Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(1): 1647-1651

Received: 13-11-2019
Accepted: 15-12-2019

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Biological control of maize stem borer, *Chilo partellus* (Swinhoe) in *Kharif* maize through combined releases of *Trichogramma chilonis* (Ishii) and *Cotesia flavipes* (Cameron) in Odisha

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Abstract
Field experiments were conducted to investigate 10 treatments comprising of individual and combined doses of egg and larval parasitoids *Trichogramma chilonis* and *Cotesia flavipes* respectively to study the biological control of maize stem borer *Chilo partellus* (Swinhoe) in *Kharif* maize in Odisha. The experiment carried on 10 isolated field each of 0.25 ha and hybrid maize variety Hishell was taken. The parasitized eggs and larvae of *C. partellus* were recorded from five plants replicated three times in same field. The data obtain were analysed by complete randomized block design. The result obtained from field trail revealed that the combination of egg and larval parasitoids of treatment: 1, 50,000 *Trichogramma chilonis* parasitized eggs + 1500 *Cotesia flavipes* pupae)/ha gave the best result with highest egg parasitisation (80.47%) and larval parasitisation (46.52%) of maize stem borer with maximum grain yield 52.54 q/ha in both *Kharif* 2014 and 52.03 q/ha in *Kharif* 2015 with most economically remunerative and highest B:C ratio of 1:1.54.

Keywords: Maize, *Chilo partellus*, *Trichogramma chilonis*, *Cotesia flavipes* and grain yield

Introduction
Maize (*Zea mays* L.) is the most important cereal crop after wheat and rice, grown virtually in every suitable agricultural region of the world. It belongs to the grasses family Poaceae (Gramineae). Maize is a fully domesticated plant which has lived with man and evolved since ancient times. It has been referred as the "Queen of cereals" due its highest yield potential among all the cereals [1] and is the second most important cereal crop next to rice in Odisha covering 2.69 lakh hectares with the production and productivity of 7.51 lakh tones and 27.90 quintals per hectare, respectively [2]. Maize is attacked by over 250 species of insect and pests [3] of those four species of tissue borers *viz*., maize stem borer or spotted stem borer (*Chilo partellus* Swinhoe), pink stem borer (*Sesamia inference*), shoot fly (*Atherigona soccata*) and Asiatic corn borer (*Ostrinia furnacalis* Guenee) are regular and serious pests of maize. Among these, maize stem borer, *C. partellus,* is the principal pest in all maize growing countries. Maize stem borer injury to maize includes leaf feeding, tunneling within stalk, disruption of the flow of nutrients to the ear, and subsequent development of "dead hearts" by damage to the central growing shoot of young plant. The first symptoms of *C. partellus* damage are the appearance of "shot hole" injury to whorl leaves. Plants that survive the initial attack show reduced inter-nodal length resulting in shoot 'rosetting'. Yield loss is attributed the physiological effects on final ear size, lodging or the complete loss of ears and formation of "dead hearts" [4]. The *C. partellus* infestation reduced the yield by 27.1 to 29. 8 per cent in India [5]. To overcome the problems of insect pests on maize crop, various components of pest management *viz*., cultural practices, chemical practices, resistant varieties, biological agents have been recommended. Trichogrammatids have been utilized as potential egg parasitoids against many insect pests on several field crops. *Cotesia flavipes* (Cameron) also has a vital role in the management of *C. partellus* in larval stage [6]. Though these parasitoids work independently, their combined effects are fatal for *C. partellus*. The peak activity period of these bio-agents is not well studied so far. Therefore, the present study has been planned to address the above shortfalls:

Materials and Methods
Field experiment was taken up at the farmers field, village-Kanpur, Soro of district Balasore, Odisha to study the biological control of maize stem borer, *Chilo partellus* (Swinhoe) in *Kharif* maize through combined releases of *Trichogramma chilonis* (Ishii) and *Cotesia flavipes* (Cameron).

Experimental layout
The field experiment was laid out in complete randomized block design with popularly grown variety "Hishell" in nine isolated field of each 0.25ha with spacing 60cmX25cm. Individual and combined doses of these two parasitoids i.e. egg parasitoids *Trichogramma chilonis* and larval parasitoid *Cotesia flavipes* of different doses listed below were released at 10 and 20 days of germination of maize plant. The parasitized eggs and larvae of *Chilo partellus* were recorded from five plants replicated three times in same field in year *Kharif* 2014 and *Kharif* 2015. The data obtained were analyzed by complete block design [7]. The yield data respective treatments were recorded and compared with control one. There were altogether ten treatments and each treatment was replicated thrice. The treatment details are given below:

Treatment details

Table 1: Bio-agents (parasitoids) with doses

Sl. No.	Treatment No.	Dose of Bio agents(parasitoids)
1	T1	50,000 eggs of *Trichogramma chilonis* per ha
2	T2	1,00,000 eggs of *Trichogramma chilonis* per ha
3	T3	1,50,000 eggs *Trichogramma chilonis* per ha
4	T4	500 pupae *Cotesia flavipes* per ha
5	T5	1000 pupae *Cotesia flavipes* per hactre
6	T6	(50,000 eggs *Trichogramma chilonis* +500 pupae *Cotesia flavipes*) per ha
7	T7	(50,000 eggs *Trichogramma chilonis* +500 pupae *Cotesia flavipes*) per ha
8	T8	(1,00,000 eggs *Trichogramma chilonis* + 1000 pupae *Cotesia flavipes*) per ha
9	T9	(1, 50,000 eggs *Trichogramma chilonis* +1500 pupae *Cotesia flavipes*) per ha.
10	T10	Untreated plot

Treatment effect on yield attributing characters of maize was assessed when the crop reached maturity. For this purpose, five randomly selected plants from each plot were harvested and observations with regards to mean number of cob per plant were recorded. After harvesting, plot wise seed yield was recorded and converted into quintal per ha. The per cent increase in yield over untreated control was also calculated for assessing the yield performance of different treatments by using following formula:

$$\frac{Y_2.....Y_9 - Y_1}{Y_1} \times 100$$

Whereas,
Y1= seed yield in untreated control
Y2....Y9= seed yield in different treatments.

Overall efficacy was compared on the basis of net monitory returns in term of rupees per hectare as well as benefit-cost ratio worked out for different treatments under study. Data so obtained from above observations were finally subjected to statistical analysis.
The benefit cost (B: C) ratio was calculated on the basis of prevailing market price of maize, bioagents and application cost. Benefit cost ratio was calculated as follows:

$$\text{B: C ratio} = \frac{\text{Gross Economic return}}{\text{Variable cost}} \times 100$$

Results
Egg parasitization per cent by egg parasitoid *Trichogramma chilonis* of *Chilo partellus* eggs during Kharif 2014 and Kharif-2015
The data presented in Fig. 1 revealed that the maximum egg parasitization (80.47%) was recorded in treatment T9:(1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha released at 10DAG and 20DAG followed by T3: 1,50,000 *Trichogramma chilonis parasitized eggs*/ha and 76.55% T8: (1,00,000 *Trichogramma chilonis parasitized* eggs+1000 *Cotesia flavipes* pupae)/ha (70.01%) which is significantly differ from all other treatments. The minimum egg parasitization (4.73%) was recorded in T10: Untreated plot. Which was at par with T4: 500 *Cotesia flavipes* pupae/ha (6.28%) T5: 1000 *Cotesia flavipes* pupae/ha (6.87%T6: 1500 *Cotesia flavipes* pupae/ha (6.58%). So from the data it inferred that the treatments *viz.*, T4, T5 and T6 involving *Cotesia flavipes* resulted in very low egg parasitization as compared with other treatments. The egg parasitization occurred due to presence of Trichogramma *chilonis* in natural condition. Similarly lowest leaf injury (LIR) 1.85 and dead heart per cent 3.5% recorded in treatment in treatment T9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha respectively which were at par with T8: (1,00,000 *Trichogramma chilonis parasitized* eggs+1000 *Cotesia flavipes* pupae)/ha and T7: (50,000 *Trichogramma chilonis* parasitizede eggs + 500 *Cotesia flavipes* pupae)/ha and shown significant difference with untreated plot (Fig. 2).

Larval parasitization per cent by larval parasitoids *Cotesia flavipes* of *Chilo partellus* during *Kharif* 2014 and *Kharif* 2015
The data presented in Fig.1 revealed that the maximum larval parasitization (46.52%) was recorded in treatmentT9:(1, 50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha released at 10DAG and 20DAG followed by T6: 1500 *Cotesia flavipes* pupae/ha (43.70%) and T8: (1, 00,000 Trichogramma *chilonis* parasitized eggs+1000 *Cotesia flavipes* pupae)/ha (41.90%) which is significantly differ from all other treatments in both *Kharif* 2014 and *Kharif* 2015. The minimum larval parasitization (2.32%) was recorded in T10: Untreated plot. From the data it inferred that the treatments *viz.*, T1, T2 and T3 involving *Trichogramma chilonis* in very

low larval parasitization as compared with other treatments (Fig. 1). Low larval parasitization occurred due to presence of *Cotesia flavipes* natural condition.

Grain yield of maize (kg/ha)

During the investigation it was found that maximum average yield (52.28q/ha)was obtained in treatment T 9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha which was followed by T8:(1,00,000 *Trichogramma chilonis* parasitized eggs+1000 *Cotesia flavipes* pupae)/ha (48.65q/ha) and T7:(50,000 *Trichogramma chilonis* parasitized eggs+500 *Cotesia flavipes* pupae*)*/ha (47.86q/ha) in both the years i.e. *Kharif* 2014 and *Kharif* 2015. The lowest yield was obtained from the T10: Untreated plot (35.60q/ha) which was significantly difference from the other treatments (Table 2).

Benefit Cost ratio

The economics of different treatments was worked out and presented in Table 2. Results showed that treatment T9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha was the most economically remunerative treatment and Cost Benefit ratio and increase in yield in per cent over untreated plot for all the treatments was calculated to know the efficacy of all the treatments in term of benefit over the cost incurred in Table 2. Increase in yield in per cent over the untreated plot was maximum in T 9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha (46.85%) followed by T8:(1,00,000 *Trichogramma chilonis* parasitized eggs+1000 *Cotesia flavipes* pupae)/ha (36.65%) and T7:(50,000 *Trichogramma chilonis* parasitized eggs+500 *Cotesia flavipes* pupae*)*/ha (32.75%). The lowest increase in yield per cent was recorded in T1:50,000 *Trichogramma chilonis* parasitized *eggs*/ha (12.16%). Similarly the highest cost benefit ratio recorded in T 9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha (1:1.54) followed by T8:(1,00,000 *Trichogramma chilonis* parasitized eggs+1000 *Cotesia flavipes* pupae)/ha (1:1.48) and T7:(50,000 *Trichogramma chilonis* parasitized eggs+500 *Cotesia flavipes* pupae*)*/ha (1:1.47). The lowest cost benefit ratio was recorded in untreated plot (1:1.15).

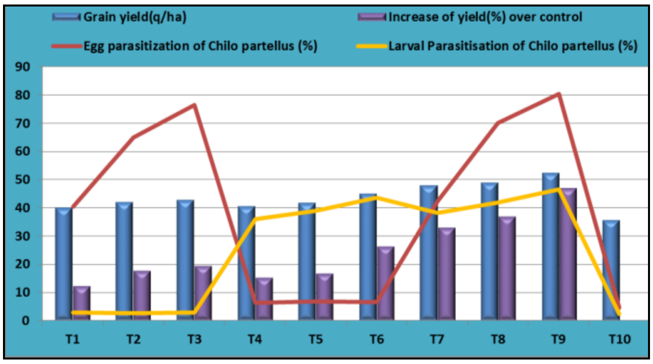

Fig 1: Graphical presentation of Egg parasitization per cent by egg parasitoid *Trichogramma chilonis and* Larval parasitization per cent by larval parasitoids Cotesia flavipes of Chilo partellus during Kharif 2014 and Kharif 2015

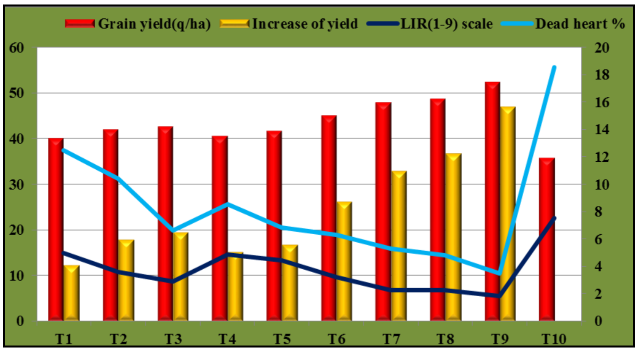

Fig 2: Graphical presentation Leaf Injury rating (LIR1-9scale) and dead heart%

Table 2: Effect of different treatments on grain yield (q/ha) in maize during *Kharif* 2014 and *Kharif* 2015

SL. No	Treatment	Grain yield(q/ha)			Increase of yield(%) over control	Gross economic return (Rs/ha)	Total variable cost (Rs/ha)	Net economic return (Rs/ha)	Benefit: Cost ratio (B:C)
		Kharif 2014	*Kharif* 2015	pooled					
T1	50,000 *Trichogramma chilonis eggs*/ha	40.98	38.88	39.93	12.16	52,308	41,360	10,942	1:1.26
T2	1,00,000 *Trichogramma chilonis eggs*/ha	42.63	41.21	41.92	17.75	54,915	41,720	13,195	1:1.32
T3	1,50,000 *Trichogramma chilonis eggs*/ha	43.51	41.56	42.53	19.46	55,714	42,080	13,634	1:1.33
T4	500 *Cotesia flavipes* pupae/ha	39.61	41.37	40.49	15.14	53,041	41,750	11,291	1:1.27
T5	1000 *Cotesia flavipes* pupae/ha	41.59	41.53	41.56	16.74	54,444	42,500	11,944	1:1.28
T6	1500 *Cotesia flavipes* pupae/ha	44.65	45.20	44.92	26.17	58,845	43,250	15,595	1:1.36
T7	(50,000 *Trichogramma chilonis* eggs+500*Cotesia flavipes* pupae*)*/ha	47.33	48.39	47.86	32.75	62,080	42,110	19,970	1:1.47
T8	(1,00,000 *Trichogramma chilonis* eggs+1000 *Cotesia flavipes* pupae)/ha	49.71	47.59	48.65	36.65	63,731	43,220	20,511	1:1.48
T9	T9: (1,50,000 *Trichogramma chilonis* eggs+1500 *Cotesia flavipes* pupae)/ha	52.54	52.03	52.28	46.85	68,486	44,300	24,186	1:1.54
T10	T10: Untreated plot	35.69	35.51	35.60		46,636	40,540	6,096	1:1.15
	S.E.m (±)	1.373	0.941						
	C.D.(0.05)	4.081	2.819						

Discussion

Parasitoids were reported to be very effective in regulating *C. partellus* population under natural conditions. It is found in nature during *Kharif* season throughout the country and proven as a dominant larval parasitoid of *Chilo partellus* by reducing the population up to 32-55 per cent [8]. Egg parasitoid, *Trichogramma chilonis* was active after release at 10DAG and 20DAG. Maximum parasitization was found in the last of July when the egg laying by *C. partellus* was maximum [9]. The data presented in Fig. 1 revealed that the maximum egg parasitization (80.47%) was recorded in treatment T9: (1,50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha released at 10DAG and 20DAG. Results of the present investigations are in complete agreement with them, activity *of T. Chilonis* was first recorded during the July and parasitization varied from 14 to 40 per cent. Similarly effectiveness of *T. Chilonis* on crop growth against *C. partellus* [10]. Result of present studies indicate that the extent of parasitization increases with the increase of number of released *Trichogramma chilonis* parasitized egg. Lowest leaf injury (LIR) 1.85 and dead heart per cent 3.5% recorded in treatment in treatment T9: (1, 50,000 *Trichogramma chilonis* parasitized eggs+1500 *Cotesia flavipes* pupae)/ha respectively. DH recorded at three weeks after release was significantly lower (1.0 and 0.62%) in plots with t-cards @ 125,000 parasitized eggs in two releases reported earlier scientists [11]. *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) is used as a classical biological control agent against *Chilo partellus* (Swinhoe) [12]. During the course of study *Cotesia flavipes* pasitoid showed preference towards late instar larvae of *C. partellus. Cotesia flavipes* (Cameron) was the dominant natural enemy of *Chilo partellus* (Swinhoe) in maize fields of Bihar agro- climatic condition and its maximum parasitization was 57 per cent. In the augmented experimentation lay out, the maximum natural infestation of *Chilo partellus* and its parasitoid was as 41.21 per cent during last week of September and 42.30 per cent during second week of November [13]. The larval parasites were active throughout the season with occasional peaks of up to 52.26% parasitism. *Cotesia flavipes,* a larval parasitoid proved to be the most abundant and showed highest per cent host mortality [14]. *Cotesia flavipes* was the dominant natural enemy of *Chilo partellus* (Swinhoe) in maize fields of Bihar agro - climatic condition and its maximum parasitization was 57 per cent. The data presented in Fig. 1. Revealed that larval parasitization increases with increase of number parasitoid pupae released in the field and the maximum larval parasitization (46.52%)was recorded in treatment T9: (1,50,000 *Trichogramma chilonis* eggs+1500 *Cotesia flavipes* pupae)/ha released at 10DAG and 20DAG followed by T6: 1500 *Cotesia flavipes* pupae/ha (43.70%) and T8: (1,00,000 *Trichogramma chilonis*eggs+1000 *Cotesia flavipes* pupae)/ha (41.90%) which is significantly differ from all other treatments in both *Kharif* 2014 and *Kharif* 2015. The minimum larval parasitization (2.32%) was recorded in T10: Untreated plot.

Maximum average yield (52.28q/ha)was obtained in treatment T9: (1,50,000 *Trichogramma chilonis* eggs+1500 *Cotesiav flavipes* pupae)/ha which was followed by T8:(1,00,000 *Trichogramma chilonis* eggs+1000 *Cotesia flavipes* pupae)/ha (48.65q/ha) and T7:(50,000*Trichogramma chilonis* eggs+500 *Cotesia flavipes* pupae)/ha (47.86q/ha) in both the years i.e. *Kharif* 2014 and *Kharif* 2015.The lowest yield was obtained from the T10:Untreated plot (35.60q/ha) and significantly different from the other treatments.

Cost benefit ratio and increase in yield in per cent over untreated plot for all the treatments was calculated to know the efficacy of all the treatments in term of benefit over the cost incurred in Table 2. Increase in yield in per cent over the untreated plot was maximum in T9: (1,50,000 *Trichogramma chilonis* eggs+1500 *Cotesia flavipes* pupae)/ha (46.85%) followed by T8:(1,00,000 *Trichogramma chilonis* eggs+1000 *Cotesia flavipes* pupae)/ha (36.65%) and T7:(50,000 *Trichogramma chilonis* eggs+500*Cotesia flavipes* pupae)/ha (32.75%). In both the years lowest increase in yield per cent was recorded in T1:50,000 Trichogramma *chilonis eggs*/ha (12.16%). The cost benefit ratio showed the similar trend and highest recorded in T 9: (1,50,000 *Trichogramma chilonis* eggs+1500 *Cotesia flavipes* pupae)/ha (1:1.54) followed by T8:(1,00,000 *Trichogramma chilonis* eggs+1000 *Cotesia flavipes* pupae)/ha (1:1.48) and T7:(50,000 *Trichogramma chilonis* eggs+500 *Cotesia flavipes* pupae)/ha (1:1.47). The lowest cost benefit ratio was recorded in untreated plot (1:1.15). The release of *T. chilonis* @ 100,000 ha^{-1} effectively reduced the damage of *C. partellus*, increased the natural enemies in maize ecosystem and provided convincing monetary benefits to the farmer [15] and field release of *T. chilonis* @ 125,000 parasitoids per hectare in two releases helps in substantial reduction of *C. partellus* inflicted damage with high economic returns [11] which are partial agreed with our study.

Thus the present study clearly demonstrated that release of 1,50,000 *Trichogramma chilonis* parasitized eggs + 1500 *Cotesia flavipes* pupae may be adopted for the management of *Chilo partellus* in endemic areas which was the most eco-friendly and economically remunerative treatment with highest record of B:C ratio

Acknowledgement

The authors are very grateful to Dr. D. swain, OIC-cum-Breeder, AICRP on Maize, OUAT, and Bhubaneswar for his help in successfully conducting the field experiments on biological control of maize stem borer *Chilo partellus* (swinhoe)

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