# Sugarcane Borer Management Strategies and Crop Loss Assessment under Changing Climatic Conditions in Andhra Pradesh, India

***Original Research Article***

## ABSTRACT

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| Sugarcane borers are among the most critical constraints to cane yield and sugar recovery in India. In Andhra Pradesh, the early shoot borer (ESB), *Chilo infuscatellus* Snellen and the internode borer (INB), *Chilo sacchariphagus indicus* Kapur are the predominant pests, causing substantial yield losses. Climate change has altered the occurrence patterns, outbreak frequency and population dynamics of stem borers across various regions of Andhra Pradesh. Considering the severe damage caused by these borers, particularly during the early stages of crop development, effective pest management is essential to maintain optimal plant density and achieve high cane yield. Currently, integrated pest management (IPM) strategies are used to manage stem borers, combining chemical communication, biological control, chemical pesticides and the development of resistant varieties. Therefore, with a view to assess the impact of borer infestation on cane yield and to evaluate the efficacy of various management strategies including chemical, non-chemical, and integrated pest management (IPM) methods, a field experiment was conducted at the Research Farm of RARS, Anakapalle for two seasons. Field studies were conducted in a randomized block design comprised of four treatments and four replications at Regional Agricultural Research Station, Anakapalle during 2023-24 and 2024-25. The data on ESB were recorded at 30, 60, 90 and 120 days after planting. The data on INB, growth parameters, juice sucrose were recorded at harvest. Standard procedures were followed for the observations and statistical analysis of the data. The results revealed that more than 30% early shoot borer (ESB) incidence and 100% internode borer (INB) infestation with 26.6% intensity reduced the number of millable canes, juice sucrose, and cane weight, resulting in 18.7 per cent yield loss compared to the protected plot with IPM module (chemical + non-chemical). The IPM module significantly reduced the ESB and INB infestations and increased cane yield by 23.1% over the untreated control, achieving a benefit-cost ratio (BCR) of 2.73. In chemical and non-chemical methods alone resulted in yield increases of 19.9% and 16.7%, with BCRs of 2.69 and 2.62, respectively. |

*Keywords: Sugarcane borers; yield loss; assessment; climate; management; IPM; Trichogramma chilonis; intercropping; trash mulching; pheromone traps; chlorantraniliprole.*

## 1. INTRODUCTION

Sugarcane (*Saccharum* spp.) is an important commercial crop in India, grown mainly for sugar, jaggery, and bioenergy from by-products like bagasse and molasses. India is the world’s second-largest producer of sugarcane (18.18%) and sugar (15.81%) after Brazil (Yadav & Yadav, 2018), and ranks second globally in sugarcane area, covering 5.88 million hectares with a production of 490.53 million tonnes (FAOSTAT, 2023). Sugarcane cultivation is increasingly threatened by a range of diseases and insect pests, among which stem borers are among the most destructive, causing substantial yield losses. These pests complete multiple generations annually, with population densities compounding over time, leading to significant economic damage from the seedling stage through to crop maturity. Among the economically important borer species in South India, the early shoot borer (*Chilo infuscatellus* Snellen (Lepidoptera: Crambidae) is one of the most noxious and destructive, causing severe damage during the early growth stages and leading to significant yield loss (Douressamy *et al*., 2018; Srikanth *et al*., 2001). It is widely prevalent across all major sugarcane-growing regions of the country (Srikanth, 2019). In Andhra Pradesh, infestations begin at the germination stage, with larvae attacking as shoot borers and may continue into the stalk formation phase as internode borers, particularly under drought or poor rainfall conditions (Avasthy & Tiwari, 1986). The pest persists year-round, with peak infestations commonly observed during May–June in high-incidence years, largely due to favourable climatological conditions (Srikanth *et al*., 2002; 2009).

In the North Coastal Zone of Andhra Pradesh, early shoot borer (ESB) infestations can affect more than 70% of shoots in rainfed sugarcane crops (Prasad Rao *et al*., 1991). The resulting losses in sugar production are estimated at 13–20%, with yield reductions reaching as high as 42.5% (Srikanth *et al*., 2016). All commercial sugarcane varieties are considered equally susceptible (David, 1987). At 15% dead heart incidence, yield loss is estimated at around 0.5 tonnes/ha, while a 30% incidence can cause a loss of up to 7 tonnes/ha, representing a 22–33% reduction in yield. In addition, such infestations may lead to a 12% decline in sugar recovery and a 27% reduction in jaggery production (Patil & Hapse, 1981).

The internode borer, *Chilo sacchariphagus indicus* Kapur (Lepidoptera: Crambidae), also poses a serious threat, affecting both commercial varieties (David & Easwaramoorthy, 1990) and germplasm collections (Mahesh *et al*., 2018). Infestations typically begin in April and intensify over time, peaking in September–October when the crop reaches 7–8 months of age (Agrawal, 1964). This pest damages the internodes, reducing their length and thickness, which leads to substantial yield and processing losses (David and Ananthanarayana, 1963). Larvae may enter from the top of the plant, feeding on or above the meristem, or they may penetrate the meristem itself, resulting in "deadheart" symptoms. Additional indicators include axial bud germination and damage to germinated buds (Srikanth & Kurup, 2011). Yield losses are further compounded by a reduction in the number of millable canes due to early shoot borer damage, and by decreased cane weight because of internode borer infestation. Juice quality and sugar recovery are also adversely affected due to the production of late tillers and secondary bud sprouting. Given the severity of damage caused by these borers, especially during the early stages of crop development, timely and effective pest management strategies are essential to maintain optimal plant stand and ensure high cane yields. In view of these challenges, the present study was undertaken to assess the yield losses caused by stem borers and to evaluate effective management strategies for controlling both early shoot borer and internode borer in sugarcane under changed climatic scenario in Andhra Pradesh.

## 2. MATERIALS AND METHODS

Field studies were conducted at the Regional Agricultural Research Station, Anakapalle for two consecutive seasons during 2023–24 and 2024–25 to assess the yield losses due to borer pests and to evaluate the effectiveness of different pest management strategies *viz.*, chemical control with chlorantraniliprole, non-chemical control through trash mulching, intercropping, field release of *Trichogramma chilonis*, detrashing and mass trapping with pheromone traps *etc*., in sugarcane. The experiment was conducted using a Randomized Block Design (RBD) with four treatments, each replicated four times over two consecutive years. The study included four treatments: chemical control, non-chemical control, integrated practices (IPM) involving both chemical and non-chemical methods, and an untreated control (Table 1). Sugarcane variety CoA 99082 (93 A 145) was planted and managed following recommended agronomic practices. Data were recorded on germination, early shoot borer (ESB) incidence at 30, 60, 90, and 120 days after planting (DAP), internode borer, growth parameters, juice sucrose content, number of millable canes (NMC), and cane yield per plot at harvest. Cumulative ESB incidence up to 120 DAP (% dead hearts), as well as the incidence and intensity of internode borer (INB), were calculated. The NMC and cane yield per hectare were estimated and all the data were subjected to statistical analysis.

**Table 1. Details of the treatment**

|  |  |  |
| --- | --- | --- |
| **S.No** | **Treatment** | **Practices**  |
| 1 | Chemical Module | Soil application of chlorantraniliprole 0.4G at 22.5 kg/ha at planting. Foliar spray of chlorantraniliprole 18.5 SC at 0.3 ml/L between 60-90 days after planting (DAP), |
| 2 | Non Chemical Module | Trash mulching @ 3t/ ha.Frequent irrigations at 7-10 days interval.Intercropping with Cow pea.installation of pheromone traps @ 25 traps/ha.Field release of *Trichogramma chilonis* (Trichocards) at 50,000/ha for six times at 7–10 day intervals from 120 DAP.Detrashing at 150 & 180 DAP. |
| 3 | IPM module (chemical + Non chemical) | Soil application of chlorantraniliprole 0.4G at 22.5 kg/ha at planting. Trash mulching @ 3t/ ha.Intercropping with Cow pea. Installation of pheromone traps @ 25 traps/ha.Field release of *Trichogramma chilonis* (Trichocards) at 50,000/ha for six times at 7–10 day intervals from 120 DAP Foliar spray of chlorantraniliprole 18.5 SC at 0.3 ml/L between 60-90 days after planting (DAP) and Detrashing at 150 & 180 DAP. |
| 4 | Unprotected control |  Spray of chlorpyriphos 20 EC @ 2.5 ml/L, monocrotophos @ 1.6ml/ L after noticing deadhearts. |

**2.1 Early Shoot Borer**

Data on early shoot borer infestation in shoots were collected on a whole-plot basis for each treatment. The total number of shoots and the number of damaged shoots (deadhearts) were recorded at 30, 60, 90, and 120 days after planting. These counts were used to calculate the cumulative percentage incidence of deadhearts (% DH).

$$Incidence of ESB = \frac{Number of infested shoots (deadhearts)}{Total shoots} X 100$$

**2.2 Internode Borer**

Observations on internode borer infestation were recorded in 100 canes for each treatment at harvest. The number of canes infested, total number of nodes and number of infested nodes in a cane were recorded. The per cent incidence and intensity were calculated.

$$Per cent incidence of INB = \frac{Number of infested canes}{ Total number of canes} X 100$$

$$Percent of intensity of INB= \frac{Number of bored internodes in the cane}{ Total number of internodes in the cane} X 100$$

**2.3 Juice Sucrose**

Juice analysis was carried out in randomly selected 10 canes in each treatment and observations on per cent juice sucrose were recorded at harvest using a sugar analysis system - Sucrolyser.

**2.4 Yield Attributing Characters, NMC & Cane Yield**

Observations on yield-attributing characters such as cane height, cane weight were recorded from 100 randomly selected plants per treatment. The number of millable canes and cane yield per plot were recorded at harvest and calculated NMC/ha (000’/ha) and tonnes per hectare (t/ha), respectively.

**2.5 Statistical Analysis**

Data on borer infestation, yield attributing parameters, juice sucrose, NMC and cane yield recorded from the different treatment modules were analyzed using OPSTAT statistical package.

## 3. RESULTS AND DISCUSSION

Data on cumulative incidence of early shoot borer up to 120 DAP, number of millable canes (NMC), incidence and intensity of internode borer, growth parameters (cane height, cane weight), cane yield, and juice sucrose recorded during 2023-24 and 2024-25 were analysed and presented in Tables 2,3 & 4.

**2023-24**

**3.1 Early Shoot Borer**

The results revealed that the IPM module (a combination of chemical and non-chemical practices) significantly reduced the cumulative incidence of early shoot borer (ESB) to 6.30% dead hearts, compared to 27.60% in the untreated control (Table 2). The IPM module included soil application of chlorantraniliprole 0.4G at 22.5 kg/ha at planting, trash mulching at 3 t/ha, frequent irrigations at 7–10 day intervals, intercropping with cowpea, foliar application of chlorantraniliprole 18.5 SC at 0.3 ml/L between 60–90 days after planting (DAP), installation of pheromone traps at 25 traps/ha, and field release of *Trichogramma chilonis* (Trichocards) at 50,000/ha, applied six times at 7–10 day intervals from 120 DAP onwards. In comparison, the chemical control module alone reduced ESB incidence to 8.60%, while the non-chemical module recorded a reduction to 14.40%, both of which were significantly lower than the unprotected control (27.60%).

**3.2 Internode Borer**

The incidence of internode borer (INB) varied considerably among the treatments, ranging from 60% to 100%. The lowest incidence was observed in the IPM module (44.0%), compared to 100% in the unprotected control. The chemical and non-chemical modules recorded internode borer incidences of 80% and 60%, respectively. A similar trend was observed for the intensity of internode borer infestation. The IPM module recorded the lowest intensity (6.1%), which was significantly lower than the unprotected control (20.4%). In comparison, the chemical and non-chemical modules recorded INB intensities of 12.6% and 10.4%, respectively (Table 2).

**3.3 Yield Attributing Characters, Juice Sucrose, NMC and Cane Yield**

The data presented in Table 2 revealed that cane height was significantly reduced in the unprotected control (1.6 m) compared to the IPM module (2.4 m) and both the chemical and non-chemical modules (2.3 m; 2.3 m). Juice sucrose content was highest in the IPM module (19.30%) and was statistically at par with the chemical (19.20%) and non-chemical modules (19.30%). In contrast, the unprotected control recorded a lower juice sucrose content (18.60%), likely due to the higher incidence of internode borer infestation.

The highest number of millable canes was recorded in the IPM module (73.33 thousand/ha), which was significantly higher than in the unprotected control (61.45 thousand/ha). The chemical module (72.92 thousand/ha) and the non-chemical module (69.50 thousand/ha) also showed significantly greater numbers of millable canes compared to the unprotected control (Table 2). The reduction in millable canes in the unprotected control was attributed to a higher incidence of early shoot borer (27.60% dead hearts). In contrast, the increased number of millable canes in the IPM module was due to a substantial reduction in early shoot borer infestation up to 120 days after planting (DAP).

Cane yield among the treatments ranged from 67.6 t/ha to 88.0 t/ha. The highest yield was recorded in the IPM module (88.0 t/ha), which significantly outperformed the unprotected control (67.6 t/ha), showing a 30.18% increase in yield. The chemical module was the next best treatment, with a yield of 87.5 t/ha with an increase of 29.43% over the unprotected control. The non-chemical module also recorded a promising yield of 83.4 t/ha, reflecting a 23.37% increase. However, the unprotected control exhibited a 23.2% yield reduction, producing only 67.60 t/ha, with lower NMC (61.45 thousand/ha) and inferior juice quality (18.60%) compared to IPM module (Table 2).

**2024-25**

**3.4 Early Shoot Borer**

During 2024–25, the incidence of early shoot borer was significantly reduced in the IPM module, recording only 12.08% dead hearts (DH) compared to 39.04% DH in the untreated control (Table 3). The chemical control module recorded 14.90% DH, while the non-chemical module showed 18.20% DH, both of which were higher than that of the IPM module.

**3.5 Internode Borer**

The incidence of internode borer varied from 61.0% to 100% across treatments. The lowest incidence was recorded in the IPM module (61.33%) compared to 72.67% in the non-chemical module, 82.33% in the chemical module, and 100% in the untreated control. Similarly, the intensity of internode borer damage ranged from 9.10% to 26.60%, with the IPM module again showing the lowest intensity (9.10%), followed by the non-chemical module (11.30%) and the chemical module (12.90%). The untreated control exhibited the highest damage intensity at 26.60%. These results clearly demonstrate that the IPM module was more effective in managing internode borer infestation than either chemical or non-chemical modules applied alone.

**3.6 Yield Attributing Characters, NMC and Cane Yield**

Growth and quality parameters (Table 2) also reflected the superior performance of the IPM module. The maximum cane height was observed in both the IPM and non-chemical modules (2.7 m), followed by the chemical module (2.6 m) and the untreated control (2.4 m). Juice sucrose content was highest in the IPM module (17.10%), followed by the non-chemical (16.90%) and chemical (16.50%) modules, while the untreated control recorded only 15.80%. The number of millable canes was highest in the IPM module (70.67 thousand/ha), followed by the chemical (67.33 thousand/ha) and non-chemical (67.17thousand/ha) modules, compared to 60.67 thousand/ha in the untreated control.

Regarding cane yield, the IPM module recorded the highest yield at 84.8 t/ha, which was 16.48% higher than the untreated control (72.8 t/ha). The chemical and non-chemical modules recorded yields of 80.8 t/ha and 80.6 t/ha, representing yield increases of 10.99% and 10.71%, respectively, over the control. The reduction in yield in the untreated control was primarily due to the high incidence of early shoot borer (39.04% DH) and severe internode borer incidence (100%) and intensity (26.60%). These pest pressures adversely impacted the number of millable canes, cane height, weight, and juice quality, resulting in a 14.15% yield reduction compared to the IPM module. Similarly, the chemical and non-chemical modules showed yield reductions of 4.72% and 4.95%, respectively, compared to the IPM approach.

The overall results presented in Table 4 indicated that the incidence of ESB up to 120 DAP was significantly reduced under the Integrated Pest Management (IPM) module, with only 9.55% dead hearts (DH), compared to 33.32% DH in the unprotected control. The chemical module and non-chemical module also recorded reduced ESB incidence at 11.75% and 16.30% DH, respectively. Similarly, the incidence and intensity of internode borer (INB) were markedly lower in the IPM module, with 53.25% incidence and 7.60% intensity, compared to 100% incidence and 23.50% intensity observed in the unprotected control (Fig. 1).

In terms of crop growth and quality parameters, the IPM module resulted in superior performance, recording a higher cane height (2.55 m), cane weight (1.2 kg), and juice sucrose content (18.20%). The number of millable canes (NMC) was significantly higher under IPM (72.0 thousand canes/ha), leading to an enhanced cane yield of 86.40 t/ha representing a 23.1% yield increase over the untreated control (Table 4; Fig. 2) and a benefit-cost ratio (BCR) of 2.73. In contrast, the unprotected control exhibited a 14.7% yield reduction, producing only 70.20 t/ha, with lower NMC (61.06 thousand/ha), inferior juice quality (17.20%), and reduced sugar recovery. The improved yields observed in the IPM, chemical and non-chemical modules were primarily attributed to the effective reduction of early shoot borer and internode borer infestations. High ESB infestation was associated with delayed tillering, while severe INB damage led to decreased cane height (2.0 m), lower cane weight (1.15 kg), and increased secondary bud sprouting.

These findings are aligned with Srikanth *et al.* (2022) who reported that the growth parameters such as length, diameter, surface area and volume of internodes, and weight, weight/unit area and weight/unit volume of cane segments were lower in affected canes than those in healthy canes. Internode borer attacked internodes became shorter and thinner than the lower unaffected internodes.

The chemical and non-chemical modules also demonstrated significant reductions in borer infestation over the control. The chemical module recorded ESB incidence of 11.75% DH, INB incidence of 81%, and intensity of 11.95%. This resulted in improved growth parameters, including cane height (2.50 m), cane weight (1.2 kg), juice sucrose (18.05%), NMC (70.13 thousand/ha), and cane yield (84.14 t/ha), representing a 19.9% yield increase over the control. The BCR for this module was 2.69. Likewise, the non-chemical module showed ESB incidence of 16.30% DH, INB incidence of 66%, and intensity of 11.65%. The module resulted in a cane height of 2.45 m, cane weight of 1.2 kg, juice sucrose of 17.90%, NMC of 68.34 thousand/ha, and cane yield of 81.90 t/ha with a 16.7% increase over the unprotected control. The corresponding BCR was 2.62 (Table 4).

The present findings are in line with earlier studies that emphasize the effectiveness of integrated pest management (IPM) strategies in controlling sugarcane borers who demonstrated that combining chemical, cultural, biological, and pheromone-based methods offer an effective approach for managing borer pests in sugarcane (Srikanth *et al*., 2012; Sheeba *et al*., 2012; Ruhela & Ruhela 2024; Sheeba & Raja Babu 2025).

The efficacy of *Trichogramma chilonis* observed in the current study corroborates the results of Rao *et al*. (2006) and Visalakshi *et al*. (2016), who reported that trash mulching at 3 t/ha along with four releases of *T. chilonis* at 50,000/ha from 30 days after planting at 7–10 day intervals effectively suppressed borer populations. Similarly, Bhavani *et al*. (2016b) also highlighted the benefit of integrating *T. chilonis* releases with mass trapping using pheromone traps (25 traps/ha) in successfully reducing both early shoot borer (ESB) and internode borer (INB) infestations. Sithanantham *et al*. (2020) validated the use of delta sticky traps for borer management in sugarcane.

The present results with chlorantraniliprole are consistent with the findings of several researchers (Nilesh *et al*., 2015; Kumar *et al*., 2017; Sunil Kumar *et al*., 2018; Assis *et al*., 2019; Bhavani, 2025a), who reported that both chlorantraniliprole 0.4G and 18.5 SC formulations are highly effective in managing ESB. These results are further supported by Choudhary *et al*. (2018) and Bhavani *et al*. (2016a), who found chlorantraniliprole application at planting and again at 60 days after planting (DAP) to significantly reduce shoot borer incidence. Comparable efficacy of

**Table 2. Impact of different management strategies against borers and assessment of cane yield losses in sugarcane during 2023-24**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Early shoot borer (%DH)** | **Internode borer** | **Cane length (m)** | **Cane weight** **(kg)** | **Juice sucrose (%)** | **NMC****(000’/ha)** | **Cane yield (t/ha)** | **Increase over untreated control (%)** | **Decrease over T3 (%)** |
| **Incidence (%)** | **Intensity (%)** |
| **T1- Chemical Module:**  Soil application of chlorantraniliprole 0.4G at 22.5 kg/ha at planting. Foliar spray of chlorantraniliprole 18.5 SC at 0.3 ml/L between 60-90 DAP | 8.60b(17.05) | 82.00c(68.46) | 12.60c(20.77) | 2.30b(1.82) | 1.20 | 19.20b(25.98) | 72.92b | 87.50a | 29.43 | - 0.57 |
| **T2-Non chemical module:**Trash mulching @ 3t/ ha.Frequent irrigations at 7-10 days interval.Intercropping with Cow pea.Installation of pheromone traps @ 25 /ha.Field release of *Trichogramma chilonis* (Trichocards) at 50,000/ha for six times at 7–10 day intervals from 120 DAP & Detrashing at 150 & 180 DAP. | 14.40c(22.29) | 60.00b(53.14) | 10.40b(18.80) | 2.30b(1.82) | 1.20 | 19.30a(26.05) | 69.50c | 83.40b | 23.37 | - 5.23 |
| **T3- IPM module:**  T1+T2 | 6.30a(14.50) | 44.00a(41.48) | 6.10a(14.29) | 2.40a(1.84) | 1.20 | 19.30a(26.05) | 73.33a | 88.00a | 30.18 | - |
| **T4-Unprotected control** | 27.60d(31.67) | 100.00d(90.00) | 20.40d(26.83) | 1.60c(1.60) | 1.10 | 18.60c(25.54) | 61.45d | 67.60d | - | - 23.18 |
| S.Em (±) | 0.46 | 4.51 | 0.32 | 0.02 | NS | 0.04 | 0.37 | 0.59 |  |  |
| CD (P=0.05) | 1.49 | 14.64 | 1.04 | 0.06 |  | 0.14 | 1.21 | 1.93 |  |  |
| CV (%) | 4.30 | 14.26 | 3.19 | 1.94 |  | 0.32 | 1.08 | 1.46 |  |  |

*DAP: Days after planting; Deadhearts; Figures in parentheses are transformed values; NMC: number of millable canes; Same letter over parentheses means the results do not differ significantly.*

**Table 3. Impact of different management strategies against borers and assessment of cane yield losses in sugarcane during 2024-25**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Early shoot borer (%DH)** | **Internode borer** | **Cane length (m)** | **Cane weight (kg)** | **Juice sucrose (%)** | **NMC****(000’/ha)** | **Cane yield (t/ha)** | **Increase over untreated control (%)** | **Decrease over** **T3 (%)** |
| **Incidence (%)** | **Intensity (%)** |
| **T1- Chemical Module**  | 14.90b(22.69) | 82.00c(64.97) | 12.90c(21.04) | 2.70a | 1.20 | 16.50b(23.96) | 67.33b | 80.80b | 10.99 | - 4.72 |
| **T2-Nonchemical module** | 18.20c(25.22) | 72.00b(58.08) | 11.30b(19.62) | 2.60a | 1.20 | 16.90a(24.26) | 67.17b | 80.60b | 10.71 | - 4.95 |
| **T3- IPM module (**T1+T2) | 12.08a(20.95) | 61.00a(51.35) | 9.10a(17.53) | 2.70a | 1.20 | 17.10a(24.42) | 70.67a | 84.80a | 16.48 |  - |
| T4-**Unprotected control** | 39.04d(38.62) | 100.00d(90.00) | 26.60d(31.03) | 2.40b | 1.20 | 15.80c(23.41) | 60.67c | 72.80c |  - | - 14.15 |
| S.Em (±) | 0.64 | 0.93 | 0.49 | 0.06 | NS | 0.05 | 0.66 | 0.65 |  |  |
| CD (P=0.05) | 2.07 | 3.03 | 1.59 | 0.19 |  | 0.16 | 2.13 | 2.12 |  |  |
| CV (%) | 4.76 | 2.82 | 4.40 | 4.42 |  | 0.42 | 1.98 | 1.64 |  |  |

*DH: Deadhearts; Figures in parentheses are transformed values; NMC: number of millable canes; Same letter over parentheses means the results do not differ significantly.*

**Table 4. Assessment of yield losses due to borer pests and their management with different practices during 2023-24 to 2024-25 (Mean data)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Early shoot borer**  | **Internode borer**  | **Cane length (m)** | **Cane weight (kg)** | **Juice sucrose****(%)** | **NMC****(000’/ha)** | **Cane yield (t/ha)** | **Increase in yield over unprotected control -T4 (%)** | **Decrease over protected control-T3 (%)** | **BCR** |
| **Incidence** **(% DH)** | **Incidence** **(%)** | **Intensity (%)** |
| **T1- Chemical Module**  | 11.75b(20.02) | 81.00c(64.14) | 11.95c(20.02) | 2.50a | 1.20 | 18.05b | 70.13a | 84.14b | 19.86 | - 2.62 | 2.69 |
| **T2-Nonchemical module** | 16.30c(23.80) | 66.00b(54.34) | 11.65b(23.80) | 2.45a | 1.20 | 17.90c | 68.34ab | 81.90c | 16.67 | - 5.21 | 2.62 |
| **T3- IPM module (**T1+T2) | 9.55a(17.99) | 53.25a(46.85) | 7.60a(17.99) | 2.55a | 1.20 | 18.20a | 72.00a | 86.40a | 23.08 | - | 2.73 |
| **T4-Unprotected control** | 33.32d(35.24) | 100.00d(90.0) | 23.50d(35.24) | 2.00b | 1.15 | 17.20d | 61.06b | 70.20d | **-** | -18.75 | 1.88 |
| **F test** | **Sig.** | **Sig.** | **Sig.** | **NS** | **NS** | **Sig.** | **Sig.** | **Sig.** |  |  |  |
| S.Em (±) | 0.28 | 0.78 | 0.28 | 0.05 |  | 0.05 | 0.94 | 0.29 |  |  |  |
| CD (P = 0.05) | 0.91 | 2.53 | 0.91 | 0.16 |  | 0.17 | 3.03 | 0.95 |  |  |  |
| CV (%) | 2.32 | 2.44 | 0.39 | 4.09 |  | 0.60 | 2.76 | 0.73 |  |  |  |

*DH: Deadhearts; Figures in parentheses are transformed values; NMC: number of millable canes; Same letter over parentheses means the results do not differ significantly.*

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|  |  |
| **Fig. 1. Impact of different management strategies against borers in sugarcane***INB: Internode borer; ESB: Early shoot borer* | **Fig. 2. The impact of different borer management strategies on NMC and cane yield in sugarcane***NMC: Number of millable canes* |

chlorantraniliprole 0.4 GR and the 20 SC formulation was also demonstrated by Pandey (2014), Shobharani *et al*. (2018) and Bhavani *et al*., (2025b) in controlling ESB infestation. Recent studies by Penn *et al*. (2025) further confirm that chlorantraniliprole sprays outperform other insecticides in reducing shoot borer infestations. Umashankar *et al*. (2018) reported that both chlorantraniliprole 0.4 GR and fipronil 0.3 GR significantly reduced cumulative incidence of *Chilo infuscatellus*, contributing to higher cane yields compared to untreated controls. Likewise, Bhawar *et al*. (2015), Kumar *et al.* (2020) and Bhavani (2025a,b) observed a significant reduction in deadheart incidence following application of chlorantraniliprole 0.4 GR at 75 g a.i./ha.

## In addition to chemical control, the effectiveness of non-chemical methods was also validated. The present findings regarding the performance of the non-chemical module are in agreement with Jaipal (2000), who reported that the cumulative use of ecology-based approaches such as timely irrigation and urea application, mechanical removal of pest stages and crop residues, earthing up, propping of cane stalks, and release of the egg parasitoid *Trichogramma chilonis* (Ishii) resulted in reduced pest damage (maintained below the economic injury level) and significantly increased yields by 22–36%. Similarly, Venugopala Rao *et al*. (2010) demonstrated that intercropping sugarcane with cowpea significantly reduced early shoot borer (ESB) incidence. Visalakshi and Bhavani (2020) further reported that six field releases of *T. chilonis* at a rate of 75,000/ha at 7–10 day intervals up to 120 days after planting (DAP), followed by six additional releases after cane formation, substantially reduced both ESB and internode borer (INB) incidence, leading to improved cane yields.

## 4. CONCLUSION

Assessment of yield losses due to sugarcane borers revealed that more than 30% early shoot borer incidence reduced the number of millable canes and 100% internode borer infestation with 26.6% intensity reduced the juice sucrose and cane weight, resulting in 18.7 per cent yield loss compared to the protected plot with integrated practices (chemical + non-chemical). Integrated management practices significantly reduced sugarcane borer infestation and increased cane yield by 23.1% over the untreated control, achieving a benefit-cost ratio (BCR) of 2.73. In comparison, chemical and non-chemical methods alone resulted in yield increases of 19.9% and 16.7%, with BCRs of 2.69 and 2.62, respectively. These results highlight the effectiveness of adopting integrated approaches over standalone chemical or non-chemical methods for sustainable borer pest management and yield enhancement in sugarcane. These findings reaffirm the value of IPM as a sustainable and economically viable strategy for managing borer pests and improving sugarcane yield and quality.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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