



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(4): 328-332
Received: 13-01-2026
Accepted: 17-02-2026

M Saicharan
Scientist (Entomology), Regional
Sugarcane and Rice Research Station,
Rudrur, PJTAU, Telangana, India

G Rakesh
Scientist (Pl. Breeding), Regional
Sugarcane and Rice Research Station,
Rudrur, PJTAU, Telangana, India

Dr. A Dinesh
Scientist (Pl. Breeding), Agricultural
Research Station, Mudhole, PJTAU,
Telangana, India

N Swapna
Asst. Professor (Agronomy), Agricultural
College, Palem, PJTAU, Telangana, India

G Narendar
Assistant Professor (Agronomy),
Agricultural Polytechnic, Madhira,
PJTAU, Telangana, India

Dr. G Eswara Reddy
Scientist (Pl. Breeding), Regional
Agricultural Research Station, Palem,
PJTAU, Telangana, India

Dr. A Krishna Chaitanya
Scientist (Soil Science), Regional Sugarcane
and Rice Research Station, Rudrur,
PJTAU, Telangana, India

Dr. Y Samatha Parameswari
Scientist (Agronomy), Regional Sugarcane
and Rice Research Station, Rudrur,
PJTAU, Telangana, India

Dr. K Pavan Chandra Reddy
Principal Scientist (Soil Science) & Head, R
egional Sugarcane and Rice Research
Station, Rudrur, PJTAU, Telangana, India

Dr. B Balaji Naik
Director, Director, Centre for Digital
Agriculture and Technology, PJTAU,
Hyderabad, Telangana, India

Dr. M Vijay Kumar
Principal Scientist (Sugarcane and Head),
Agricultural Research Station, Basanthpur,
PJTAU, Telangana, India

Corresponding Author:
M Saicharan
Scientist (Entomology), Regional
Sugarcane and Rice Research Station,
Rudrur, PJTAU, Telangana, India

Evaluation of sugarcane clones for resistance to Early Shoot Borer (*Chilo infuscatellus*) and Internode Borer (*Chilo sacchariphagus indicus*) in Eksali Season at Rudrur

M Saicharan, G Rakesh, A Dinesh, N Swapna, G Narendar, G Eswara Reddy, A Krishna Chaitanya, Y Samatha Parameswari, K Pavan Chandra Reddy, B Balaji Naik and M Vijay Kumar

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4e.5367>

Abstract

Twenty eight sugarcane clones were evaluated for resistance against early shoot borer (ESB), *Chilo infuscatellus* Snellen, and internode borer (INB), *Chilo sacchariphagus indicus* Kapur, at the Regional Sugarcane and Rice Research Station (RS&RRS), Rudrur, Telangana, during the Eksali season 2023-24. Dead heart counts were recorded at 45, 60, 90, and 120 days after planting (DAP) for ESB assessment, while internode borer incidence was assessed from a sample of 30 canes per variety at the time of harvest. Classification was done following AICRP on Sugarcane (2014-15) scale. For ESB, thirteen clones (46.4%) were rated as Less Susceptible (LS), twelve (42.9%) as Moderately Susceptible (MS), and three (10.7%) CO-8014 (33.54%), 2019 R 87 (31.33%), and 2019 R 12 (34.55%) as Highly Susceptible (HS). For INB, seventeen clones (60.7%) were LS, ten (35.7%) were MS and only CO-8014 (43.25%) was HS. Clone 2018 R 200 recorded the lowest ESB incidence (6.02%) while 2019 R 3 exhibited the lowest INB incidence (5.55%). Clones 2018 R 163, 2019 R 92, 2018 R 152, 2019 R 3, 2019 R 4, and 2016 R 74 showed consistently low susceptibility to both pests and are recommended for priority advancement in multi-location evaluation. The results provide a robust baseline for borer resistant variety development in the Telangana sugarcane improvement programme.

Keywords: Sugarcane, early shoot borer, internode borer, resistance screening, dead heart, per cent incidence.

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is one of the world's most significant agro-industrial crops, prized as the principal source of sucrose globally and increasingly valued as a feedstock for bioenergy production (Waclawovsky *et al.*, 2010) [17]. The genus *Saccharum* has a complex polyploid genome, with Mukherjee (1957) [9] establishing its South and South-East Asian centre of origin, a finding that underpins modern inter specific hybridisation strategies for varietal improvement. Globally, sugarcane is cultivated across approximately 27 million hectares with total production exceeding 1.9 billion metric tonnes (FAOSTAT, 2022) [3]. India ranks second among producing nations, contributing nearly 22% of global output with annual production of 400-450 million tonnes from approximately 5.5 million hectares (FAOSTAT, 2022) [3]. The crop is indispensable to the Indian rural economy, providing livelihoods to approximately 50 million farmers and supporting several million workers in the sugar industry and allied sectors (Viswanathan *et al.*, 2014) [16].

India's sugarcane production zone is broadly divided into the subtropical northern belt (Uttar Pradesh, Bihar, Haryana and Punjab) and the tropical belt (Maharashtra, Karnataka, Andhra Pradesh, Telangana and Tamil Nadu). Heinz (1987) [5] documented that the tropical belt consistently achieves higher cane and sugar yields owing to longer growing seasons and favourable temperature regimes. Telangana is an important sugarcane producing state in peninsular India, with the crop grown under irrigated and semiarid rainfed conditions. The Eksali

(plant crop) season in which planting occurs in February-March and harvest in January-February of the following year is widely practised in the Nizamabad and Kamareddy districts, where RS&RRS, Rudrur is located. Productivity in this region is, however, frequently constrained by a complex of stem borer pests, which Srikanth *et al.* (2017) ^[13] identified as the most economically destructive insect complex in Indian sugarcane cultivation.

Among the lepidopterous borers of sugarcane in India, the early shoot borer (ESB), *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae) and the internode borer (INB), *Chilo sacchariphagus indicus* Kapur (Lepidoptera: Crambidae), are of foremost economic significance. Mohan and Jayaraj (1987) ^[8] detailed the biology of *C. infuscatellus* in peninsular India, demonstrating that the species completes multiple overlapping generations during the crop cycle, with peak larval activity during the early tillering stage (30-120 DAP). Dead heart formation caused by ESB during this critical period reduces the number of productive millable canes, ultimately depressing cane yield. Srivastava and Rao (2002) ^[14] estimated that ESB-induced yield losses ranged from 12% to as high as 80% in severely infested fields. David and Nandagopal (1986) ^[2] further established that varieties with tight leaf sheaths, high silica content and elevated phenolic concentrations exhibited lower dead heart rates, providing the physiological basis for resistance breeding.

The internode borer, *C. sacchariphagus indicus*, is a late-season pest that attacks internodes during the grand growth phase, producing characteristic shot holes, dead whorls and wind-throw. Rao and Murthy (1966) ^[11] described the biology and mass rearing of this species, noting that larval damage to the internodal tissue disrupts sucrose partitioning and predisposes the cane to secondary infections. Srikanth and Salin (2001) ^[12] demonstrated that INB-infested canes suffer reductions in cane weight of 20-30% and a significant decline in commercial cane sugar percentage, emphasising the importance of managing this pest. Goebel and Sallam (2011) ^[4] reviewed emerging borer threats in the context of expanding sugarcane-based bioeconomy, stressing that rising global demand for sugarcane bio-products elevates the economic damage threshold for borer pests considerably.

Chemical management through prophylactic and reactive applications of insecticides such as chlorpyrifos, carbofuran and emamectin benzoate has been widely practised (Srivastava and Rao, 2002). ^[14] However, growing concerns over insecticide residues in sugar, non-target ecological impacts, and escalating input costs necessitate a shift towards sustainable management options. Keeping and Kvedaras (2008) ^[6] demonstrated that silicon supplementation significantly reduced herbivore damage in graminaceous crops including sugarcane, but stressed that varietal resistance remains the most durable and farmer accessible strategy. Host-plant resistance, once incorporated into high yielding varieties, provides passive, cost-free protection that is compatible with integrated pest management frameworks (Viswanathan, 2018; Srikanth *et al.*, 2017). ^[15, 13]

Advances in sugarcane biotechnology and marker-assisted selection (Lakshmanan *et al.*, 2005) ^[7] have opened new avenues for accelerating the introgression of resistance genes. Nevertheless, phenotypic screening of clones under natural field infestation, following the standardised AICRP on Sugarcane (2014-15) protocol, remains the primary and most reliable method for identifying LS clones for advancement through the varietal pipeline. Rao *et al.* (2002) ^[10] emphasised that multi-environment, multi-season screening is essential to confirm the

stability of borer resistance before clones are nominated for coordinated trials. The present study was therefore undertaken to screen 28 advanced sugarcane clones for their reaction to ESB and INB under natural infestation conditions during *Eksali* 2023-24 at RS&RRS, Rudrur, contributing to the long-term goal of developing borer resistant varieties for Telangana.

2. Materials and Methods

2.1 Experimental Site and Season

The field experiment was conducted at the Regional Sugarcane and Rice Research Station (RS&RRS), Rudrur, Nizamabad district, Telangana, during the *Eksali* (plant crop) season 2023-24. The experimental site experiences a semi-arid climate with an average annual rainfall of approximately 950 mm, predominantly received during the southwest monsoon (June-October). Soils at the site are medium deep red loam with moderate water retention.

2.2 Experimental Material and Design

A total of 28 sugarcane clones were evaluated, comprising 24 advanced breeding clones, one variety, 83 R 23, developed through the RS&RRS, Rudrur selection programme, and three widely cultivated varieties, namely CO 86032, CO 671, and the susceptible check CO 8014. The experiment was laid out in an augmented block design, with CO 8014 as the common check replicated in each block. Each experimental unit consisted of three rows, each 6 m long, with an inter-row spacing of 1.5 m, planting was done on 23rd February 2023 using three budded setts and the crop was harvested on 05th February 2024.

2.3 Agronomic Management

The crop was maintained under the recommended agronomic package for the Telangana tropical zone. Fertilisers were applied at 250:100:120 kg N:P₂O₅:K₂O per ha in split doses. Irrigation was supplied through the canal network as per crop water requirement. Earthing up and trash mulching were carried out as per requirement at the recommended stages. No borer-specific insecticide treatment was applied in order to ensure that natural pest pressure developed uniformly across entries, thereby providing reliable discrimination among clones.

2.4 Assessment of Early Shoot Borer (ESB)

Dead heart counts were recorded on all shoots and tillers in each plot at 45, 60, 90, and 120 days after planting (DAP) following the standard AICRP on Sugarcane (2014-15) methodology. The cumulative per cent incidence of ESB was computed as:

$$\text{Cumulative Per cent incidence (ESB)} = \left(\frac{\text{Total dead hearts}}{\text{Total number of shoots including dead hearts}} \right) \times 100$$

Classification was as follows: Less Susceptible (LS) - <15.0%; Moderately Susceptible (MS) - 15.1 to 30.0%; Highly Susceptible (HS) - >30.0% (AICRP on Sugarcane, 2014-15).

2.5 Assessment of Internode Borer (INB)

At harvest, 30 canes per variety were randomly sampled and longitudinally split to assess internode borer damage following the AICRP (2014-15) protocol as adapted by Srikanth and Salin (2001) ^[12]. The per cent incidence was computed as:

$$\text{Per cent incidence (INB)} = \left(\frac{\text{Number of affected canes}}{30} \right) \times 100$$

Classification: Less Susceptible (LS) - <20.0%; Moderately

Susceptible (MS) - 20.1 to 40.0%; Highly Susceptible (HS) - >40.0% (AICRP on Sugarcane, 2014–15).

2.6 Statistical Analysis

The actual per cent incidence values recorded for ESB and INB were used directly for analysis. Clones were classified into susceptibility categories (LS, MS, and HS) based on the AICRP on Sugarcane (2014-15) scale using the observed per cent incidence. Frequency and percentage of clones falling in each susceptibility class were computed separately for ESB and INB.

3. Results

3.1 Cumulative Per Cent Incidence of Early Shoot Borer (ESB)

The cumulative per cent incidence of ESB among the 28 clones screened during *Eksali* 2023-24 is presented in Table 1. ESB

incidence ranged from 6.02% (2018 R 200) to 34.55% (2019 R 12), with an overall mean of 17.51%. The check variety CO-8014 recorded 33.54%, confirming its established Highly Susceptible status as documented by AICRP on Sugarcane (2014–15).

Based on the AICRP scale, thirteen clones (46.4%) were rated Less Susceptible (LS). These included 2018 R 200 (6.02%), 2018 R 163 (8.56%), 2019 R 92 (9.45%), 2018 R 31 (10.29%), 2018 R 235 (10.29%), 2019 R 4 (11.76%), 2018 R 152 (12.47%), 2019 R 3 (12.55%), 2019 R 105 (12.59%), 2016 R 74 (13.45%), 2019 R 65 (13.84%), 2019 R 63 (14.33%) and 2013 R 81 (14.68%). Twelve clones (42.9%) were Moderately Susceptible (MS), with incidence ranging from 15.65% (CO-671) to 28.52% (2018 R 116). Three clones (10.7%) were Highly Susceptible (HS): CO-8014 (33.54%), 2019 R 87 (31.33%) and 2019 R 12 (34.55%).

Table 1: Cumulative Per cent Incidence of Early Shoot Borer (ESB) during 2023-24

S. No	Entry	% Incidence	Grade	S. No	Entry	% Incidence	Grade
1	2018 R 7	22.54	MS	15	2019 R 3	12.55	LS
2	2018 R 31	10.29	LS	16	2019 R 4	11.76	LS
3	2018 R 37	18.27	MS	17	2019 R 7	16.65	MS
4	2018 R 62	22.58	MS	18	CO-671	15.65	MS
5	2018 R 68	23.75	MS	19	2019 R 92	9.45	LS
6	CO-86032	28.33	MS	20	2019 R 87	31.33	HS
7	2018 R 184	16.52	MS	21	2019 R 65	13.84	LS
8	2018 R 163	8.56	LS	22	2019 R 63	14.33	LS
9	2018 R 152	12.47	LS	23	2019 R 12	34.55	HS
10	2018 R 116	28.52	MS	24	83 R 23	16.32	MS
11	2018 R 78	24.14	MS	25	2019 R 100	16.89	MS
12	CO-8014	33.54	HS	26	2019 R 105	12.59	LS
13	2018 R 200	6.02	LS	27	2016 R 74	13.45	LS
14	2018 R 235	10.29	LS	28	2013 R 81	14.68	LS

LS = Less Susceptible; MS = Moderately Susceptible; HS = Highly Susceptible. Scale: AICRP on Sugarcane (2014–15).

3.2 Per Cent Incidence of Internode Borer (INB)

Per cent incidence of INB assessed at harvest from 30 canes per variety is presented in Table 2. INB incidence ranged from 5.55% (2019 R 3) to 43.25% (CO-8014) with an overall mean of 20.30%. The check CO-8014 was the sole entry classified as Highly Susceptible.

Seventeen clones (60.7%) were Less Susceptible (LS) to INB. Notable entries with very low incidence included 2019 R 3 (5.55%), 2018 R 200 (6.56%), 2019 R 65 (10.23%), 2019 R 105

(10.33%), 2018 R 116 (12.47%), 2018 R 163 (12.56%), 2019 R 100 (12.14%), 2019 R 63 (13.85%), 2019 R 87 (13.64%), 2013 R 81 (14.28%), CO-86032 (15.68%), 2019 R 92 (15.65%), 2018 R 37 (16.55%), 2018 R 152 (18.57%), 2016 R 74 (18.69%), 2019 R 4 (18.98%) and 2019 R 12 (17.55%). Ten clones (35.7%) were Moderately Susceptible (MS), ranging from 23.35% (83 R 23) to 34.52% (2018 R 7). Only CO-8014 (43.25%) was Highly Susceptible (HS) exceeding the 40% threshold.

Table 2: Per cent Incidence of Internode Borer (INB) during 2023-24

S. No	Entry	% Incidence	Grade	S. No	Entry	% Incidence	Grade
1	2018 R 7	34.52	MS	15	2019 R 3	5.55	LS
2	2018 R 31	32.56	MS	16	2019 R 4	18.98	LS
3	2018 R 37	16.55	LS	17	2019 R 7	33.45	MS
4	2018 R 62	27.98	MS	18	CO-671	25.65	MS
5	2018 R 68	33.45	MS	19	2019 R 92	15.65	LS
6	CO-86032	15.68	LS	20	2019 R 87	13.64	LS
7	2018 R 184	23.65	MS	21	2019 R 65	10.23	LS
8	2018 R 163	12.56	LS	22	2019 R 63	13.85	LS
9	2018 R 152	18.57	LS	23	2019 R 12	17.55	LS
10	2018 R 116	12.47	LS	24	83 R 23	23.35	MS
11	2018 R 78	29.33	MS	25	2019 R 100	12.14	LS
12	CO-8014	43.25	HS	26	2019 R 105	10.33	LS
13	2018 R 200	6.56	LS	27	2016 R 74	18.69	LS
14	2018 R 235	28.65	MS	28	2013 R 81	14.28	LS

LS = Less Susceptible; MS = Moderately Susceptible; HS = Highly Susceptible. Scale: AICRP on Sugarcane (2014–15).

3.3 Combined Susceptibility Profile across Both Borers

When ESB and INB responses were considered together, clones

that maintained LS status for both pests included 2018 R 163, 2019 R 92, 2018 R 152, 2019 R 3, 2019 R 4, 2016 R 74, and

2013 R 81. Among these, 2018 R 163 (ESB: 8.56%, INB: 12.56%) and 2019 R 3 (ESB: 12.55%, INB: 5.55%) exhibited the lowest combined borer pressure. Clones CO-86032 and 2018 R 116, though Moderately Susceptible for ESB, were Less

Susceptible for INB (15.68% and 12.47% respectively), indicating partial resistance that merits further investigation. A summary of the frequency distribution of clones across susceptibility classes is given in Table 3.

Table 3: Frequency distribution of clones across susceptibility classes

Pest	Category	Criterion	No. of Clones	% of Total	Check Status
Early Shoot Borer (ESB)	LS	<15.0%	13	46.4	—
	MS	15.1–30.0%	12	42.9	—
	HS	>30.0%	3	10.7	CO-8014 (HS)
Internode Borer (INB)	LS	<20.0%	17	60.7	—
	MS	20.1–40.0%	10	35.7	—
	HS	>40.0%	1	3.6	CO-8014 (HS)

4. Discussion

The natural field screening under *Eksali* conditions at Rudrur provided sufficient and differential borer pressure to enable reliable discrimination among the 28 clones. The wide range of ESB incidence (6.02–34.55%) and INB incidence (5.55–43.25%) recorded in the present study is consistent with reports of differential host-plant reactions across sugarcane breeding populations in peninsular India (Srikanth *et al.*, 2017; Rao *et al.*, 2002; Srivastava and Rao, 2002) [13,10,14].

The classification of 46.4% of entries as LS for ESB is an encouraging outcome for the RS&RRS, Rudrur programme. The lowest ESB incidence of 6.02% in 2018 R 200 and 8.56% in 2018 R 163 is comparable to the resistant standards. The physiological basis of ESB resistance in such genotypes is likely multifactorial: David and Nandagopal (1986) [2] documented that tight leaf sheaths impede oviposition, while Keeping and Kvedaras (2008) [8] demonstrated that elevated silicon deposition in epidermal cells significantly raises the mechanical barrier against early instar larvae. Elevated concentrations of phenolic compounds and hydrogen cyanamide in resistant accessions have also been implicated in larval antixenosis and antibiosis (Mohan and Jayaraj, 1987). [8]

For INB, the higher proportion of LS entries (60.7%) relative to ESB screening suggests that the current Rudrur clone pool may harbour greater genetic diversity for internode borer resistance. The exceptionally low INB incidence in 2019 R 3 (5.55%) and 2018 R 200 (6.56%) is especially noteworthy. Srikanth and Salin (2001) [12] demonstrated that hard rind texture, narrow internodes, and elevated fibre content are negatively correlated with INB incidence, while Rao and Murthy (1966) [11] highlighted the role of cane architectural traits in determining borer access to intermodal tissue. The morpho anatomical basis of INB resistance in elite performing clones from the current screening should be investigated in future studies.

The HS classification of the check variety CO-8014 for both ESB (33.54%) and INB (43.25%) provides critical validation of the screening environment. CO-8014 is widely recognised as the standard susceptible check in AICRP trials across multiple locations (AICRP on Sugarcane, 2014–15) [1] and its consistently high incidence in the present study confirms that adequate and representative pest pressure was experienced during the season. This is an essential prerequisite for the validity of field resistance screening data (Viswanathan *et al.*, 2014). [16]

The contrasting borer responses of certain clones emphasises the partial independence of ESB and INB resistance mechanisms. For example, 2019 R 87 was HS for ESB (31.33%) but LS for INB (13.64%), whereas 2018 R 7 was MS for ESB (22.54%) but MS for INB (34.52%). This pattern aligns with the observations of Viswanathan *et al.* (2014), [16] who noted that resistance to early-season borers does not necessarily confer protection

against late season internode borers, reflecting differences in the developmental windows and feeding sites of the two species. Simultaneous evaluation for both pests is therefore essential for comprehensive resistance characterisation.

Goebel and Sallam (2011) [4] emphasised that in the expanding global bioeconomy, new pest pressure patterns may emerge as sugarcane cultivation expands into non-traditional areas, necessitating broad-based resistance in new varieties. In this context, clones with dual LS status particularly 2018 R 163, 2019 R 3, 2019 R 92, 2018 R 152, 2019 R 4, and 2016 R 74 are of considerable strategic value. These entries, if they also demonstrate satisfactory cane yield and sugar recovery across locations, could be utilised as resistant donors in the hybridisation programme or advanced directly as candidate varieties for borer endemic zones in Telangana. Biotechnological approaches described by Lakshmanan *et al.* (2005) may further facilitate the pyramiding of resistance alleles from diverse LS parents into elite high yielding backgrounds.

Continuation of multi-season screening of the promising LS clones will be necessary to confirm the durability and stability of resistance across years, as seasonal variation in pest population dynamics can influence incidence levels. Rao *et al.* (2002) [11] stressed that clones should be evaluated for at least two to three consecutive seasons under variable pest pressure before being recommended for zonal trials. The present study provides the foundational year one dataset for such longitudinal assessment within the RS&RRS, Rudrur improvement pipeline.

5. Conclusion

The evaluation of 28 sugarcane clones under *Eksali* 2023–24 natural field conditions at RS&RRS, Rudrur, demonstrated appreciable variability in susceptibility to both early shoot borer (*Chilo infuscatellus*) and internode borer (*Chilo sacchariphagus indicus*). For ESB, thirteen clones were rated Less Susceptible, twelve Moderately Susceptible, and three 2019 R 12, CO-8014 and 2019 R 87 - Highly Susceptible. For INB, seventeen clones were Less Susceptible, ten Moderately Susceptible and CO-8014 alone was Highly Susceptible. Clones 2018 R 163, 2019 R 3, 2019 R 92, 2018 R 152, 2019 R 4, and 2016 R 74 consistently showed low susceptibility to both pests and are recommended for priority advancement in the varietal evaluation pipeline. The check CO-8014 served as a reliable susceptible standard, validating the screening methodology. These results will contribute to targeted resistance breeding and the eventual development of borer-tolerant varieties suited to the *Eksali* growing environment of Telangana.

6. Acknowledgements

The authors extend their sincere gratitude to the Principal Scientist & Head, Regional Sugarcane and Rice Research

Station, Rudrur, Telangana and the Principal Scientist (Sugarcane) & Head, Agricultural Research Station, Basanthpur for their invaluable support and guidance during trial execution. Financial and technical assistance from the Director of Research, Professor Jayashankar Telangana State Agricultural University (PJTUA) is also gratefully acknowledged.

References

1. AICRP on Sugarcane. Annual progress report of the All India Coordinated Research Project on Sugarcane. Indian Council of Agricultural Research, New Delhi, India; 2014-2015.
2. David H, Nandagopal V. Pests of sugarcane and their control. Indian Council of Sugarcane Research, Lucknow, India; 1986. p. 1-200.
3. FAOSTAT. Crops and livestock products. Food and Agriculture Organization of the United Nations, Rome, Italy; 2022. <https://www.fao.org/faostat/en/#data/QCL>
4. Goebel FR, Sallam N. New pest threats for sugarcane in the new bioeconomy and how to manage them. Curr Opin Environ Sustain. 2011;3(1-2):81-89.
5. Heinz DJ, editor. Sugarcane improvement through breeding. Elsevier Science Publishers, Amsterdam, The Netherlands; 1987. p. 1-603.
6. Keeping MG, Kvedaras OL. Silicon as a plant defence against insect herbivory: response to Massey, Ennos and Hartley. J Anim Ecol. 2008;77(3):631-633.
7. Lakshmanan P, Geijskes RJ, Aitken KS, Grof CLP, Bonnett GD, Smith GR. Sugarcane biotechnology: the challenges and opportunities. *In vitro* Cell Dev Biol Plant. 2005;41(4):345-363.
8. Mohan S, Jayaraj S. Biology and some aspects of population ecology of the early shoot borer *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae) in sugarcane. Proc Indian Acad Sci Anim Sci. 1987;96(1):51-58.
9. Mukherjee SK. Origin and distribution of *Saccharum*. Bot Gaz. 1957;119(1):55-61.
10. Rao GP, Gaur RK, Ghosh A. Sugarcane diseases in India. International Book Distributing Company, Lucknow, India; 2002. p. 220-240.
11. Rao PRM, Murthy VNK. *Chilo sacchariphagus* indicus (Kapur) (Lepidoptera: Pyralidae): biology and mass rearing. Proc Int Soc Sugar Cane Technol. 1966;12:1026-1035.
12. Srikanth J, Salin KP. Damage potential of the top borer, *Scirpophaga excerptalis* Walker and the internode borer, *Chilo sacchariphagus* indicus (Kapur) (Lepidoptera: Crambidae) in sugarcane. Sugar Tech. 2001;3(4):133-137.
13. Srikanth J, Singaravelu B, Salin KP, Mahesh P, Kurup NK. Pest management in sugarcane: an Indian perspective. In: Agrawal SB, Agrawal M, editors. Environmental contamination and remediation. Cambridge Scholars Publishing, Newcastle upon Tyne, UK; 2017. p. 1-60.
14. Srivastava AK, Rao KC. Sugarcane production technology in India. Indian Institute of Sugarcane Research, Lucknow, India; 2002. p. 155-180.
15. Viswanathan R. Sugarcane yellow leaf disease in India: distribution, diagnosis, characterisation of causal agent and disease management. Sugar Tech. 2018;20(2):134-152.
16. Viswanathan R, Karuppaiah R, Balamuralikrishnan M, Malathi P. Resistance in sugarcane (*Saccharum* spp. hybrids) against insect pests: principles and progress. In: Rao GP, Rajput CBS, Rao KC, editors. Microbial biotechnology and crop protection. Daya Publishing House, New Delhi, India; 2014. p. 240-268.
17. Waclawovsky AJ, Sato PM, Lembke CG, Moore PH, Souza GM. Sugarcane for bioenergy production: an assessment of yield and regulation of sucrose content. Plant Biotechnol J. 2010;8(3):263-276.