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RESEARCH ARTICLE

Parasitic Potential of *Bracon brevicornis* Wesmael (Hymenoptera: Braconidae) on *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae)

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ABSTRACT

Maize is one of the most important cereal crops and is called 'the queen of cereals' because of its high yielding potential than other cereals. Fall armyworm, *Spodoptera frugiperda* is one of the serious invasive pests found to cause higher yield loss and extensive damage on maize. Considering the ecological and environmental consequences, biological control of insect pests is gaining importance as an alternative to insecticides. However, the success of any biological control programme depends on the appropriate parasitoid: host ratio and the biological stage of the pest susceptible to parasitoid. To fortify the above facts, the present study was aimed to determine the parasitic potential of *B. brevicornis* on *S. frugiperda* through free and no choice tests. This study indicated highest parasitization at the parasitoid: host ratio of 5:1 with 68.60 and 64.95 per cent parasitization on the VI instar followed by V instar (57.75 and 56.95 %), IV instar (48.80 and 46.60 %) and III instar (32.40 and 30.67 %) respectively under free and no choice conditions, respectively. Among the parasitoid host ratios tested 5: 1 was found to be the best indicating that the parasitic potential of *B. brevicornis* was directly proportional to the parasitoid densities. Biological parameters of *B. brevicornis* studied on different *S. frugiperda* instars recorded highest number of eggs (32.00), grub (30.75), cocoon (29.75) and adults (28.00) on sixth instar larva of *S. frugiperda* followed by fifth instar larva of *S. frugiperda*. The results revealed that the larval size was directly proportional to the progeny development of *B. brevicornis*. The egg, grub and cocoon period of B. brevicornis on S. frugiperda ranged from 24.20 to 26.20 h, 72.26 to 73.20 h, 96.20 to 98.20 h, respectively. The total life cycle was completed in 192.66 to 195.80 h in all instars and was found to be on par with all the instars studied. The longevity of adults emerged from different instars were found to be on par with each other and it ranged from 362.0 to 362.8 h.

Keywords: *S. frugiperda; B. brevicornis; Parasitic potential; Free choice test; No choice test*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops grown throughout the plains. Fall armyworm (FAW), *Spodoptera frugiperda* (J.E.Smith, 1797) (Lepidoptera: Noctuidae) native to tropical and subtropical regions of America, is one of the most devastating pests of more than 80 plant species, causing damage to economically important crops such as maize, rice, sorghum, vegetable crops and cotton. Management of *S. frugiperda* using insecticides is mostly ineffective due to its cryptic habit (Goergen *et al*., 2016). Biological control is the most appropriate method to control the pest and is also safe to the environment. Several predators *viz*., Ladybird beetles, Ground beetle, Earwigs, Assassin bug, Flower bug, Big eyed bug and Pirate bug and parasitoids *viz*., *Telenomus remus*, *Chelonus insularis*, *Campoletis sonorensis*, *Cotesia icipe*, *Habrobracon hebetor*, *Winthemia trinitatis*, *Archytas marmoratus* and *Lespesia archippivora*, pathogens *viz*., viruses namely, *S. frugiperda granulovirus* (SfGV) (Beta baculovirus) and multiple nucleopolyhedrovirus (SfMNPV) (Alpha baculovirus), bacteria (*Bacillus thuringiensis*) and fungus (*Beauveria bassiana*) were reported on FAW (Prasanna *et al*., 2018). Among the natural enemies, the ectolarval parasitoid, *Bracon*

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brevicornis of the family Braconidae was also documented on FAW under field conditions (Prasanna *et al*., 2018). In view of the above facts, the present investigation was carried out to find out the parasitic potential of the larval parasitoid, *Bracon brevicornis* (Hymenoptera: Braconidae) available at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

MATERIAL AND METHODS

Host culture of Fall armyworm, S. frugiperda

Disease free healthy colonies of FAW was maintained at the Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore, India. For culturing the FAW, field collected larvae were placed individually in plastic containers (3 × 4 × 4 cm) and provided with CIMMYT diet until pupation (Bueno *et al*., 2009). The lids of the containers were provided with holes of 12mm diameter, covered with a fine mesh synthetic fabric for ventilation purpose. After pupation, pupae were kept in adult emergence cages (30 × 30 × 30 cm). The adults emerging from the pupae were sexed and released in pairs into oviposition cages for mating. The adults were fed with sugar: honey solution (1:1) supplemented with two to three drops of Vitamin E and multivitamin drops. Fifteen days old maize seedlings grown under hydroponics were provided as oviposition substrate. The eggs from the seedlings were collected and transferred to a clear transparent plastic box (17 × 11 × 5 cm) containing the diet pieces and 10 d old fresh sterile maize seedlings for hatching and neonates established on the diet. The second or early third instar larvae were transferred to individual rearing container (3 × 4 × 4 cm) with diet pieces until pupation to avoid cannibalism. The cycle was maintained for continuous larval supply and used for various experimental purposes (Bueno *et al*., 2010).

Culturing of Bracon brevicornis

B. brevicornis was cultured by sandwich method (Jhansi, 1984). The culture was maintained in a plastic container of 18 × 12 × 12 cm size. Fully grown *Corcyra cephalonica* larvae, laboratory host, were placed on muslin cloth and subjected to parasitization by mated females of *B. brevicornis* at the parasitoid: host ratio 1: 20. The muslin cloth containing the *C. cephalonica* larvae was immediately closed with another khada cloth and fastened with rubber bands to arrest the movement of larvae and facilitate easy parasitization by *B. brevicornis*. The larvae were replaced once in 24 hours until the death of the parasitoid. Each day, the parasitized *C. cephalonica* larvae were removed and placed on filter papers until pupation of *B. brevicornis*. These filter papers containing pupae of *B. brevicornis* were transferred to plastic containers to aid the emergence of the adults of *B. brevicornis* for continuing the parasitoid culture. The emerging adults were provided with sugar: honey solution (1: 1) dipped in cotton swab and stuck within the plastic containers for the nourishment of adult parasitoids.

Parasitic potential of Bracon brevicornis on larvae of S. frugiperda – Free choice test

The experiments were carried out in a plastic container of 18 × 12 × 12 cm size, by sandwich method (Jhansi, 1984) with four replications as free choice test under laboratory conditions. The III, IV, V and VI instar larvae of *S. frugiperda* were subjected to parasitization by gravid females of *B. brevicornis* at different parasitoid: host ratios (1:1, 2:1, 3:1, 4:1, 5:1). The larvae were separated from each other by cardboard strips to prevent larval cannibalism among FAW. After 24 h of exposure, observations were made on per cent parasitization.

$$\% \text{ Parasitization} = \frac{\text{Number of FAW larvae parasitized (containing eggs of } \textit{B. brevicornis})}{\text{Number of FAW larva exposed for parasitization}} \times 100$$

Biology of B. brevicornis on larvae of S. frugiperda – No choice test

Based on the results of the above experiment, the best parasitoid: host ratio was identified and utilized for further studies on parasitic potential and biology of *B. brevicornis* on different instars of *S.frugiperda* larva (III, IV, V and VI instars). The larvae were subjected to parasitization separately by gravid females of *B. brevicornis* under no choice test at the best parasitoid: host ratio (5: 1). The biological parameters of *B. brevicornis viz*., number of eggs / host larva, number of grubs / host larva, number of cocoons / host larva and number of adults emerged / host larva were recorded and the developmental duration of *B. brevicornis* on FAW instars was computed (Thanavendan and Jeyarani, 2010).

Statistical analysis

The data obtained from the laboratory studies were subjected to analysis of variance (ANOVA) by Completely Randomized Design (CRD) using AGRES software. Per cent parasitization was subjected to arcsine transformation and No. of biological stages of *B. brevicornis* / FAW larva was subjected to square root transformation. Means were differentiated using Least Significant Difference (LSD) (Laminou *et al*., 2020).

Results and Discussion

Laboratory experiment on the parasitic potential study indicated highest parasitization at the parasitoid: host ratio of 5:1 with 68.60 per cent parasitization on the VI instar followed by 57.75 per cent on the V instar, 48.80 per cent on the IV instar and 32.40 per cent on the III instar (Table 1), which revealed that the parasitic potential of *B. brevicornis* was directly proportional to the increased parasitoid densities. Parasitic potential on different instars of larva under no choice test also recorded highest parasitization on VI instar larva with 64.95 per cent followed by V instar with 56.95 per cent, IV instar with 46.60 per cent and III instar with 30.67 per cent (Table 2).

The current findings agree with the findings of Ghosh *et al*., (2022) who studied on the parasitic potential of *B. brevicornis* on larva of *S. litura* and *S. frugiperda*. The results revealed, in no – choice assay, the parasitoid development was highest on fifth instar larvae of *S. litura* larvae with 62 per cent egg hatching, 76 per cent pupation and 78 per cent adult emergence. Similarly, these parameters were highest on fifth instar *S. frugiperda* larvae with 57 per cent egg hatching, 80 per cent pupation, 70 per cent adult emergence. In two choice assay, *B. brevicornis* preferred fourth or fifth over third instar larvae of both hosts under laboratory conditions. Also, 76 and 84 per cent parasitism was observed on fifth instar larvae of *S. litura* and *S. frugiperda*, respectively in pot culture study. Evaluation on the performance of *B. brevicornis* in maize fields showed 54 per cent average reduction in FAW damage.

Our findings are in affirmation with the findings of Gerling and Rotary (1973) who manifested that Spodoptera litoralis was a least preferred for parasitization by *Bracon spp*. which reinforces that Spodoptera spp. is not a preferable host for B. brevicornis. Latha *et al*., (2019) proclaimed that when *Spodoptera litura* larva was subjected to parasitization by *B. hebetor*, no parasitization was observed, instead the larva turned black, dried up and eventually died which is in affirmation with our findings. According to the same authour, among the host larvae (*C. cephalonica*, *Helicoverpa armigera*, *S. litura* and *S. frugiperda*) subjected to parasitization by *B. hebetor*, *S. frugiperda* was the least preferred host compared to *S. litura*. This non – preference may be the reason for the requirement of higher number of parasitoids for effective parasitization of *S. frugiperda* larva by *B. brevicornis*. Khalil *et al*., (2019) observed that the plasticity of the *Spodoptera spp*. was responsible for the non – preference of the B. brevicornis. Similarly, thickness of cuticle and body contents of the host larva influence the preference of the parasitoid as reported by Bakr *et al*., (2014). The cuticle of *S. frugiperda* larva is thicker compared to the cuticle of *C. cephalonica* larva. The aforementioned findings present details on the non – preference of *Spodoptera* spp. by *B. brevicornis* which may be the reason for the increased parasitoid: host ratio for successful parasitization by *B. brevicornis*. Our findings are in line with the findings of Temerak, (1983) who examined that the nutritional value of the host insect was responsible for the preference of the parasitoid.

Biology study of *B. brevicornis* on different instars of *S. frugiperda* larva at 5: 1 ratio recorded highest number of eggs (32.00), grub (30.75), cocoon (29.75) and adults (28.00) of *B. brevicornis* on sixth instar larva of *S. frugiperda* followed by fifth instar larva of *S. frugiperda*. The size of the host larva was directly proportional to the parasitic potential of *B. brevicornis* (Table 2). The present findings are in line with the findings of Srinivasan and Chandrikamohan, (2017) who observed the emergence of 39.52 adults of *B. brevicornis* from a single parasitized larva of *C. cephalonica* and the presence of 29 eggs of *B. brevicornis* on a single parasitized larva of *Opisinia arenosella*. The current findings are in accordance with the findings of Thanavendan and Jeyarani, (2009) who reported that later instars of lepidopteran larvae were preferred most by the braconid parasitoids. Early instars were killed by mutilation of the parasitoid but biological stages of B. brevicornis were absent in the early instars (II instar). The findings of Ghimire and Phillips, (2010) depict that *B. hebetor* did not lay eggs on all the host it parasitizes which reinforce the relevance of our findings. Our findings are concurrent with the findings of Bakr *et al*. (2014) who reported that *B. brevicornis* preferred to oviposit on last instar larva compared to early instars. According to Kandil *et al*. (2018) the total soluble proteins, carbohydrates, fats were present in larger quantities in bigger larvae or later instars compared to early instars, which is a key factor influencing the preference of later instars over early instars. After host location, *B. brevicornis* injects venom within the host larva leading to paralysis of the host. Thus, the host larva becomes paralyzed / immobile and allows parasitization (egg laying) by *B. brevicornis*.

The egg, grub and cocoon period of *B. brevicornis* on *S. frugiperda* ranged from 24.20 to 26.20 h, 72.26 to 73.20 h and 96.20 to 98.20 h respectively. The total life cycle was completed in 192.66 to 195.80 h in all instars and was found to be on par with all the instars studied. The longevity of adults emerged from different instars were found to be on par with each other and it ranged from 362.0 to 362.8 h. There was no significant difference between instars, with regard to developmental duration of B. brevicornis (Figure 1) which is in line with the findings of Srinivasan and Chandrikamohan, (2017) and Bakr *et al*. (2014). In contrary, Kandil *et al*. (2018) reported

that the developmental duration was shorter on small sized hosts like *Pectinophora gossypiella* (Saunders) and *Earias vitella* (Fabricius), but longer on large sized hosts like *Spodoptera littoralis* (Boisduval) and *Helicoverpa armigera* (Hubner). Our findings are in consonance with the findings of Thanavendan and Jeyarani, (2010) who reported that the nutritional quality of the host insect influenced the developmental biology of the parasitoid which is in conformity with our results. In the present work, *S. frugiperda* larva was larger with enormous amount of nutrients than the factitious host, *C. cephalonica* which may be responsible for the faster development.

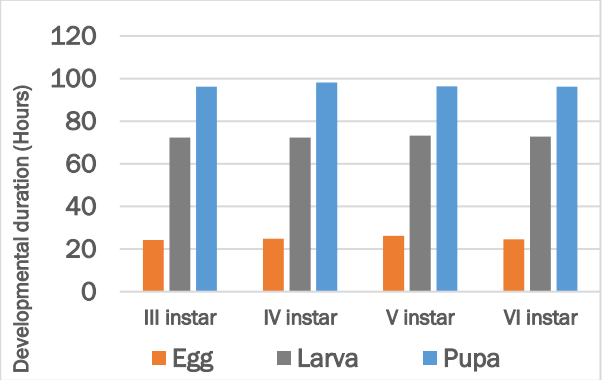

Figure. 1. Developmental duration of *B. brevicornis* on different larval stages of *Spodoptera frugiperda*

Table 1. Parasitic potential of *Bracon brevicornis* on larvae of *Spodoptera frugiperda* – Free choice test

Parasitoid: host ratio	III instar	IV instar	V instar	VI instar
1: 1	14.68 (22.53)^{e}	28.42 (32.22)^{e}	32.12 (34.52)^{e}	32.24 (34.60)^{e}
2: 1	16.84 (24.23)^{d}	30.48 (33.51)^{d}	38.62 (38.42)^{d}	44.68 (41.95)^{d}
3: 1	24.85 (29.90)^{c}	38.86 (38.56)^{c}	48.24 (43.99)^{c}	52.24 (46.28)^{c}
4: 1	28.25 (32.11)^{b}	44.62 (41.91)^{b}	52.64 (46.51)^{b}	60.48 (51.05)^{b}
5: 1	32.40 (34.70)^{a}	48.80 (44.31)^{a}	57.75 (49.46)^{a}	68.60 (55.92)^{a}
SE(d)	0.23	0.32	0.31	0.29
CD (0.05)	0.50	0.69	0.68	0.62

The values are mean of 4 replications; Figures in parentheses are arcsine transformed values; Means followed by different letters differ significantly at (p=0.05). Means were differentiated by LSD.

Table 2. Biology of *B. brevicornis* on larvae of *Spodoptera frugiperda* – No choice test

Treatment	Parasitization (%)	Life stages of *B. brevicornis* (No. / larva @ 5: 1)			
		Egg	Grub	Cocoon	Adult
III instar	30.67 (33.63)^{d}	4.75 (2.29)^{c}	3.75 (2.06)^{c}	3.25 (1.94)^{c}	3.25 (1.94)^{c}
IV instar	46.60 (43.05)^{c}	12.25 (3.57)^{b}	10.75 (3.35)^{b}	9.50 (3.16)^{b}	8.75 (3.04)^{b}
V instar	56.95 (48.99)^{b}	27.75 (5.32)^{a}	26.50 (5.20)^{a}	25.50 (5.10)^{a}	24.50 (5.00)^{a}
VI instar	64.95 (53.70)^{a}	32.00 (5.70)^{a}	30.75 (5.59)^{a}	29.75 (5.50)^{a}	28.00 (5.34)^{a}
SE(d)	0.52	0.19	0.21	0.21	0.20
CD (0.05)	1.11	0.41	0.47	0.47	0.44

The values are mean of 5 replications; Figures in parentheses are square root transformed values; Means followed by different letters differ significantly at (p=0.05). Means were differentiated by LSD.

CONCLUSION

This study paves way for further research on ascertaining the efficacy of *B. brevicornis* under field conditions. Field release depends on presence of biological stage of FAW prone for parasitization. Field efficacy can be similar to laboratory based on the availability of nectar and pollen rich plants and the ability of the parasitoid to locate the FAW larva, which is usually present within the whorls / cob of the plant.

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Consent for publication

All the authors agreed to publish the content.

Competing interests

There was no conflict of interest in the publication of this content

Data availability

Not applicable for this manuscript.

Author contributions

SJ, NS, SM and SN provided the technical guidance. SLP carried out the research.

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