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Evaluation of augmentative biological control options against fruit and shoot borer, *Conogethes punctiferalis* (Guenée) (Lepidoptera: Crambidae) in guava in India

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Abstract

Background *Conogethes punctiferalis* (Guenée) (Lepidoptera: Crambidae) has emerged as one of the important pests of guava in Punjab, India. Chemical insecticides have been used for its management, which could have serious implications on environmental and human health. As an alternative to chemical insecticides, biocontrol is the most appropriate alternative for its eco-friendly management. Two field experiments were therefore, conducted to evaluate efficacy of two biocontrol agents, *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) (egg parasitoid) and *Chelonus blackburni* Cameroon (Hymenoptera: Braconidae) (egg-larval parasitoid) against the borer during rainy season, 2020 and winter season, 2020–21.

Results Four releases of both parasitoids at various dosages were carried out at weekly intervals starting from first week of July in rainy season and first week of October in winter season. *Trichogramma chilonis* @ 2000 parasitized eggs per tree was the best in reducing the fruit damage and increasing yield and net income over check in both rainy as well as winter season crops. There was 73.6% reduction in damage over control, 1.70 Metric tons (MT) increase in yield over control and 258.36 US $ per acre increase in net income over control in rainy season crop. During winter season, there was 62.5% reduction in damage, 1.98 MT increase in yield and 488.23 US $ per acre increase in net income over control.

Conclusion Four augmentative releases of *T. chilonis* @ 2000 parasitized eggs per tree successfully controlled the fruit and shoot borer incidence in guava during rainy and winter season.

Keywords Guava, Borer, Biocontrol, *Trichogramma chilonis*, *Chelonus blackburni*

Background

Guava, *Psidium guajava* L., (Myrtaceae) is grown in tropical as well as subtropical regions of the globe, owing to its wider adaptability. The guava trees bear fruits twice a year, i.e. during rainy months (August–September) as well as winter season (December-January) (Anonymous 2018). It is also known as "poor man's apple" because of its affordable price and high nutritional value (Joseph and Priya 2011). It is rich in vitamin C, containing about 150–200 mg/ 100 g of pulp (Anonymous 2021). The guava fruits also possess anti-oxidant factors which help in controlling systolic blood pressure (Anonymous 2021). In India, guava was cultivated in an area of 265 thousand hectares in 2017–18, with a total production of 4054 thousand tonnes (Anonymous 2018). In Punjab, it is second most important fruit crop after the mandarin hybrid,

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Kinnow in terms of area under production. In Punjab, it was grown on 9730 hectares of land with a total production of 219,850 MT during 2020–21 (Anonymous 2021).

In India, around 80 species of insect pests have been reported on guava. Among these, nine major insect pests, viz. fruit flies; *Bactrocera dorsalis* (Hendel) and *B. zonata* (Saunders); bark eating caterpillar, *Indarbela quadrinotata* Walker); striped mealybug, *Ferrisia virgata* Cockerell; scale insect, *Pulvinaria psidii* Maskell; fruit borer, *Deudorix isocrates* (Fabricius)' shoot and fruit borer *Conogethes punctiferalis* (Guenée), rugose spiralling whitefly, *Aleurodicus dispersus* Russell; tea mosquito bug, *Helopeltis antonii* V. Signoret and stem borer, *Aristobia testudo* (Fabricius) cause significant losses to the guava growers (Rai et al. 2019). One of the major threats to the production and productivity of various fruit crops are the lepidopteran borer pests. They cause damage to the stem, fruits, roots, inflorescences, etc., thereby reducing the quantity as well as quality of the produce. Crambids are known worldwide for their extensive damage to various agricultural and horticultural crops, *C. punctiferalis* being one of them (Kumar et al. 2021).

Among the major pests of guava, the fruit and shoot borer, *C. punctiferalis* (Lepidoptera: Crambidae) is widely distributed in Asia and Australia (Rai et al. 2019). *C. punctiferalis* is a highly polyphagous borer pest, known to feed on more than 120 species of wild and cultivated plants. It is known by various common names such as yellow peach moth, maize moth or peach pyralid moth, castor shoot and capsule borer, castor seed caterpillar, durian fruit borer, durian husk borer, Queensland bollworm, smaller maize borer and cone moth in various parts of the world. The female moths feed, oviposit and develop primarily in buds and fruits of all kinds of host plants (Li et al. 2015). Among the fruit crops, it has been reported on apple, banana, citrus, grape, guava, litchi, mango, peach, pear, plum, pomegranate and sapota (Reddy et al. 2020). *C. punctiferalis* is observed to cause fruit damage ranging from 10–12% on guava in Punjab, India.

In the past few decades, there has been excessive use of chemical pesticides for the control of insect pests on various crops which has caused serious complications such as persistence of pesticide residue in crop products, pest resistance development, and secondary pest outbreaks in general (Wytinck et al. 2020). Apart from this, the chemical insecticides have a negative impact on the natural control of insect pests by killing their natural enemies (Crowder et al. 2010). For eco-friendly management of insect pests, biological control is the most preferred one for a sustainable alternative to the chemical insecticides (Barratt et al. 2018). Therefore, the objective of the present study was to evaluate two biocontrol agents, *Trichogramma chilonis* Ishii, an egg parasitoid and *Chelonus blackburni* Cameroon, an egg-larval parasitoid (both native to India) for the management of *C. punctiferalis* in guava, and its impact on yield of guava fruits and economics of their releases.

Methods

This study was conducted at the Fruit Research Farm, Punjab Agricultural University (PAU), Ludhiana (30^0.54′14.112"N, 75^0.47′36.672"E) and University Seed Farm (USF), Ladhowal (30^0.97′683"N, 75^0.75′725"E), elevation 247 m, Ludhiana, Punjab, India. The treatments included: 1) *Trichogramma chilonis*—1000 parasitized eggs/tree; 2) *T. chilonis*—1500 parasitized eggs/tree; 3) *T. chilonis*—2000 parasitized eggs/tree; 4) *Chelonus blackburni*—100 adults/tree; 5) *C. blackburni*—150 adults/tree; 6) *C. blackburni*—200 adults/tree and 7) Untreated control. A 100 m distance was maintained between treated and untreated plots. Both biocontrol agents (10^{th} generation) were obtained from the Biocontrol Section, Department of Entomology, PAU, Ludhiana.

Augmentative releases

Trichogramma chilonis

Tricho-cards (10 × 15 cm) were cut into strips (size 0.75 × 5 cm), each having 500 parasitized *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) eggs. These tricho-strips were stapled on the lower surface of leaves in the middle of tree canopy. Trees of treatments 1, 2 and 3 were stapled with 2, 3 and 4 tricho-strips, respectively.

Chelonus blackburni

Adults of *C. blackburni* were released by hanging 4, 6 and 8 perforated vials per tree containing 25 adults in each vial for treatments 4, 5 and 6, respectively.

Four releases were made at weekly interval from first week of July in rainy season, 2020 and first week of October in winter season, 2020–21. The research study was conducted on 'Allahabad Sufeda' cultivar of guava. There were 5 replications (3 trees per replication) for each treatment.

Observations recorded

Fruit infestation was recorded by counting number of infested fruits out of hundred randomly selected fruits at 7, 14 and 21 days after the fourth release. The per cent reduction in damage over untreated control was also calculated. The impact on yield of guava fruits was assessed by counting number of marketable fruits from each tree in each replication. Average weight of 50 fruits was taken, which was 96 g/fruit. Fruit yield (kg/tree) was calculated by multiplying average weight of fruit (96 g) with number of fruits/trees and multiplied by 1000 to convert it into kg/tree. Yield/acre (metric tons) was calculated by multiplying fruit yield (kg/tree) with total number of trees in one acre (132 trees) and dividing by 1000. The gross income over control was calculated by multiplying increase in yield over check by market price of guava, which was 0.18 US $ per kg in rainy season and 0.27 US $ per kg in winter season. Net income over control was calculated by subtracting cost of biocontrol agents and labor cost of their production from the gross income over control.

Data analysis

The data were subjected to analysis of variance (ANOVA) using Randomized Block Design (RBD). Similar results were recorded during both the years and therefore, results were pooled. The significance of differences between treatment means was compared using F test at 5% probability. Before statistical analysis, percentage data were subjected to square root transformation to meet normality test and homogeneity of variances (Panse and Sukhatme 1954).

Results

Fruit infestation in rainy season (2020)

The fruit infestation due to *C. punctiferalis* was found to be non-significant before releases ($F=0.60$; $df_{6,24}$; $p=0.7275$). Among the various treatments, the releases of *T. chilonis*—2000 parasitized eggs /tree were significantly effective in reducing borer damage in all the observations ($F=30.64$; $df_{6,24}$; $p<0.0001$; Table 1). Fruit infestation in aforesaid treatment varied from 2.00 ± 0.32% (7 days after 4 releases) to 3.40 ± 0.51% (21 days after 4 releases). The mean fruit infestation was significantly less in *T. chilonis* released—2000 parasitized eggs /tree (2.73 ± 0.25%) than its lower doses and releases of *C. blackburni* (100, 150 and 200 adults/ tree). Significantly higher fruit infestation (10.33 ± 0.52%) was recorded in untreated control ($F=103.47$; $df_{6,72}$; $p<0.0001$). The maximum reduction in damage over control was 73.6%, which was brought about by *T. chilonis*—2000 parasitized eggs/tree (Fig. 1). *Chelonus blackburni*—200 adults/tree was best among all its doses, where reduction in damage over control was 35.5%.

In terms of yield, the *T. chilonis* treatments outperformed *C. blackburni* treatments. Significantly higher yield (4.64 MT/acre) was recorded in trees treated with *T. chilonis*—2000 parasitized eggs/tree, with number of marketable fruits/tree and fruit yield/tree being 366.60 and 35.19 kg, respectively (Table 2). In untreated control, the number of marketable fruits/tree, fruit yield/tree and yield/acre were 232.00, 22.27 kg and 2.94 MT, respectively ($F=29.23$; $df_{6,24}$; $p<0.0001$).

The economic benefits in *T. chilonis*—2000 parasitized eggs/tree was maximum wherein, the net income of 258.10 US $ per acre was achieved over control as compared to its lower doses, i.e. 1500 parasitized eggs/tree (206.39 US $) and 1000 parasitized eggs/tree (165.52 US $). The releases of *C. blackburni* (100, 150 and 200 adults/ tree) were not economical at all, causing economic losses of 910.21 US $, 1363.82 US $ and 1799.36 US $ per acre, respectively during rainy season, 2020 (Table 3).

Fruit infestation in winter season (2020–21)

Before parasitoid releases, the fruit infestation due to *C. punctiferalis* in all treatments was non-significant ($F=0.40$; $df_{6,24}$; $p=0.8716$). The releases of *T.*

Table 1 Evaluation of biocontrol agents against *C. punctiferalis* in guava during rainy season, 2020

Treatments	Pre-treatment	% fruit damage			
		Post treatment (days after 4 releases) **			
		7	14	21	Pooled mean
T. chilonis—1000 parasitized eggs/tree	0.60 ± 0.24a	4.80 ± 0.49b	5.60 ± 0.20bc	6.20 ± 0.20c	5.53 ± 0.24c
T. chilonis—1500 parasitized eggs/tree	0.40 ± 0.24a	3.80 ± 0.20b	4.60 ± 0.24b	5.00 ± 0.32b	4.47 ± 0.19b
T. chilonis—2000 parasitized eggs/tree	0.60 ± 0.24a	2.00 ± 0.32a	2.80 ± 0.20a	3.40 ± 0.51a	2.73 ± 0.25a
C. blackburni—100 adults/tree	1.20 ± 0.37a	7.40 ± 0.40cd	8.00 ± 0.37e	8.20 ± 0.37d	7.87 ± 0.24e
C. blackburni—150 adults/tree	0.80 ± 0.49a	7.00 ± 0.32cd	6.80 ± 0.37d	7.60 ± 0.75cd	7.13 ± 0.29de
C. blackburni—200 adults/tree	0.60 ± 0.40a	6.40 ± 0.40c	6.40 ± 0.51cd	7.20 ± 0.37cd	6.67 ± 0.23d
Untreated control	1.00 ± 0.32a	8.20 ± 0.37d	10.60 ± 0.51f	12.20 ± 0.58e	10.33 ± 0.52f
F value	0.60	36.34	41.53	30.64	103.47
Df	6.24	6.24	6.24	6.24	6.72
P value	0.7275	< 0.0001	< 0.0001	< 0.0001	< 0.0001

* Mean (± SE) of 5 replications; **4 releases at weekly intervals; Data were subjected to square root transformation and original values are given; Means followed by different letters within column differ significantly ($p<0.05$)

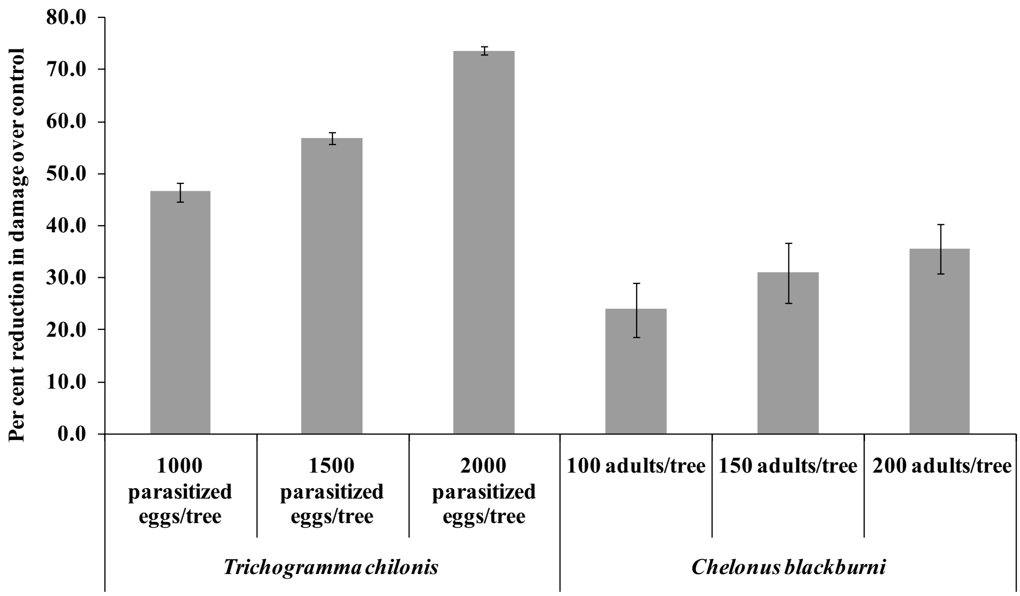

Fig. 1 Per cent reduction in *C. punctiferalis* damage due to release of biocontrol agents during July–August 2020 (rainy season) in guava

Table 2 Impact of release of biocontrol agents against *C. punctiferalis* on number and yield of marketable guava fruits during rainy season, 2020

Treatments	No. of marketable fruits/tree*	Fruit yield (kg/tree)**	Yield/acre (MT)
T. chilonis—1000 parasitized eggs/tree	319.20 ± 9.16b	30.64 ± 0.88b	4.04 ± 0.12b
T. chilonis—1500 parasitized eggs/tree	340.40 ± 8.98b	32.68 ± 0.86b	4.31 ± 0.11b
T. chilonis—2000 parasitized eggs/tree	366.60 ± 9.62a	35.19 ± 0.92a	4.64 ± 0.12a
C. blackburni—100 adults/tree	258.80 ± 10.63d	24.84 ± 1.02d	3.28 ± 0.13d
C. blackburni—150 adults/tree	269.40 ± 7.93 cd	25.86 ± 0.76 cd	3.41 ± 0.10 cd
C. blackburni—200 adults/tree	287.60 ± 7.04c	27.61 ± 0.68c	3.64 ± 0.09c
Untreated control	232.00 ± 7.46e	22.27 ± 0.72e	2.94 ± 0.09e
F value			29.23
Df			6.24
p value			< 0.0001

* Mean (± SE) of 5 replications; **no. of trees/acre = 132; average weight of fruit = 96 g; Means followed by different letters within column differ significantly ($p < 0.05$)

Table 3 Cost of release of biocontrol agents for the management of *C. punctiferalis* in guava during rainy season, 2020

Treatments	Cost of protection (US $/acre)*	Increase in yield over control (MT)	Gross income over control# (US $/acre)	Net income over control (US $ /acre)
T. chilonis—1000 parasitized eggs/tree	33.36	1.10	198.89	165.52
T. chilonis—1500 parasitized eggs/tree	41.32	1.37	247.71	206.39
T. chilonis—2000 parasitized eggs/tree	49.28	1.70	307.37	258.10
C. blackburni—100 adults/tree	972.12	0.34	61.47	− 910.64
C. blackburni—150 adults/tree	1449.45	0.47	84.98	− 1364.47
C. blackburni—200 adults/tree	1926.78	0.70	126.57	− 1800.21
Untreated control	–	–	–	–

* Cost of protection (cost of tricho card = 0.60 US $ per card; cost of *C. blackburni* culture = 1.81 US $ per 100 adults; labour charges = 4.36 US $/person/day); #Market price of guava = 0.18 US $ per kg

chilonis—2000 parasitized eggs /tree significantly reduced the borer damage in all the observations ($F = 20.71–38.30$; $df_{6,24}$; $p < 0.0001$; Table 4). The fruit infestation in this treatment varied from 3.00 ± 0.32% (7 days after 4 releases) to 4.20 ± 0.49 per cent (21 days after 4 releases). Significantly lower fruit infestation was recorded in treatment in which *T. chilonis* was released—2000 parasitized eggs /tree (3.60 ± 0.25%) as compared to its lower doses and releases of *C. blackburni* (100, 150 and 200 adults/ tree). Highest fruit infestation (9.60 ± 0.52%) was recorded in untreated control ($F = 75.09$; $df_{6,72}$; $p < 0.0001$). The maximum reduction in damage (62.50%) over control was recorded in *T. chilonis*—2000 parasitized eggs/tree (Fig. 2). *Chelonus blackburni*—200 adults/tree was best among all its doses, where reduction in damage over control was 27.81%.

All the treatments with the releases of *T. chilonis* gave more fruit yield than *C. blackburni* treatments. Significantly higher yield (5.13 MT/acre) was recorded in trees treated with *T. chilonis*—2000 parasitized eggs/tree, with number of marketable fruits/tree and fruit yield/tree being 405.00 and 38.88 kg, respectively (Table 5). In

Table 4 Evaluation of biocontrol agents against *C. punctiferalis* in guava during winter season, 2020–21

Treatments	Pre-treatment	% fruit damage			
		Post treatment (days after 4 releases)**			
		7	14	21	Pooled mean
T. chilonis—1000 parasitized eggs/tree	0.80 ± 0.37a	5.20 ± 0.37b	5.80 ± 0.37c	6.40 ± 0.40bc	5.80 ± 0.24c
T. chilonis—1500 parasitized eggs/tree	0.80 ± 0.37a	4.20 ± 0.20b	5.00 ± 0.32b	5.60 ± 0.40b	4.93 ± 0.23b
T. chilonis—2000 parasitized eggs/tree	0.60 ± 0.24a	3.00 ± 0.32a	3.60 ± 0.40a	4.20 ± 0.49a	3.60 ± 0.25a
C. blackburni—100 adults/tree	1.60 ± 0.68a	7.20 ± 0.37 cd	8.00 ± 0.45e	8.80 ± 0.58d	8.00 ± 0.31e
C. blackburni—150 adults/tree	1.00 ± 0.32a	6.60 ± 0.51 cd	7.60 ± 0.24de	8.20 ± 0.49d	7.47 ± 0.29de
C. blackburni—200 adults/tree	0.80 ± 0.37a	6.40 ± 0.24c	6.80 ± 0.37d	7.60 ± 0.51 cd	6.93 ± 0.25d
Untreated control	1.20 ± 0.37a	7.80 ± 0.37d	9.80 ± 0.37f	11.20 ± 0.58e	9.60 ± 0.45f
F value	0.40	22.92	38.30	20.71	75.09
Df	6.24	6.24	6.24	6.24	6.72
P value	0.8716	< 0.0001	< 0.0001	< 0.0001	< 0.0001

* Mean (± SE) of 5 replications; **4 releases at weekly intervals; Data were subjected to square root transformation and original values are given; Means followed by different letters, ($p < 0.05$) within column differ significantly

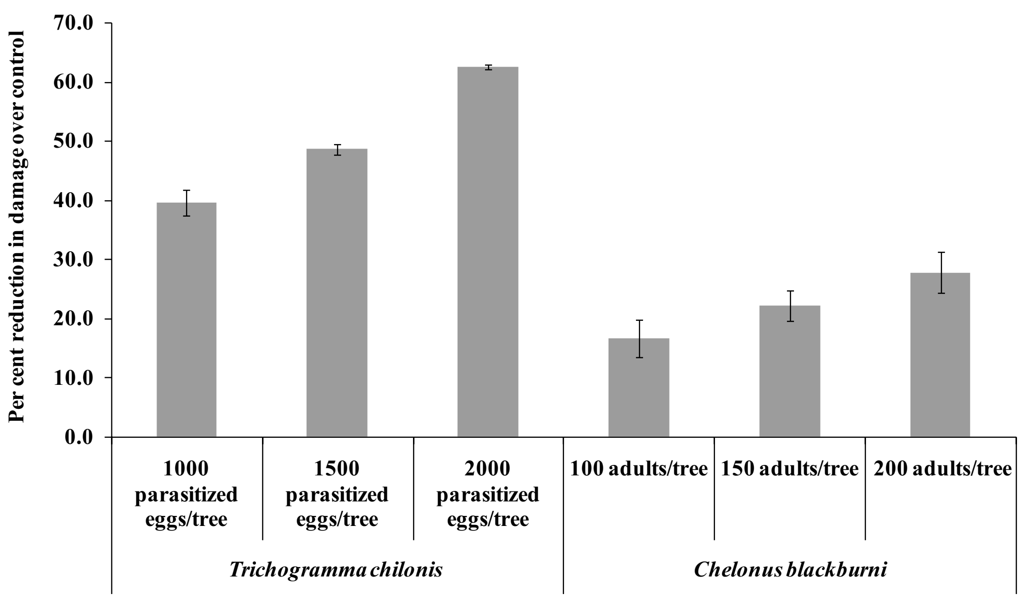

Fig. 2 Per cent reduction in *C. punctiferalis* damage due to release of biocontrol agents during winter season, 2020–21

Table 5 Impact of release of biocontrol agents against *C. punctiferalis* on number and yield of marketable guava fruits during winter season, 2020–21

Treatments	No. of marketable fruits/tree*	Fruit yield (kg/tree)**	Yield/acre (MT)
T. chilonis—1000 parasitized eggs/tree	339.40 ± 8.08c	32.58 ± 0.78c	4.30 ± 0.10c
T. chilonis—1500 parasitized eggs/tree	369.80 ± 7.48b	35.50 ± 0.72b	4.69 ± 0.09b
T. chilonis—2000 parasitized eggs/tree	405.00 ± 9.35a	38.88 ± 0.90a	5.13 ± 0.12a
C. blackburni—100 adults/tree	285.20 ± 10.61d	27.38 ± 1.02d	3.89 ± 0.17d
C. blackburni—150 adults/tree	293.20 ± 13.78d	28.15 ± 1.32d	3.71 ± 0.17d
C. blackburni—200 adults/tree	307.40 ± 13.03d	29.51 ± 1.25d	3.61 ± 0.13d
Untreated control	249.00 ± 12.22e	23.90 ± 1.17e	3.15 ± 0.15e
F value			27.13
Df			6,24
p value			< 0.0001

* Mean (± SE) of 5 replications; **no. of trees/acre = 132; average weight of fruit = 96 g; Means followed by different letters, ($p < 0.05$) within column differ significantly

untreated control, the number of marketable fruits/tree, fruit yield/tree and yield/acre were 232.00, 22.27 kg and 2.94 MT, respectively ($F = 27.13$; $df_{6,24}$; $p < 0.0001$).

The economic benefits in *T. chilonis*—2000 parasitized eggs/tree was maximum wherein, the net income of 487.49 US $ per acre was achieved over control as compared to its lower doses, i.e. 1500 parasitized eggs/tree (373.46 US $) and 1000 parasitized eggs/tree (278.40 US $). The releases of *C. blackburni* (100, 150 and 200 adults/tree) were not economical at all, causing economic losses of 771.06 US $, 1296.96 US $ and 1801.17 US $ per acre, respectively during winter season, 2020–21 (Table 6).

Discussion

So far, there have been very few studies on *Trichogramma* being used as biocontrol agent for the management of *C. punctiferalis.* Zhang (2007) observed higher rate of parasitism of *C. punctiferalis* eggs by *Trichogramma dendrolimi* Matsumura in chestnut (*Castanea crenata* Mill.) orchards in Beijing, China. He et al. (2008) evaluated *T. chilonis* for management of *C. punctiferalis* on litchi in Beijing, China and found that 28.8% of *C. punctiferalis* eggs were parasitized. Ballal et al. (2018) suggested that augmentative release of *Trichogramma* spp. and *C. blackburni* can be helpful for the control of this borer in south India. However, this was first ever use of *T. chilonis* for the management of this pest on guava in Punjab. In field crops, it is possible to measure actual egg parasitism as crops are of less height. But in fruit crops, it is very difficult to locate eggs of *C. punctiferalis*. So, in the present study, we conceded per cent reduction in fruit damage as evaluation indicator.

Augmentative biological control, which involves mass production and release of large quantities of biocontrol agents, has shown promising results in terms of reduction or even elimination of the insecticidal use (Eilenberg et al. 2001). The trichogrammatids have widely been used as egg parasitoids for the management of lepidopteran pests. *Trichogramma* releases have been carried out on about 32.0 million ha area annually in more than 50 countries including India (van Lenteren et al. 2017). The genus *Trichogramma*, having their ability to parasitize eggs of multiple pest species, make them good egg parasitoids for biocontrol program (Zucchi et al. 2010). In the

Table 6 Cost of release of biocontrol agents for the management of *C. punctiferalis* in guava during winter season, 2020–21

Treatments	Cost of protection (US $/ acre)*	Increase in yield over control (MT)	Gross income over control# (US $/acre)	Net income over control (US $/acre)
T. chilonis—1000 parasitized eggs/tree	33.36	1.15	311.89	278.53
T. chilonis—1500 parasitized eggs/tree	41.32	1.53	414.95	373.63
T. chilonis—2000 parasitized eggs/tree	49.28	1.98	537.00	487.72
C. blackburni—100 adults/tree	972.12	0.74	200.70	− 771.42
C. blackburni—150 adults/tree	1449.45	0.56	151.88	− 1297.57
C. blackburni—200 adults/tree	1926.78	0.46	124.76	− 1802.02
Untreated control	–	–	–	–

* Cost of protection (cost of tricho card = 0.60 US $ per card; cost of *C. blackburni* culture = 1.81 US $ per 100 adults; labour charges = 4.36 US $/person/day; #Market price of guava = 0.27 US $ per kg

present study, *T. chilonis* has shown promising results against the borer, *C. punctiferalis* in guava. Karthikeyan et al. (2007) evaluated *T. chilonis* against rice leaf folder, *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Crambidae) in Kerala, India and found that there was 41.68–98.60% damage over conventional insecticide (triazophos and lambda-cyhalothrin) application.

Comprehensive studies have been conducted in India for evaluation of various trichogrammatids against tissue borers in various crops indicating their importance for the management of lepidopteran pests. Shenhmar et al. (2003) conducted a large-scale field demonstration using *T. chilonis* against *Chilo auricilius* Dudgeon (Lepidoptera: Crambidae) in Punjab, India during 2000–01 and found that there was reduction in damage over the control by 52.04% during 2000, while 60.03% during 2001. Kumar et al. (2004) concluded that five inundative releases of *T. chilonis*—1,00,000 parasitized eggs/ha at weekly intervals in *Punjab Chhuhara* cultivar of tomato caused 62.19% reduction in damage caused by *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) over control in their studies conducted at PAU, Ludhiana, Punjab. Shera et al. (2017) assessed on farm impact of inundative releases of *T. chilonis* against maize borer, *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) in various districts of Punjab, India and found that there was 56.86 and 56.10% reduction in damage over control in *Kharif* maize in 2014 and 2015, respectively, which translated into net returns of 93.18 US $ and 112.79 US $ over control in year 2014 and 2015, respectively. Sangha et al. (2018) also reported the releases of trichogrammatids resulted in the reduction in damage caused by lepidopteran pests of basmati rice over control up to an extent of 61.50% in the farmers' field. Sharma et al. (2020) evaluated *T. chilonis* against lepidopteran tissue borers of sugarcane crop in various districts of Punjab, India and reported 57.4 and 61.4% reduction in damage over control in case of *Chilo infuscetallus* Snellen (Lepidoptera: Crambidae) and *C. auricilius*, respectively. Benefit: Cost ratio of 1.68 and 1.70 was achieved in biocontrol treatments against *C. infuscetallus* and *C. auricilius*, respectively.

Conclusion

Four augmentative releases of egg parasitoid *T. chilonis*—2000 parasitized eggs/tree at weekly interval caused lesser percentage of damage fruits and significant reduction in damage over control in both rainy and winter season guava, which thereby resulted in higher fruit yield and net returns over control in both seasons. Thus, the use of biocontrol-based technologies involving inundative releases of this trichogrammatid is an alternative to chemical insecticides for sustainable and eco-friendly management of *C. punctiferalis* in guava orchards, Punjab, India.

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Author contributions
S, VS, PS, RK and KM planned the trial. SS, VS, PS, MS and RK implemented the trial and recorded the data. SS wrote the MS and VS, KM, PS, RK improved the MS and did data analysis.

Funding
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Availability of data and material
The datasets used during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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