Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp.

By

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(2019-11-245)

THESIS

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DECLARATION

I, Sreelakshmi K. B. (2019-11-245) hereby declare that the thesis entitled **"Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp."** is a bonafide record of research done by me during the course of research and that it has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp."** is a record of research work done independently by **Ms. Sreelakshmi K. B. (2019-11-245)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

Introduction

1. INTRODUCTION

Brinjal or eggplant (*Solanum melongena* L.) is a major vegetable crop in many South Asian countries especially India, Bangladesh, Nepal, and Sri Lanka contributing around 50.00 per cent of global area under cultivation (Alam *et al*., 2003). In India, eggplant is grown throughout the year in almost all the states. It holds the status of most popular and affordable vegetable in India. Brinjal has been cultivated in an area of 0.73 million hectares and reported to be having a production of 12.80 million tonnes (GoI, 2018). It is a highly cosmopolitan and popular vegetable regarded as “poor man’s crop” in India (Abhishek and Dwivedi, 2021). The warm and moist climate is very well congenial for the growth of brinjal, which is also preferred by many insect pests. The canopy and succulent nature of the crop invites maximum number of pests. The chances of pest carry over from one season to next also stand high as it is cultivated throughout the year (Mandal *et al*., 2010).

The major constraint that hinders the crop from realization of yield potential is the infestation of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) in Asia (Purohit and Khatri, 1973; Kuppuswamy and Balasubramanian, 1980). In India, this pest is widespread across the country and has been classified as the most destructive and serious one, inflicting great losses in brinjal (Patil, 1990). Gangwar and Sachan (1981) reported 26.30 to 62.50 per cent damage to fruits. Substantial loss of about 70.00 per cent was reported on severe infestation (Sandanayake and Edirisinghe, 1992).

Since the pest is an internal borer, farmers adopt prophylactic spray of insecticides to reduce severe yield loss (Chatterjee and Roy, 2004; Mishra and Dash, 2007). The irrational use of insecticides has led to the destruction of natural enemies, development of resistance in insect, health hazards to farmers and consumers, pesticide residue problems and environmental pollution (Abhishek and Dwivedi, 2021). It is high time to adopt safe, eco-friendly and sustainable alternatives for the management of brinjal shoot and fruit borer.

Biological control is a safe, ecologically sound, cheap, and sustainable approach (de Bach, 1964). Biological control using *Trichogramma* egg parasitoids are considered to be the most viable and promising strategy. Many species of *Trichogramma* are reported to be having the ability to parasitise the eggs of *L. orbonalis*. However, wide variations have been reported in the relative success of various species. So far, no studies have been taken up for the evaluation of different species of *Trichogramma* against *L. orbonalis* in Kerala.

Hence, the present study entitled "Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp." was carried out with the following objective.

- To identify an effective species of *Trichogramma* for the management of brinjal shoot and fruit borer, *Leucinodes orbonalis*

Review of literature

2. REVIEW OF LITERATURE

A review on the literature pertaining to the study entitled “Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp.” is presented in this chapter. Since the previous studies on the topic are limited, related works on other crop pests are also reviewed.

2.1 BRINJAL SHOOT AND FRUIT BORER

Leucinodes orbonalis was reported to be an important concealed borer pest, which cause damage of 6.54 per cent in shoot and 52.30 per cent in fruit regardless of the time of planting (Tripathy *et al*., 1997). Rosaiah (2001) reported yield loss of 70.00 to 92.00 per cent in brinjal. In early stages of the crop growth, larvae bore into the shoots and tunnel inside leading to drooping, withering and drying of the infested shoots. During the reproductive stage, early instar larvae bore into the flower buds and fruits and the bored holes loom as plugged with faeces. Infested fruits are no longer suitable for human consumption due to a loss of quality and lose their market value (Sharma and Tayde, 2017).

The life cycle of *Leucinodes orbonalis* was studied by Maureal *et al.* (1982) on brinjal. According to them, the insect had a total development period of 23.45 and 24.39 days for males and females respectively. The fecundity was 210 eggs per female, laying an average of 65.18 eggs per day. Adult females had higher longevity of 9.08 days compared to males (7.87 days).

According to Kavitha *et al.* (2008), the life cycle of *L. orbonalis* was completed in 35.27 days. The duration of egg, larval and pupal stages were 2.98, 16.32 and 8.01 days respectively. The total number of eggs laid by a female moth averaged 170 during the life span. Adult males and females lived for 3.50 and 5.70 days respectively.

Wankhede *et al.* (2009) reported that the larval and pupal stages of brinjal shoot and fruit borer lasted for 13.80 and 10.20 days respectively. The incubation period was 3.80 days. An adult male lived for 1.70 days, whereas females had a longevity of 3.30 days.

According to Yadav (2020) the egg, larval and pupal period of *L. orbonalis* on brinjal lasted 3.61, 18.76 and 8.95 days respectively. The adult longevity was 3.28 and 2.57 days for females and males respectively.

2.2 *Trichogramma* EGG PARASITOIDS

Trichogramma wasps, the tiny hymenopteran egg parasitoids belong to the family Trichogrammatidae. These tiny parasitic wasps are of 0.2 to 1.5 mm size (Pinto and Stouthamer, 1994). *Trichogramma* spp. is distributed all over the world and more than 800 species have been described in 89 genera (Querino *et al*., 2009). These wasps naturally occupy on almost all terrestrial habitats. The identification between species is difficult as they have small size and uniform morphological features. Studies on male genitalia characters along with wing venation, body colour and features of antenna makes the identification much accurate (Knutson, 1998).

Based on the genitalia characters, the species can be classified into different groups like the Australicum group, Minutum group, Euproctidis group, Flandersi group, Japonicum group, Agriae group, Maltbyi group, Parkeri group and Achaea group. The Australicum group is characterized by broad genitalia, broad dorsal expansion of gonobase (DEG), with two prominent lateral lobes and broad median ventral projection (MVP). This group includes *australicum* Girault, *poliae* Nagaraja, *dendrolimi* Mats., *nubilalum* Ertle and Davis, *ivelae* Pang and Chen, and *closterae* Pang and Chen.

The Minutum group is having somewhat narrow, triangular DEG with distinct constrictions at base, lacking lateral lobes and with a narrow MVP. It is the largest group and includes *minutum*, *evanescens*, *perkinsi*, *fasciatum*, *semifumatum*, *pretiosum chilotraeae* Nagaraja and Nagarkatti, *brasiliensis* Ashmead, *papilionidis* Viggiani, *papilionis* Nagarkatti, *platneri* Nagarkatti, *californicum* Nagaraja and Nagarkatti, s*emblidis* Aurivillius, *retorridum* Girault, *embryophagum* Hartig, *leucaniae* Pang and Chen and *ostriniae* Pang and Chen.

The Euproctidis group is a monotypic group comprising only *euproctidis*, characterized by the linear and very narrow male genitalia, the distal part being somewhat constricted near the gonoforceps, with a very short and narrow MVP and short aedeagus.

The Flandersi group has a spatulate extension of the DEG distally, minute MVP, and a short aedeagus. This group includes *flandersi* Nagaraja and Nagarkatti, *hesperidis* Nagaraja, *bennetti* Nagaraja and Nagarkatti, *beckeri* Nagarkatti, and *lingulatum* Pang and Chen.

The Japonicum group is having a horseshoe-shaped DEG, inconspicuous MVP, and a long aedeagus with short apodemes. This group includes *japonicum* and *pallidiventris* Nagaraja.

The Agriae group is characterized by a minute MVP and a short DEG which does not reach the chelate structures. This group includes *agriae* Nagaraja, *rojasi* Nagaraja and Nagarkatti, and *plasseyensis* Nagaraja. The Maltbyi group is monotypic, comprising only of *maltbyi* Nagaraja and Nagarkatti. The DEG appears cup-shaped when viewed caudally and is constricted at the base. The chelate structures are very close to the tips of the gonoforceps.

The Parkeri group is characterized by its extremely linear appearance and the elongate DEG. This group is also monotypic and includes only *parkeri* Nagarkatti. The Achaeae group is characterized by a simple and narrow DEG without lateral lobes and a blunt posterior extremity. The MVP is inconspicuous.

This group includes *achaeae* Nagaraja and Nagarkatti and *raoi* Nagaraja (Nagarkatti and Nagaraja, 1977).

2.3 BIOCONTROL POTENTIAL OF *Trichogramma* spp.

The trichogrammatids (*Trichogramma, Trichogrammatoidea*) control many agricultural pests (van Lenteren, 2000).

Owing to the short life cycle and easiness on rearing on factitious hosts, many species of *Trichogramma* serve as biocontrol agents of many lepidopteran insect pests (Smith, 1996). *Trichogramma* parasitoids are known to be biocontrol agents for the management of several agricultural pests belonging to the genera like *Ostrinia, Heliothis, Helicoverpa, Scirpophaga, Chilo, Diatraea. Cnaphalocrocis, Spodoptera, Anticarsis, Leucinodes, Mythimna, Pieris, Agrotis etc*. (Cherif *et al*., 2021).

According to Hassan (1993), Trichogrammatids had strong preference towards the eggs of many lepidopteran pests. They reported that the host finding activity of the adult parasitoid is stimulated by kairomones, the semiochemicals produced by the hosts. During the oviposition the female injects a venom due to which the yolk and embryo of host egg get digested. The larva of *Trichogramma* feed on this digested egg's content. The three larval stages and pupation are completed within the host egg, and the parasitized host eggs turn black when they reach pupal stage. During the third larval instar, just before pupation melanin granules are deposited on the inner surface of egg chorion making it appear black. After pupation, adult wasp emerges by chewing and making circular hole on the egg shell. Males emerge first and wait near to the host eggs for the emerging females to mate. According to Chan and Chou (2000), the males and females differ in their antenna and genitalia that are visible under microscope. Females have clubbed antenna with few hairs whereas males have antenna with many hairs. The aedeagus of males and ovipositor of females can be clearly seen under microscope. Also, in males the mesoscutellum is expanded.

Among different species of *Trichogramma*, the literature pertaining to *T. chilonis* (Ishii), *T. pretiosum* (Riley), *T. evanescens* (Westwood) and *T. embryophagum* (Hartig) is briefed hereunder.

2.3.1 *Trichogramma chilonis* (Ishii)

2.3.1.1 Biocontrol potential of *T. chilonis* on *L. orbonalis*

2.3.1.1.1 Laboratory screening

Murali *et al*. (2017) screened different species of *Trichogramma* for the management of *L. orbonalis.* In the laboratory experiment, *T. chilonis* exhibited 92.00 per cent parasitism on the eggs of *L. orbonalis.* Similarly, the adult emergence and female adult emergence was 95.60 and 65.20 per cent respectively. While working out the dosage in cage experiment also, *T chilonis* was the best species with mean parasitism and adult emergence of 75.60 and 74.40 per cent respectively at a dose of 1.50 lakh adults ha^{-1}.

Ranjith *et al*. (2018) reported higher mean parasitism and adult emergence of 65.56 and 81.37 per cent respectively for *T. chilonis* on one day old eggs of *L. orbonalis* under laboratory condition.

2.3.1.1.2 Field efficacy evaluation

Hanapur (2002) reported the parasitism efficiency of *T. chilonis* on the eggs of brinjal shoot and fruit borer under laboratory and field conditions. In the laboratory, *T. chilonis* caused 64.00 per cent parasitism. Under field condition, five releases of *T. chilonis* @ 3.00 lakh ha^{-1} at 10 days interval starting from 30 days after transplanting resulted in higher yields (5.35 t ha^{-1}) over untreated control (3.08 t ha^{-1}) and significant reduction in shoot infestation. Parasitoid released plots recorded 40.03 per cent reduction in shoot infestation over control.

Sathpathy *et al*. (2005) assessed the suitability of using *T. chilonis* in integrated management of brinjal shoot and fruit borer. Release of *T. chilonis* @

2.50 lakh ha^{-1} on integration with a chemical, recorded the fruit infestation of 58.00 per cent, followed by *T. chilonis* @ 2.50 lakh ha^{-1} coupled with weekly clipping of shoot and 4.00 per cent neem seed kernel extract (60.00%). Control plot recorded significantly higher fruit infestation (84.32%).

Release of *T. chilonis* @ 7.5 cc eggs ha^{-1} in brinjal field resulted in 57.62 per cent reduction in shoot infestation over control on 3 and 7 days after sowing and 52.42 per cent reduction in shoot infestation over control on 14 days after sowing. The reduction in infestation on fruit was 42.66 per cent and 45.07 per cent over control (27.42 and 28.02%) in terms of weight and fruit number respectively. Moreover, 78.12 per cent increase of marketable yield over the control plot was obtained (Budhvat and Magar, 2014).

Sathe *et al*. (2016) conducted a study on the ecology and control of lepidopteran insect pests of brinjal and reported that the release of *T. chilonis* @ 1.00 to 1.50 lakh ha^{-1} was effective against *L. orbonalis* and *Euzophera perticella*.

Sumathi *et al*. (2018) reported that IPM practice involving release of *T. chilonis* @ 8 cc eggs ha^{-1} for four times at weekly interval resulted in significant reduction of damage by shoot and fruit borer on brinjal. The shoot damage was 13.60 and 19.60 per cent in plots of IPM and insecticide respectively. IPM plots recorded 15.90 per cent fruit damage, whereas it was 25.00 per cent in insecticide application.

Singh *et al*. (2019) reported that six and eight releases of *T. chilonis* @ 1.5 lakhs eggs ha^{-1} were highly effective in lowering the crop damage due to brinjal shoot and fruit borer. The shoot damage was 11.96 per cent on releasing the parasitoid for eight times, whereas 12.66 per cent shoot damage was recorded at six times release. In the control plot, the shoot infestation was 22.27 per cent. The mean fruit damage was 11.67 and 9.80 per cent on number basis for six and eight releases respectively. The fruit damage on weight basis was 11.59 per cent at six releases and 9.90 per cent with eight releases. Highest parasitism on eggs of brinjal shoot and fruit borer was recorded for the same treatments (47.05 and 47.61%) compared to lower rates of release.

Augmenting the IPM practice with the release of *T. chilonis* @ 3 cc eggs acre^{-1} for 4 weeks at weekly interval resulted in lesser infestation (8.90%) of brinjal shoot and fruit borer compared to chemical control (25.00%). The benefit cost ratio was also found to be higher (3.03) compared to chemical treated plots (2.09) (Divya *et al*., 2019).

Biswas *et al.* (2021) reported that *T. chilonis* was able to reduce the shoot infestation by 89.17 per cent over the control on releasing the parasitoid @ 1.00 lakh ha^{-1}. The mean shoot infestation averaged 6.90 and 16.45 per cent in *T. chilonis* released and control plots respectively.

2.3.1.2 Biocontrol potential of *T. chilonis* on other lepidopteran pests

2.3.1.2.1 Laboratory screening

Ballal and Singh (2003) conducted a study using *T. chilonis* against *Helicoverpa armigera*. In the laboratory experiment, *T. chilonis* exhibited 66.79 ± 5.0 per cent parasitism, whereas in the screenhouse experiment, it recorded 50.10 per cent when released at 50,000 no. ha^{-1}.

Unmole (2010) reported the ability of *T. chilonis* in parasitising the eggs of *Maruca vitrata* and recorded 56±2.5 and 26.3±0.5 per cent parasitism on one and two day old eggs. Adult females caused 77.10 and 79.20 per cent mortality of one and two day old eggs through oviposition. In the choice test, the parasitoid had higher preference towards the eggs of *H. armigera* (19.20%) compared to that of *M. vitrata* (10.00%).

The eggs of *Spodoptera litura* when subjected to oviposition by *T. chilonis* for 24 hours, 89.50 to 91.10 per cent parasitism were recorded. When the exposure time was reduced to 16 hours, the parasitism was reduced (88.60 - 90.00%) (Saljoqi *et al*., 2015).

Manideepthi (2020) observed 91.20 per cent parasitism and 77.80 per cent adult emergence by *T. chilonis* on the eggs of *Corcyra cephalonica* in the laboratory.

Jin *et al*. (2021) stated that *T. chilonis* is an effective biocontrol agent of *Spodoptera frugiperda* and in the laboratory studies they could find that in the first 96 hours, 180 eggs of *S. frugiperda* were parasitised by *T. chilonis*.

2.3.1.2.2 Field efficacy evaluation

In a study conducted to find out an effective *Trichogramma* sp. for the control of *H. armigera* in redgram, Ballal and Singh (2003) reported 5.50, 11.40 and 16.00 per cent parasitism by *T. chilonis* @ 50,000, 1,00,000 and 1,50,000 no. ha^{-1}. The parasitism was in the range of 2.80 to 4.40 per cent and 2.10 to 3.20 per cent respectively for *Trichogramma brasiliense* and *T. pretiosum*.

Singh *et al*. (2008) studied the usefulness of *T. chilonis* in managing *Chilo auricilius* infesting sugarcane. They concluded that 11 to 12 releases of *T. chilonis* at 50,000 no. ha^{-1} for four months reduced the stalk borer incidence by 55.00 to 60.00 per cent.

Masood *et al*. (2011) assessed the performance of *T. chilonis* against *H. armigera* and *Earias insulana* on different varieties of cotton. Release of the parasitoid @ 20 cards $acre^{-1}$ (500 eggs/card) aided the suppression of *H. armigera* attack over the control plot up to 31.73 to 36.45 per cent. The damage caused by *E. insulana* was 32.43 to 45.49 per cent less compared to control. The results of the study revealed that *T. chilonis* can be an indispensable component of integrated pest management.

Visalakshmi *et al*. (2013) suggested the release of *T. chilonis* as an important component of management module for rice stem borer. The module comprising the release of *T. chilonis* @ 1.00 lakh adults ha^{-1} starting from 15 days after transplanting for five times at an interval of 10 days reduced the stem borer infestation to a level of 6.80 per cent, while in farmers' practice, the infestation was 7.50 per cent. Greater grain yield (5.89 tonnes ha^{-1}) and benefit cost ratio (1:2.38) were also obtained from the module comprising of *T. chilonis*. The farmers' practice recorded a grain yield of 4.60 tonnes ha^{-1} and benefit cost ratio of 1: 1.90.

Release of *T. chilonis* is an integral component of Bio- Intensive Pest Management (BIPM) practice in different crops. According to Borkakati *et al.* (2019), weekly release of *T. chilonis* @ 1.00 lakh ha^{-1} for six weeks since flower initiation along with seedling root dip treatment with *Pseudomonas* 2.00 per cent solution, installation of yellow sticky trap @ 50 no. ha^{-1}, NSKE @ 5.00 per cent spray against sucking pests, installation of pheromone traps @ 15 no. ha^{-1} against *H. armigera* and rouging of leaf curl disease affected plants was effective in controlling insect pests with mean insect population of 2.32 no. $plant^{-1}$ compared to chemical control (3.02 no. $plant^{-1}$).

2.3.2 *Trichogramma pretiosum* (Riley)

2.3.2.1 Biocontrol potential of *T. pretiosum* on *L. orbonalis*

2.3.2.1.1 Laboratory screening

Brower and Press (1990) opined that *T. pretiosum* have substantial ability to scale down the storage pest population based on a study conducted in Indian meal moth, *Plodia interpunctella* and Almond moth, *Cadra cautella*. The population of Indian meal moth was reduced to 37.30 and that of almond moth to 96.70 per cent on exposure to *T. pretiosum* @ 1500 adults $25m^{-3}$ metallic structures.

Niranjana and Sridhar (2014) conducted a lab study to evaluate the efficiency of *T. pretiosum* in parasitizing the eggs of *L. orbonalis*. The per cent parasitism obtained was 91.99 and 75.15 per cent on one and two day old eggs of *L. orbonalis* respectively. The adult emergence from one and two day old eggs were 87.52 and 89.93 per cent respectively. These findings implied the ability of *T. pretiosum* in managing the *L. orbonalis*.

Ranjith *et al.* (2018) conducted a laboratory study to evaluate the parasitism efficiency of *Trichogramm*a spp. and reported 90.00 and 91.03 per cent parasitism and adult emergence respectively on one day old eggs of *L. orbonalis* by *T. pretiosum*.

2.3.2.1.2 Field efficacy evaluation

The results of a study conducted by Ranjith *et al*. (2019) had shown that twelve releases of *T. pretiosum* @1.25 lakh ha^{-1} at weekly interval reduced the shoot and fruit damage by 53.76 and 38.91 per cent respectively over untreated control. The mean shoot and fruit damage were significantly low (0.26 and 19.25% respectively) when released with *T. pretiosum* compared to untreated control (4.01 and 47.08%).

2.3.2.2 Biocontrol potential of *T. pretiosum* on other lepidopteran pests

2.3.2.2.1 Laboratory screening

Ballal and Singh (2003) assessed the performance of *T. pretiosum* in parasitising the eggs of *H. armigera* on sunflower and red gram. Laboratory studies indicated that *T. pretiosum* is a promising species to be used in a biocontrol programme exhibiting 76.60 per cent parasitism.

de Freitas *et al*. (2012) studied the parasitism efficiency of *T. pretiosum* on the eggs of soybean looper, *Pseudoplusia includens*. *T. pretiosum*, on an average parasitized 7.40, 11.10, 10.10, 14.00, 13.30, 13.30 and 8.70 eggs of *P. includens* at 18, 20, 22, 25, 28, 30 and 32^{o}C respectively. The total number of eggs parasitized by a female parasitoid in the lifespan was 31.85, 44.95, 38.75, 40.90, 43.85, 33.80

and 28.50 at same temperature range. These results emphasized on the capability of *T. pretiosum* as an ideal biocontrol agent against *P. includens.*

de Freitas *et al*. (2012) assessed the efficacy of *T. pretiosum* against velvet bean caterpillar, *Anticarsia gemmatalis*, a major pest of soyabean at different temperatures. According to them, *T. pretiosum* can parasitise on an average 4.00, 4.50, 7.10, 9.30, 8.40, 8.40 and 8.30 eggs of *A. gemmatalis* at 18, 20, 22, 25, 28, 30 and 32^{o}C respectively. Similarly, 38.90, 29.85, 29.58, 33.04, 40.44, 45.36 and 38.0 eggs of *A. gemmatalis* were lifetime parasitized at the same temperature range. The adult females of *T. pretiosum* lived for 11.10, 7.00, 5.00, 8.30, 6.00 and 4.00 days on the above-mentioned temperature range.

Ballal *et al*. (2016) evaluated the ability of *T. pretiosum* in killing the invasive pest, *Tuta absoluta*. The rate of parasitism and adult emergence was 51.10 and 97.50 per cent respectively. These findings paved way towards a biocontrol programme against *T. absoluta* by *T. pretiosum.*

Lethal effects of buprofezin, chlorantraniliprole, spirotetramat, flonicamid, flubendiamide, spiromesifen and cyflumetofen on immature and adult parasitoids of *T. pretiosum* were evaluated by Khan and Ruberson (2017) and revealed the compatibility of *T. pretiosum* with these insecticides in integrated pest management programmes.

Jin *et al*. (2021) conducted a study to assess the parasitism efficiency of *T. pretiosum* against *S. frugiperda* and found that 90.00 per cent of eggs were parasitized within the first 96 h.

2.3.2.2.2 Field efficacy evaluation

Goulart *et al*. (2011) studied the interactive effect between *T. pretiosum* and *Teleonomus remus* for curtailing the population of different species of *Spodoptera* on soybean. All the combinations of *T. pretiosum* and *T. remus* gave positive results offering broad spectrum control over *Spodoptera* spp.

According to a study conducted by de Lourdes *et al*. (2015), *T. pretiosum* parasitised 79.20 per cent of egg masses of *S. frugiperda*, a major pest of maize in Brazil.

2.3.3 *Trichogramma evanescens* (Westwood)

The literature pertaining to the biological control of insect pests using *T. evanescens* is found to be scanty.

2.3.3.1 Biocontrol potential of *T. pretiosum* on *L. orbonalis*

Murali *et al*. (2017) evaluated different species of *Trichogramma* in laboratory against brinjal shoot and fruit borer and recorded the highest parasitism and adult emergence of 93.20 and 94.40 respectively in *T. evanescens*. In the cage experiment, at a dose of 15 adults m^{-2}, the per cent parasitism and adult emergence was 57.70 and 56.60 per cent respectively.

2.3.3.2 Biocontrol potential of *T. pretiosum* on other lepidopteran pests

2.3.3.2.1 Laboratory screening

Mandour *et al.* (2012) investigated the efficiency of *T. evanescens* in controlling potato tuber moth, *Pthorimaea operculella* infesting stored potatoes. Release of *T. evanescens* pupae @ 6 no. per kg of potato tubers resulted in 71.67±6.01 per cent infestation in parasitoid acted potatoes, whereas 96.67±3.33 per cent infestation was recorded in the control treatment after two months of storage. The number of moth pupae recovered from *Trichogramma* released cage was 62.00±7.37, significantly lesser than control (208.67±2.96). The number of mines made by the moth was also low in *Trichogramma* released cage (51.00±1.53 mines per 20 tubers) compared to control (154.00±7.09 mines per 20 tubers). They also reported that the reduction in moth infestation was greater in combination of *T. evanescens* and bioinsecticides than either of the treatment alone. When Neemix, a bioinsecticide was applied alone, the per cent infestation was 86.67±8.82 per cent, whereas when integrated with *T. evanescens*, it was 45.00±2.89 per cent.

Adarkwah *et al*. (2015) studied the efficacy of *T. evanescens* in preventing *C. cephalonica* from infesting stored rice. The number of *C. cephalonica* emerged in parasitoid and control treatments were 0.86 ± 1.18 and 25.00 ± 3.25 respectively. More number of shrunk eggs of *C. cephalonica* (5.18 ± 3.26) indicative of mortality was observed in *T. evanescens* compared to the untreated control (3.06 ± 2.08).

Nasir *et al*. (2017) studied the parasitism by *T. evanescens* and *T. cacoeciae* on the eggs of *Plodia interpunctella* and found that these species parasitized 19.90 ± 9.05 and 2.80±3.68 eggs respectively. *T. evanescens* was chosen as the promising species for the biological control of *P. interpunctella*.

2.3.3.2.2 Field efficacy evaluation

Oztemiz (2008) studied the rate of natural parasitism and the field efficacy of *T. evanescens* against cotton boll worm, *H. armigera*. In the plot released with parasitoid, 52.50 per cent parasitism was observed on the eggs of *H. armigera*, whereas in the control plots only 28.50 per cent parasitism was achieved. Release of *T. evanescens* resulted in 33.30 and 42.80 per cent reduction respectively in the number of *H. armigera* larvae and damaged bolls. The experiment concluded with the usefulness of *T. evanescens* as a potent biocontrol agent against *H. armigera*.

Agamy (2010) reported that *T. evanescens* could effectively bring down the attack of olive moth, *Prays oleae* (Bern.) infesting olives. The reduction in damage was 42.90 and 69.90 per cent in two consecutive years.

El-Heneidy and El-Dawwi (2010) investigated the potential of *T. evanescens* in managing *H. armigera* in tomato field. The pest infestation in the released plot was 1.50 per cent compared to 5.50 per cent in the control plot. Release of parasitoid resulted in 72.70 per cent reduction in fruit damage.

Shawer *et al*. (2013) reported that *T. evanescens* when released twice @ 30,000 wasps per acre in rice fields infested with stem borer, resulted in 49.30 to 63.36 per cent reduction in dead hearts and 63.15 to 65.18 per cent reduction in white ears.

Sigsgaard *et al*. (2017) conducted a study to find out a suitable *Trichogramma* sp. for the management of apple codling moth, *Cydia pomonella.* They concluded that *T. evanescens* was the suitable species in managing *C. pomonella* and recorded low fruit damage (2.80%) compared to control (7.10%).

Oztemiz *et al*. (2017) performed an experiment to analyse the compatibility and suitability of *T. evanescens* for the ecofriendly management of *C. pomonella* in Turkey. The parasitoids were released @ 1.00 lakh adults ha^{-1} twice in 7 to 10 days interval and recorded reduction in egg and larval numbers with values of 52.15 and 68.00 per cent respectively. The rate of egg parasitism was recorded 58.64 per cent for *T. evanescens.* The fruit infestation was significantly low in *T. evanescens* released plot (9.66%) compared to control plot (34.00%)

Bagheri *et al.* (2019) made an attempt to develop an ecofriendly tactic for the management of *H. armigera* in tomato by comparing the release of *Trichogramma* and insecticide application. According to them, the proportion of infested fruits was lower in plot released with *T. evanescens* (3.38 ± 0.51) compared to plot applied with chemical insecticide (3.68 ± 0.51). The total yield was also highest in plot released with *T. evanescens* (1186kg $plot^{-1}$) compared to plot applied with chemical (1039kg $plot^{-1}$).

Salem (2021) reported the effectiveness of *T. evanescens* against *Pectinophora gossypiella* and *E. insulana*. A reduction in larval population of 98.10 and 97.90 per cent was achieved for *P. gossypiella* and *E. insulana* respectively. On an average, 97.50 and 97.10 per cent reduction in fruit infestation was obtained against respective pests.

2.3.4 *Trichogramma embryophagum* (Hartig)

The literature on biocontrol of brinjal shoot and fruit borer using *T. embryophagum* is also found to be scanty.

2.3.4.1 Biocontrol potential of *T. embryophagum* on *L. orbonalis*

A study conducted by Niranjana *et al*. (2018) revealed that *T. embryophagum* had the highest parasitism (90.02 per cent), emergence rate (90.22 per cent) and ability for parthenogenetic reproduction on the eggs of *L. orbonalis.*

2.3.4.2 Biocontrol potential of *T. embryophagum* on other lepidopteran pests

2.3.4.2.1 Laboratory screening

Jalali *et al*. (2002) reported *T. embryophagum* as the most promising species of Trichogrammatid against coconut leaf eating caterpillar, *Opisina arenosella.* It showed higher parasitism and fecundity of 88.00 and 42.20 per cent respectively. In the host searching experiment with eggs laid within feeding galleries, *T. embryophagum* could parasitise 82.10 per cent of eggs.

2.3.4.2.2 Field efficacy evaluation

Jalali *et al*. (2005) conducted a study to find out a suitable *Trichogramma* species against *O. arenosella.* Release of *T. embryophagum* @ 1,000 to 4,000 parasitised eggs per palm resulted in reduction of larval population by 88.80, 75.00, 66.70 and 75.00 per cent during first, second, third and fourth generations of the pest.

2.4 ABIOTIC FACTORS AFFECTING FIELD EFFICACY OF *Trichogramma* spp.

The field performance of *Trichogramma* spp. is greatly influenced by temperature, rainfall, photoperiod and wind. Foerster *et al*. (2013) studied the effect of four different temperatures (14, 18, 21, 26 and 30°C) on the parasitism, adult emergence, age-specific survival, progeny production, and longevity. The number of parasitised eggs by

Trichogramma pretiosum, *T. atopovirilia*, *T. acacioi*, *T. lasallei* and *T. rojasi* were lower at 14°C (10.6, 4.6, 16.6, 2.8, and 3.3 respectively) compared to higher temperatures. At 18, 21, 26, and 30°C, the number of parasitized eggs varied significantly according to the parasitoid species. At 30°C, significantly higher number of parasitized eggs were observed in *T. pretiosum* (41) compared to *T. lasallei* (7.7), *T. acacioi* (8.1) and *T. rojasi* (9.1). In the case of *T. atopovirilia*, highest number of parasitized eggs (50.9 and 55.7) were recorded at 21 and 26°C respectively. The progeny production was found to be reduced at 14 and 30°C for all species. In all temperatures evaluated, *T. pretiosum* lived the longest compared to the other parasitoids.

Altoe *et al*. (2012) studied the biological characteristics and thermal requirements of *T. pretiosum* on the eggs of *Trichoplusia ni* at temperatures of 18, 21, 24, 27, 30 and 33 ±1°C. According to them, *T. pretiosum* performed well on *T. ni* eggs at all studied temperature (from 18 to 33°C) suggesting its usefulness as a biological control agent of the pest in regions with the tested temperature range.

Long term photoperiods may affect the efficiency of parasitoid by increasing the longevity and sex ratio. Rahimi- Kaldeh *et al.* (2018) studied the effect of photoperiod on parasitization of the eggs of *Ephestia kuchniella* by *Trichogramma* under several photoperiodic regimes of L: D = 0: 24, 3: 21, 6: 18, 9: 15, 12: 12, 15: 9, 18: 6, 21: 3 and 24:0. The least fecundity and longevity was observed for those that kept under 18L: 6D. The highest fecundity and longevity were recorded for those that kept under 21L: 3D and absolute darkness, respectively.

The fecundity of *T. chilonis*, was influenced by photoperiod as the number of eggs laid (9.92 ± 0.13 eggs/female/ day) was higher at L14:D10 compared to other photoperiod regimes of 12:12 and 16:8 L: D (Shirazi, 2006).

Zhou *et al.* (2019) studied the influence of wind on the dispersal and efficacy of *Trichogramma dendrolimi* in the field. Adopting a release-recapture method, they reported that the number of recaptured wasps and parasitized eggs increased with the relative wind speed in the daytime during the first three days of release. Also, the effective dispersal radius increased with the relative wind speed during the daytime.

Greatti and Zandigiacomo (1995) reported the effect of downward wind on egg parasitoids. The percentage of host egg masses parasitized by parasitoid decreased with the distance from the point of release.

Fournier and Boivin (2000) studied the comparative dispersal of *T. evanescens* and *T. pretiosum* with respect to environmental conditions. They reported that dispersion of *T. evanescens* decreased with wind speed above 15 km h^{-1} for 4 hours a day, whereas, with *T. pretiosum*, 8 hours of wind at 15 km h^{-1} speed reduced dispersion.

Materials and methods

3. MATERIALS AND METHODS

The study entitled "Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp." was carried out at College of Agriculture, Vellanikkara during the period 2020-2022. The materials used and methods employed during the laboratory and field experiment are explained in this chapter.

3.1 LABORATORY SCREENING OF DIFFERENT SPECIES OF *Trichogramma* AGAINST *Leucinodes orbonalis*

Efficacy of four different species of *Trichogramma viz*., *T. chilonis* (Ishii), *T. pretiosum* (Riley), *T. evanescens* (Westwood) and *T. embryophagum* (Hartig) were evaluated in the laboratory.

3.1.1 Mass production of *Trichogramma* spp.

The nucleus cultures of different species of *Trichogramma* were maintained on the eggs of rice meal moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae).

3.1.1.1 Mass culturing of *Corcyra cephalonica*

The semi synthetic medium of *C. cephalonica* was prepared as per the specifications given by Rao *et al*. (2003). The composition of the medium is given in Table 1.

Table 1. Composition of fortified bajra medium

Sl. No.	Ingredients	Quantity
1	Bajra	2.5 kg
2	Groundnut	100 g
3	Dry yeast	5 g
4	Streptomycin sulphate (0.1 %)	40 ml
5	Sulphur	5 g

Corcyra cephalonica was reared on food grade bajra (Plate 1). Bajra was purchased after confirming the absence of storage pest. Crushed bajra grains were taken in clean dry plastic basins of 90 cm diameter, 15 cm height and of five litre capacity. The plastic basins were initially washed using 0.50 per cent detergent solution and dried well under sunlight.

Crushed groundnut kernel was added into the plastic basin containing crushed bajra grains and mixed thoroughly along with yeast. Groundnut was put into the medium to supplement protein for the developing larvae of *Corcyra*. Yeast was added to enhance the fecundity of female moths. To prevent bacterial contamination, streptomycin sulphate (0.1%) was added and mixed well. Streptomycin sulphate solution was prepared by adding one gram of streptomycin sulphate in 1000 ml of water. To prevent storage mite infestation, sulphur powder was sprinkled along the inner border of the basin. The prepared media was charged with 0.3 cc of *C. cephalonica* eggs.

The basins containing the media were covered and tied with muslin cloth and kept undisturbed in insect proof culture room at a temperature of 28±2º C and relative humidity of 70±5 per cent (Plate 2). Temperature was maintained in the room by air conditioner and humidity was maintained using humidifier (®Rotek Instruments). Care was taken to protect the *Corcyra* culture room from rodents, ants and lizards. A yellow bulb was hung from the roof of culture room to attract and trap braconids. A basin containing water with kerosene drops was kept below the bulb to kill the attracted insects.

When the adult moths started emerging after 35 to 40 days, they were collected using a moth collection apparatus (Plate 3) and transferred to an oviposition chamber for mating and oviposition. The oviposition chamber with wire mesh ventilation at sides and bottom is placed in another basin to collect eggs. The adults were fed with diluted honey (50.00%) mixed with one vitamin E tablet

Plate 1. Preparation of fortified bajra media

Plate 2. Culture of *Corcyra cephalonica*

(Evion 400 mg). Eggs were collected on a daily basis and sieved to get rid of scales and other body parts of the insect.

3.1.1.2 Mass culturing of *Trichogramma* spp.

The nucleus cultures of *T. chilonis, T. pretiosum, T. evanescens* and *T. embryophagum* (Plate 4) were procured from NBAIR, Bengaluru. They were maintained on eggs of *C. cephalonica* (Plate 5). Paper cards for preparing egg cards were applied with a thin coat of diluted gum. Over to these cards, the cleaned eggs of rice meal moth were sprinkled uniformly using a tea strainer. The prepared cards were exposed to UV light of 30 Watts for 45 minutes in UV chamber in order to kill the embryo of *C. cephalonica*. The UV exposed egg cards and nucleus cards of *Trichogramma* at 6:1 ratio was put inside polypropylene covers for successful parasitisation. They were kept as such for three to four days to get parasitised. *Trichogramma* adults emerging from the eggs of *Corcyra* were further used in the experiment and also to maintain the culture in the laboratory.

3.1.2 Mass culturing of *L. orbonalis*

Larvae of *L. orbonalis* were collected from the field of AICRP on BCCP, Vellanikkara and were reared on potato as per the standard procedure (Boopal *et al*., 2013). Cleaned PET bottles were taken and sliced potatoes were placed inside (Plate 6). On pupation, they were collected and placed in another bottle. On adult emergence, a male and female were transferred to a PET bottle and the mouth end of the bottle was secured with black muslin cloth (Plate 7). Adults were fed with 50.00 per cent honey solution by means of a piece of cotton. A moist cotton swab was kept inside the bottle to maintain the humidity inside. The eggs laid on the black cloth (Plate 8) were collected daily until the adults were dead. These eggs were used for conducting the laboratory evaluation.

3.1.3 Laboratory screening of different species of *Trichogramma* against *L. orbonalis*

Efficacy of four different species of *Trichogramma viz*., *T. chilonis, T. pretiosum, T. evanescens* and *T. embryophagum* were evaluated in the laboratory along with an untreated control at room temperature.

Two hours after emergence, different species of *Trichogramma* were anesthetised by exposing them to carbon dioxide for 15 seconds (Paul, 1973) (Plate 9). Females were identified based on the antenna, abdomen tip and genital region under a zoom stereo microscope (Chan and Chou, 2000). Those gravid females were taken for the experiment (Plate 10).

The per cent parasitism and adult emergence of each species of *Trichogramma* was evaluated on the eggs of *L. orbonalis* at a host parasitoid ratio of 6:1. The experiment was laid out in completely randomised design with five treatments and four replications. Each replication was maintained as a set of four test tubes (Plate 11). The fresh one day old eggs of *L. orbonalis* were counted and pasted onto paper cards at the rate of 30 eggs per card (Plate 12). These egg cards were placed inside a test tube. Five gravid females of *Trichogramma* were released into each test tube. The same method was repeated for each species. Untreated control was kept without introducing the parasitoid. Observations on number of eggs parasitized and number of adults emerged were recorded and per cent parasitism and emergence were worked out.

Design	CRD
No. of treatments	5
No. of replications	4
No. of eggs of *L. orbonalis* per tube	30

Plate 3. Collection of moths using moth collector

Plate 4. Nucleus cultures of *Trichogramma* spp.

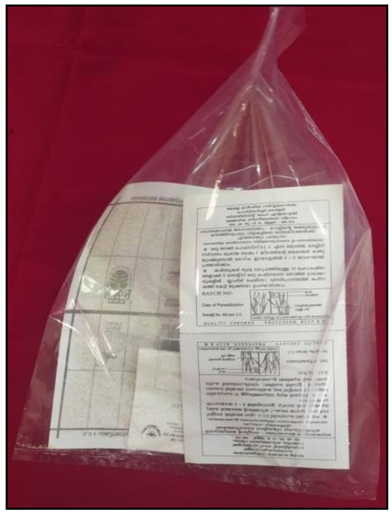

Plate 5. Mass culturing of *Trichogramma*

Plate 6. Rearing *Leucinodes orbonalis* on potato

Plate 7. Adult moth kept for oviposition

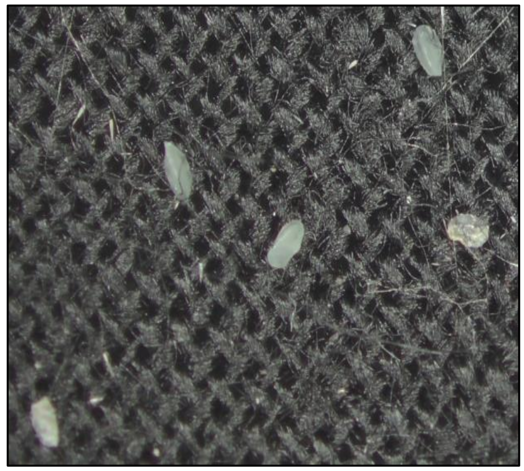

Plate 8. Eggs of *Leucinodes orbonalis*

Plate 9. Anesthetisation of *Trichogramma* spp.

Plate 10a. Broad end of abdomen and ovipositor of female

Plate 10b. Clubbed antenna of female

Plate 10c. Narrow end of abdomen and antenna with hairs in male

Plate 10. Sexual dimorphism in *Trichogramma*

T_1 – *T. chilonis*

T_2 – *T. pretiosum*

T_3 – *T. evanescens*

T_4 – *T. embryophagum*

T_5 – Control

Plate 11. Experimental arena of laboratory screening

Plate 12. Card containing eggs of *Leucinodes orbonalis*

$$\text{Parasitism (\%)} = \frac{\text{Number of eggs that turned black}}{\text{Total number of eggs}} \times 100$$

$$\text{Adult emergence (\%)} = \frac{\text{Number of eggs with emergence hole}}{\text{Number of parasitized eggs}} \times 100$$

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3.2 EVALUATION OF FIELD EFFICACY OF SELECTED SPECIES OF *Trichogramma* AGAINST *L orbonalis*

The efficacy of *Trichogramma pretiosum* and *T. chilonis* identified as the promising species in the laboratory experiment was evaluated against *L. orbonalis* under field condition. The experiment was laid out in exploded block design at the farm of KVK, Thrissur (10.5469°N, 76.2680°E). Four plots each of 40 m² containing 88 plants were used for conducting the experiment. A distance of eight metre was maintained between the plots to prevent mixing up of species. The F_1 hybrid of brinjal, Neelima was transplanted at a spacing of 75 cm × 60 cm. Two plots were selected for releasing *Trichogramma* spp. To prevent the movement of *Trichogramma*, each plot was screened with muslin cloth. One plot was selected for spraying NSKE (5.00%) and a control plot was maintained in the field without any parasitoid or spray (Plate 13). The weather parameters obtained from Agro-Met Observatory, Department of Agricultural Meteorology, College of Agriculture, Vellanikkara is presented in Appendix I.

3.2.1 Preparation of *Trichogramma* cards

The cleaned eggs of *Corcyra* were collected for card preparation. The eggs were counted and pasted on to the paper cards that were previously given a coat of gum arabica. Fine bush was used for handling the eggs. After UV sterilization in the UV chamber, the prepared egg cards were kept aside to get rid off the moisture. These cards were exposed to two selected species of *Trichogramma* separately by packing inside polypropylene covers at 6:1 ratio. The parasitised cards at pupal stage one day prior to emergence were used for field release.

3.2.2 Preparation of neem seed kernel extract (NSKE 5.00%)

The neem seed kernels were grounded coarsely and weighed 50.00g for preparing one litre of five per cent NSKE. It was tied in a muslin cloth and immersed in water. After 12 hours, it was squeezed well to get the extract completely.

3.2.3 Field evaluation of selected species of *Trichogramma* against *L. orbonalis*

A pre-release assessment of pest status was done in all plots. *Trichogramma pretiosum* and *T. chilonis* were released @1,00,000 numbers ha^{-1}. Eight releases were made at weekly interval during the evening hours. The parasitized egg cards were stapled on to the undersurface of leaves, so that the eggs were facing ground. On rainy days, the Trichocards were inserted to disposable cups to avoid rains and kept in the fields using wooden sticks (Plate 14). Four sprays of NSKE (5.00%) were given at 14 days interval (Shioram, 2011). Twenty plants were selected and tagged for taking observations (Plate 15).

Observation on shoot and fruit infestation was recorded at weekly intervals after release. At weekly interval, the fruits from each plant were sorted into healthy and infested. The fruits were counted and weighed to calculate infestation and marketable yield. Constant monitoring of other insect pests was also done.

Plot released with *T. chilonis* – outside view

Plot released with *T. chilonis* – inside view

Plot released with *T. pretiosum* – outside view

Plot released with *T. pretiosum* – inside view

T_3 – NSKE (5.00%) treated plot

T_4 –Control plot

Plate 14. Clipping of Trichocards

Plate 15. Taking observations

$$\text{Shoot infestation (\%)} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

$$\text{Fruit infestation based on number (\%)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\text{Fruit infestation based on weight (\%)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

3.3 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

The data on per cent parasitism and adult emergence from laboratory evaluation were subjected to Analysis of Variance after arc sin transformation.

In field evaluation, data on per cent fruit infestation in terms of number and weight were subjected to arc sin transformation. The data on shoot infestation was subjected to square root transformation. The transformed data on infestation were subjected to Analysis of Variance using randomized block design.

Results

4. RESULTS

The results of the study on "Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp." carried out at College of Agriculture, Vellanikkara, Kerala Agricultural University during the period from 2020-2022 are presented in this chapter.

4.1 LABORATORY SCREENING OF DIFFERENT SPECIES OF *Trichogramma* AGAINST *L. orbonalis*

Efficacy of four different species of *Trichogramma viz*., *T. chilonis, T. pretiosum, T. evanescens* and *T. embryophagum* was evaluated in the laboratory (Plate 16). The results of the laboratory evaluation of rate of parasitism on the eggs of *L. orbonalis* and adult emergence of different species of *Trichogramma* are presented in Table 2.

4.1.1 Parasitism efficiency of *Trichogramma* spp. on the eggs of *L. orbonalis*

All the four species of *Trichogramma* used in the study resulted in the parasitism of eggs of *L. orbonalis*. Black discolouration of eggs was an indication of successful parasitism (Plate 17). Parasitism by different species of *Trichogramma* on the eggs of *L. orbonalis* varied significantly among different treatments. Mean parasitism by different species of *Trichogramma* ranged from 34.92 to 90.83 per cent with *T. pretiosum* resulting in significantly highest parasitism (90.83%). *Trichogramma chilonis* caused parasitism of 76.67 per cent followed by *T. embryophagum* (67.49%). *Trichogramma evanescens* resulted in significantly lowest parasitism of 34.92 per cent. *Trichogramma pretiosum* was the superior one among different species in terms of mean parasitism under laboratory condition. All the treatments were found to be significantly different to each other.

4.1.2 Adult emergence of *Trichogramma* spp. from the eggs of *L. orbonalis*

The presence of emergence holes on the parasitised eggs was indicative of the adult emergence (Plate 18). Adult emergence was significantly different among different treatments. The mean adult emergence varied between 36.08

and 82.84 per cent. Mean adult emergence averaged 82.84 and 81.77 per cent for *T. chilonis* and *T. pretiosum* respectively, and were on par with each other. *Trichogramma embryophagum* resulted in mean adult emergence of 71.36 per cent, and was on par with *T. chilonis* and *T. pretiosum*. The lowest mean adult emergence was observed in *T. evanescens* (36.08 %).

Table 2. Parasitism and adult emergence of *Trichogramma* spp. on the eggs of *Leucinodes orbonalis*

Treatments	Mean parasitism* (%)	Mean adult emergence* (%)
$T_{1:}$ *T. chilonis*	76.67±5.44 (61.23±10.38)[b]	82.84±6.39 (65.89±4.90)[a]
$T_{2:}$ *T. pretiosum*	90.83±3.19 (72.55±2.69)[a]	81.77±7.61 (65.27±5.98)[a]
$T_{3:}$ *T. evanescens*	34.92±6.91 (36.29±3.64)[d]	36.08±14.01 (36.54±8.52)[b]
$T_{4:}$ *T. embryophagum*	67.49±5.00 (55.29±2.66)[c]	71.36±10.04 (58.03±6.60)[a]
$T_{5:}$ Control	0.00±0.00 (0.64±0.64)[e]	0.00±00 (0.64±0.64)[c]
CD (P=0.05)	4.79	10.32

***** Mean of 16 observations

******Values in the parentheses are arc sin transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

4.2 EVALUATION OF FIELD EFFICACY OF SELECTED SPECIES OF *Trichogramma* AGAINST *L. orbonalis*

The laboratory study revealed that *T. pretiosum* and *T. chilonis* are the two promising species with higher parasitism and adult emergence. Hence, these two species were selected for evaluating their efficacy under field condition.

Plate 16a. ***Trichogramma chilonis***

Plate 16b. ***Trichogramma pretiosum***

Plate 16c. ***Trichogramma evanescens***

Plate 16d. ***Trichogramma embryophagum***

Plate 16. Microscopic view of *Trichogramma* adults

Plate 17a. Egg of *L. orbonalis* on 5th day - control

Plate 17b. Eggs of *L. orbonalis* on 5th day – parasitised by *Trichogramma*

Plate 17. Unparasitised and parasitised eggs of *Leucinodes orbonalis*

Plate 18. Emergence holes of *Trichogramma* spp.

4.2.1 Treatment effect on shoot infestation by *L. orbonalis* in field

The data on mean shoot infestation recorded at weekly interval are presented in the Table 3. A gradual reduction in the infestation of *L. orbonalis* was noticed in all plots during the experiment period. No significant difference was observed among the treatments during the first three weeks.

The level of infestation in the plot released with *T. chilonis* was 2.89 per cent which was comparable with 1.85 per cent in plot released with *T. pretiosum* prior to the release. The pre-treatment shoot infestation level was recorded as 3.14 and 2.93 per cent in the plot sprayed with NSKE and control respectively. At one week after the first release, the plot released with *T. pretiosum* recorded lower infestation of 1.13 per cent, followed by plots released with *T. chilonis* (2.21%). NSKE treated and control plots recorded a shoot infestation of 3.56 and 3.94 per cent respectively.

In the second week after receiving two releases, the lowest shoot infestations were recorded in the plot released with *T. pretiosum* (2.09%), followed by the plot treated with NSKE (2.13%). The plot released with *T. chilonis* and control plot recorded a mean infestation of 2.51 and 3.28 per cent respectively.

No significant difference was observed in shoot infestation during the third week. The shoot infestation ranged from 0.96 to 3.59 per cent, with release of *T. chilonis* resulted in low infestation (0.96%), followed by release of *T. pretiosum* (1.39%), NSKE (2.34%) and control plot (3.59%).

In the fourth week, the mean shoot infestation varied significantly among treatments. No shoot infestation was observed in plot released with *T. pretiosum*, which was on par with plot released with *T. chilonis* (0.67%). The mean infestation in NSKE applied plot was 2.27 per cent and was on par with control (4.38%).

In the fifth week, no significant difference in shoot infestation was observed among treatments. However, the mean shoot infestations ranged from

0.36 to 2.23 per cent, with lower infestation recorded in plot released with *T. pretiosum*. *Trichogramma chilonis* and NSKE applied plots recorded mean shoot infestation of 0.56 and 1.24 per cent respectively. Control plot recorded 2.23 per cent infestation.

Significant difference was observed among treatments at sixth week. Plot released with *T. chilonis* had no shoot infestation, which was followed by plot released with *T. pretiosum* with 0.31 per cent infestation. These treatments were on par with each other. The respective values of shoot infestation were 3.55 and 6.01 per cent for NSKE and control plots and both were on par with each other.

In the seventh week, significant difference was observed in shoot infestations due to treatment effects. No shoot infestation was recorded in the plot released with *Trichogramma* irrespective of species. The corresponding values were 1.44 and 2.17 per cent in NSKE and control plots respectively.

In eighth week, significant difference was recorded among different treatments in terms of shoot infestation. Like the previous week, same trend was observed in eighth week also. No shoot infestation was recorded in plots released with both species of *Trichogramma*. Control plots recorded significantly highest infestation of 2.21 per cent, followed by NSKE (1.45%), and they were on par with each other.

The data on cumulative mean shoot infestation and per cent reduction over control was enough to state the potential of *T. chilonis* and *T. pretiosum* in managing *L. orbonalis* (Table 4).

All the treatments were significantly different among each other in terms of cumulative mean shoot infestation. Among different treatments, *T. pretiosum* and *T. chilonis* recorded significantly lower mean shoot infestation with values of 0.53 and 0.79 per cent respectively, and being on par with each other. NSKE treated plots recorded shoot infestation of 2.14 per cent. Control plots recorded significantly highest infestation of 3.44 per cent.

The reduction in shoot infestation was 48.97 and 44.33 per cent respectively for plots released with *T. pretiosum* and *T. chilonis.* NSKE (5.00%) was able to reduce infestation by 18.04 per cent over control.

4.2.2 Treatment effect on fruit infestation by *L. orbonalis* in field

Effect of different treatments on fruit infestation by *L. orbonalis* based on number and weight of fruits is detailed hereunder.

4.2.2.1 Treatment effect on fruit infestation by *L. orbonalis* based on number of fruits

The results of fruit infestation by *L. orbonalis* at weekly interval based on number of fruits are illustrated in Table 5.

The first harvest was done before the first treatment application and none of the treatments differed significantly. A significant difference was observed among treatments from second to seventh week of harvest. Second harvest was done one week after the first release.

In the second harvest, a decline in fruit infestation was observed in plots except control. The least fruit infestation (36.53%) was recorded in plot released with *T. pretiosum*, which was on par with that of *T. chilonis* plot (37.36%) and NSKE treated plot (51.13%). Control plots recorded significantly highest infestation of 66.67 per cent.

During the third pick, fruit infestation recorded in the plot released with *T. chilonis* was 28.32 per cent, which did not vary significantly from the plot released with *T. pretiosum* (28.71%). In NSKE applied plot, 49.46 per cent infestation was recorded which was on par with control (58.09%).

During the fourth pick, least infestation was observed in plot released with *T. pretiosum* (27.22%), which was on par with *T. chilonis* (39.09%). The infestation observed in NSKE plot (39.44%), which was on par with control plot with fruit infestation of 69.36 per cent.

During the fifth harvest, *T. chilonis* treated plot recorded the lowest fruit infestation (41.81%), which was on par with *T. pretiosum* (44.40%) and NSKE (41.88%). The fruit infestation in untreated control was 59.86 per cent, which was significantly highest among the treatments.

In the sixth pick, fruit infestation increased in all the plots except in plot released with *T. pretiosum*. Least fruit infestation of 33.08 per cent was observed in plots released with *T. pretiosum*, which was on par with *T. chilonis* and NSKE treatment with values of 48.82 and 48.91 per cent respectively. Control plot recorded the highest infestation of 62.99 per cent.

During the seventh harvest, *T. pretiosum* recorded the lowest infestation of 22.66 per cent which was on par with *T. chilonis* with 32.79 per cent. The respective value for fruit infestation was 45.04 per cent in NSKE treatment. Untreated control recorded significantly higher infestation (67.92%).

The pest infestation increased in the eighth and nineth harvests and there observed no significant difference between the treatments. Towards the eighth week, no significant reduction in infestation over the previous week was noticed. However, during the eighth and nineth pick, lower fruit infestation was recorded in plots released with *T. pretiosum* with values of 51.78 and 50.83 per cent respectively.

When the cumulative mean fruit infestation was analysed, it was clear that significantly lower infestation was observed in plot released with *T. pretiosum* (38.35%), which was on par with plot released with *T. chilonis* (40.02%). NSKE also contributed to a lower infestation of 47.52 per cent compared to control plot (63.65%) (Table 5).

The per cent reduction in fruit infestation based on number was 27.90 and 25.96 respectively for *T. pretiosum* and *T. chilonis* released plots. By the foliar application of NSKE (5.00%), the infestation was decreased by 17.73 per cent (Table 6).

Table 3. Pre and post treatment per cent shoot infestation by *Leucinodes orbonalis* on brinjal

Treatments	Pre treatment shoot infestation (%)	Post treatment shoot infestation (%)								
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Cumulative mean*
T_1: *T. chilonis*	2.89 (1.53)	2.21 (1.35)	2.51 (1.47)	0.96 (1.05)	0.67 (0.89)^{bc}	0.56 (0.91)	0.00 (0.71)^{b}	0.00 (0.71)^{b}	0.00 (0.71)^{b}	0.79±0.84 (1.08±0.28)^{c}
T_2: *T. pretiosum*	1.85 (1.23)	1.13 (1.04)	2.09 (1.27)	1.39 (1.08)	0.00 (0.71)^{c}	0.36 (0.83)	0.31 (0.82)^{b}	0.00 (0.71)^{b}	0.00 (0.71)^{b}	0.53±0.44 (0.99±0.21)^{c}
T_3: NSKE 5%	3.14 (1.65)	3.56 (1.73)	2.13 (1.39)	2.34 (1.38)	2.27 (1.36)^{ab}	1.24 (1.11)	3.55 (1.82)^{a}	1.44 (1.19)^{ab}	1.45 (1.20)^{ab}	2.14±1.08 (1.59±0.26)^{b}
T_4: Control	2.93 (1.55)	3.94 (1.79)	3.28 (1.61)	3.59 (1.78)	4.38 (1.93)^{a}	2.23 (1.39)	6.01 (2.35)^{a}	2.17 (1.39)^{a}	2.21 (1.40)^{a}	3.44±1.72 (1.94±0.33)^{a}
CD (P=0.05)	NS	NS	NS	NS	0.63	NS	0.63	0.49	0.49	0.33

*Mean of 160 observations

**Values in the parentheses are square root transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 4. Treatment effect on cumulative mean shoot infestation by *Leucinodes orbonalis* on brinjal

Treatments	Cumulative mean shoot infestation* (%)	Per cent reduction over control
T_{1}: *T. chilonis*	0.79±0.84 (1.08±0.28)[c]	44.33
T_{2}: *T. pretiosum*	0.53±0.44 (0.99±0.21)[c]	48.97
T_{3}: NSKE 5%	2.14±1.08 (1.59±0.26)[b]	18.04
T_{4}: Control	3.44±1.72 (1.94±0.33)[a]	-
CD (P=0.05)	0.33	-

*Mean of 160 observations

**Values in the parentheses are square root transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 5. Fruit infestation by *Leucinodes orbonalis* on brinjal based on number of fruits

Treatments	Fruit infestation (%)									
	Picking 1	Picking 2	Picking 3	Picking 4	Picking 5	Picking 6	Picking 7	Picking 8	Picking 9	Cumulative mean*
$T_{1:}$ *T. chilonis*	71.99 (61.71)	37.36 (37.40)[b]	28.32 (30.74)[b]	39.09 (38.54)[b]	41.81 (39.51)[b]	48.82 (45.57)[ab]	32.79 (32.35)[bc]	52.22 (47.57)	51.53 (45.92)	40.02±13.08 (39.22±9.40)[c]
$T_{2:}$ *T. pretiosum*	62.42 (53.62)	36.53 (35.67)[b]	28.71 (28.62)[b]	27.22 (28.93)[b]	44.40 (41.74)[b]	33.08 (32.43)[b]	22.66 (23.82)[c]	51.78 (48.55)	50.83 (44.20)	38.35±13.36 (38.19±10.08)[c]
$T_{3:}$ NSKE 5%	65.73 (58.67)	51.13 (47.05)[ab]	49.46 (44.67)[a]	39.44 (38.77)[b]	41.88 (39.52)[b]	48.91 (44.38)[ab]	45.04 (42.03)[b]	53.47 (47.06)	61.11 (54.05)	47.52±8.54 (43.58±6.53)[b]
$T_{4:}$ Control	72.64 (62.18)	66.67 (58.70)[a]	58.09 (52.29)[a]	69.36 (57.96)[a]	59.86 (52.09)[a]	62.99 (54.21)[a]	67.92 (58.13)[a]	57.64 (50.78)	60.28 (53.57)	63.65±5.43 (52.97±3.83)[a]
CD (P=0.05)	NS	13.43	13.59	15.10	9.96	15.04	15.38	NS	NS	2.99

* Mean of 160 observations

** Values in the parentheses are arc sin transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 6. Treatment effect on cumulative mean fruit infestation by *Leucinodes orbonalis* on brinjal based on number of fruits

Treatments	Cumulative mean fruit infestation* (%)	Per cent reduction over control
T_1: *T. chilonis*	40.02±13.08 (39.22±9.40)[c]	25.96
T_2: *T. pretiosum*	38.35±13.36 (38.19±10.08)[c]	27.90
T_3: NSKE 5%	47.52±8.54 (43.58±6.53)[b]	17.73
T_4: Control	63.65±5.43 (52.97±3.83)[a]	-
CD (P=0.05)	2.99	-

* Mean of 160 observations

**Values in the parentheses are arc sin transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

4.2.2.2 Effect of different treatments on fruit infestation by *L. orbonalis* based on weight of fruits

The results of fruit infestation based on weight of fruits are illustrated in Table 7. No significant difference was observed between the treatments in the pre-release period. Treatments were found to be significantly different from second to seventh harvests.

During the second harvest, significantly lowest infestation was observed in plots released with *T. pretiosum* (35.88%), followed by *T. chilonis* (41.16%), both being on par with each other. The infestation recorded in the NSKE treated plot (54.44%) was significantly higher than parasitoid released plot. Control plot recorded the highest infestation of 61.72 per cent, which was on par with NSKE plot.

In the third harvest, plot released with *T. pretiosum* recorded significantly lower infestation of 21.11 per cent, which was on par with *T. chilonis* (28.15%). Control plot recorded significantly higher infestation with value of 65.23 per cent, which was on par with NSKE plot (50.72%).

In the fourth harvest, the infestation was 26.09, 33.89 and 37.37 per cent respectively for *T. pretiosum*, *T. chilonis* and NSKE plots. Significantly higher infestation of 69.72 per cent was recorded in control plots. All the treatments were superior over control.

In the fifth harvest, significantly lowest infestation of 38.07 per cent was recorded in plot released with *T. pretiosum*, which was on par with *T. chilonis* (40.49%) and NSKE (41.31%). All the treatments were statistically superior over control (65.16%) in reducing the fruit infestation.

A significant difference was observed among treatments during the sixth pick. The mean values of fruit infestation ranged from 36.08 to 67.17 per cent. The plot released with *T. pretiosum* recorded 36.08 per cent fruit infestation followed by *T. chilonis* (38.51%) and NSKE (39.70%), and were on par with each other. Control plot recorded significantly highest infestation of 67.17 per cent.

In the seventh harvest, the fruit infestation in all the treated plots were on par with each other. Plot released with *T. pretiosum* recorded 22.86 per cent infestation followed by *T. chilonis* (32.84%) and NSKE plots (40.24%). All the treatments were on par with each other and control recorded the highest fruit infestation (67.17%).

No significant difference was observed among treatments during eighth and nineth picks. However, in the eighth harvest, the mean values of infestation ranged from 49.99 to 54.52 per cent. The plot released with *T. pretiosum* recorded a lower value of infestation (49.99%). In nineth pick, the mean value of infestation ranged from 56.23 to 58.87 per cent. The same trend was observed in nineth week also. Plot released with *T. pretiosum* recorded lower value of infestation (56.23%).

The results on cumulative mean fruit infestation on weight basis also revealed the potential of trichogrammatids. In the plot released with *T. pretiosum*, the mean infestation was 34.76 per cent which was comparable with the infestation (37.74%) in plots released with *T. chilonis*. Control plot recorded significantly higher infestation (64.85%), followed by NSKE plot (44.50%). Both the treatments were significantly different to each other (Table 7).

The per cent reduction over control was more pronounced in plots released with trichogrammatids and was 33.11 and 29.56 respectively for *T. pretiosum* and *T. chilonis*. NSKE treated plots caused 22.23 per cent reduction over control (Table 8).

4.2.3 Marketable yield

The weight of marketable fruits obtained during the experiment is presented in Table 9. The highest marketable yield of 1178.06 g plant^{-1} was obtained in plots released with *T. pretiosum*, which was on par with the yield obtained from plots released with *T. chilonis* (1078.41 g plant^{-1}). NSKE (5.00%) gave marketable yield of 739.01 g plant^{-1}. Control plot recorded significantly lower marketable yield of 526.16 g plant^{-1}.

4.2.4 Different insect pests observed during the field study

The list of other insect pests and their damage symptoms observed (Plate 19) during the field study are given in Table 10. The caterpillars of brinjal stem borer, *Euzophera perticella* were found tunnelling and feeding within the plant stem. This resulted in sudden wilting and drying up of plants. The leaf roller, *Antoba olivacea* were found feeding inside the leaf folds. As a result of continuous desapping by the nymphs and adults of *Amrasca biguttula biguttula*, hopper burn symptom was observed in the field. The grubs of epilachna beetle, *Henosepilachna vigintioctopunctata* scraped off the entire leaf lamina turning leaves into papery structures, which dried later. The feeding of leaves by the adults of ash weevil, *Myllocerus discolor,* resulted in notching of leaf margins.

Table 7. Fruit infestation by *Leucinodes orbonalis* on brinjal based on weight of fruits

Treatments	Fruit infestation based on weight (%)									
	Picking 1	Picking 2	Picking 3	Picking 4	Picking 5	Picking 6	Picking 7	Picking 8	Picking 9	Cumulative mean*
$T_{1:}$ (*T. chilonis*)	65.00 (57.71)	41.16 (39.70)^{bc}	28.15 (30.37)^{b}	33.89 (34.12)^{b}	40.49 (38.18)^{b}	38.51 (39.14)^{b}	32.84 (32.16)^{b}	50.45 (47.04)	56.61 (48.90)	37.74±9.39 (37.87±6.64)^{bc}
$T_{2:}$ (*T. pretiosum*)	67.64 (56.80)	35.88 (35.19)^{c}	21.11 (23.18)^{b}	26.09 (29.39)^{b}	38.07 (37.95)^{b}	36.08 (34.27)^{b}	22.86 (23.76)^{b}	49.99 (47.55)	56.23 (51.01)	34.76±12.54 (35.96±10.14)^{c}
$T_{3:}$ (NSKE 5%)	65.77 (58.29)	54.44 (48.93)^{ab}	50.72 (47.90)^{a}	37.37 (36.88)^{b}	41.31 (38.50)^{b}	39.70 (38.75)^{b}	40.24 (38.92)^{b}	51.28 (45.74)	58.22 (52.35)	44.50±7.9 (41.81±5.91)^{b}
$T_{4:}$ (Control)	69.99 (60.53)	61.72 (55.79)^{a}	65.23 (56.60)^{a}	69.72 (58.36)^{a}	65.16 (55.35)^{a}	67.17 (56.98)^{a}	67.17 (56.98)^{a}	54.52 (48.85)	58.87 (52.69)	64.85±5.02 (53.76±3.05)^{a}
CD (P=0.05)	NS	12.72	15.08	13.21	10.80	15.74	16.39	NS	NS	4.103

*Mean of 160 observations

**Values in the parentheses are arc sin transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 8. Treatment effect on cumulative mean fruit infestation by *Leucinodes orbonalis* on brinjal based on weight of fruits

Treatments	Cumulative mean fruit infestation* (%)	Per cent reduction over control
$T_{1:}$ (*T. chilonis*)	37.74±9.39 (37.87±6.64)^{bc}	29.56
$T_{2:}$ (*T. pretiosum*)	34.76±12.54 (35.96±10.14)^{c}	33.11
$T_{3:}$ (NSKE 5%)	44.50±7.9 (41.81±5.91)^{b}	22.23
$T_{4:}$ (Control)	64.85±5.02 (53.763.05)^{a}	-
CD (P=0.05)	4.10	-

*Mean of 160 observations

**Values in the parentheses are arc sin transformed. In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 9. Treatment effect on marketable yield of brinjal

Treatments	Marketable yield* (g $plant^{-1}$)
$T_{1:}$ (*T. chilonis*)	1078.41±344.44[a]
$T_{2:}$ (*T. pretiosum*)	1178.06±249.87[a]
$T_{3:}$ (NSKE 5%)	739.01±235.29[b]
$T_{4:}$ (Control)	526.16±186.37[b]
CD (P=0.05)	221.34

* Mean of 160 observations

**In a column, mean followed by a common alphabet do not differ significantly by DMRT (P = 0.05)

Table 10. List of other insect pests observed during the field study

Common name	Scientific name	Order	Family
Stem borer	*Euzophera perticella* (Ragonot)	Lepidoptera	Pyralidae
Leaf roller	*Antoba olivacea* (Walker)	Lepidoptera	Erebidae
Leaf hopper	*Amrasca biguttula biguttula* (Ishida)	Hemiptera	Cicadellidae
Epilachna beetle	*Henosepilachna vigintioctopunctata* (Fabricius)	Coleoptera	Coccinellidae
Ash weevil	*Myllocerus discolor* (Schoenherr)	Coleoptera	Curculionidae

Plate 19a. Shoot damage by brinjal shoot and fruit borer

Plate 19b. Fruit damage by brinjal shoot and fruit borer

Plate 19c. Damage by epilachna beetle

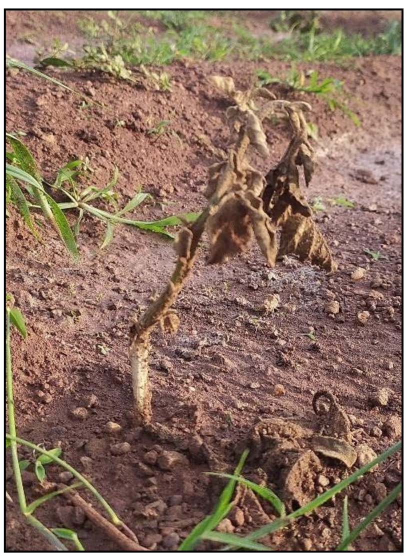
Plate 19d. Damage by leaf hoppers

Plate 19. Different pests and symptoms observed in the field

Contd…

Plate 19e. Damage by ash weevil

Plate 19f. Damage by leaf roller



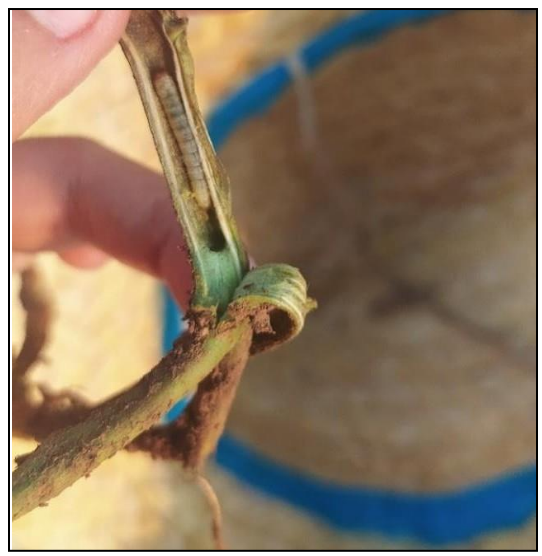


Plate 19g. Damage by brinjal stem borer

Plate 19. Different pests and symptoms observed in the field

Discussion

5. DISCUSSION

A study was conducted at College of Agriculture, Vellanikkara, Kerala Agricultural University to find out the promising species of *Trichogramma* against the brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee). The discussion on the results obtained in the study is detailed hereunder.

5.1 LABORATORY SCREENING OF DIFFERENT SPECIES OF *Trichogramma* AGAINST *L. orbonalis*

Efficacy of four different species of *Trichogramma viz*., *T. chilonis*, *T. pretiosum*, *T. evanescens* and *T. embryophagum* were evaluated in the laboratory. The mean per cent parasitism and adult emergence of *Trichogramma* spp. indicated the efficacy of promising species against *L. orbonalis.*

5.1.1 Parasitism efficiency of *Trichogramma* spp. on the eggs of *L. orbonalis*

All the four species of *Trichogramma* used in the study resulted in the parasitism of eggs of *L. orbonalis* at different rates (Fig. 1). *T. pretiosum* caused 90.83 per cent parasitism, which was significantly superior over other three species.

The finding on supremacy of *T. pretiosum* in parasitising the eggs of *L. orbonalis* in the present study is in close agreement with Niranjana and Sridhar (2014), who reported a mean parasitism of 91.99 per cent on the eggs of *L. orbonalis* during kharif season (25 ± 2°C).

The results were also in confirmation with the findings of Ranjith *et al.* (2018). They reported 90.00 per cent parasitism of *T. pretiosum* on one day old eggs of *L. orbonalis* at 25 ± 2°C. Funde (2018) evaluated the parasitism efficiency of *T. pretiosum* and *T. chilonis* on one day old eggs of *L. orbonalis* in Maharashtra and the results were in line with the findings of present study. *Trichogramma pretiosum* recorded highest parasitism (78.33%) and proved effective than *T. chilonis* (15.53%) in causing mortality of eggs.

In the present study, *T. chilonis* could parasitise 76.67 per cent eggs. Similar parasitism value (76.21%) was recorded by Vigneswaran *et al*. (2017) on *Corcyra cephalonica*. Choudhury *et al*. (2016) reported a parasitism of 85.50 and 93.80 per cent respectively on the eggs of *Sitotroga cerealella* and *C. cephalonica* by *T. chilonis*. Similarly, a parasitism of 65.56 per cent on eggs of *L. orbonalis* by *T. chilonis* has been recorded by Ranjith *et al.* (2018).

The results of the present study were found to be in contradiction with the findings of Niranjana *et al.* (2018), who reported the inefficacy of *T. chilonis* in parasitizing the eggs of *L. orbonalis.*

Trichogramma embryophagum could parasitise 67.49 per cent eggs of *L. orbonalis* in the present study. Nevertheless, according to Niranjana *et al.* (2018) *T. embryophagum* had the highest parasitism ability (90.02%) on eggs of *L. orbonalis*. Jalali *et al*. (2002) also reported 88.00 per cent parasitism on the eggs of *Opisina arenosella*, which is not in confirmation with the present results. More comparisons could not be done due to the want of literature.

Trichogramma evanescens resulted in 34.92 per cent parasitism of eggs in the present study. The conclusion of research findings of Choudhury *et al.* (2016) stood in agreement with present results. They conducted a micro-plot technique and reported a low parasitism rate of 38.83 per cent on eggs of *L. orbonalis* by *T. evanescens.* Niranjana *et al.* (2018) arrived at a conclusion that was totally in disagreement with the result of the present study. They stated that *T. evanescens* completely failed in parasitizing eggs of *L. orbonalis.* Due to the want of previous reports on the potential of *T. evanescens,* further comparisons could not be undertaken.

5.1.2 Adult emergence of *Trichogramma* spp. from the eggs of *L. orbonalis*

When the rate of adult emergence was compared, *T. chilonis* and *T. pretiosum* were found to be the promising species (Fig. 2). The rate of adult

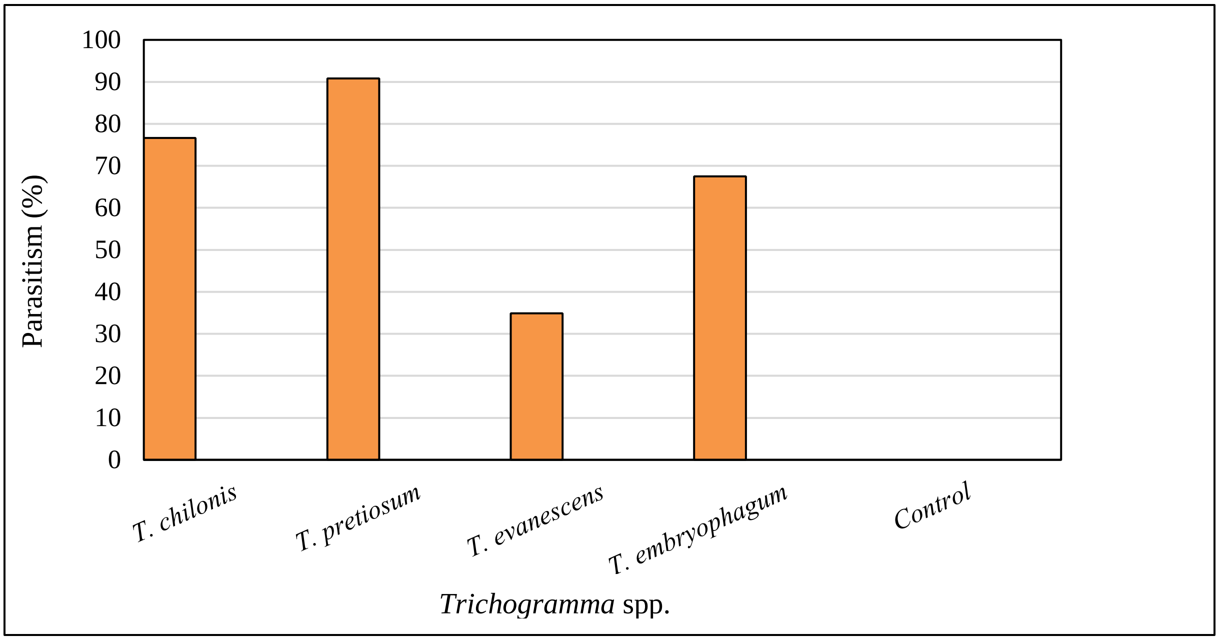


Fig. 1. Parasitism efficiency of *Trichogramma* spp. on the eggs of *Leucinodes orbonalis*

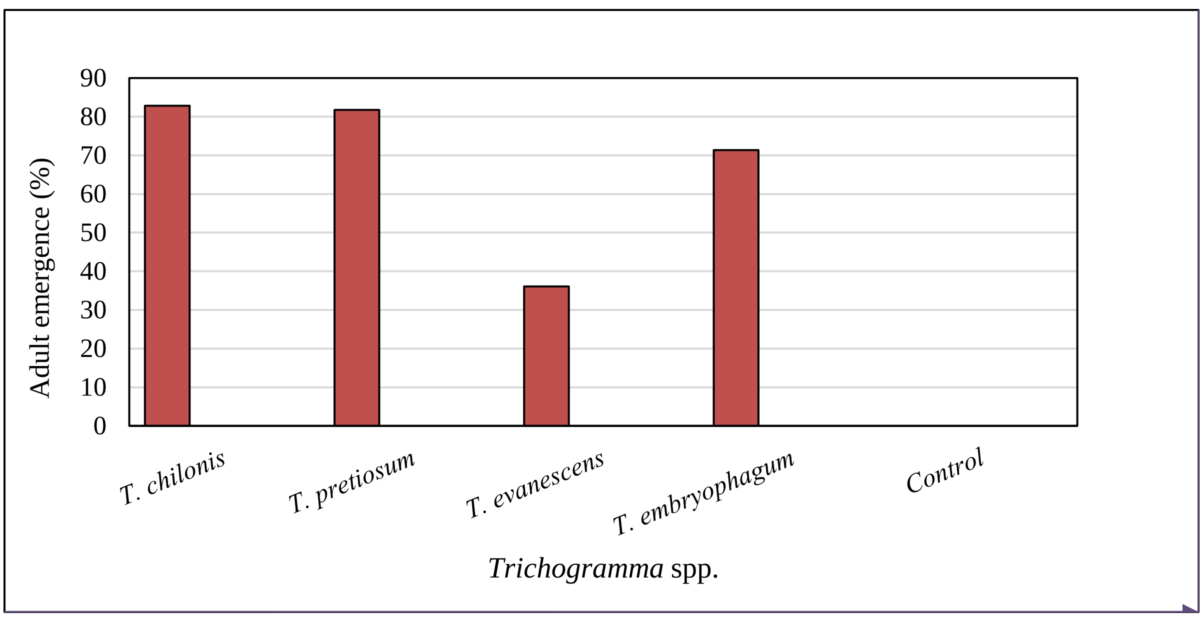


Fig. 2. Adult emergence of *Trichogramma* spp. from the eggs of *Leucinodes orbonalis*

emergence in *T. chilonis* was 82.84 per cent and was on par with *T. pretiosum* (81.77%). The present study was in conformity with the findings of Ranjith *et al*. (2018) who reported 81.37 per cent adult emergence of *T. chilonis* from the eggs of *L. orbonalis*. Funde (2018) also arrived at a similar result of 78.33 per cent adult emergence. Nonetheless, Niranjana *et al.* (2018) reported no emergence of *T. chilonis* adults since it failed to parasitise the eggs. Uma (2018) reported 90.00 per cent adult emergence of *T. chilonis* from the eggs of *C. cephalonica* which is comparable with results of the present study.

In the present study, *T. pretiosum* recorded 81.77 per cent adult emergence and Ranjith *et al*. (2018) arrived at a comparable result. It was reported that 91.03 per cent of adults emerged from the eggs of *L. orbonalis* when subjected to oviposition by the parasitoid. Niranjana *et al.* (2018) reported 87.89 and 82.11 per cent adult emergence in rabi and kharif season when *L. orbonalis* eggs were exposed to *T. pretiosum*, which is in line with the results of present study. Funde (2018) also reported 89.30 per cent adult emergence which validates the findings of present study.

The rate of adult emergence of *T. embryophagum* observed in the present study was 71.36 per cent. Niranjana *et al.* (2018) reported 76.14 and 77.81 per cent adult emergence from two day old eggs of *L. orbonalis* during kharif (30.6±1.3°C) and rabi (29.7±0.8°C), which is comparable with the findings of present study.

In the present study only 36.08 per cent adults of *T. evanescens* emerged from the parasitized eggs of *L. orbonalis*. Ayvaz *et al*. (2008) recorded 81.25 to 90.67 per cent adult emergence of *T. evanescens* at a temperature range of 24 to 33°C which is not in agreement with findings of the present study.

5.2 EVALUATION OF FIELD EFFICACY OF SELECTED SPECIES OF *Trichogramma* AGAINST *L. orbonalis*

The performance of the promising species was evaluated against *L. orbonalis* under field condition. *Trichogramma chilonis* and *T. pretiosum* were compared along with botanical pesticide, neem seed kernel extract (5.00%). An untreated plot was also maintained in the field.

5.2.1 Effect of different treatments on shoot infestation by *L. orbonalis*

The shoot infestation was less compared to the fruit infestation in all the treatments as reported by Biswas (2019). The shoot infestation was found to be decreased over the weeks in all plots during the experiment period as reported by Singh (2017) (Fig. 3). In the plots released with parasitoid, there was gradual reduction in shoot infestation. In the sixth week, no infestation was observed in plots released with *T. chilonis*. During seventh and eighth weeks, no infestation was observed in both the *Trichogramma* released plots. No definite dynamics were observed in the NSKE treated and untreated control plots. In the parasitoid released plots, shoot infestation was less than that in control at every week of observation. Nevertheless, no significant difference was visible except at fourth, sixth, seventh and eighth week.

The reduction in shoot infestation could also be attributed to the fact that shoot infestation diminishes as the crop starts to bear fruits. Kaur *et al*. (2014) reported that the caterpillars of brinjal shoot and fruit borer infested brinjal shoots initially, moved to fruits once fruits are developed, and shoot infestation diminished over time.

When cumulative shoot infestation is taken into consideration, least infestation was observed in plot released with *T. pretiosum* (0.53%), followed by *T. chilonis* (0.79%), both being on par with each other. Both the species of *Trichogramma* showed a consistent superior performance over NSKE treated and

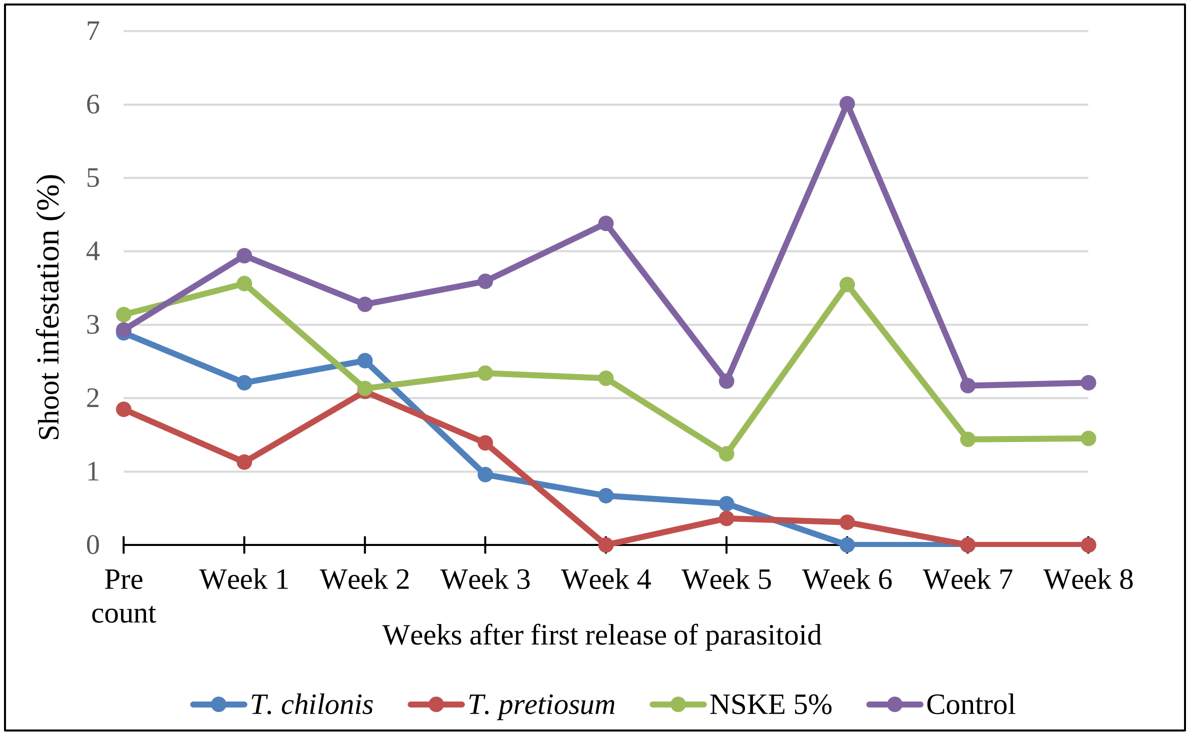


Fig. 3. Trend of effect of treatments on shoot infestation by *Leucinodes orbonalis* on brinjal

control plots (Fig. 6). Plots released with *T. pretiosum* and *T. chilonis* resulted in highest value for per cent reduction of infestation at 48.97 and 44.33 per cent respectively. Among the two species of *Trichogramma*, *T. pretiosum* showed a consistent supreme effect on shoot infestation by *L. orbonalis* except at third week.

5.2.2 Effect of different treatments on fruit infestation by *L.orbonalis*

Effect of different treatments on fruit infestation based on number and weight of fruits was compared to find out the efficient one. Both the species of *Trichogramma viz.*, *T. pretiosum* and *T. chilonis* were found to be equally effective against *L. orbonalis* on the basis of fruit infestation (Fig 6).

5.2.2.1 Effect of different treatments on fruit infestation by *L. orbonalis* based on number of fruits

A steep decline in fruit infestation was observed in parasitoid released plots compared to control plots after the first release (Fig. 4). The reduction in fruit infestation was remarkable in the plots released with trichogrammatids compared to NSKE and control. The same trend was observed during third and fourth harvests. *Trichogramma chilonis* and *T. pretiosum* recorded significantly lower fruit infestation on weight and number basis with values of 28.32 and 39.09 per cent, and 28.71 and 27.22 per cent respectively for third and fourth weeks. During this period, NSKE did not have significant influence on fruit infestation and was on par with control.

During fifth harvest, in contrast to the trend in previous harvest, NSKE also showed remarkable influence on borer infestation along with Trichogrammatids. During sixth and seventh harvests, *T. pretiosum* recorded lower fruit infestation with values of 33.08 and 22.66 per cent respectively, and was on par with *T. chilonis* (48.82%, 32.79%) and NSKE (48.91%, 45.04%). Release of Trichogrammatids resulted in a consistent reduction of fruit infestation throughout the study period except for eighth and nineth weeks. No significant difference was observed among different treatments at eighth and nineth weeks. These weeks where increased infestation was experienced coincided with rains (Appendix I). Heavy rains might have affected the efficiency of parasitoids to curb the pest population. However, *T. pretiosum* released plot recorded lower infestation of 51.78 and 50.83 per cent respectively at eighth and nineth harvests.

The mean cumulative fruit infestation was low in plot released with *T. pretiosum* (38.35%) compared to *T. chilonis* (40.02%) (Fig. 6). But no significant difference was evident between two species of Trichogrammatids. Both the species released @ 1,00,000 no. ha^{-1} showed performance superior to NSKE (5.00%). In addition, Trichogrammatids resulted in more than 25 per cent reduction in pest infestation. By analyzing the results, it is inferred that *T. pretiosum* and *T. chilonis* were equally effective against *L. orbonalis* (Fig. 6).

5.2.2.2 Effect of different treatments on fruit infestation by *L. orbonalis* based on weight of fruits

The result on fruit infestation on weight basis also followed a deflective pattern (Fig. 5). The infestation decreased in the second harvest in all the plots. The infestation was low in the parasitoid released plots and NSKE treated plots compared to control plots at all weeks of observation throughout the release period. During the second harvest, significantly low infestation was recorded in *Trichogramma* released plots and both being on par. *Trichogramma pretiosum* and *T. chilonis* recorded 35.88 and 41.16 per cent infestation respectively at second week. NSKE and control plots were also on par with each other. The same trend was observed in third week also. *Trichogramma pretiosum* and *T. chilonis* recorded 21.11 and 28.15 per cent infestation respectively at third week. Both the species of *Trichogramma* resulted in a sustained reduction in pest infestation. During fourth, fifth, sixth and seventh week, the effect of Trichogrammatids in reducing fruit infestation was on par with NSKE (5.00%). The maximum temperature recorded during the week prior to fourth harvest was 37.2°C, which might have affected the

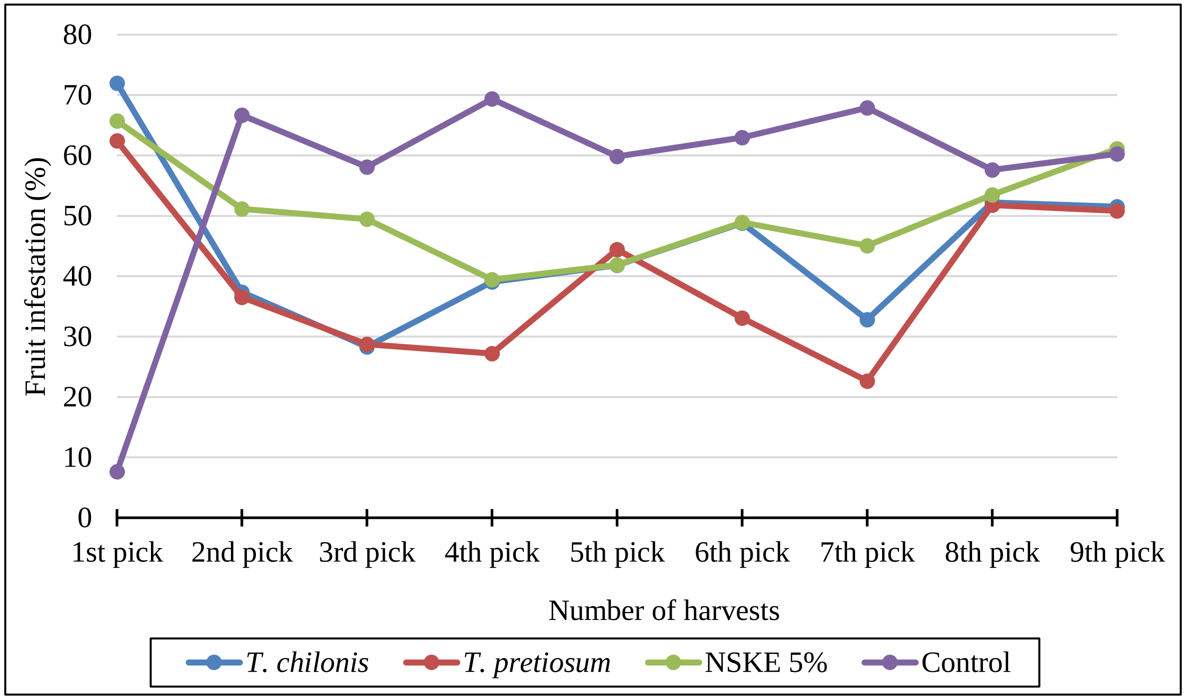


Fig. 4. Trend of effect of treatments on fruit infestation by *Leucinodes orbonalis* based on number of fruits

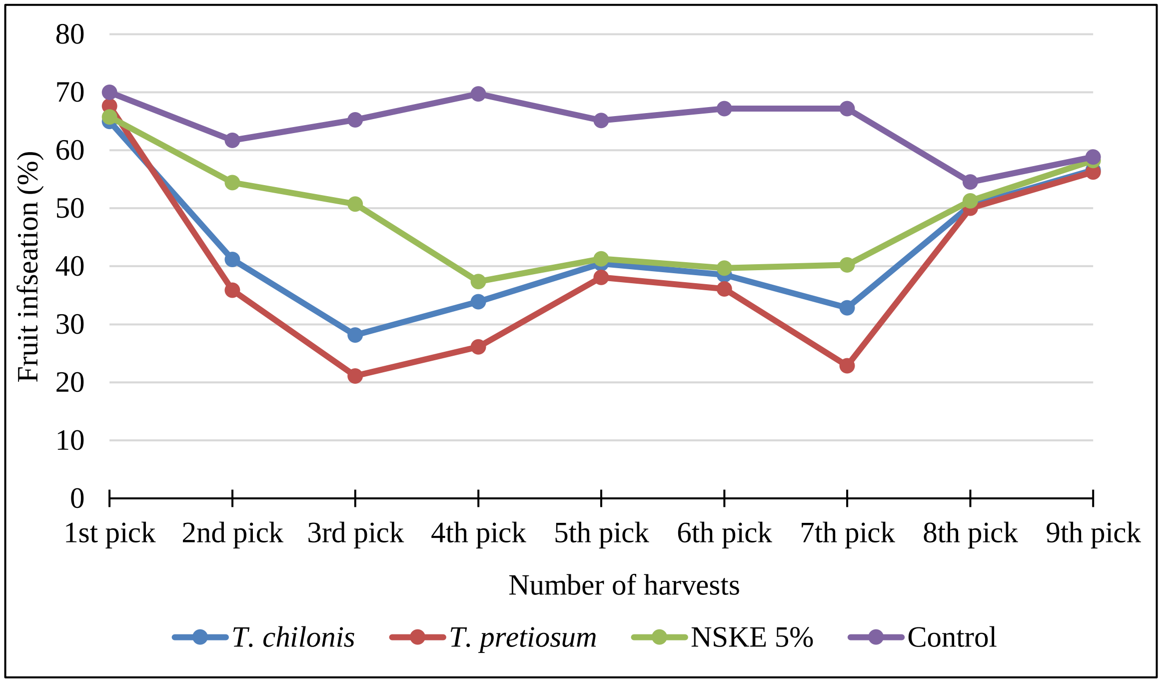


Fig. 5. Trend of effect of treatments on fruit infestation by *Leucinodes orbonalis* based on weight of fruits

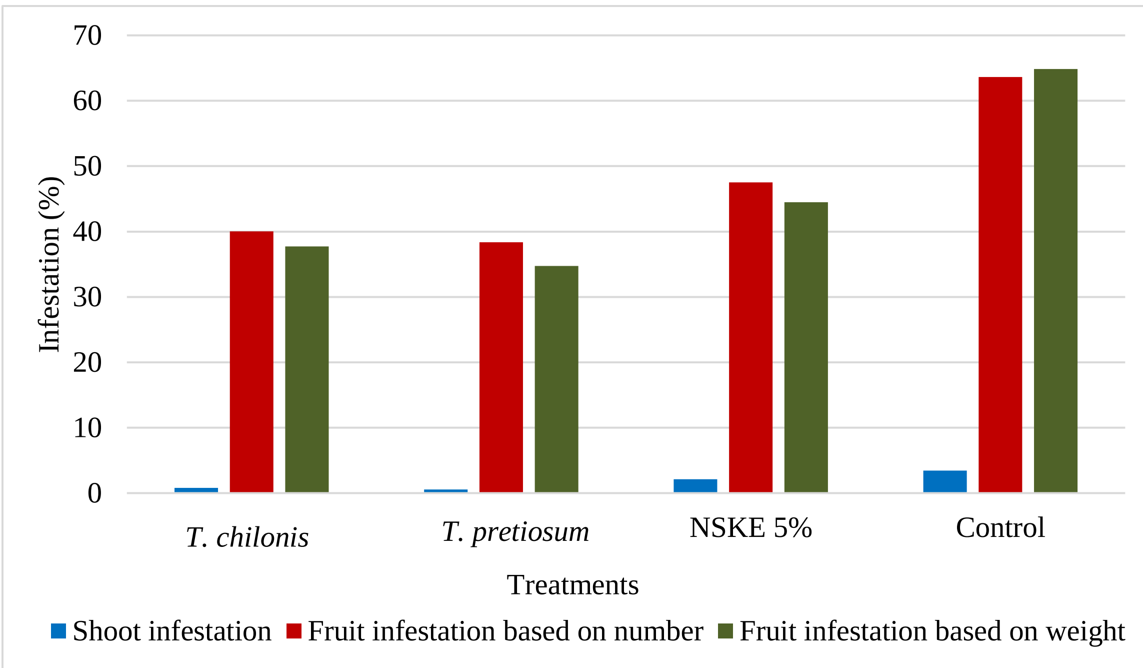


Fig. 6. Effect of different treatments on cumulative infestation on brinjal by *Leucinodes orbonalis*

performance of trichogrammatids. A sudden increase in fruit infestation observed in the fourth pick might be due to the reduction in emergence of parasitoids as influenced by temperature. The report of Lopez and Morrison (1980) on the negative impact of temperature greater than 37^{o}C on the adult emergence of *T. pretiosum* supports the finding with increased infestation level during high temperature. Chihrane and Lauge (1996) also opined the reduction of parasitisation efficacy of *T. brassicae* when exposed to high temperatures. The pre adult stage of parasitoid was found to be highly susceptible to high temperature leading to failure in adult emergence.

All the treatments resulted in significant reduction in fruit infestation by *L. orbonalis*. No significant difference was observed among treatments during eighth and nineth harvest. However, lower values were recorded in *T. pretiosum* plots with 49.99 and 56.23 per cent fruit infestation respectively.

With regard to the mean fruit infestation based on weight, both the species were found to be equally effective (Fig. 6). Plot released with *T. pretiosum* resulted in infestation of 34.76 per cent, which was on par with *T. chilonis* released plot (37.74%). The per cent reduction in fruit infestation was high in plot released with *T. pretiosum* (33.11%) followed by *T. chilonis* released plot (29.56%). These findings clearly indicate the potential of *T. pretiosum* and *T. chilonis* against brinjal shoot and fruit borer, *L. orbonalis*.

The findings on effect of Trichogrammatids in reducing fruit infestation by *L. orbonalis* was in agreement with the results of Niranjana *et al*. (2019), who evaluated *T. pretiosum* @ 1,00,000 eggs acre^{-1} starting from 15 DAT at 20 days interval as part of a Bio Intensive Integrated Pest Management (BIPM) practice. They reported the field efficacy of *T. pretiosum* in reducing the infestation of shoot and fruit borer and suitability for incorporating in integrated pest management of *L. orbonalis*. In the BIPM plot, 64.01 and 80.58 per cent reduction in shoot and fruit infestation was observed.

The potential of *T. pretiosum* in reducing the infestation by *L. orbonalis* corroborates with Ranjith *et al.* (2019), wherein release of *T. pretiosum* @ 1.25 lakh per ha on weekly interval for about 12 weeks resulted in 53.76 per cent reduction in shoot infestation by *L. orbonalis*. As our present study, a steady decrease in shoot damage was documented on exposure to *T. pretiosum* and recorded a mean shoot infestation of 0.26 per cent. They reported 53.76 and 38.91 per cent reduction in shoot and fruit infestation over control by the action of *T. pretiosum.*

The efficacy of *T. chilonis* in controlling the *L. orbonalis* under field condition is supported by several research works. Biswas (2019) conducted a two year field study and reported the potential of *T. chilonis* in suppressing the infestation by brinjal shoot and fruit borer in the field as our present study. They reported that release of *T. chilonis* ten times @ 1 lakh no. ha^{-1} at an interval of ten days resulted in significant reduction of shoot infestation over the weeks. The reduction in shoot and fruit infestation was reported to be 36.52 and 34.53 per cent and 75.58 and 77.68 per cent respectively in first and second year in plots released with *T. chilonis*.

The results of the study conducted by Reddy (2012) also supported the potential of *T. chilonis* in reducing the pest infestation. The reduction in shoot infestation was 42.28 and 40.34 per cent at seven and fourteen days after release respectively when the parasitoid released @ 1 lakh no. ha^{-1}. The mean fruit infestation on weight basis was 21.63 per cent and reduction over control was 27.66 per cent. On number basis, the mean fruit infestation was 21.19 per cent and reduction over control was 27.61 per cent.

The study conducted by Singh (2017) confirmed the efficacy of *T. chilonis* in suppressing the infestation of brinjal shoot and fruit borer in the field. Owing to the release of the parasitoid @ 1 lakh no ha^{-1}, the shoot infestation reduced to 15.10 per cent from 16.34 per cent. The fruit infestation based on number as well as weight also recorded a pronounced reduction over the weeks.

5.2.3 Effect of treatments on marketable yield of brinjal

The marketable yield per plant was higher and comparable in plot released with *T. pretiosum* and *T. chilonis*. Both *T. pretiosum* and *T. chilonis* were the superior treatments over NSKE and control in terms of marketable yield. The present study was validated by the findings of Reddy (2012) who reported a significant increase in yield brinjal in the *Trichogramma* released fields compared to the control. The marketable yield from plot released with *Trichogramma* @ 1.50 lakh eggs per ha averaged 16.7 t ha^{-1} which was significantly superior over control (9.36 t ha^{-1}).

Singh (2017) also reported increase in marketable yield, which averaged 15.9 tonnes ha^{-1} over the control when *Trichogramma* sp. was released @ 1 lakh no. ha^{-1} at 10 days interval for eight times in brinjal. The results confirmed the findings of present study.

Though the results of laboratory evaluation were in favour of *T. pretiosum,* field study proved the efficacy of both *T. pretiosum* and *T. chilonis* in the management of brinjal shoot and fruit borer, *L. orbonalis.* So, the present study confirmed the significant role of *T. pretiosum* and *T. chilonis* in suppressing the population of *L. orbonalis* under Kerala condition.

Summary

6. SUMMARY

Brinjal, *Solanum melongena* L. is one of the popular and affordable vegetables grown in India. The major yield loss of the crop is attributed to the infestation of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee). Since the pest is an internal borer, farmers opt for prophylactic insecticidal application to combat the severe yield loss. It is high time to adopt safe, eco-friendly and sustainable alternative for the management of brinjal shoot and fruit borer. So, the study entitled "Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp." was carried out at Department of Agriculture, College of Agriculture, Vellanikkara during 2020-2022 period. The objective of the study was to identify the most effective species of *Trichogramma* for the management of brinjal shoot and fruit borer, *L. orbonalis.* The salient findings of the present study are summarized below.

The efficacy of *Trichogramma chilonis*, *T. pretiosum*, *T. evanescens,* and *T. embryophagum* was evaluated out on one day old eggs of *L. orbonalis* in the laboratory. Maximum number of eggs parasitized and adults emerged was observed with *T. pretiosum* and *T. chilonis*. The significantly highest parasitism was recorded in *T. pretiosum* (90.83%) followed by *T. chilonis* (76.67%). Both *T. pretiosum* and *T. chilonis* were found to be the most performing species with 81.77 and 82.84 per cent adult emergence respectively and both being on par.

The parasitism potential of the two selected species, *T. pretiosum* and *T. chilonis* were evaluated in the field against *L. orbonalis* along with neem seed kernel extract (NSKE) 5.00 per cent. The parasitoid release was carried out @1,00,000 numbers per hectare at weekly interval for eight weeks. NSKE (5.00%) was applied in the field at fortnightly interval. There was a gradual reduction in shoot infestation. The shoot infestation in both plots released with *T. pretiosum* and *T. chilonis* were less compared to other treatments in all the weeks. However, significant difference was observed between the treatments only at fourth, sixth, seventh and eighth weeks.

Plot released with *T. pretiosum* had the least shoot infestation (0.53%), which was on par with *T. chilonis* (0.79%). The per cent reduction in infestation over control supported the more effective nature of *T. pretiosum* in suppressing the pest infestation over *T. chilonis.* The per cent reduction in infestation over control was 48.97 and 44.33 with *T. pretiosum* and *T. chilonis.*

The fruit infestation based on number experienced a reduction in the treatment applications on comparison with untreated control. The performance of parasitoids varied according to the weather conditions. In the mean infestation, the lowest value was recorded in plot released with *T. pretiosum* (38.35 %), which was comparable with plot released with *T. chilonis* (40.02 %). The release of parasitoids was found to be superior treatments over NSKE (5.00%) application. Both *T. pretiosum* and *T. chilonis* were found to be successful in lowering the infestation level by 27.90 and 25.96 per cent respectively over the control.

Under congenial weather conditions, the performance of *T. pretiosum* and *T. chilonis* was superior over control. In the mean fruit infestation based on weight, plot released with *T. pretiosum* had lowest infestation of 34.76 per cent, which was on par with plot released with *T. chilonis* (37.74 %). The mean infestation recorded in NSKE was 44.50 per cent that was comparable with *T. chilonis*. From the values of per cent reduction in infestation over control, it was concluded that both *T. pretiosum* and *T. chilonis* had the potential in minimizing the infestation to the tune of 33.11 and 29.56 per cent over controlrespectively.

The marketable yield in plot released with *T. pretiosum* was 1178.06g plant^{-1} which was on par with plot released with *T. chilonis* (1078.41 g). In NSKE 5.0 %, the marketable yield was 739.01g plant^{-1} which was comparable to that of control (526.16g plant^{-1}). The marketable yields were higher in the *Trichogramma* released plots.

Under the field conditions both *T. pretiosum* and *T. chilonis* were effective in minimizing the infestation by *L. orbonalis.* However, in the laboratory evaluation *T.*

pretiosum was found to be the most effective species in parasitising the eggs of *L. orbonalis*. From the study, it was concluded that both *T. pretiosum* and *T. chilonis* were effective in the management of brinjal shoot and fruit borer under Kerala condition.

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Appendix

APPENDIX I

Weather data over the release period

Week	Temperature			Relative Humidity (%)	Rainfall (mm)
	Maximum (℃)	Minimum (℃)	Mean (℃)		
Week 1	36.2	23.9	30.05	41	0
Week 2	36.9	23.7	30.30	48	0
Week 3	37.2	24.7	30.95	59	0
Week 4	34.6	24.9	29.75	72	8
Week 5	35.2	26	30.60	73	9
Week 6	35.4	25.2	30.30	73	6.8
Week 7	32.2	23.9	28.05	82	45.2
Week 8	34.5	25.7	30.1	79	24.4
Week 9	34.7	25.9	30.3	76	6.8

Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp.

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Brinjal (*Solanum melongena* L.) holds the status of most popular and affordable vegetable in India. The major constraint that hinders the crop from realization of yield potential is the infestation of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee). Farmers completely rely upon insecticides for immediate management of this pest. The irrational use of insecticides has led to the destruction of natural enemies, development of resistance in insect, health hazards to farmers and consumers, pesticide residue problems and environmental pollution. It is high time to adopt safe, eco-friendly and sustainable alternatives for the management of brinjal shoot and fruit borer.

Biological control using *Trichogramma* egg parasitoids are considered to be the most viable and promising strategy. Many species of *Trichogramma* are reported to be having the ability to parasitise the eggs of *L. orbonalis*. However, wide variations have been reported in the relative success of each species. So far, no studies have been taken up for the evaluation of *Trichogramma* spp. against *L. orbonalis* in Kerala. Hence, the present study entitled “Management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Lepidoptera: Crambidae) using *Trichogramma* sp.” was carried out to identify an effective species of *Trichogramma* for the management of brinjal shoot and fruit borer, *L. orbonalis*.

Efficacy of four different species of *Trichogramma viz*., *T. chilonis, T. pretiosum. T. evanescens* and *T. embryophagum* were evaluated in the laboratory. It was observed that *T. pretiosum* exhibited significantly higher parasitism (90.83%) followed by *T. chilonis* (76.67%). Adult emergence was comparable between *T. chilonis* (82.84%) and *T. pretiosum* (81.77%). The laboratory study revealed that *T. pretiosum* and *T. chilonis* are the two promising species with the highest parasitism and adult emergence. Hence, these promising species were selected for evaluating their efficacy under field condition.

The effectiveness of *T. pretiosum* and *T. chilonis* against *L. orbonalis* on brinjal was evaluated in the field using the F_1 hybrid, Neelima. The parasitoids were evaluated in comparison with neem seed kernel extract (5.00%) and an untreated control. Releases of *Trichogramma* were done @1,00,000 numbers per hectare at weekly interval for eight weeks.

Among different treatments, *T. pretiosum* and *T. chilonis* recorded significantly lower mean shoot infestation with values of 0.53 and 0.79 per cent respectively, while the respective values were 2.14 per cent in NSKE and 3.44 per cent in control. The per cent reduction in shoot infestation over control was 48.97 and 44.33 respectively for *T. pretiosum* and *T. chilonis.*

The supremacy of *T. pretiosum* and *T. chilonis* in lowering the mean fruit infestation on number basis was evident with infestation levels of 38.35 per cent and 40.02 per cent respectively compared to NSKE (47.52%) and control (63.65%). The per cent reduction in fruit infestation based on number over control was 27.90 and 25.96 respectively for *T. pretiosum* and *T. chilonis.*

The results on fruit infestation on weight basis also revealed the potential of trichogrammatids over control. In plot released with *T. pretiosum*, the mean infestation was 34.76 per cent, which was comparable with the infestation (37.74 %) in plot released with *T. chilonis*. The per cent reduction over control was more pronounced in plots released with trichogrammatids and was 33.11 and 29.56 respectively for *T. pretiosum* and *T. chilonis* plots. Highest marketable yields were obtained from plot released with *T. pretiosum* (1178.06g $plant^{-1}$) which was on par with plot released with *T. chilonis* (1078.41g $plant^{-1}$).

The study confirmed the significant role of *T. pretiosum* and *T. chilonis* in suppressing the population of *L. orbonalis* under Kerala condition.