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Efficacy Of Eco-Friendly Integrated Pest Management (IPM) Strategies Against The Sugarcane Shoot Borer In Maihar (Pondi) Tehsils Of Madhya Pradesh

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ABSTRACT

Overutilization of artificial chemical pesticides during the cultivation of sugarcane leads to adverse effects on the soil and ecological systems, as well as development of insect resistance to them, which demands the use of sustainable measures to protect sugarcane. This research is aimed at investigating the effectiveness of environmentally friendly integrated pest management (IPM) strategies for the control of three main sugarcane stem borers, namely, Early Shoot Borer (ESB), Top Shoot Borer (TSB) and Internode Borer (INB) in Maihar, Madhya Pradesh, India throughout the whole cropping season (July 2023–March 2025). The use of Co. 86032 cultivar of sugarcane was practiced along with monitoring of pest dynamics and weather conditions. IPM measures were applied to the crop in accordance with crop growth phases. The control of ESB pests (35–80 DAP) was provided with the help of *Trichogramma chilonis* (50,000/ha) and Chilo Granulovirus (ChGV) spray resulting in 68.14% reduction of the pest population. More significantly, for extremely resilient INB (120 DAP to harvest), the synergistic interaction of entomopathogenic fungal species (B. bassiana and M. anisopliae), coupled with increased numbers of *T. chilonis* application (100,000/ha), achieved a very significant 73.83% overall reduction in pests. This is a marked improvement over previously conducted separate biocontrol efforts for the management of INB. These results prove that when used timely through phenology-based application, biologicals and botanics exhibit comparable efficacy to synthetic options. Using such an environmentally friendly IPM system will help to ensure sustainable cultivation of sugar cane in the future.

Keywords: Sugarcane stem borer, Integrated Pest Management (IPM), *Trichogramma chilonis*, Entomopathogenic fungi, Sustainable agriculture

INTRODUCTION

India is a crucial player in the international food security arena and a source of major agricultural products. India is home to crops that are essential to the country's economy, including sugar cane (Family Poaceae), which is one of those. Sugarcane industry in India occupies about 7.5 percent of the rural workforce in India, and it is expected to grow 454.61 million tons of sugar cane by 2024-25. Even though it was used as food crops at the beginning, it is now vital as cash crops in bioeconomy globally. It is perennial and drought-resistant. Sugar cane crop offers feedstock for sustainable bioenergy, bioplastics, green chemicals and pharmaceuticals (Damaj et al., 2020; Teferi et al., 2025).

Despite economic and ecological significance of sugarcane, it suffers from some serious biotic limitations. For instance, according to the Vasantdada Sugar Institute, there are 287 species of insect and pests which can affect sugarcane. Out of them, 19 are major pests in India. Most significant among them are the stem borers such as Early Shoot Borer (ESB, *Chilo infuscatellus*), Internode Borer (INB, *Chilo sacchariphagus indicus*) and Top Shoot Borer (TSB, *Scirpophaga excerptalis*) (Bhavani, 2025). Farmers traditionally used synthetic insecticides for pest management; Endosulfan, Carbofuran and Monocrotophos are examples of such insecticides.

However, there were several adverse effects caused by overusing of chemical fertilizers and pesticides (Tudi et al., 2021). Continuous usage of chemicals leads to soil microflora destruction, disturbance of nutrient cycle, soil acidification and degradation of organic matter (Meena et al., 2020; Li et al., 2025). Moreover, waste of agriculture pollutes the water resources causing eutrophication. Ecologically, synthetic insecticides have one mode of action leading to pests' adaptation and killing natural predators.

To ensure sustainability in growing sugarcane in future, it is crucial that the shift be made from use of chemicals to environmentally friendly IPM approaches. U.S. Environmental Protection Agency state that IPM uses natural products and biological processes to curb pest population. This includes use of pheromones that inhibit the reproductive process in insects, microbial biopesticides like *Trichoderma* fungus and *Bacillus thuringiensis* as well as introduction of biological enemies including lady bugs and parasitoid wasps (Angon et al., 2023). Botanical biopesticides including Neem oil act as growth inhibitors, anti-feedants and repellents (Campos et al., 2016). They are safe and have no risks compared to synthetic pesticides that result in toxic substances such as hydroxymethylfurfural (HMF) (Surma et al., 2023).

Therefore, this study sought to assess the efficiency of various eco-friendly IPM methods on sugarcane shoot borer. The assessment of these eco-friendly strategies would provide a solution to the chemical methods used in this study and make it environmentally sustainable.

MATERIALS AND METHODS

The above field experiment was carried out in the sugarcane fields of Maihar (Pondi) Tehsil in the state of Madhya Pradesh, India. This experiment was carried out for one full crop season from July 2023 to March 2025. The commonly used sugarcane variety in the experiment was Co. 86032 since it was the most prevalent variety among farmers.

Pest Monitoring and Data Collection

Monitoring was conducted on the incidence and population dynamics of some of the common stem borers viz., ESB, TSB and INB as described by Rahman et al. (2013), Bharati and Dwarka (2023), Kumar et al. (2025) and Anand et al. (2023).

- **Field Scouting:** Data collection was done on the third day of the Standard Meteorological Week (SMW). The observations were made after selecting a sample size of 100 tillers from each plot to assess the rate of stem borer infestation using agricultural standards. All the infested tillers were flagged to avoid any duplication in the next sampling period.

- **Pheromone Trapping:** The deployment of three pheromone traps was made within the study site in order to assess the activity levels of the adult male moths.

- **Meteorological Data:** Meteorological Data for each SMW period, including maximum and minimum temperatures, relative humidity (as percentages in the morning and evening) and rainfall were collected weekly at the local weather station.

The data collected from field scouting and trapping were analysed for developing two key indices: the total per cent infestation in the field and the average number of moths caught daily by trap.

Preparation of Eco-Friendly Interventions

In order to assess the efficiency of IPM, five different bio-botanical pesticides were acquired, standardized, and applied in combination.

- **Azadirachtin:** The commercial formulation of Azadirachtin (AzaNeem-300®) was purchased locally and applied in the form of a foliar spray at a dilution rate of 0.5 mL/L.

- **Egg Parasitoids (*T. chilonis*):** Commercially available "TRI CARDS," containing about 18,000 to 20,000 parasitized eggs per card, were used for field releases.

- **Entomopathogenic Fungi:** Metarhizium anisopliae powder (5×10^8 CFU/g) and *Beauveria bassiana* 1.15% W.P. (1×10^8 CFU/g) were made into suspension in water with a concentration of 1×10^8 CFU/mL.

- **Chilo Granulovirus (ChGV):** A culture of the virus was prepared and standard concentration of 1.1×10

IPM Treatment Schedule

The IPM interventions were strategically scheduled based on the specific crop growth stage, days after planting (DAP), and the targeted pest species (Table 1).

Table 1: Schedule of Eco-Friendly IPM Interventions in Sugarcane

S. No.	Crop Stage (DAP)	Target Pest	IPM Interventions Applied
	35 – 80 DAP	ESB	Release of *T. chilonis* (50,000 parasitoids/ha) followed by ChGV viral foliar spray.
	90 – 150 DAP	TSB	Azadirachtin (neem-based) foliar spray, followed by subsequent releases of *T. chilonis*.
	120 DAP to Harvest	INB	Application of entomopathogenic fungi (*B. bassiana* and *M. anisopliae*) alongside intensified releases of *T. chilonis* (100,000 parasitoids/ha).

RESULT AND DISCUSSION

The above field experiment was conducted in the sugarcane farms of Maihar (Pondi) Tehsil in the state of Madhya Pradesh, India. The experiment was conducted for a complete crop season from July 2023 to March 2025. Data are presented systematically.

Meteorological parameters recorded at Study Site showed a significant variation during the season (July to March). During the rainy season, Study Site registered maximum amount of precipitation with July and August having maximum average precipitation values of 328.0 ± 12.20 mm and 320.5 ± 11.10 mm, respectively. At the same time, this period had high humidity levels, with the morning relative humidity (RH) being the maximum in August, with 86 ± 2.3%. As a result, temperatures were high, and the maximum temperature level was observed in August, with 32.8 ± 1.80 °C (Table 2).

The seasonal shift from autumn to winter resulted in a decline in rainfall, recording 36.5 ± 2.35 mm in October and attaining its minimum at 5.5 ± 0.12 mm in December. The RH in both the morning and evening sessions recorded significant decreases in values during this period from the monsoon highs. There was an evident decrease in thermal conditions, as the minimum and maximum temperature were 7.2 ± 0.72 °C and 24.1 ± 1.20 °C, respectively, in January (Table 2).

However, by March when the season had become spring, conditions changed once more. The minimum temperature in March was observed to be 18.1 ± 0.62 °C, and the maximum was 32.2 ± 1.68 °C, close to that of the previous summer. Humidity was low in March, with evening RH at 26 ± 1.25% (Table 2).

Table 2: Meteorological Data Across the Study Site (Study Site)

Month	Maximum Temp (°C)	Minimum Temp (°C)	Morning RH (%) (08:30 IST)	Evening RH (%) (17:30 IST)	Average Rainfall (mm)
July	31.2 ± 1.90	25.9 ± 1.15	84 ± 2.5	73 ± 3.90	328.0 ± 12.20
August	32.8 ± 1.80	24.3 ± 1.10	86 ± 2.3	76 ± 3.75	320.5 ± 11.10
September	32.1 ± 1.65	24.4 ± 1.25	83 ± 2.1	71 ± 3.65	195.0 ± 9.70
October	31.6 ± 1.50	20.1 ± 1.10	67 ± 2.9	48 ± 3.70	36.5 ± 2.35
November	28.6 ± 1.42	13.3 ± 0.90	63 ± 2.7	44 ± 3.15	6.0 ± 0.16
December	25.2 ± 1.22	8.7 ± 0.80	68 ± 3.1	46 ± 3.45	5.5 ± 0.12
January	24.1 ± 1.20	7.2 ± 0.72	72 ± 3.7	47 ± 3.25	13.0 ± 0.98
February	26.5 ± 1.35	12.2 ± 0.32	65 ± 3.3	38 ± 2.50	22.0 ± 1.22
March	32.2 ± 1.68	18.1 ± 0.62	45 ± 3.2	26 ± 1.25	14.2 ± 0.91

Efficacy of Eco-Friendly IPM Modules

Aside from meteorological variations, efficiency of the employed IPM modules greatly varied depending upon the specific pest targeted and crop stage (Table 3).

In ESB management (35 to 80 Days After Planting [DAP]), application of *T. chilonis* (50,000/ha) and ChGV virus spray resulted in individual efficiencies of 59.87% and 54.25%, respectively. The duo worked together to give a combined pest reduction efficiency of 68.14%. In the case of TSB (90 to 150 DAP), spraying of Azadirachtin and *T. chilonis* release gave individual efficacies of 55.94% and 66.19%, resulting in 69.12% pest reduction efficiency. Lastly, in INB control (120 DAP to harvest), entomopathogenic fungus combination of Beauveria bassiana and Metarhizium anisopliae along with a high-density release of *T. chilonis* (100,000/ha) resulted in individual efficacies of 49.16% and 56.13%, respectively, giving 73.83% pest reduction efficiency.

Table 3: Efficacy of IPM Modules Across Study Sites

Target Pest	Crop Stage	Executed IPM Modules	Efficacy of Individual Components (%)	Projected Combined Pest Reduction (%)
ESB	35 to 80 DAP	*T. chilonis* (50,000/ha)	59.87	68.14
		ChGV Viral Spray	54.25	
TSB	90 to 150 DAP	Azadirachtin Spray	55.94	69.12
		T. chilonis releases	66.19	
INB	120 DAP to Harvest	*B. bassiana* + *M. anisopliae*	49.16	73.83
		T. chilonis (100,000/ha)	**56.13**	

Discussion

In the current study, it has been showed that appropriate timing and environmentally friendly IPM strategies can result in substantial suppression of the sugarcane stem borers. The effectiveness of egg parasitoid releases is consistent with the recommendations given by Satyagopal et al. (2014), who suggested *Trichogramma* spp. (20,000 per acre) as a general strategy for managing the TSB, INB, and ESB in agricultural fields. Regarding specific pests' reduction, according to earlier studies by Visalakshi et al. (2016), the application of biocontrol techniques for managing ESB is successful and results in a 91.58% reduction, which proves high efficiency of biological treatments in terms of preventing early losses in crops. Nonetheless, these authors reported extremely low efficiency of the same biological agents in reducing INB pressure (only 18.82%). As opposed to this result, the current study has reached a highly statistically significant reduction of INB – 73.83%. Such improvement can be explained by the use of the current study's intensive strategy: a combination of entomopathogenic fungi (*B. bassiana* and *M. anisopliae*) along with a higher density of *T. chilonis* release (100,000/ha) from 120 DAP to harvest time.

Moreover, successful utilization of these particular microbial and fungal biological organisms has been further justified through the work conducted by Saha (2022) in reviewing the applicability of biopesticides for use in IPM systems. The effectiveness of viruses (ChGV), fungi (*M. anisopliae* and *B. bassiana*) and certain bacteria has been proved by Saha (2022), affirming their status as potent and sustainable alternatives to chemical pesticides in today's agriculture. Finally, it can be concluded that the use of particular botanical, fungal and biological agents depending on certain phases of crop phenology contributes greatly to pest management.

Conclusion

The evolution from chemical farming practices towards sustainable biological approaches is essential for the future development of bioeconomies globally and environmental security. The current research provides unequivocal evidence about how the adoption of a bio-friendly Integrated Pest Management (IPM) approach can be an efficient and durable solution to tackle the damaging stem borers in sugarcane production. In this particular case, using biological and botanical products depending on the particular phenological period of crops helped to reach considerable pest control results. Applying *T. chilonis* alongside with ChGV virus applications enabled the researchers to decrease ESB pests up to 68.14%, and applying the combination of Azadirachtin and parasitoids resulted in the 69.12% pest elimination of TSB pests. The most important contribution of this research to the field of IPM management is the ability to tackle the persistent pest INB. Using high-dose applications of *T chilonis* (100,000/ha) with entomopathogenic fungi (*B. bassiana* and *M. anisopliae*), it was possible to reduce INB pests by 73.83%. The above findings reveal that multi-component botanical and biological extracts that function as multi-functional antifeedants and growth inhibitors can overcome the problems of resistance associated with single component chemical substances. Application of the above approach helps to prevent any hazardous toxic residues in the environment, stop the degradation of the soil micro flora and preserve natural predators. Finally, the integration of microbial, fungal and botanical organisms at different stages creates a sustainable system of agriculture that would ensure productivity of sugarcane and protect rural economies.

Conflict of Interest
There is no conflict of interest between authors

Ethical Aspects

Oral informed consent has been obtained from the farmers, and they have been assured of confidentiality and a commitment to use the observations only for the present research.

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