Plant Archives Vol. 26, No. 2, 2026 pp. 2010-2014 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.276

FIELD EFFICACY AND ECONOMIC PERFORMANCE OF BIORATIONAL TACTICS AGAINST SPOTTED STEM BORER, *Chilo partelluS* (SWINHOE), IN DUAL-PURPOSE FODDER SORGHUM

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(Date of Receiving-16-07-2026; Date of Revision-19-09-2026; Date of Acceptance-01-10-2026)

ABSTRACT

Field efficacy and economic performance of selected biorational tactics were evaluated against the spotted stem borer, *Chilo partellus* (Swinhoe), in dual-purpose sorghum cultivar HC 541 during *Kharif* 2021 at the Research Area of the Forage Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. Six biorational treatments—Nimbecidine 300 ppm, *Beauveria bassiana*, *Verticillium lecanii*, *Metarhizium anisopliae*, the egg parasitoid *Trichogramma chilonis* and a *Bacillus thuringiensis* formulation were compared with Carbofuran 3.0 CG as a chemical standard and an untreated control in a randomized block design with five replications. Plant stand, plant vigour, oviposition, deadheart formation and green fodder yield were recorded and treatment economics were assessed using incremental cost–benefit ratio (ICBR). Deadheart incidence ranged from 5.49% with Carbofuran to 34.90% in the untreated control. Among the biorational treatments, T. *chilonis* (6.34%) and B. *bassiana* (8.73%) produced the lowest deadheart incidence and were statistically comparable with the chemical standard. These treatments also recorded high green fodder yields of 320.8 and 317.1 q ha^{-1}, respectively, compared with 284.4 q ha^{-1} in the control. T. chilonis recorded the highest reported ICBR (1.99), followed by Carbofuran (1.25), Bt (0.36) and B. bassiana (0.27). The results identify T. *chilonis* and B. *bassiana* as promising biorational options for reducing stem-borer damage and sustaining fodder productivity under the conditions of the study. Because the experiment was conducted at one location in one season, validation across seasons and locations is required before wider recommendation.

***Key words*:** Biological control; *Chilo partellus*; fodder sorghum; integrated pest management;

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal and fodder crop cultivated extensively in the semi-arid regions of India because of its adaptability to relatively high temperatures and limited moisture conditions. In Haryana, sorghum is predominantly cultivated as a dual-purpose crop, providing both grain and valuable green fodder for livestock. However, sorghum productivity is adversely affected by a diverse range of insect pests, among which the spotted stem borer, *Chilo partellus* Swinhoe (*Lepidoptera: Crambidae*), is considered one of the major insect pests limiting crop growth and yield. The pest is particularly damaging during the early vegetative stage, when young larvae feed within the leaf whorl and subsequently penetrate the stem. Feeding on the growing tissues interferes with plant growth and frequently results in the formation of characteristic deadhearts, which can substantially reduce plant vigour and fodder productivity (Garhwal and Yadav, 2024). Management of C. *partellus* has traditionally relied on the use of synthetic insecticides. Although insecticides can provide effective and relatively rapid suppression of stem-borer populations, their repeated and indiscriminate use, particularly in fodder crops, may lead to several

undesirable consequences, including pesticide residues, development of insecticide resistance, disruption of beneficial arthropod populations and other non-target effects. These limitations have encouraged the exploration of safer and more environmentally compatible pest-management options. Consequently, biorational approaches, including entomopathogenic microorganisms, botanical insecticides, microbial formulations and biological control agents, have received increasing attention as potential components of integrated pest management programmes. Among the biological and biorational options investigated against stem borers, entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* have shown potential for suppressing larval populations through fungal infection. Similarly, formulations based on *Bacillus thuringiensis* have attracted considerable interest because of their selective insecticidal activity and comparatively favourable environmental profile. Neem-based formulations containing biologically active limonoids, particularly azadirachtin, may affect pest feeding, development and oviposition. In addition, the egg parasitoid *Trichogramma chilonis* Ishii has been used as a biological control agent against lepidopteran stem borers by parasitizing their eggs and thereby reducing the subsequent larval population. Despite the availability of these individual management options, comparative field assessment of different biorational treatments under the same agro-ecological conditions is essential for identifying effective and economically viable combinations for practical pest management. The present investigation was, therefore, undertaken to evaluate selected biorational treatments against C. *partellus* in sorghum cultivar HC 541 under field conditions. The study focused on their comparative effects on pest incidence and oviposition, deadheart formation, plant growth and performance, green fodder yield and economic returns. An incremental cost–benefit analysis was also conducted to assess the economic feasibility of the evaluated treatments and to identify promising biorational options for incorporation into an integrated management programme for spotted stem borer in fodder sorghum.

Materials and methods

Experimental site

The field experiment was conducted during *Kharif* 2021 at the Research Area of the Forage Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India (29.1492° N, 75.7217° E; 215 m above mean sea level). The region falls under agro-climatic zone II. Recommended agronomic practices for *Kharif* fodder sorghum were followed, except that plant-protection operations were governed by the experimental treatments.

Experimental design and treatments

Variety : HC 541
Plot size : 3.6 × 4 m^2
Design : Randomized Block Design (RBD)
Replications : Five
Treatments : 8 (including control)
Sowing time : 21st July, 2021

Treatments	Name	Dose
T_1	Nimbecidine 300 ppm	2.5 L/ha
T_2	*Beauveria bassiana* (1×10^9 CFU/g)	4.0 kg/ha
T_3	*Verticillium lecanii* (1×10^9 CFU/g)	4.0 kg/ha
T_4	*Metarhizium anisopliae* (1×10^8 CFU/g)	4.0 kg/ha
T_5	Carbofuran 3.0 CG	8.2 kg/ha
T_6	Egg parasitoids, *Trichogramma chilonis*	75000/ha
T_7	*Bt.* Formulation	1.0 kg/ha
T_8	Control	-

Observations

Plant stand and plant vigour were recorded at 12 days after crop emergence (DAE). Plant vigour was assessed on a 1–5 visual scale as described by Sharma and Nwanze (1997), with lower scores representing greater vigour. The number of C. *partellus* eggs on the underside of leaves of five randomly selected seedlings per treatment was recorded at 35 DAE. Deadheart formation was recorded on all plants in each plot at 45 DAE and expressed as a percentage of plants observed. Green fodder yield was recorded at harvest and converted to q ha^{-1}.

Statistical analysis

Treatment data were analysed using analysis of variance in OPSTAT (Sheoran *et al.*, 1998). Deadheart percentages were angular-transformed and egg counts were square-root transformed before analysis. Treatment means were compared at P = 0.05. The reported critical difference (CD) and standard error of the mean (SEm) are presented with the treatment means in Table 1.

Economic analysis

Economic performance was expressed as incremental cost–benefit ratio (ICBR) using the

Table 1: Effect of application of biorational management on stem borer, *Chilo partellus* in dual purpose sorghum, HC 541.

Sr.	Treatment	Dead heart* (%) 45 DAE	Plant stand	Plant vigour (Scale 1-5)	No. of eggs 35DAE**	Fodder yield (q/ha)
1.	Nimbecidine 300 ppm @ 2.5 L/ha	16.86^{c} (24.22)	287.00	2.67^{d,e}	15.00^{d,e} (3.99)	291.1^{c,d}
2.	*Beauveria bassiana* (1× 10^{9} CFU/g) @ 4.0 kg/ha	8.73^{a} (16.17)	285.67	1.67^{a,c}	11.67^{b,c} (3.55)	317.1^{a}
3.	*Verticillium lecanii* (1 × 10^{9} CFU/g @4.0 kg/ha	14.54^{b,c} (22.40)	286.67	2.33c,d,e	13.67^{c,d} (3.82)	298.0^{b,c}
4.	*Metarhizium anisopliae* (1× 10^{8} CFU/g 4.0 kg/ha	14.50^{b,c} (22.35)	279.67	2.00b,c,d	14.67^{d,e} (3.95)	301.0^{b}
5.	Carbofuran 3.0 CG @ 250 g a.i./ ha or8.2 kg/ha	5.49^{a} (13.47)	283.00	1.00^{a}	8. 67^{a}(3.10)	324.9^{a}
6.	Egg parasitoid, *Trichogramma chilonis*@ 75000/ha	6.34^{a} (14.56)	285.00	1.33^{a,b}	10.33^{a,b} (3.37)	320.8^{a}
7.	Application of *Bt* formulation @ 1.0 kg/ha	11.18^{b} (19.52)	282.33	2.33c,d,e	13.33^{c,d} (3.78)	305.0^{b}
8.	Control	34.90^{d} (36.19)	281.00	3.00^{e}	16.67^{e} (4.20)	284.4^{d}
	Mean	**14.11**	**283.79**	**2.04**	**13.00**	**305.28**
	SE(m)±	1.09	-	0.27	0.11	2.62
	CD (*P*=0.05)	3.32	NS	0.81	0.31	8.03

*Figure in parenthesis are angular transformed values; In column 5, **figure in parenthesis are square root transformed values, Figures with the same alphabet in same column are statistically at par

incremental yield over the untreated control, the fodder price of Rs. 125 q^{-1} and the reported cost of plant-protection inputs plus one labour application at Rs. 360 per labour-day. The ICBR values reported in the original dataset are retained in Table 2.

Results

Plant stand and plant vigour

The data presented in (Table 1) showed that the treatments had no significant effect on plant stand. The plant stand varied from 279.67 to 287.00 plants among the different treatments. The highest plant stand was recorded in Nimbecidine 300 ppm @ 2.5 L/ha (287.00 plants), followed by V. *lecanii* (286.67 plants) and B. *bassiana* (285.67 plants). The lowest plant stand was observed in M. *anisopliae* (279.67 plants). Plant vigour, on the other hand, varied significantly among the treatments. The lowest vigour score (1.00) was recorded with Carbofuran 3.0 G @ 250 g a.i./ha or 8.2 kg/ha. It was followed by T. *chilonis* (1.33), B. *bassiana* (1.67). The highest vigour score (3.00) was observed in the control. Thus, the application of the different biorational treatments did not cause any significant change in plant stand, but a significant difference was observed in plant vigour among the treatments. The non-significant difference in plant stand may be because plant establishment was mainly affected by germination, soil moisture and other initial growing conditions. Since the treatments were applied after crop establishment, they had little effect on the number of surviving plants (Singh *et al*., 2012). However, plant vigour differed significantly among the treatments, which may be attributed to differences in their efficacy of different biorational management on stem borer against the pest complex and the consequent reduction in pest-induced damage to the plants (Karabhantanal and Dharavath, 2023). The lower vigour score with Carbofuran 3.0 G suggests better suppression of the pest complex and less feeding damage (Reddy and Kumar, 2021). The microbial and botanical treatments showed intermediate vigour, possibly because of their slower or more specific action (Ayilara *et al*., 2023). The highest vigour score in the untreated control may be due to higher pest pressure and greater plant damage Thus, the treatments had little effect on plant stand but influenced plant vigour.

Number of eggs

The results presented in (Table 1) revealed that the treatments significantly influenced the number of eggs laid by the stem borer at 35 days after emergence (DAE). The minimum number of eggs was recorded in Carbofuran 3.0 G (8.67 eggs/5 plants), followed by *Trichogramma chilonis* (10.33 eggs/5 plants), indicating comparatively lower oviposition under these treatments. The maximum number of eggs was recorded in the untreated control (16.67 eggs/5 plants), which was statistically at par with Nimbecidine (15.00 eggs/5 plants) and M. *anisopliae* (14.67 eggs/5 plants). The lower egg deposition in Carbofuran and T. *chilonis* treatments may be due to better suppression of the stem borer population, which reduced adult moth activity and oviposition on the treated plants (Shah *et al*., 2023; Khan *et al*., 2026). Effective pest management also reduces the number of suitable sites available for egg laying, resulting in fewer eggs (Zhang & Wang, 2025). In contrast, the higher egg population in the untreated control may be due to higher pest activity and continuous availability of suitable host plants for oviposition (Daelemans *et al*., 2023).

Table 2: Economics of various biorational treatments in sorghum variety, HC 541 during *Kharif*, 2021.

Treatments	Dose (lit/ kg or number/ ha)	Yield (q/ha)	Incremental yield (q/ha)	Cost of incremental yield (Rs/ha)	Cost of protection (Rs/ha)	Net profit (Rs/ha)	ICBR
Nimbecidine 300 ppm	2.5	291.1	6.7	837.5	3095	-2257	-0.85
Beauveria bassiana	4.0	317.1	32.7	4087.5	2960	1127.5	0.27
Verticillium lecanii	4.0	298.0	13.6	1700	2960	-1260	-0.30
Metarhizium anisopliae	4.0	301.0	16.6	2075	3040	-965	-0.37
Carbofuran 3.0 CG	8.2	324.9	40.5	5062.5	2278	2784.5	1.25
Egg parasitoid, *Trichogramma chilonis*	75000	320.8	36.4	4550	1200	3350	1.99
Bt formulation	1.0	305.0	20.6	2575	1700	875	0.36
Control	-	284.4	0.0	-	-	-	-

Price of sorghum fodder= Rs. 125 q^{-1}; No. of labour required per spray/ha = 1; labour charges = Rs 360/labour / day; Maximum retail price of insecticides: Nimbecidine @ Rs. 475/Kg, *B. bassiana* @Rs 280/kg, *V. lecanii* @ Rs 280/kg, *M. anisopliae* @ Rs 290/kg, Carbofuran @ Rs 90/kg, *Trichograma chilonis* @ 60/card , *B. thuringiensis* @ Rs 490/lit

Dead heart formation

The results presented in (Table 1) showed that the minimum deadheart incidence (5.49%) was recorded with Carbofuran 3.0 G @ 250 g a.i./ha or 8.2 kg/ha, which was at par with *Beauveria bassiana* (8.73%). The maximum deadheart incidence (34.90%) was recorded in the untreated control. The lower deadheart incidence in Carbofuran and B. *bassiana* treatments may be due to better suppression of stem borer larvae, which reduced their feeding and damage to the growing shoot, thereby limiting shoot drying and deadheart formation (Sudha *et al*., 2018;) The higher deadheart incidence in the untreated control may be attributed to unrestricted larval feeding in the central whorl and developing stem, which damages meristematic tissues and disrupts nutrient and water transport, ultimately causing drying of the central shoot and deadheart formation (Ramesh *et al*., 2023

Fodder

The results presented in (Table 1) showed that fodder yield differed significantly among the treatments. The highest fodder yield (324.9 q/ha) was recorded with Carbofuran 3.0 CG @ 250 g a.i./ha or 8.2 kg/ha, which was at par with *Trichogramma chilonis* (320.8 q/ha) and *Beauveria bassiana* (317.1 q/ha). The lowest fodder yield (284.4 q/ha) was recorded in the untreated control, which was significantly lower than all the other treatments. The higher fodder yield in Carbofuran, T. *chilonis* and B. *bassiana* treatments may be attributed to better suppression of stem borer infestation, resulting in reduced shoot damage and improved plant growth and biomass accumulation (Kumar *et al*., 2017). In contrast, the lower yield in the control may be due to greater stem borer damage, which reduced functional plant tissue and consequently limited biomass production. (Mahesha *et al*., 2025).

Economics

The economic analysis presented in Table 2 showed considerable variation among the treatments in terms of incremental yield, cost of plant protection, net profit and incremental cost–benefit ratio (ICBR). *Trichogramma chilonis* recorded the highest net profit of Rs 3,350 ha^{-1} with an ICBR of 1.99. The treatment produced 320.8 q ha^{-1} of fodder, with an incremental yield of 36.4 q ha^{-1} over the untreated control. Carbofuran 3.0 CG recorded the highest fodder yield (324.9 q ha^{-1}) and an incremental yield of 40.5 q ha^{-1}, resulting in a net profit of Rs 2,784.5 ha^{-1} and an ICBR of 1.25. Among the other treatments, *Beauveria bassiana* recorded a net profit of Rs 1,127.5 ha^{-1} with an ICBR of 0.27, while the *Bacillus thuringiensis* formulation gave a net profit of Rs 875 ha^{-1} with an ICBR of 0.36. Nimbecidine, *Verticillium lecanii* and *Metarhizium anisopliae* resulted in negative net returns and ICBR values. The higher economic return obtained with T. *chilonis* was associated with its relatively lower plant-protection cost and higher incremental fodder yield. Similar importance of economic evaluation in biological management of *Chilo partellu* has been reported by Aggarwal and Jindal (2013) and Kumar *et al*., (2017). Overall, the results indicated that *T. chilonis* provided a favourable economic return under the conditions of the present experiment.

Conclusion

Overall, the results showed that the biorational treatments were useful in reducing stem borer infestation and maintaining crop performance in sorghum. Plant stand was not significantly affected, indicating that the treatments had little influence on crop establishment. In contrast, plant vigour differed significantly, with Carbofuran 3.0 G recording the best vigour. The lowest egg population at 35 DAE was recorded with Carbofuran 3.0 G, followed by T. *chilonis*. Similarly, deadheart

incidence at 45 DAE was lowest with Carbofuran 3.0 G, followed by B. *bassiana*. The untreated control recorded the highest egg population and deadheart incidence, reflecting greater stem borer pressure. Carbofuran 3.0 G also produced the highest fodder yield (324.9 q/ha) among the treatments. B. *bassiana* and T. *chilonis* also performed well in reducing pest damage and maintaining fodder yield. From the economic point of view, T. *chilonis* gave the highest net profit (Rs 3350/ha) and ICBR (1.99). Carbofuran 3.0 G ranked next, with a net profit of Rs 2784.5/ha and an ICBR of 1.25. Thus, although Carbofuran gave better pest suppression and yield, T. *chilonis* was the most economically viable treatment under the conditions of the experiment.

Acknowledgements

The authors gratefully acknowledge the Department of Entomology and the Forage Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, for providing the experimental facilities used in this study.

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