partellus*. Lower thresholds for development and degree days (DD) of *T. lutea* from egg to adult were 12.8 °C and 105.4 DD on *H. armigera*, 11.3 °C and 141.6 DD on *C. partellus* and 12.9 °C and 118.2 DD on *C. cautella*, respectively. Based on these results, *H. armigera* is the most suitable host for mass rearing of *T. lutea* for biological control of Lepidoptera pests because of the relatively high parasitism levels, short development time, greater clutch size and balanced sex ratio. *C. cautella* may also be used although longer exposure times might be required due to lower parasitism levels.

1. Introduction

Knowledge of thermal requirements and determination of the most suitable host species is vital for development of mass rearing programmes for polyphagous parasitoid species. Host suitability

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for parasitoid development differs with species, particularly for egg parasitoids where different host species are characterised by variable host egg volume, chorion thickness and nutritional content (Barret and Schmidt, 1991). In idiobionts, i.e. parasitoids that paralyse or kill hosts at oviposition (Vinson, 1998), host size has a major effect on the fitness of progeny, as larger parasitoids tend to develop from larger hosts and larger females have a higher fecundity compared to smaller females (Godfray, 1994; Greenberg et al., 1998). In addition, host size influences the sex ratio of the progeny as female offspring of parasitoids are usually allocated to larger hosts. In gregarious parasitoids, clutch size (the number of siblings developing per host) rather than host size influences offspring size. Host size can also determine development time of idiobiont parasitoids, which may be faster in smaller compared to larger hosts (Godfray, 1994). Therefore, host species influence growth and survival of immature parasitoids, as well as their sex ratio, fecundity, longevity and fitness of adults (Vinson and Iwantsch, 1980; Greenberg et al., 1998). Furthermore, several studies have shown that the life history of parasitoids can be affected by the interactions between temperature and host quality (Pratissoli and Parra, 2000; Bazzocchi et al., 2003; Li and Mills, 2004).

Parasitoids of the genus *Trichogramma* (Hymenoptera: Trichogrammatidae) and to a lesser extent of the related genus *Trichogrammatoidea* are the most extensively studied (Smith, 1996) and successfully used egg parasitoids for biological control (Li, 1994; Greenberg et al., 1996) against Lepidoptera pests (Thomson et al., 2001). Their success is based on their short generation time, high reproductive potential (Pak and Oatman, 1982) and ease of rearing, which includes using eggs of factitious hosts (Greenberg et al., 1996). Factitious hosts do not necessarily share a natural habitat with the parasitoid but can support mass production of the parasitoid without compromising its quality (Fedde et al., 1982). For example, egg parasitoids such as *Trichogramma minutum* Riley and *Trichogramma brassicae* Bezdenko have been successfully reared on eggs of *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) and *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae) as factitious hosts (Greenberg et al., 1996).

Trichogrammatoidea lutea Girault (Hymenoptera: Trichogrammatidae), a facultatively gregarious polyphagous egg parasitoid of Lepidoptera species (Kfir, 1982), is indigenous to southern Africa (Parsons and Ullyett, 1936). Its hosts include the African bollworm *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) (Parsons and Ullyett, 1936; Parry Jones, 1937; Kfir and Van Hamburg, 1988), the spotted stemborer *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae), the spiny bollworm *Earias biplaga* Walker (Lepidoptera: Nolidae) (Nagarkatti and Nagaraja, 1977), and the codling moth *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (Wahner, 2008). Because *T. lutea* is polyphagous, its life history parameters on different host species are likely to vary.

Since the 1930s, several studies have been undertaken to assess the suitability of *T. lutea* as a biological control agent against *H. armigera* and *C. pomonella* (Parsons and Ullyett, 1936; Parry Jones, 1937; Kfir, 1982; Kfir and Van Hamburg, 1988; Wahner, 2008). Except for Parry Jones (1937) and Wahner (2008), who examined temperature-related development of *T. lutea* on *H. armigera* and *C. pomonella*, respectively, no detailed comparative studies have been done on its thermal biology on different host species.

Knowledge of the thermal biology of *T. lutea* on different host species is crucial for developing a cost-effective mass rearing programme for this parasitoid, as it has potential for use in augmentative biological control of Lepidoptera pests. The objectives of this study were to assess parasitism levels, number of progeny per parasitized host species, sex ratio and development time of *T. lutea* on eggs of *H. armigera*, *C. partellus* and *Cadra cautella* (Walker) (Lepidoptera: Pyralidae) at six constant temperatures.

2. Materials and methods

2.1. Insect cultures

Laboratory cultures of *H. armigera* and *C. partellus* were maintained in the insectary of the Agricultural Research Council – Plant Protection Research Institute (ARC-PPRI), Rietondale Campus (25°44′S, 28°13′E) in Pretoria, Gauteng, South Africa. The culture of *H. armigera* was established from individuals collected in cotton fields during 1974 at Springbok Flats (29°40′S 17°53′E), and this culture was supplemented periodically with individuals collected in cotton fields at Groblersdal (25°15′S, 29°25′E) in Mpumalanga, South Africa. *H. armigera* larvae were reared individually in glass vials (2.5 cm high × 10 cm diameter) on an artificial diet following procedures described by Kfir (1994). The culture of *Chilo partellus* was established with field-collected material from maize and grain sorghum at Springbok Flats in 1975. To improve genetic variability, the culture was supplemented several times with larvae collected at the Brits Research Farm (25°38′S, 27°76′E) of the ARC–Industrial Crops Institute, North West Province, South Africa. The larvae of *C. partellus* were reared in glass jars (12 cm high × 7 cm diameter) on an artificial diet following procedures described by Kfir (1992). The eggs of *C. cautella* were obtained from a culture that was established in the late 1980s from individuals collected from several stored grain locations around South Africa. The culture of *C. cautella*, started in the late 1980s with specimens collected from stored grain from several localities in South Africa, was kept at ARC-PPRI, Roodeplaat campus (25°39′S, 28°20′E) near Pretoria. Larvae of *C. cautella* were maintained in glass jars (22 cm high × 14 cm diameter) on artificial diet consisting of yeast, glycerine, honey, wheat and maize meal (pers. comm. Tanya Saymann, ARC-PPRI).

A laboratory culture of *T. lutea* was maintained at ARC-PPRI, Rietondale campus. It was established in 2006 from parasitized eggs of *H. armigera* collected in cotton fields at Groblersdal and Rust de Winter (25°13′S, 28°28′E), Gauteng, South Africa. *T. lutea* was reared on the above three host species for at least six generations before use in experiments. The parasitoid was maintained in wooden cages (30 × 30 × 42 cm) consisting of a glass top, gauze back and gauze sleeves in front. The culture was kept in a climate-controlled room at 26 °C, 60% RH and 16L:8D photoperiod. Water and honey were provided in the cages as food for the parasitoids.

2.2. Parasitism levels, development time, number of progeny per parasitized host and sex ratio of *T. lutea* on three host species at different constant temperatures

Eggs of *H. armigera*, *C. partellus* and *C. cautella* were irradiated under a UV light for 15 min (TUV 30W/G30T8, Philips, Holland; 254 nm; in a fitting with a reflective aluminium backing) at a distance of 6 cm from the eggs (Mawela et al., 2010). This period was sufficient to kill the embryos of all three species in order to avoid cannibalism by hatching larvae (Kfir and van Hamburg, 1988; Mawela et al., 2010) and improve survival of immature parasitoids (Cônsoli et al., 2000). Batches of 50 less than 24-h old eggs of each host species were exposed to 16 mated and naive *T. lutea* females with no oviposition experience, for 4 h in individual glass jars (12 cm high × 6.5 cm diameter) at six constant temperatures (18, 21, 24, 27, 30 and 35 °C). Preliminary trials with different host/parasitoid ratios at different exposure times indicated that the ratio and the short exposure time used were suitable for carrying out the trials of this study. As the parasitoid/host ratio was kept constant in all trials, it was assumed that interference between searching female parasitoids at each temperature was the same and did not affect the comparative results between the various hosts. The