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EVALUATION OF ECO-FRIENDLY APPROACHES FOR THE MANAGEMENT OF SPOTTED STEM BORER, *C. PARTELLUS*

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SUMMARY

Chilo partellus is serious pest of sorghum causing heavy loss in grain and fodder yield. An experiment was conducted at research field of CCS HAU, Hisar to manage *C. partellus* through eco-friendly tactics including inter cropping and bio agents. Eight treatments were used. . In the first and second treatments, sorghum variety (HJ 541) and cowpea variety (CS 88) were intercropped in ratios of 4:2 and 4:1, respectively. The third and fourth treatments involved intercropping sorghum and cluster bean variety (HG 365) at ratios of 4:2 and 4:1. In the fifth treatment, *Beauveria bassiana* were applied at a rate of 2.5-3 kg/ha at 20 and 35 days after emergence. The sixth treatment included placing *Trichogramma chillonis* cards on the lower leaf surface of the plot's central portion at 20 and 35 days after emergence to minimize interference with neighbouring plots. Pearl millet was planted along the border of the sixth treatment to monitor movement. The seventh treatment consisted of applying Bt formulation spray at 20- and 35-days after emergence. The results of this investigation showed that the treatment of *Trichogramma chilonis* @ 150000/ha resulted in the lowest percentage of dead hearts (7.5) and the lowest percentage of leaf damage (3.3) at 35 DAE followed by *Beauveria bassiana* treatment ($1x10^8$ CFU /g @ 2.5-3.0 kg/ha). Green fodder yield, plant height, and the total number of stalks were all counted at harvest. Maximal plant height (154.5 cm), total number of stalks/plant (13.9), and yield (350.3t/ha) were observed in the *Trichogramma chilonis* treatment plot @150000/ha. The plot exhibited the lowest levels of stem tunnelling (2.6), stalk damage (4.4), and larval number (0.3). Hence *Trichogramma chilonis* treatment plot @ 150000/ ha was found to be superior among all treatments followed by *Beauveria bassiana* treatment ($1x10^8$ CFU/g @ 2.5-3.0 kg/ha).

Key words: Sorghum, *Chilo partellus*, intercropping, eco-friendly

Sorghum [*Sorghum bicolor* (L.) Monech] is an important cereal crop in India, popularly known as Jowar or 'Great millet'. It is the fifth most important cereal crop worldwide after wheat, rice, maize, and barley. It is extensively cultivated in poor soils in rainfed fields of the semi-arid tropics of India. It is used both for grain and fodder purposes. Sorghum grain is the staple diet for rural families in India and is an important source of calories and proteinson average derive 15% of their daily calories and 16% of their daily protein from sorghum. In India, it is cultivated on 4.09 million hectares with a production of 3.48 million tonnes in 2019 (Anonymous, 2021).

The major insects that attack sorghum are sorghum shoot fly, *Atherigona soccata* Rondani, stem borer, *Chilo partellus* (Swinhoe), sorghum shoot bug, *Perigrinus maidis* Ashmead, earhed bug, *Calocoris angustatus* Lethir, army worm, *Mythimna separata* Walker, midge fly, *Contarinia sorghicola* Coquillette, sorghum aphid, *Melanaphissacchari* Zehntner, Gram caterpillar, *Helicoverpa armigera* Hubner, earhead hairy caterpillar, *Euproctis subnotata* Walker (Okosun *et. al.*, 2021).

The spotted stem borer, *Chilo partellus* (Swinhoe) (Order-Lepidoptera, Family-Pyralidae) is the most important pest of maize and sorghum. The grown-up caterpillars are about 20-25 mm long and dirty greyish white, with black head and four brownish longitudinal stripes on the back. The adults are yellowish-grey moths, about 25 mm acrossthe wings

when spread. Initially, the larvae feed on the *adaxial* surface of the whorl leaves, leaving the lower surface intact as transparent windows (Balikai and Sajjanar, 2012). Adults are nocturnal and live for 2 to 3 days, female lays 200 to 600 scale-like eggs in overlapping batches of 10 to 80 eggs on the undersides of leaves, mostly near the midribs.

First and second instar larvae feed actively on the tender whorl leaves causing pinholes and elongated lesions. Larval entry at the apical meristem results in the drying of 2-3 central leaves, known as a 'dead heart', resulting reduces plant vigour, photosynthetic efficiency, and grain filling. Third-instar larvae leave the whorl leaves and bore into the stem base causing extensive stem tunneling. It affects the nutrient supply to the developing grain and also results in partial or completely chaffy panicles. Stem tunneling also weakens the stems and may cause lodging. Before pupation, the full-grown larvae cut exit holes in the stem to enable the emerging moths to escape.

Cultural pest management practices such as early planting, destruction of stover, biological control and developing insect-resistant cultivars are being used to control stem borer. The application of insecticide for stem borer control is uneconomical under subsistence farming. Intercropping is also an important component of small-farm agriculture in the tropics. Intercropping may create a microclimate different from monocrop influencing host, pest and parasitoid relationships (Pats and Ekbom, 1994). The main objective of performing intercropping of sorghum with pulses was to study the mechanism underlying a possible reduction in incidence and yield increase in sorghum intercropping with different pulses.

MATERIALS AND METHODS

Experiment was conducted at the Research Area of Chaudhary Charan Singh Haryana Agricultural University, Hisar (29.1492° N, 75.7217° E, 215 m above sea level), during *kharif* 2022. Eight treatments were evaluated with three replications using a Randomized Block Design in plot size of 3.6 by 4 m consisted eleven crop row in each plot. In the first and second treatments, sorghum variety (HJ 541) and cowpea variety (CS 88) were intercropped in ratios of 4:2 and 4:1, respectively. The third and fourth treatments involved intercropping sorghum and cluster bean variety (HG 365) at ratios of 4:2 and 4:1. In the fifth treatment, *Beauveria bassiana* were applied at a rate of 2.5-3 kg/ha at 20 and 35 days after emergence. The sixth treatment included placing *Trichogramma Chillonis* cards on the lower leaf surface of the plot's central portion at 20 and 35 days after emergence to minimize interference with neighboring plots. Pearl millet was planted along the border of the sixth treatment to monitor movement. The seventh treatment consisted of applying Bt formulation spray at 20- and 35-days after emergence (Table 1).

TABLE 1
Treatment details of the experiment

Treatment	Treatment details	Crop ratio/ Rate of application/ha
T_1	Sorghum + Cowpea	(4:2)
T_2	Sorghum + Cowpea	(4:1)
T_3	Sorghum + Cluster bean	(4:2)
T_4	Sorghum + Cluster bean	(4:1)
T_5	*Beauveria bassiana* ($1x10^8$ CFU /g)	2.5-3.0 kg/ha
T_6	*Trichogramma chilonis*	150000/ha
T_7	Bt formulation (*Besiluss thruingensis*)	1kg/ha
T_8	Control	

All observations were recorded in all three replications in each treatment and compared to the untreated control plots. Plant population recorded at harvest.Leaf damage were recorded using 0-9 scaleat 35 days of emergence, per cent dead heart, were counted 45 DAE.

$$\text{Per cent dead hearts dur to stem borer} = \frac{\text{No. of plants with dead hearts/plot}}{\text{Total no. of plants/plot}} \times 100$$

Plant height, Stem tunneling, Number of Stalks per plant, Number of damaged stalks per plant and Number of larvae per plantswere recorded at the time of harvesting from five randomly selected plants. The green fodder yield was also recorded per plot at the time of harvesting.

Data from every treatment was analyzed by one-factor analysis using OPSTAT software (Sheoran et al., 1998)

RESULTS AND DISCUSSION

4.3 Eco-friendly approaches for the management of spotted stem borer, *Chilopartellus*

During *Kharif*2022, an experiment was undertaken to determine the effectiveness of various

eco-friendly techniques to manage sorghum stem borer, *Chilo partellus*. Efficacy of treatments such as Sorghum + Cowpea (4:2), Sorghum + Cowpea (4:1), Sorghum + Cluster bean (4:2), Sorghum + Cluster bean (4:1), *Beauveria bassiana* ($1x10^8$CFU/g) @2.5-3.0 kg/ha, *Trichogramma chilonis* @ 150000/ha and Bt formulation @ 1 kg/ha were evaluated regarding leaf injury at 35 DAE, plant population, per cent dead heart at 45 DAE, stem tunnelling, plant height, number of Stalks/plant, number of damaged stalks/plants, number of larvae/ plant, green fodder yield during *Kharif* 2022, applied to determine the most effective treatment against sorghum stem borer. Findings of the experimentation about the relative efficacy of various treatments against sorghum stem borer during *Kharif*, 2022 are presented as:

4.3.1 Plant population

According to the data collected during *Kharif* 2022, no treatment demonstrated its superiority over control against stem borer infestations in sorghum crops, and there were no significant difference between treatments in terms of the number of plants per plot (Table 11).

The results revealed that application of *Trichogramma chilonis* @ 150000/ha recorded maximum number of plants i.e. 147.3 followed by *Beauveria bassiana* @ 2.5-3.0 kg/ha (146.0), Sorghum intercropped with Cluster bean in ratio of 4:2 (144.3), Sorghum: Clusterbean @ 4:1 (136.7), Control (136.7), Sorghum: Cowpea @ 4:2 (136.0), Bt formulation @ 1 kg/ha (133.7) and Sorghum: Cowpea @ 4:1 (123.7) but all the differences were non-significant.

4.3.2 Leaf injury at 35 DAE

The observations on the mean number of plants with leaf injury in the sorghum variety HJ 541 at 35 days after emergence during *Kharif*, 2022 presented in Table 11 showed that all treatments were better than the control except T_4 and T_2. The mean value of leaf injury in different treatments varied from 3.3 to 6.0 being lowest in T_6 (*Trichogramma* @ 150000/ha) and maximum (6.0) in control (T_8).

Following this were *Beauveria bassiana* @2.5–3.0 kg/ha (3.7) and Bt formulation @1 kg/ha (3.7), both of which showed comparable statistical performance. Next in terms of effectiveness was the Sorghum: Cowpea (4:2) intercropping, which recorded leaf injury of 4.0 at 35 DAE. This was statistically comparable to the leaf injury of 4.3 and 4.7 at 35 DAE recorded by the Sorghum: Cluster bean (4:2) and Sorghum: Cowpea (4:1) intercropping. The maximum leaf injury (6.0) was recorded in control and it was no better than T6 treatment (Sorghum+Cluster bean 4:1 ratio) (Table 11).

3.3 Per cent dead heart at 45 DAE

In Sorghum crop, when the larvae hatch, they crawl to the plant whorl and droop between the leaf folds to feed at the growth point, which leads to the formation of a dead heart. The observations on the average number of plants with dead hearts in the sorghum variety HJ 541 was recorded at 45 DAE (Table 2).

The minimum dead heart percentage was recorded in the plot treated with *Trichogramma*

TABLE 2

Effect of application of eco-friendly management practices on leaf injury against stem borer, *Chilo partellus* infestation in dual purpose sorghum during *Kharif* 2022

Treatment	Plant population	Leaf injury at 35 DAE	Per cent Dead heart at 45 DAE
T1: Sorghum:Cowpea (4:2)	136.0	4.0	11.5 (19.8)
T2: Sorghum:Cowpea (4:1)	123.7	4.7	15.1 (22.7)
T3: Sorghum:Clusterbean (4:2)	144.3	4.3	13.9 (21.8)
T4: Sorghum:Clusterbean (4:1)	136.7	5.0	17.4 (24.6)
T5:*Beauveria bassiana* ($1x10^8$ CFU/g @ 2.5-3.0 kg/ha)	146.0	3.7	10.0 (18.3)
T6:*Trichogramma chilonis* (150000/ha)	147.3	3.3	7.5 (15.8)
T7: Bt formulation (1 kg/ha)	133.7	3.7	12.1 (20.3)
T8: Control	136.7	6.0	20.5 (26.8)
Mean	138.0	4.3	13.5 (21.3)
C.D. (p=0.05)	NS	1.3	(4.9)
SE(m)±	6.9	0.4	1.6

DAE = Days after emergence, Leaf injury at 35 DAE= Scale 1-9, *Values in parenthesis are angular transformed values.

chilonis (7.5), which was followed by *Beauveria bassiana* (10.0%) and Bt formulation (12.1), which were statistically similar to each other. The next effective treatment observed was Sorghum: Cowpea @4:2 (11.5) statistically at par with Sorghum: Cluster bean @4:2 (13.9) and Sorghum: Cowpea @4:1 (15.1). The maximum dead heart percentage recorded in the control plot (20.5) followed by T_4 (Sorghum: Cluster bean @4:1 (17.4)) and T_2 (Sorghum: Cowpea@ 4:1 (15.)).

4.3.4 Stem tunnelling (%)

The data presented in Table 12 exhibited that stem tunnelling (%) varied from 2.6 to 9.7 in different treatments. The mean stem tunnelling in different treatment was 4.9. The plants in the treatment of *Trichogramma chilonis* @ 150000/ha recorded the minimum stem tunnelling (2.6) among all the treatments followed by *Beauveria bassiana* @ 2.5–3.0 kg/ha (3.0). These two treatments were statistically similar. The maximum stem tunnelling was observed in the control plot (9.7), which was at par with that observed in treatment of Sorghum: Cowpea @ 4:1 (5.9). The other treatments *i.e*. Bt formulation @ 1 kg/ha, Sorghum: Cowpea @ 4:2, Sorghum: Cluster bean @ 4:2, Sorghum: Cowpea @ 4:1 showed stem tunnelling 3.4, 4.5, 4.9 and 5.6 per cent stem tunnelling respectively.

4.3.5 Number of larvae per plant

The mean number of larvae recorded per plant was 0.7. The lowest number of larvae were recorded in the treatment of *Trichogramma chilonis* @ 150000/ ha (0.3) followed by *Beauveria bassiana* @ 2.5–3.0 kg/ha (0.4) and Bt formulation @1kg/ha (0.5). The highest number of larvae per plant observed in control was 1.7 followed by Sorghum: Cluster bean @4:1 (1.1) and were at par with the treatments Sorghum: Cowpea @4:2, Sorghum: Cluster bean @4:2, and Sorghum: Cowpea @4:1 showed stem tunnelling per cent was 0.5, 0.6 and 0.7 respectively which were statistically similar to each other (Table 12).

4.3.6 Green fodder yield

The mean fodder yield recorded in all the treatments was 304.4q/ha. The maximum yield was recorded in treatments of *Trichogramm achilonis* @150000/ha (350.3q/ha) followed by *Beauveria bassiana* @2.5–3.0 kg/ha (331.7q/ha), Bt formulation @1kg/ha (323.7q/ha) and Sorghum: Cowpea @ 4:2 (309.3q/ha) which were statistically at par each other. The minimum fodder yield was produced in control plots (262.6q/ha), which was at par with those produced in Sorghum: Cluster bean @4:1 (275.3q/ha), Sorghum: Cluster bean @4:2 (302.3) and Sorghum: Cowpea @4:1 (280.0q/ha) respectively (Table 3).

4.3.7 Plant height

The maximum mean plant height of 154.5cm was recorded in *Trichogrammachilonis*@150000/ha followed by, Bt formulation (1 kg/ha), *Beauveria bassiana* @2 .5–3.0 kg/ha, Sorghum: Cowpea (4:2) and Sorghum: Cluster bean (4:2), with

TABLE 3
Effect of application of eco-friendly management practices on damage symptoms and green fodder yield against stem borer, *Chilopartellus* infestation in dual purpose sorghum, HJ 541

Treatment	Dead heart at 45 DAE (%)	Stem tunnelling (%)	No. of larvae/ plant	Green fodder yield (q/ha)
T1: Sorghum:Cowpea (4:2)	11.5(19.8)	4.5(12.1)	0.5	309.3
T2: Sorghum:Cowpea (4:1)	15.1(22.7)	5.6(12.4)	0.7	280.0
T3: Sorghum:Clusterbean (4:2)	13.9(21.8)	4.9(12.7)	0.6	302.3
T4: Sorghum:Clusterbean (4:1)	17.4(24.6)	5.9(14.0)	1.1	275.3
T5:*Beauveria bassiana* ($1x10^8$ CFU/g @ 2.5-3.0 kg/ha)	10.0(18.3)	3.0(9.8)	0.4	331.7
T6:*Trichogramma chilonis* (150000/ha)	7.5(15.8)	2.6(9.1)	0.3	350.3
T7: Bt formulation (1 kg/ha)	12.1(20.3)	3.4(10.4)	0.5	323.7
T8: Control	20.5(26.8)	9.7(18.1)	1.7	262.6
Mean	13.5(21.3)	4.9(12.3)	0.7	304.4
C.D. (p=0.05)	4.9	(5.1)	0.6	44.7
SE(m)±	1.6	1.7	0.2	14.6

a mean plant height of 148.6, 147.3, 146.8 and 144.7 cm and were at par with each other. The minimum mean plant height of 128.5 cm was recorded in the control plot; followed by Sorghum: Cluster bean @4:1 with 134.5 cm during *Kharif* 2022 (Table 4).

4.3.8 Number of stalks per plant

The number of stalks per plant varied from 9.5 to 13.9 in different treatments with a mean value of 11.1 The maximum number of stalks were observed in the treatment of *Trichogramma chilonis* (13.9) and it proved better than all other treatments.The next most effective treatment; *Beauveria bassiana* recorded a total stalk was 12.0 with which was statistically at par with those treated with Bt formulation (11.0), Sorghum: Cowpea @ 4:2 (10.9), Sorghum: Cowpea @ 4:1 (10.7), Sorghum: Cluster bean @ 4:2 (10.6).

The lowest number of stalks per plant was recorded in the plot of control (9.5) followed by Sorghum: Clusterbean @4:1 (10.2).

4.3.9 Damaged stalk per plant

The data presented in Table 13 revealed that number of damaged stalks per cent varied from 4.4 to 16.3 per cent in different treatments. The minimum damaged stalks observed in the treatment of egg parasitoid, *Trichogramma chilonis* was 4.4 which was statistically at par with the treatment of *Beauveria bassiana* (6.6). The next treatment in this order was Bt formulation (9.7) followed by Sorghum: Cowpea @4:2 (10.1), Sorghum: Cluster bean @4:2 (10.6).

The maximum damaged stalks/plant were recorded in the plot of control (16.3) followed by Sorghum: Cluster bean @4:1 (13.1%) and Sorghum: Cowpea@ 4:1 (11.3%).

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There was no difference between different treatments for number of plants. The treatment plot of *Trichogramma chilonis* at 150000/ha showed the highest plant population of 147.3. The results of this investigation showed that the treatment of *Trichogramma chilonis* @150000/ha resulted in the lowest proportion of dead hearts (7.5) and the lowest percentage of leaf damage (3.3) at 35 DAE.

Green fodder yield, plant height, and the total number of stalks were all counted at harvest. Maximal plant height (154.5 cm), total number of stalks/plant (13.9), and yield (350.3 q/ha) were observed in the *Trichogramma chilonis* treatment plot @150000/ ha. The plot exhibited the lowest levels of stem tunnelling (2.6), stalk damage (4.4), and larval number (0.3). The second-best treatment was *Beauveria bassiana* @ ($1x10^8$ CFU /g@2.5-3.0 kg/ha) which showed minimum dead heart and plant injury.

The maximum dead heart (20.5%) and leaf injury at 35 DAE (6.0) were recorded in the control plot followed by Sorghum: Cowpea @4:1.Similarly, Ali *et al*. (2014) in an experiment reported lower plant infestation and dead hearts (23.01 & 9.37%) in treatment with two releases of *T. chilonis* @1,00,000 lac/ha at 15 and 26 DAS as compared to untreated control (38.29 & 13.67%) at 40 DAS.

The present results were in agreement with the findings of Aggarwal and Jindal (2013). They reported low dead heart incidence (2.55%) in biocontrol treated plots (release of *T. chilonis* parasitized eggs @ 1,00,000/ha at 12 DAG) as compared to farmer practices (3.85%) (two sprays

TABLE 4

Effect of application of eco-friendly management practices on plant height and stalk damage percentage against stem borer, *Chilo partellus* infestation in dual purpose sorghum, HJ 541 during *Kharif*, 2022

Treatment	Plant height (cm)	No. of stalks/plant	Stalkdamage (%)
T1: Sorghum:Cowpea (4:2)	146.8	10.9	10.1(18.3)
T2: Sorghum:Cowpea (4:1)	139.6	10.7	11.3(19.6)
T3: Sorghum:Cluster bean (4:2)	144.7	10.6	10.6(18.9)
T4: Sorghum:Cluster bean (4:1)	134.5	10.2	13.1(21.2)
T5:*Beauveria bassiana* ($1x10^8$ CFU/g @ 2.5-3.0 kg/ha)	148.6	12.0	6.6(14.8)
T6:*Trichogramma chilonis* (150000/ha)	154.5	13.9	4.4(11.9)
T7: Bt formulation (1 kg/ha)	147.3	11.0	9.7(18.1)
T8: Control	128.5	9.5	16.3(23.8)
Mean	143.1	11.1	10.3(18.3)
C.D. (p=0.05)	14.0	1.7	(4.3)
SE(m)±	4.5	0.5	1.4

of deltamethrin 2.8 EC @ 200 ml ha^{-1} at 15 and 30 DAG). Kumar and Kanta (2011) reported maximum egg parasitisation (44.8%) when *T. chilonis* (single release @ 1,00,000/ha) was released on 12-day old crop as compared to treatment (deltamethrin 2.8 EC @ 200 ml/ha) (1.00%) followed by untreated control (4.4%) give support to present findings. They also reported higher yield (25.9 q t/ha) in treatment (*T. chilonis* @ 1,00,000/ha) as compared with untreated control (18.62 t/ha).

The results of the present studies were in line with Halagatti (2012) who recorded a higher yield (8633 kg/ha) in treatment, two releases of *T. chilonis* @ 1,00,000/ha at the weekly interval as compared to untreated control (3044 kg/ha). They further reported a higher cost: benefit ratio (1:3.72) when two releases of *T. chilonis* @ 1,00,000/ha were made at weekly intervals as compared to one release of *T. chilonis* @ 1,00,000/ha (1:2.75) and untreated control (1:0.72) further give support to the present studies. Anuradha et al. (2010) & Spurthi *et al.* (2009) also reported a reduction in dead hearts when maize was intercropped with cowpea. Kaur *et al.* (2017) recorded that leaf injury rating was less in cowpea intercropped maize (1.09) as compared with sole maize treated with endosulfan spray (1.36).

In the management studies, eight treatments were used in three replications. Observations were recorded on the leaf injury at 35 DAE, per cent dead heart at 45 DAE, plant height, the total number of stalks per plant, damaged stalks, number of holes per plant, number of larvae per plant, stem tunnelling and green fodder yield.

There was no discernible change in the number of plants in either treatment. The treatment plot of *Trichogramma chilonis* @ 150000/ha showed the highest plant population (147.3).

The results of this investigation showed that the treatment of *Trichogramma chilonis* @ 150000/ha resulted in the lowest percentage of dead hearts (7.5) and the lowest percentage of leaf damage (3.3) at 35 DAE followed by *Beauveria bassiana* treatment ($1x10^8$ CFU /g @ 2.5-3.0 kg/ha).

Green fodder yield, plant height, and the total number of stalks were all counted at harvest. Maximal plant height (154.5 cm), total number of stalks/plant (13.9), and yield (350.3t/ha) were observed in the *Trichogramma chilonis* treatment plot @ 150000/ha. The plot exhibited the lowest levels of stem

Photo 2. Cowpea as inter crop in sorghum

*Figure in parenthesis are angular transformed values

Photo 1. Damage symptoms showed in Sorghum variety HJ 541 due to *Chilo partellus.*

tunnelling (2.6), stalk damage (4.4), and larval number (0.3). The maximum dead heart and plant injury recorded in the control plot followed by Sorghum: Cowpea @ 4:1. Hence *Trichogramma chilonis* treatment plot @150000/ha was found to be superior among all treatments followed by *Beauveria bassiana* treatment ($1x10^8$ CFU/g @ 2.5-3.0 kg/ha).

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