Biological Control 64 (2013) 10–15

Contents lists available at SciVerse ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Host suitability and fitness-related parameters of *Campoletis sonorensis* (Hymenoptera: Ichneumonidae) as a parasitoid of the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae)

Henry Murillo [a,*], David W.A. Hunt [b], Sherah L. VanLaerhoven [a]

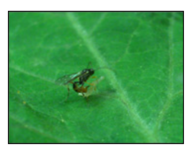
[a] *Department of Biology, Faculty of Science, University of Windsor, 401 Sunset Ave., Windsor, Ontario, Canada N9B 3P4*

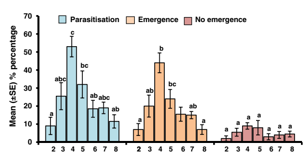
[b] *Agriculture and Agri-Food Canada – Greenhouse and Processing Crops Research Centre, 2585 County Rd. 20, Harrow, Ontario, Canada N0R 1G0*

HIGHLIGHTS

- ▸ The suitability of *Trichoplusia ni* as host of *Campoletis sonorensis* was studied.
- ▸ Early 2nd larval instar (3–5 day-old larvae) was the most suitable host stage.
- ▸ Parasitoid fitness was affected negatively by early and late larval instars.

GRAPHICAL ABSTRACT





ARTICLE INFO

Article history:
Received 21 April 2011
Accepted 26 September 2012
Available online 2 November 2012

Keywords:
Campoletis sonorensis
Trichoplusia ni
Host suitability
Fitness

ABSTRACT

The seven age-classes of *Trichoplusia ni* (Hübner) larvae evaluated in this study as hosts of *Campoletis sonorensis* indicates that early 2nd larval instar (3–5 day-old larvae) of *T. ni* represents the most suitable host stage for the development of the larval endoparasitoid *C. sonorensis*. The higher suitability of early 2nd larval instar of *T. ni* resulted in more parasitised larvae, a higher rate of successful parasitoid emergence, a higher rate of female progeny, and a lower rate of immature parasitoid mortality. The fitness gain of *C. sonorensis* on late 1st larval instar (2 day-old larvae) and late 2nd larval instar –early 3rd instars (6–8 day-old larvae) stages of *T. ni* is negatively affected by the trade-offs between the different physiological and behavioral characteristics influencing their suitability as hosts of *C. sonorensis*.

1. Introduction

A suitable host is one that provides an environment in which the parasitoid offspring can develop successfully up to fertile adults (Salt, 1938). Host suitability evaluation by female parasitoids during the host selection and the tradeoffs in fitness of the parasitoid are very important because the host quality and the developmental requirements of the immature parasitoid may result in an increased or lowered gain (Vinson, 1990; Godfray, 1994; Beckage and Gelman, 2004).

Fitness is used to describe the individual performance of an organism into a population and is usually measured by life-history parameters such as survival, fecundity, development time, sex ratio, and size of the parasitoid offspring (Godfray, 1994; Roitberg et al., 2001). Consequently, the relationship between host characteristics at oviposition and fitness gain of the parasitoid is variable and depends on the degree of combination of at least four different factors: (1) the physiology and behavior of the host instars (Liu et al., 1984; Lin and Ives, 2003), (2) host–plant quality (Kouame and Mackauer, 1991; Stadler and Mackauer, 2007), (3) the feeding ecology of the host (Harvey and Strand, 2002), and (4) rearing conditions (Hoelscher and Vinson, 1971; Roitberg et al., 2001).

* Corresponding author. Fax: +1 519 971 3609.
E-mail address: murillo@uwindsor.ca (H. Murillo).

1049-9644/$ - see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.biocontrol.2012.09.020

Host size at parasitoid oviposition and the relationship of this parameter with the size and development time of the emerging parasitoid have been commonly related to fitness (Nicol and Mackauer, 1999; Harvey et al., 2000; Chau and Mackauer, 2001). Female parasitoids are expected to oviposit more in high quality hosts because their fitness suffers more on low quality ones, e.g., selecting small host will produce small parasitoid female offspring that will produce fewer eggs (Charnov et al., 1981; Godfray, 1994).

Trichoplusia ni (Lepidoptera: Noctuidae), an important pest of crucifers and many other field crops in Ontario, is now a year-round pest in the vegetable greenhouse crops in Canada (Gillespie et al., 2002). Canadian populations of this insect pest are usually established through annual migration of adult moths from the south (Lafontaine and Poole, 1991). The overwintering *T. ni* populations inside Canadian greenhouses have increased the development of resistance to *Bacillus thuringiensis var. kurstaki* (Janmaat and Myers, 2003) which has resulted in increased use of chemical pesticides that are not compatible with other biocontrol agents and bumble bee pollinators.

Campoletis sonorensis (Cameron) (Hymenoptera: Ichneumonidae) is a solitary larval endoparasitoid that has been reported on about 30 Lepidoptera crop pests, primarily of the family Noctuidae (Lingren and Noble, 1972; De Moraes et al., 1991; Machuca et al., 1989; CAB International, 2007). This generalist parasitoid has demonstrated potential to suppress populations of the tobacco budworm, *Helicoverpa virescens* (Fabricious) (Lepidoptera: Noctuidae), the corn earworm/tomato fruitworm, *Helicoverpa zea* (Boddie) and the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in tobacco (*Nicotiana tabacum* L.) (Solanaceae), tomatoes (*Lycopersicon esculentum* Mill.) (Solanaceae), cotton (*Gossypium hirsutum* L.) (Malvaceae), corn (*Zea mays* L.) (Gramineae) and sorghum (*Sorghum bicolor* L.) (Poaceae) (Hoelscher and Vinson, 1971; Lingren, 1977; Isenhour, 1986) and as reported by Murillo et al. (2009), it has been found to be a major factor in the regulation of *T. ni* populations in tomato fields and greenhouses in south-western Ontario.

The objectives of this study were to measure which larval stage of *T. ni* is the most suitable stage for the development of the parasitoid *C. sonorensis*, and to measure the effect of different larval age classes of *T. ni* on parasitism, offspring sex ratio, mortality and development time parameters of *C. sonorensis*.

2. Materials and methods

2.1. T. ni rearing

The colony was maintained in an environmental chamber at 24 °C, 60% RH and a photoperiod of 12–12 (L–D). Approximately 50 adults were kept in a 5 L plastic container. Adults were fed a 5% sugar solution and every other day the eggs were collected from paper towels used as the lid of the container and as oviposition substrate. The eggs were disinfected with a 0.5% solution of commercial bleach. Once the eggs hatched, larvae were reared on a pinto bean diet (Shorey and Hale, 1965) in 12-oz Styrofoam containers. Larvae were moved into individual 1-oz transparent plastic cups (Solo Cup Company, Urbana, USA) once they developed to the second instar.

2.2. C. sonorensis rearing

The parasitoid colony was maintained under the same conditions as the *T. ni* colony, with 4 day-old *T. ni* larvae (early second larval instar) provided as hosts. In small plastic transparent cages (17 × 12 × 15 cm) on the same artificial diet as stated above, *T. ni* larvae were exposed to naïve (with no parasitising experience) mated *C. sonorensis* females for 24 h. Within each cage, there was a ratio of 20 larvae: 1 parasitoid female, with a total of up to five parasitoids/cage. Subsequently, each *T. ni* larva was placed into individual 1-oz plastic cups to allow the parasitoid to develop to adult. When *C. sonorensis* adults emerged, they were separated into cages by sex. After 24 h, females were introduced into male cages to allow mating for 48 h (ratio of 3 males: 1 female) (Isenhour, 1986; Hoelscher and Vinson, 1971).

2.3. Fitness and host suitability for C. sonorensis on T. ni

Larvae of *T. ni* were separated into seven age class treatments based on date of eclosion (i.e. 2–8 day-old). The selection of age classes was based on the natural survey rearing results in which the 2nd larval instar of *T. ni* was the most frequent developmental stage parasitised by *C. sonorensis* (Murillo, 2008). Under the rearing conditions described, three daily observations of 100 newly emerged larvae under a stereoscope allowed us to determined that *T. ni* larvae reached 2nd instar at 3–4 days and 3rd instar at 7–8 days. Twenty *T. ni* larvae of each age class were placed on tomato leaves in small transparent cages (17 × 12 × 15 cm). The tomato leaves chosen consisted of the three distal leaflets of a new side shoot, which were removed and kept in a plastic cup with wet cotton. One naïve mated *C. sonorensis* female was introduced to the cage for 24 h. After exposure to the parasitoid, the *T. ni* larvae were placed individually in 0.5-oz cups (Solo Cup Company, Urbana, USA) with diet. Cups were checked daily for parasitoid or moth development and the time of formation of parasitoid cocoons and parasitoid emergence were recorded. Upon emergence, the sex of each parasitoid was determined. Both the cages and the rearing cups were held in an environmental chamber set at 27 °C, 60% RH and a photoperiod of 12: 12 L:D. Each age class treatment was replicated 10 times.

The *C. sonorensis* fitness parameters measured were of four types: (1) The parasitism ratio and success parameters: (a) parasitisation rate as the percentage of the total number of hosts that produced parasitoid cocoons, (b) emergence rate as the percentage of parasitoids that emerged from the total number of cocoons and, (c) no emergence rate as the percentage of cocoons where adult parasitoids didn't emerge. (2) offspring sex ratio parameter: sex ratio as proportion of male offspring of the emerged parasitoid where >0.5 is a male-biased ratio, (3) mortality parameters: (a) mortality rate, and (b) corrected mortality rate, which were calculated as percentage of dead larvae, which was then corrected against that in the control for each host age according to Abbott (1925):

$$M_{\text{corrected}} = \frac{M_{\text{treatment}} - M_{\text{control}}}{100 - M_{\text{control}}} \times 100 \qquad (1)$$

And (4) offspring development time parameters: (a) parasitisation to cocoon formation, (b) cocoon formation to adult emergence, and (c) parasitisation to adult emergence (or total development time). These parameters were calculated individually for males and females.

2.4. Statistical analysis

The effect of different *T. ni* age classes on fitness parameters (except for developmental time) of *C. sonorensis* were analyzed using the Kruskal–Wallis test for nonparametric data, followed by Dunn's Multiple Comparison Test (Zar, 1999) when significant differences were found between the host age classes. One-sample sign test was used to compare the mean sex ratio of each age class with an equal mean sex ratio (0.5) and Kruskal–Wallis test was used to compared sex ratios between host age classes. ANCOVA was used to analyze a possible relationship between no emergence rate and parasitism rate through the age classes where no emer-