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SURVEY AND RELATIVE ABUNDANCE OF SUGARCANE SHOOT BORERS IN ANDHRA PRADESH

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ABSTRACT

An extensive roving survey was conducted in different sugarcane growing districts of Andhra Pradesh during 2023-24 during different cane developmental stages at bimonthly intervals. Among all the sugarcane shoot borers, Inter nodal borer, *Chilo sacchariphagus indicus*) was predominant species (42.12%) followed by Top shoot borer, *Scirpophaga excerptalis* (31.22%) and Early shoot borer, *Chilo infuscatellus*, (25.29%). Survey in different growth stages of sugarcane in Andhra Pradesh revealed that 100% damage was due to INB during grand growth stage and vegetative stage was attacked by both ESB (35.50%) and INB (64.50%), whereas INB (57.50%) and TSB (42.50%) was recorded at harvesting. Adult shoot borers were identified morphologically using keys and confirmed through DNA barcoding and deposited in BOLD with species confirmation achieved through male genitalia dissections. Anakapalle district recorded highest mean per cent incidence of INB, TSB (57.09 and 41.05) followed by Krishna (40.86 and 36.35), Vizianagaram (36.80 and 24.53) and Tirupati (33.74 and 22.94) across all the surveyed stages of sugarcane. Where as in case of ESB highest mean per cent incidence was recorded in Vizianagaram district (31.43). However, the emergence of dead hearts is the main symptom of sugarcane that resulted in the death and elimination of potential millable canes which necessitates the estimation of a comprehensive damage levels and yield losses. In the Humid growing tracts of coastal Andhra Pradesh *C. sacchariphagus indicus* is also acting as a early shoot borer especially in ratoon sugarcane crop.

***Key words*:** Bunchy top, *Chilo infuscatellus, Chilo saccharipahgus indicus*, Dead hearts, *Scirpophaga excerptalis*, *Saccharum officinarum*, Meristem damage.

Introduction

Sugarcane (*Saccharum officinarum* L.: Poaceae) is a tropical “Wonder cane” because of its versatility and ability to grow in almost all agroecological conditions. Sugarcane is one of the important cash crops in India, contributing significantly to the agricultural economy and rural livelihoods. It is a source of income for millions of farmers and supports numerous ancillary industries such as sugar mills, ethanol production, and biomass-based power generation. Sugarcane production has a vast and varied market worldwide and pivotal for industrial usage of sugar, biofuels, and spirits (Easwaramoorthy S. and Nandagopal V. 1986). Sugarcane has a highly efficient photosynthetic process known as C4 photosynthesis, which allows it to grow well in high temperatures and high light conditions while using water and nutrients efficiently. These features make sugarcane a vital crop for many economies, especially in tropical regions, where it supports both local economies and global sugar markets (Srikanth *et al*., 2016). Brazil is the leading producer with

a immerse production of 752.9 million tons, followed by India with 405.4 million tons (www.fao.org/faostat,2022-23). In India, 21% of the agricultural land is used for sugarcane production and yields 22% of the total sugarcane in the world (Abdullah *et al.*, 2006). In Andhra Pradesh sugarcane was cultivated in an area of 0.89 lakh hectares with an annual production of about 8.25 Metric tonnes with an average productivity of 77.43 tonnes ha^{-1} (http://des.ap.gov.in, 2022-23). Sugarcane crop is currently facing severe crises in the country both sugar industry and the sugarcane farmers are striving for sustainable cane production and growth (Srikanth J. and Kurup N.K. 2011). One of the major constraints in maintaining sustainable cane yield losses is due to insect pests, as sugarcane is known to be attacked by as many as 212 insect pests and 76 non-insect pests c. (Patil *et al.*, 2004), in India right from germination to harvest. However, 15 pests are reported to cause considerable losses in yield (Kumar A. 2009; ram *et al.*, 2017). Sugarcane shoot borers are the major destructive pests that cause 8 to 10% cane yield losses at the farmer's level and 10 to 15% sugar recovery losses in sugar industries (Kumarasinghe N.C 1999; Ahad *et al.*, 2016). About 45% of yield losses in sugarcane are due to infestation by borer pests in different stages in sugarcane cultivation includes germination, tillering, early growth, active growth and elongation (Rao *et al.*, 2009; Rossato *et al.*, 2013). Among them, Early shoot borer, *Chilo infuscatellus*, inter nodal borer *Chilo sacchariphagus indicus* and top shoot borer *Scirpophaga nivella* and *Scirpophaga excerptalis* are the major shoot borer pests distributed in all the sugarcane growing regions of India (Chavan *et al.*, 2021). Knowing the pest affecting the specific crop stage enables farmers to choose the most appropriate control measures. Knowledge of the relative abundance of distinct shoot borer species infesting sugarcane is very crucial in estimating the targeted control which reduces indiscriminate pesticide use, which is beneficial for environmental and economic reasons. In this connection a roving survey was conducted in different sugarcane growing districts of Andhra Pradesh at different growth stages of sugarcane during 2023-2024 to know the shoot borer species diversity, species composition and their relative abundance.

Materials and Methods

Roving survey was conducted in different villages of four sugarcane growing districts of Andhra Pradesh *viz.*, Vizianagaram (18.34° N & 83.21° E), Anakapalle (17.80° N & 82.96° E), Krishna (16.11° N & 80.93° E) and Tirupati (13.37° N & 79.32° E) of Andhra Pradesh, India during April 2023-May 2024 (Fig. 1). Destructive Sampling was done at different growth stages of sugarcane *viz.*, Tillering, grand growth and harvesting. From each district, three villages and from each village, five farmers were selected for the survey. The survey techniques were followed as suggested by Rao *et al.*, (2009). Shoot borer larvae were collected by destructive sampling method from ten randomly selected spots from each spot 10 plants were selected for larval collection. The symptoms of damage caused by different shoot borers were indicated by dead hearts in young tillers (*C. infuscatellus*), internodal damage with reddening of tissue and circular hole is pulgged with excreta (*C. sacchariphagus indicus*) and bunchy top appearance and dead heart on the top of the cane, shot holes on top

Fig. 1: Map showing the major sugarcane growing districts of Andhra Pradesh surveyed during 2023-2024.

Table 1: Mean per cent incidence (Mean ± SE) and Relative abundance of Sugarcane Shoot borers in surveyed districts of Andhra Pradesh during 2023-24.

S. NO	District	Village *	GPS-Ordinates (Latitude & Longitude)	% Incidence of Sugarcane Shoot borers (Mean±SE)**			Mean Intensity of INB(Mean ± SE)	
				ESB	INB	TSB	Grand growth Stage	Harvesting Stage
1	Vizianagaram	Bobbili	18.34° N & 83.21° E	33.53 ± 0.88 (35.39)^{a}	36.88± 1.33 (37.38)^{cd}	24.90 ± 0.20 (29.93)^{i}	10.80± 0.22 (19.18)^{b}	9.26± 0.20 (17.71)^{def}
2		Kottapenta	18.63° N & 83.34° E	31.50 ± 0.60 (34.14)^{b}	37.24± 0.75 (37.60)^{cd}	22.86 ± 0.20 (28.57)^{j}	10.00± 0.36 (18.42)^{b}	8.80± 0.21 (17.25)^{ef}
3		Gollapalli	18.57° N & 83.35° E	29.26 ± 0.58 (32.75)^{c}	36.32± 0.68 (37.05)^{cd}	25.83 ± 0.72 (30.55)^{h}	10.08± 0.38 (18.49)^{b}	10.10± 0.30 (18.52)^{cd}
		Mean for district		**31.43**	**36.80**	**24.53**	**10.29**	**9.38**
4	Anakapalle	Govada	17.80° N & 82.96° E	26.24 ± 0.64 (30.81)^{e}	59.84± 0.45 (50.67)^{a}	45.10 ± 2.45 (42.19)^{a}	12.06± 0.06 (20.32)^{a}	11.82± 0.46 (20.09)^{a}
5		Bangarmmapalem	17.68° N & 83.00° E	25.20 ± 0.67 (32.22)^{f}	56.70± 0.47 (48.85)^{a}	42.40 ± 1.30 (40.63)^{b}	10.32± 0.17 (18.73)^{b}	11.48± 0.16 (19.80)^{ab}
6		Venkupalem	17.69° N & 83.00° E	28.43 ± 0.52 (30.18)^{d}	54.74± 0.81 (47.72)^{a}	35.66 ± 0.44 (36.67)^{d}	12.44± 0.136 (20.65)^{a}	10.32± 0.17 (18.73)^{cd}
		Mean for district		**26.62**	**57.09**	**41.05**	**11.60**	**11.20**
7	Krishna	Challapalle	16.11° N & 80.93° E	24.46 ± 0.61 (29.65)^{g}	43.48± 2.84 (41.22)^{b}	32.90 ± 0.20 (35.00)^{f}	10.50± 0.25 (18.90)^{b}	9.24± 0.26 (17.68)^{def}
8		Lakshmipuram	16.39° N & 81.44° E	22.06 ± 1.27 (28.02)^{i}	42.20± 0.72 (40.51)^{bc}	35.50 ± 0.28 (36.57)^{e}	8.18± 0.42 (16.59)^{d}	8.38± 0.17 (16.82)^{f}
9		Lankapalle	16.22° N & 80.84° E	19.50 ± 0.57 (26.21)^{l}	36.90± 1.31 (37.39)^{cd}	40.66 ± 0.27 (39.62)^{c}	9.62± 0.31 (18.05)^{bc}	10.40± 0.31 (18.80)^{bc}
		Mean for district		**22.00**	**40.86**	**36.35**	**9.43**	**9.34**
10	Tirupati	Perumallapalle	13.37° N & 79.32° E	20.13 ± 0.08 (26.66)^{k}	33.72± 1.85 (35.47)^{d}	26.33 ± 1.85 (30.87)^{g}	10.40± 0.43 (18.79)^{b}	9.62± 0.31 (18.05)^{cde}
11		Mittapalem	13.58° N & 79.35° E	22.33 ± 0.60 (28.20)^{h}	34.22± 1.98 (35.77)^{d}	21.50 ± 0.28 (27.62)^{k}	8.80± 0.25 (17.24)^{cd}	10.54± 0.33 (18.93)^{bc}
12		Sanambatla	13.60° N & 79.32° E	20.93 ± 0.80 (27.23)^{j}	33.28± 1.75 (35.20)^{d}	21.00 ± 0.57 (27.27)^{l}	8.54± 0.18 (16.98)^{cd}	8.80± 0.12 (17.25)^{ef}
		Mean for district		**21.13**	**33.74**	**22.94**	**9.24**	**9.65**
		Overall mean		**25.29**	**42.12**	**31.22**	**10.14**	**9.89**
	CD(p=0.05)*			2.16	3.65	3.07	0.856	0.79
	F value			39.32	56.18	68.00	18.38	14.79
	P value			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

**- Average of data from five farmers' fields in each village, Per cent dead hearts/Per cent damaged canes ; Means followed by same letters are not significantly different by DMRT; Figures in parentheses are arc sine transformed values : ESB – Early shoot borer, INB- Internodal borer, TSB- Top shoot borer

leaves at harvest stage (*S. excerptalis*). The percentage incidence, damage intensity (*C. sacchariphagus indicus*), and relative abundance of sugarcane shoot borers was calculated using the following formulae.

$$\text{Per cent dead hearts} = \frac{\text{Total number of dead hearts}}{\text{Total number of plants}} \times 100$$

$$\text{Per cent incidence} = \frac{\text{Total number of infested canes}}{\text{Total number of canes}} \times 100$$

$$\text{Per cent intensity (INB)} = \frac{\text{Total number of infested nodes}}{\text{Total number of nodes}} \times 100$$

$$\text{Relative abundance (\%)} = \frac{\text{Total number of individuals for each species}}{\text{Total number of individuals of all species}} \times 100$$

Results and Discussion

This study clearly indicated the presence of three major shoot borer species among the surveyed districts of Andhra Pradesh *viz.*, Early shoot borer, *C. infuscatellus*, Inter nodal borer *C. sacchariphagus indicus* and Top shoot borer, *S. excerptalis* by considering the morphological characters of larvae, adults and damage symptoms, (Fig. 1). Based on crop stages surveyed, the damage pattern and symptoms of damages caused by the shoot borers. the per cent incidence of shoot borers of ESB, INB and TSB were ranged from 19.50 to 33.53, 33.28 to 59.84 and 21.00 to 45.10 respectively in the surveyed villages of Vizianagaram (Bobbili, Kottapenta Gollapalli), Anakapalle (Govada, Bangarammapalem, Venkupalem), Krishna (Challapalle, Lakshmipuram, Lankapalle) and Tirupati (Perumallapalle, Sanambatla, Mittapalem) districts of Andhra Pradesh at different stages of sugarcane. Overall mean incidence of three shoot borers ranged from 25.29 (ESB), 42.12 (INB) and 31.22 (TSB) in twelve surveyed villages of four districts of Andhra Pradesh. In which Anakapalle district recorded highest mean per cent incidence of INB, TSB (57.09 and 41.05) followed by Krishna (40.86 and 36.35), Vizianagaram (36.80 and 24.53) and Tirupati (33.74 and 22.94) across all the surveyed stages of sugarcane (Table 1). Where as in case of ESB highest mean per cent incidence was recorded in Vizianagaram district (31.43) followed by Anakapalle (26.62), Krishna (22.00) and Tirupati (21.13), Tirupati district (21.13, 33.74 and 22.94) recorded the lowest mean per cent incidence for all three shoot borers compared to other districts (Table 1). Govada village of Anakapalle district recorded the highest percent incidence with INB (59.84) and TSB (45.10) respectively, followed by Bangarammapalem (56.70 and 42.40) and Venkupalem (54.74 and 35.66) (Table 1). Lowest incidence was recorded in Sanambatla village of Tirupati district during grand growth stage and harvesting stage (33.28 and 21.00). In case ESB Bobbili village of Vizianagaram district recorded the highest percent incidence (33.53) followed by Kottapenta (31.50) and Gollapalli (29.26). Least incidence of 19.50 was recorded in Lankapalle village of Krishna district (Table 1).

Overall mean intensity of INB, *C. sacchariphagus indicus viz.*, 10.14 (grand growth stage) and 9.89 (Harvest stage) recorded in all surveyed villages of four districts of AP. Similar trend was also observed in case of INB intensity. The Highest mean intensity during grand growth stage observed in Anakapalle district (11.60) followed by >Vizianagaram (10.29) > Krishna > (9.43) >Tirupati (9.24). At harvest stage also Anakapalle district recorded the highest mean intensity (11.20) followed by > Tirupati (9.65) >Vizianagaram (9.38) > Krishna (9.34) (Table 1). Among the all shoot borers Inter nodal borer, *C. sacchariphagus indicus* was predominant species (42.12%) followed by Top shoot borer, *S. excerptalis* (31.22%) and Early shoot borer, *C. infuscatellus*, (25.29%). (Table 1). *C. sacchariphagus indicus* recorded the highest mean relative abundance (64.50, 100.0 and 57.50) at tillering, grand growth and harvest stages respectively. *S. excerptalis* recorded the relative abundance of 42.50 by infesting at harvest stage only. *C. infuscatellus* recorded 35.50 of relative abundance at tillering stage (Table 2). Among the four surveyed districts, Vizianagaram recorded highest mean relative abundance of ESB (60.50) followed by Anakapalle (30.20), Krishna (6.30) and Tirupati (3.00) respectively. Similar trend of relative abundance in case of INB, TSB was observed in which Anakapalle recorded highest mean relative abundance (40.20, 50.20) followed by Krishna (25.50, 25.30), Tirupati (21.50, 18.00) least abundance was recorded in Vizianagaram (12.80,6.50) (Table 3). From this study it was evident that the Inter nodal borer was dominant and showed overlapped incidence with early shoot borer as it affects the early stages of sugarcane causing similar damage symptoms (dead hearts) of ESB especially in ratoon sugarcane it resulted in higher incidence in districts where the relative abundance of ESB is low. Similarly INB also dominated other shoot borers from tillering to

Table 2: Mean per cent relative abundance of Sugar cane shoot borers across three stages during 2023-2024

Different cane development stages	ESB (*C. infuscatellus*)	INB (*C. sacchariphagus indicus*)	TSB (*S. excerptalis*)
Vegetative stage	35.50	64.50	0.00
Grand growth stage	0.00	100.0	0.00
Harvest stage	0.00	57.50	42.50

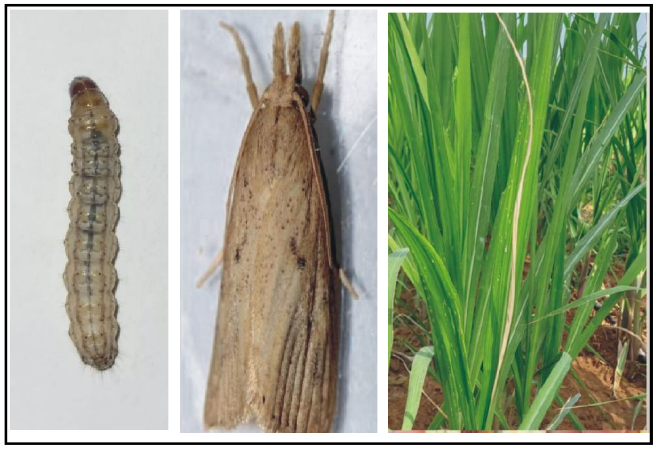

Fig. 2: Larva, Adult and dead heart symptom of Early shoot borer, *C. infuscatellus* in Sugarcane.

harvest stages resulted in higher incidence in districts where the relative abundance of TSB was low. A detailed analysis of the data from the 60 farmer fields from 12 villages of 4 districts indicated that at tillering stage of suagarcane was attacked by both ESB and INB. At grand growth stage only INB was predominant and at harvest stage both INB and TSB were recorded from all surveyed districts of Andhra Pradesh.

Nature and symptoms of damage by sugarcane shoot borers

The nature and symptoms of damage were very distinct in sugarcane as per the damage caused by different shoot borers. Early shoot borer, (*C. infuscatellus*) is severe at germination to tillering. The larvae is creamish with five violet stripes located dorsally and dorso laterally on its body with dark brown head. Adult Moth is small, slender, greyish brown or straw coloured with labial palpi projected upwards. Larva makes entrance hole at the ground level of sugarcane causes dead hearts which can be easily pulled out. The dead heart emits offensive smell, and it will be identified upto

Fig. 3: Larva, Adult and inter node damage symptoms of Inter nodal borer, *C. sacchariphagus indicus* in Sugarcane

45-50 days after sowing and in the set plantings rather than ratoon (Fig. 2). Inter nodal borer (*C. sacchariphagus indicus*) is affected the crop from cane formation to till harvest. Moth is small, straw coloured. Forewings have a marginal dark line and the hind wings are whitish Caterpillar has a white body with dark spots and a brown head. The caterpillar bores at the nodal region and enters the stem. The tissues turn red and the hole is usually plugged with excreta. A larva may attack a number of nodes. Moth is medium sized, creamy white, slightly bigger than early shoot borer moth (Fig. 3). Top shoot borer *S. excerptalis* Female has tuft of orange red coloured hairs at the tip of the abdomen. In case of certain males, each of the forewings has a black spot. caterpillar is creamy white in colour with yellow head. Some of the caterpillar are white in colour have black colour dorsal line with red colour head. A number of shot holes on affected leaves due to biting across the spindle, reddish brown charred dead heart that cannot be easily pulled out at later stages of the crop. Interference with apical growth gives rise to side shoots and critical bunchy top symptom (Fig. 5).

Different damaging patterns of INB, C. sacchariphagus indicus

A cursory examination of the data from the 60 farmer fields from 12 villages of 4 districts indicated that the overall INB incidence generally increased with crop age. Varied patterns of internode, meristem and spindle damage came to light when infested canes were split open. The borer caused different patterns of internode and spindle damage, with or without the involvement of the meristem. Dead hearts were visibly shorter and thinner than neighbouring healthy canes. Bored hole was observed at the base of the stem, dried dead hearts could be pulled out easily. Thus, when INB larvae entered the spindle

Fig. 4: Different damaging symptoms by , *C. sacchariphagus indicus*- Meristem Feeding (Spindle damage) & Bored hole plugged with excreta.

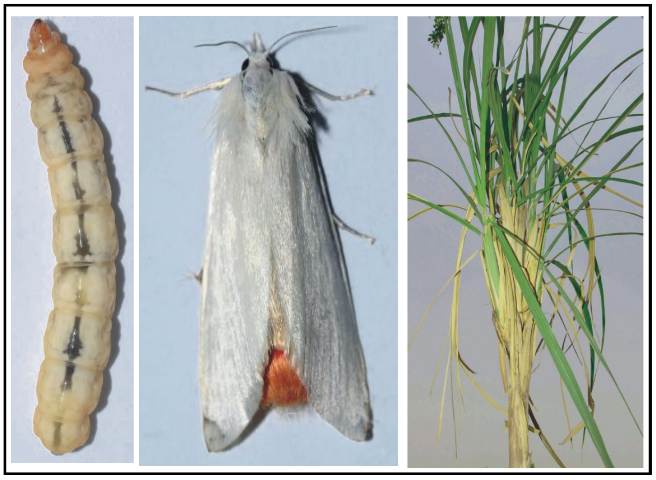

Fig. 5: Larva, Adult and bunchy top symptom of Sugarcane by Top shoot borer, S. *excerptalis.*

stage, dead heart formation occurred with actual meristem feeding. Since plants (90-150 days) are unlikely to develop in to millable canes, they contribute to direct loss in yield equivalent to their potential weight. Thus, the occurrence of dead heart due to meristem damage assumes significance during the tillering period (Fig. 4).

Larvae entering the formative internodes (240-280 days) generally restricted themselves to below-meristem zone and failed to cause dead hearts. Despite of several samples examined from early stage to harvest, single live larva was observed in the larval tunnels of formative internodes and also with bore hole damage. In several cases of fresh or old internode damage, they were characterized by the presence of wet or dry frass extruding from the bore hole externally, larval tunnels were present in one of the top four to five internodes. In this type of attack, the tunnels spanned the internode without crossing the internodes. The tissues turned from red to black. internode damage is generally restricted to a few visible internodes leading to their thinning and hardening. This type of damage generally allows near normal growth of cane above the damaged internodes. Thus, loss is restricted to a small proportion of cane weight and complete loss of cane is a rarity occurring only when the affected cane breaks above or below the damaged internode.

The variation in INB feeding pattern in the currently popular varieties, due to ratoon cropping pattern is the major concern for the alter feeding behaviour of INB due continuous availability of crop stand so it was acts as early shoot borer due to overlapping of generations and altered feeding behaviour and the propensity of the borer to cause higher proportions of dead hearts with crop age and playing a crucial role in altered feeding behavior of *C. infuscatellus*. Climatic factors and availability of suitable young crop for their colonization is also could be the major cause resulting in dead heart formation. Differential nutritional composition of the meristem and formative internodes in different varieties and soil types could be a factor that promotes such altered feeding behaviour. Also Interestingly, early shoot borer *C. infuscatellus* an early stage pest of sugarcane throughout the country, often bores into the tops of grown-up or mature canes in the sugarcane tracts of humid coastal Andhra Pradesh State, probably behaving as a 'late shoot borer. In contrast to that conditions now in the same humid growing tracts of coastal Andhra Pradesh Inter nodal borer *C. sacchariphagus indicus* acts as an early shoot borer.

The current results are in line with Rao *et al*., (2009) who reported that the ESB, *C. infuscatellus*, INB, *C. sacchariphagus indicus*, TSB, *S. nivella* as a major shoot borers in Andhra Pradesh. The findings are also similar with the Ahad *et al.,* (2016) who reported *C. infuscatellus* as major a cane borer in Bangladesh and also Chavan *et al.*, (2021) who reported the *C. sacchariphagus* indicus as dominaant cane borer in the early stages of sugarcane in south Gujarat. Kumar A. (2009) who reported that early shoot borer and top borer were widely distributed over Western Uttar Pradesh. Abdullah *et al.,* (2006) who also reported the early shoot borer and top borer were major shoot borer pests in Bangaldesh.

The present findings are in confimity with Mukunthan N. and Rakkiyappan P. (1989) who observed the INB larva entered the spindle and moved down to formative internodes; also, spindle feeding and dead heart formation caused greater crop losses than the internode damage below meristem. Thus, meristem feeding by INB is neither a new phenomenon nor exclusive to the any cultivars and also they stated that the phenomenon is not location-specific. Srikanth J. and Kurup N.K. (2011) also reported the same damage pattern by internodal borer *C. sacchariphagus indicus* in Tamil Nadu.

Table 3: Mean per cent relative abundance (Mean ± SE) of Sugar cane shoot borers across in surveyed districts of Andhra Pradesh during 2023-2024.

Districts	ESB (*C. infuscatellus)*	INB (*C. sacchariphagus indicus*)	TSB (*S. excerptalis*)
Vizianagaram	60.50 ± 0.05	12.80 ± 0.01	6.50 ± 0.06
Anakapalle	30.20 ± 0.05	40.20 ± 0.05	50.20 ± 0.05
Krishna	6.30 ± 0.03	25.50 ± 0.03	25.30 ± 0.02
Tirupati	3.00 ± 0.02	21.50 ± 0.05	18.00 ± 0.04

Conclusion

With the detailed survey and investigation of sugarcane shoot borers in present study clearly indicated the presence of three major shoot borer species in the surveyed districts of Andhra Pradesh viz., Early shoot borer, *C. infuscatellus*, Inter nodal borer, *C. sacchariphagus indicus* and Top shoot borer *S. excerptalis*. INB larvae affected the spindle stage, dead heart formation occurred with actual meristem feeding at 90-150 days are unlikely to develop in to millable canes. INB larvae attacking the formative stage (240-280 days) resulted in internodal damage, with reddened and rottened portion of cane.

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