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RESEARCH ARTICLE

Evaluation of sugarcane clones for yield, juice quality, borer and red rot resistance

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Abstract

Field experimental trials were conducted to evaluate the thirty-one sugarcane clones for cane yield and quality traits along with borer resistance. To assess the borer resistance of sugarcane clones, early shoot borer and inter-node borer incidence were recorded periodically. Data on the number of tillers, number of millable canes, cane height, cane yield, brix per cent, sucrose content, commercial cane sugar (%) and sugar yield (t. ha^{-1}) were recorded to identify the promising pre-release sugarcane clones. Clone C 32028 recorded the highest cane yield (151.52 t. ha^{-1}) followed by clone C 32016 (144.93 t. ha^{-1}) and C 33144 (143.75 t. ha^{-1}). For sucrose content, clone C 33035 recorded the highest sucrose content (18.07%) followed by C 33024 (18.02%) and C 33260 (17.95%). For sugar yield, the test clone C 32028 (19.47 t. ha^{-1}) recorded the highest sugar yield followed by the clone C 32016 (18.58 t. ha^{-1}), C 33114 (18.47 t. ha^{-1}) and C 33075 (18.23 t. ha^{-1}). Among the test clones, C 32028, C 32016, C 33114, C 33075 and C 33276 outperformed the check varieties in cane yield, sucrose content, sugar yield and borer resistance. Hence it was recommended that, selected promising clones could be forwarded for the next evaluation trials for variety release.

Keywords

cane yield; CCS %; resistance to shoot borer; sucrose %; sugarcane; sugar yield

Introduction

Sugarcane (*Saccharum* spp. hybrids) is an essential industrial cash crop, cultivated in different agro-climatic conditions of the world (1). In terms of both production (376.91 million tons) and area (48.67 lakh ha), India is the world's second-largest producer of sugarcane, after Brazil. Tamil Nadu leads the Indian states in productivity and comes in fourth in terms of area and production, after Uttar Pradesh, Maharashtra and Bihar (2). Significant issues with the sugarcane crop include lower productivity, poor sugar recovery and high cost of cultivation. Low-yielding variety selection has a substantial impact on productivity and the amount of cultivable land under sugarcane (3). Subsequently, at present there is an urgent need to develop better-performing high-yield varieties (4). Sugarcane productivity was greatly influenced by the selection of variety, season, timely practice of agronomic methods and application of adequate essential nutrients (5).

Over 200 insect pest species affect sugarcane crops, with borer causing the most substantial financial losses for farmers (6). Borer infestations lead to economic losses of 22% in cane yield and 15% in sugar recovery (7). In India, *Chilo infuscatellus* is one of these borers that cause significant losses in the early stages of sugarcane growth, particularly in the summer (8). In various regions of India, *Scirpophaga excerptalis* has been identified as a significant pest of sugarcane, reducing yield (up to 45%) and sugar recovery (2.0 units) (9). Hence, the present study was carried out to screen the sugarcane clones for yield, juice quality and resistance to early shoot borer and inter-node borer under natural environmental conditions.

Materials and Methods

Experimental materials and layout

The current study was carried out at Sugarcane Research Station (SRS), Tamil Nadu Agricultural University (TNAU), Cuddalore, Tamil Nadu, India during 2020-21. The experimental materials consisted of thirty-one sugarcane clones and two check varieties Co 86032 and CoC (Sc) 24. All the test clones were planted in a Randomized Block Design and replicated twice during the December to January planting season in Tamil Nadu. Each plot size was 5 m in length and 1.20 m in width and six rows were followed. In each row, sixty buds (12 buds/m) were planted. Recommended agronomic practices were followed for the entire cropping period.

Data collection and analysis

The data were collected from ten canes chosen at random from each entry of the primary stalk (canes). Among these traits, tillers count (×1000 ha^{-1}) was documented at a 4-month-old crop and other characters were measured during harvest. For quality analysis, ten canes were randomly selected from each test clone and juice was extracted by power crusher and evaluated for brix per cent and the sucrose percentage was recorded as per standard method (10). The sugar yield was worked out by Commercial Cane Sugar per cent (CCS %) and cane yield (t. ha^{-1}). Collected data pertaining to three trials were analysed using the statistical procedure (11).

Principle component analysis

Principle component analysis (PCA) was carried out to find the diversity of sugarcane clones. Optimal cluster number was established by repetitive analyses for diverse numbers till the cluster sum of squares touched its minimum value. The PCA included computing mean, eigen vectors and eigen values, covariance matrix and selecting components vector (12). The PCA was analysed using the R software version 4.4.1 (13).

Screening for borer and red rot resistance

1. Assessment of early shoot borer infestation : From each genotype, twenty-five plants were chosen randomly in every clone, the number of dead hearts and total shoots were recorded during the 30th, 60th and 90th days old and cumulative damage was calculated and categorised based on the classification outlined in an earlier research article (14).

0-15% incidence; Less Susceptible (LS)

15.1-30% incidence: Moderately Susceptible (MS)

> 30%: Highly Susceptible (HS)

2. Assessment of internode borer infestation : In each plot 20 canes were selected randomly, healthy and inter-node borer-infested clones were recorded and mean percentage occurrence was calculated by following formulae and categorised (14).

$$\text{Incident percentage (\%)} = \frac{\text{Number of canes affected}}{\text{Total no. of canes}} \times 100$$

0-30% incidence: Less Susceptible (LS)

30.1-50% incidence: Moderately Susceptible (MS)

> 50% incidence: Highly Susceptible (HS)

3. Assessment of red rot resistance: Canes of eight months old (20 Nos. in each clone) were inoculated with 0.5 ml of conidial suspension (10^6 colony forming unit/ml) of *Colletotrichum falcatum* pathotype CF06 at 2nd inter-node from the bottom (plug method) and after two months the inoculated canes were split opened and assessed. Based on the condition of top, nodal transgression, white spot and lesion width, disease scoring was done on a 0–9 scale and categorised as

0 – 2.0 = Resistant

2.1 – 4.0 = Moderately Resistant

4.1 – 6.0 = Moderately Susceptible

6.1 – 8.0 = Susceptible

> 8 = Highly Susceptible

Results and Discussion

The analysis of variance in the present study revealed significant differences in the means of yield, quality and their contributing characters. The genetic difference between genotypes may account for the variance in cane yield and yield components. High variability in sugarcane clones for yield and related traits has been reported earlier (15).

Growth parameters

The results pertaining to yield and its contributing traits in the present study are presented in Table 1. The study revealed that the maximum number of tillers (×1000 ha^{-1}) was recorded in the test clone C 32014 (136.15), while the minimum was observed in C 32005 (116.75). The clone C 32014 recorded the highest number of tillers (136.15 ha^{-1}) followed by C 32028 (134.99 ha^{-1}) and C 33267 (132.75 ha^{-1}). Among test clones, only nine clones expressed the highest tiller numbers over the best standard CoC (Sc) 24 (128.55 ha^{-1}). A similar result on tiller counts in sugarcane genotypes has been reported in an earlier study (16). The result indicated that the number of millable canes per hectare varied from 104.25 to 125.67 (×1000 ha^{-1}). Only six test clones performed better than the checks for this trait; namely, C 33276 (125.67 ha^{-1}), C 32028 (125.23 ha^{-1}), C 33144 (124.81 ha^{-1}), C 33267 (123.45 ha^{-1}), C 33273 (122.74 ha^{-1}) and C 33075 (122.37 ha^{-1}). The number of millable canes directly impacts the cane yield by the joint interface of germination per cent and tillers count. The current study results were in agreement with similar referenced studies (17, 18).

Table 1. Mean performance of sugarcane clones for cane yield and its contributing traits

S. No	Genotypes/ Clone	No. of Tillers ('000 ha^{-1})	No. of millable canes ('000 ha^{-1})	Cane length (Cm)	Cane thickness (Cm)	Cane Yield (t. ha^{-1})
1	C 32005	116.75^{b}	104.25^{d}	263.4^{f}	2.86^{abcde}	115.70^{gh}
2	C 32009	126.12^{ab}	116.15^{abcd}	275.12^{abcdef}	2.80^{abcdefgh}	121.15^{efgh}
3	C 32012	125.86^{ab}	115.52^{abcd}	285.15^{abcde}	2.90^{abcd}	137.45^{abcd}
4	C 32014	136.15^{a}	112.23^{abcd}	277.52^{abcdef}	2.82^{abcdefg}	130.42^{bcdef}
5	C 32016	124.27^{ab}	118.45^{abc}	281.85^{abcdef}	2.94^{abc}	144.93^{ab}
6	C 32023	125.13^{ab}	112.85^{abcd}	275.55^{abcdef}	2.65^{ijk}	115.75^{gh}
7	C 32027	131.20^{ab}	117.42^{abcd}	280.62^{abcdef}	2.85^{cdefg}	122.50^{efg}
8	C 32028	134.99^{a}	125.23^{a}	295.35^{ab}	3.05^{a}	151.52^{a}
9	C 33004	127.90^{ab}	114.81^{abcd}	272.65^{cdef}	2.75^{abcdefgh}	121.45^{efgh}
10	C 33024	128.07^{ab}	112.43^{abcd}	281.42^{abcdef}	2.45^{k}	115.62^{gh}
11	C 33025	127.11^{ab}	117.85^{abc}	290.45^{abc}	2.95^{ab}	135.45^{bcde}
12	C 33035	117.60^{ab}	105.35^{cd}	285.75^{abcde}	2.51^{jk}	116.75^{fgh}
13	C 33042	128.31^{ab}	115.74^{abcd}	287.45^{abcde}	2.85^{abcde}	132.83^{bcdef}
14	C 33046	126.38^{ab}	117.21^{abcd}	295.31^{ab}	2.88^{abcde}	130.15^{cdef}
15	C 33056	128.26^{ab}	120.44^{ab}	294.72^{ab}	2.91^{abc}	134.45^{bcde}
16	C 33060	127.65^{ab}	115.39^{abcd}	274.22^{bcdef}	2.79^{abcdefg}	121.46^{efgh}
17	C 33074	123.95^{ab}	114.85^{abcd}	267.35^{ef}	2.84^{abcdef}	118.12^{fgh}
18	C 33075	131.06^{ab}	122.37^{ab}	287.65^{abcdef}	2.87^{cdefg}	141.62^{abcd}
19	C 33108	119.95^{ab}	116.22^{abcd}	275.88^{abcdef}	2.76^{cdefgi}	126.34^{defg}
20	C 33114	131.70^{ab}	124.81^{ab}	289.45^{abcd}	2.93^{abc}	143.75^{abc}
21	C 33122	122.15^{ab}	111.35^{bcd}	275.32^{abcdef}	2.63^{ijk}	110.56^{h}
22	C 33123	125.15^{ab}	115.24^{abcd}	268.95^{def}	2.75^{cdefg}	121.47^{efgh}
23	C 33206	128.97^{ab}	117.95^{abc}	282.61^{abcdef}	2.67^{fgij}	123.74^{efg}
24	C 33232	128.05^{ab}	114.39^{abcd}	274.21^{bcdef}	2.73^{cdefg}	120.81^{efgh}
25	C 33237	125.83^{ab}	112.93^{abcd}	271.65^{cdef}	2.63^{ijk}	119.36^{fgh}
26	C 33245	127.85^{ab}	116.71^{abcd}	268.32^{def}	2.71^{defgh}	120.78^{efgh}
27	C 33250	130.65^{ab}	119.67^{ab}	276.33^{abcdef}	2.68^{fgij}	121.84^{fgh}
28	C 33260	121.12^{ab}	114.81^{abcd}	281.54^{abcdef}	2.72^{cdefg}	118.65^{fgh}
29	C 33267	132.75^{a}	123.45^{ab}	294.57^{ab}	2.88^{abcde}	129.25^{cdefg}
30	C 33273	131.65^{ab}	122.74^{ab}	284.65^{abcdef}	2.75^{cdefg}	119.37^{fgh}
31	C 33276	129.75^{ab}	125.67a	296.34^{a}	2.87^{abcde}	137.74^{abcd}
	Checks					
1.	Co 86032	123.74^{ab}	117.65^{abc}	277.41^{abcdef}	2.63^{ijk}	125.35^{efg}
2.	CoC(Sc) 24	128.55^{ab}	120.52^{ab}	287.75^{abcde}	2.90^{abcd}	130.50^{bcdef}
	S.Em±	5.68	5.01	8.75	0.07	5.35
	CD (0.05%)	16.36	13.83	21.42	0.18	14.74
	CV (%)	6.33	6.10	5.44	3.26	6.24

Means followed by the same letter do not differ statistically among themselves by Duncan's test (*p* £ 0.05).

Yield contributing traits

For cane length, the maximum cane length recorded was in C 33276 (296.34 cm) and the minimum in C 32005 (263.41 cm). Ten test clones showed better cane length than the best standard CoC (Sc) 24 (287.75 cm). Cane length contributes significantly towards final cane yield, as longer canes typically result in greater biomass and sugar content. Sugarcane seedlings with a cane length of approximately 2.5 m are considered suitable for advancement to the next generation (19). The research work on the cane length has already been reported (20, 21). The cane thickness in the test clones ranged from 2.15 cm (C 33024) to 3.05 cm (C 32028). The maximum average cane thickness was exhibited in the genotypes C 32028 (3.05 cm) and C 33025 (2.95 cm). Among the 31 clones, only five clones exhibited greater cane thickness than the check variety CoC (Sc) 24 (2.90 cm). Cane thickness is a significant yield-contributing trait and genotypes with greater cane diameter, augment the farmer's acceptance (16). The cane thickness of sugarcane has already been reported (21, 22).

The results on cane yield indicated that the test clones and checks ranged from 110.56 t. ha^{-1} (C 33122) to 151.52 t. ha^{-1} (C 32028). The clone C 32028 yielded the highest tonnage (151.52 t. ha^{-1}) followed by the clone C 32016 (144.93 t. ha^{-1}). The top performing clones for cane yield over best checks are C 32028 (151.52 t. ha^{-1}), C 32016 (144.93 t. ha^{-1}), C 33114 (143.75 t. ha^{-1}), C 33075 (141.62 t. ha^{-1}) and C 33276 (137.74 t. ha^{-1}). Among the evaluated clones, eight clones were observed to have better cane yield over better standard CoC (Sc) 24 (130.50 t ha^{-1}). Cane yield is a key factor in determining a variety's economic potential and it depends on the combined effects of genotypes and environmental responses (16). The present study results were almost similar to the earlier findings (23, 24).

Juice quality and its component traits

The mean performance of juice quality and its component traits for sugarcane clones in the current study are presented in Table 2. Brix per cent plays a vital part in determining the quality of the sugarcane genotype. Brix % in this study shows the highest brix per cent was recorded in C 33035 (21.91%) and lowest in C 33206 (19.83%). Among the 31 clones studied, eight test clones showed numerically higher brix per cent over best check Co 86032 (21.62%). Sugar recovery is an important prime factor from both millers' and breeders' point of view. The present investigation results on brix per cent were almost similar to the earlier findings (25). Sugarcane genotypes had different levels of brix per cent as reported in earlier studies (26).

The sucrose per cent in the experiments were fluctuated from 16.45 to 18.07%. Among 31 clones, only four test clones such as C 32035 (18.07%), C 32024 (18.02%), C 33260 (17.95%) and C 33276 (17.86%) were recorded higher sucrose content over the best check Co 86032 (17.84%). Sucrose content is a significant quality character of

Table 2. Mean performance of sugarcane clones for juice quality traits

S. No	Genotype	Brix (%)	Sucrose (%)	CCS (%)	Sugar yield (t. ha^{-1})
1	C 32005	21.26^{fg}	17.06^{defgh}	12.71^{ef}	14.71^{no}
2	C 32009	19.85^{n}	16.75^{ghij}	12.52^{gh}	15.16^{klm}
3	C 32012	21.35^{efg}	17.12^{def}	12.75^{def}	17.52^{de}
4	C 32014	21.45^{def}	17.05^{defgh}	12.77^{def}	16.66^{fg}
5	C 32016	21.71^{abc}	17.82^{ab}	12.82^{cde}	18.58^{b}
6	C 32023	21.22^{fgh}	17.31^{cde}	12.63^{fg}	14.62^{no}
7	C 32027	20.85^{ijk}	16.95^{efgh}	12.63^{fg}	15.48^{ijk}
8	C 32028	21.07^{hi}	17.25^{cde}	12.85^{bcde}	19.47^{a}
9	C 33004	20.95^{hij}	16.92^{fghi}	12.25^{i}	14.88^{lmn}
10	C 33024	21.75^{ab}	18.02^{ab}	12.95^{abcd}	14.98^{lmn}
11	C 33025	21.23^{fgh}	17.11^{defg}	12.78^{def}	17.31^{ef}
12	C 33035	21.91^{a}	18.07^{a}	13.12^{a}	15.32^{jkl}
13	C 33042	21.15^{gh}	17.77^{ab}	12.82^{cde}	17.03^{f}
14	C 33046	20.55^{l}	17.35^{cde}	12.67^{efg}	16.49^{g}
15	C 33056	21.64^{bcd}	17.73^{ab}	12.85^{cde}	17.28^{ef}
16	C 33060	20.62^{kl}	16.65^{hij}	12.52^{gh}	15.21^{klm}
17	C 33074	20.25^{m}	16.45^{j}	12.51^{gh}	14.78^{mno}
18	C 33075	21.10^{gh}	17.22^{cdef}	12.87^{cde}	18.23^{bc}
19	C 33108	21.05^{hi}	17.05^{defgh}	12.61^{fg}	15.83^{hi}
20	C 33114	21.55^{bcde}	17.83^{ab}	12.85^{bcde}	18.47^{b}
21	C 33122	21.56^{bcde}	17.63^{bc}	12.95^{abcd}	14.32^{o}
22	C 33123	20.75^{ijk}	16.52^{ij}	12.55^{gh}	15.24^{klm}
23	C 33206	19.83^{n}	16.91^{fghi}	12.46^{h}	15.60^{ijk}
24	C 33232	21.63^{bcd}	17.45^{cd}	13.02^{abc}	15.72^{ij}
25	C 33237	21.71^{abc}	17.68^{ab}	12.95^{abcd}	15.46^{ijk}
26	C 33245	21.45^{def}	17.32^{cde}	12.81^{de}	15.47^{ijk}
27	C 33250	21.65^{bcd}	17.75^{ab}	12.94^{abcd}	15.77^{hij}
28	C 33260	21.75^{ab}	17.95^{ab}	13.05^{ab}	15.48^{ijk}
29	C 33267	20.61^{kl}	17.25^{cde}	12.68^{efg}	16.39^{g}
30	C 33273	21.47^{cdef}	17.62^{bc}	12.77^{def}	15.24^{klm}
31	C 33276	21.84^{a}	17.86^{ab}	12.92^{abcd}	17.80^{cd}
	Checks				
1	Co 86032	21.62^{bcd}	17.84^{ab}	12.95^{abcd}	16.23^{gh}
2	CoC(Sc) 24	20.21^{m}	16.85^{fghi}	12.65^{fg}	16.51^{g}
	S.Em±	0.08	0.14	0.07	0.16
	CD (0.05%)	0.24	0.42	0.20	0.46
	CV (%)	0.47	1.18	0.57	1.42

Means followed by the same letter do not differ statistically among themselves by Duncan's test (*p* £ 0.05).

sugarcane. Its assessment is helpful in determining the sugarcane's quality and affects factory sugar production and recovery (26). A study on sucrose content in sugarcane juice has already been reported (27). The commercial cane sugar (CCS) percentage ranged from 12.46 to 13.12%. Among 31 clones, only two test clones, such as C 33035 (13.12%) and C 33260 (13.05%), recorded a higher CCS percentage than the best control variety Co 86032 (12.95%). The other three clones, C 33024 (12.95%), C 33122 (12.95%) and C 33237 (12.95%), were recorded on the column with the best standard Co 86032. CCS per cent in sugarcane is the best tool for evaluating the clone's quality for the breeders and millers and it decides the sugar recovery in the factory for sugar production. Similar reports on CCS per cent in sugarcane have been already reported (28, 29).

The sugar yield in the investigation varied from 14.32 to 19.47 t. ha^{-1}. Among the evaluated clones, ten clones expressed the highest sugar yield over the best standard CoC (Sc) 24 (16.51 t. ha^{-1}). The top five clones with respect to sugar yield were C 32028 (19.47 t. ha^{-1}), C 32016 (18.58 t. ha^{-1}), C 33114 (18.47 t. ha^{-1}), C 33075 (18.23 t. ha^{-1}) and C 33276 (17.80 t. ha^{-1}). Cane yield to the equivalent commercial cane sugar percentage is referred to as sugar yield. These findings are analogous to earlier study results (30, 31).

Principal component analysis was performed for nine quantitative traits, to assess the sugarcane clones and the results are depicted in Table 3. The pictorial representation (scree plot) was generated with the 'X' axis with nine dimensions and 'y' with variation per cent (Fig. 1). On the basis of Eigenvalues, 77.59% of the total cumulative variation was contributed by the first two components explained. PC1 explained 46.04% of variation while PC 2 explained 31.55% of the total variation. The present findings corroborated with findings in sugarcane with over 80% variability (32, 33). A biplot describing the traits projection on the first two principal components is given in Fig. 2. The biplot ordination represented that yield and quality-contributing characters were positively associated among themselves. Similarly,

Table 3. Eigen values (λ), variance (%) and cumulative variance (%) for nine principal

PC	Eigenvalue (λ)	Percentage of variance (%)	Cumulative percentage of variance (%)
PC 1	4.1432	46.0355	46.0355
PC 2	2.8396	31.5495	77.5850
PC 3	0.8209	9.1210	86.7061
PC 4	0.4939	5.4877	92.1937
PC 5	0.2508	2.7864	94.9802
PC 6	0.1931	2.1455	97.1257
PC 7	0.1811	2.01273	99.1384
PC 8	0.0772	0.8583	99.9967
PC 9	0.0003	0.0033	100.0000

characters such as brix value, CCS % and Sucrose % showed a positive relation, since the angle between the vectors is less than 90°. All the traits had positive vectors on PC 1. The biplot ordination in two or more dimensions highlighted the relationships among the traits (34).

The PCA was related to Eigenvector values and varimax rotation. The related communalities are presented in Table 4 and Fig. 3. The cumulative variability of 85% was due to the contribution of four Rotated Components (RCs). The maximum variation was contributed by RC 1 (31%), followed by RC 2 (30%), RC 3 (13%) and RC 4 (11%). In each of the rotational components, the characteristics with high Eigenvector loadings were essential. Present study characters including cane thickness, cane yield and sugar yield were shown to hold extreme vector values in the first rotated factor while the quality characters *viz.*, brix value, sucrose (%) and CCS (%) added involvement in RC 2. The third component, RC 3, involved high loadings for a number of tillers which was considered a significant yield-attributing trait. Based on the values, the characters in the study were effective in describing the differences between the sugarcane clones. Varimax rotation was used to rotate the components and the rotated primary components exhibited a comparable level of variability (76%). The traits with high vector loadings are considered as significant contributors and hence RC 1 is related to the plant architecture, while RC 2 is related to the quality characters. Traits in this study were consistent and effectively explained the variation, as indicated by communalities greater than 0.5 (Fig. 4). Each sugarcane clone was exceptional in their trait and none of them were frequently found in all the four components.

Table 4. Communalities and eigenvectors of different quantitative traits for the first four varimax rotated components

Eigenvectors	RC 1	RC 2	RC 3	RC 4	Communalities
Number of Tillers	0.26	-0.08	**0.93**	0.13	1.3
Number of millable cane	0.45	-0.05	0.42	0.25	2.7
Cane length	0.46	0.17	0.20	**0.83**	1.9
Cane thickness	**0.76**	-0.29	0.11	0.10	2.3
Cane Yield	**0.94**	0.04	0.20	0.20	1.2
Brix value	0.04	**0.96**	-0.03	0.10	1.2
Sucrose (%)	0.00	**0.91**	-0.05	0.26	1.4
CCS (%)	0.05	**0.90**	-0.04	0.11	1.5
Sugar yield	**0.92**	0.19	0.22	0.15	1.4
Proportion explained	0.31	0.30	0.13	0.11	-
Cumulative Proportion	0.31	0.61	0.75	0.85	-

(Rotated components with Eigenvector scores more than 0.5 were made bold)

Resistance to borer complex

Early shoot borer screening: Early shoot borer incidence of 31 sugarcane clones was recorded and the mean cumulative percentage of incidence is depicted in Table 5. The larvae bore into the mother shoot and destroy the apical meristem resulting in the drying of shoots causing drying of the entire clump during the germination phase. This incidence during the tillering phase causes mortality of the tiller resulting in poor cane formation leading to a reduction in yield and sucrose content (35). The results pertaining to the mean per cent damage level of early shoot borer in different sugarcane clones ranged from 12.35 (C 33206) to 55.15 (C 33250). The results indicated that 10 clones were classified as highly susceptible to early shoot borer damage, while 21 clones were rated as moderately susceptible (MS). Only three clones *viz.*, C 323206, C 32009 and CoC (Sc) 22 were rated low susceptible (LS) to early shoot borer with mean per cent damage. The lower susceptibility of these clones may be due to the inherent capacity to produce more tillers. The results are corroborated with earlier findings (36, 37).

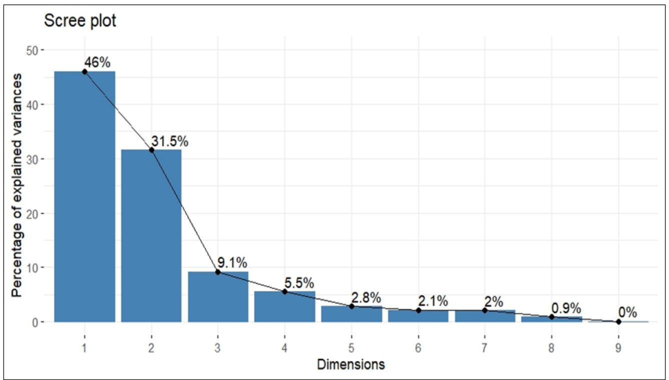

Fig. 1. Scree plot depicting all nine dimensions with the percentage of variances.

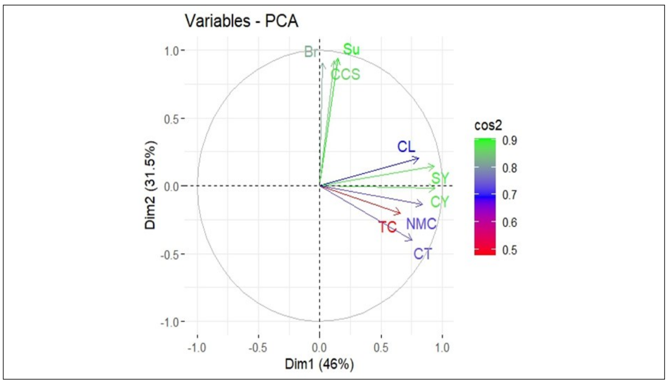

Fig. 2. PCA - Biplot depicting two-dimensional ordination for nine quantitative traits on Two-component axes.

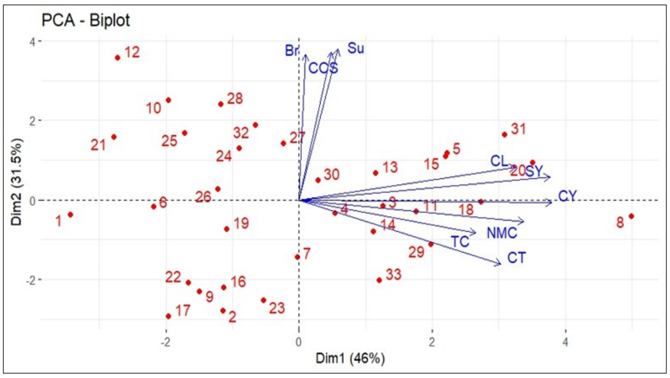

Fig. 3. PCA - Biplot depicting two-dimensional ordination for nine quantitative traits on Two-component axes.

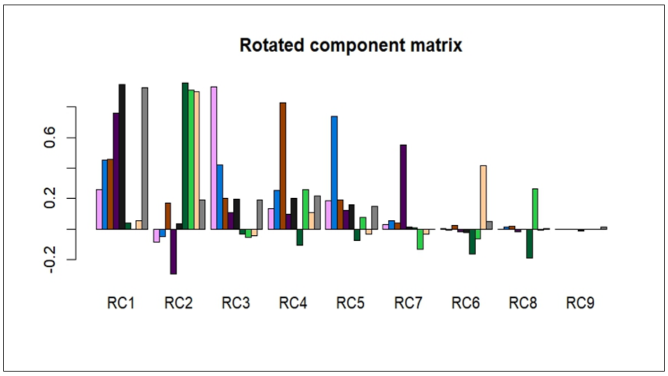

Fig. 4. Rotated factor loadings for different metric variables of sugarcane clones.

Table 5. Damage level of early shoot and inter-node borers and resistance to red rot disease in sugarcane clones

S. No	Genotype / Clones	Early Shoot Borer (ESB)		Internodes borer (INB)		Red rot	
		Cumulative mean % damage	Damage rating	Mean % of damage	Damage rating	Score	Reaction
1	C 32005	21.35	MS	10.75	LS	4.7	MS
2	C 32009	14.85	LS	10.53	LS	2.2	MR
3	C 32012	22.75	MS	15.65	LS	2.8	MR
4	C 32014	30.52	HS	25.35	LS	3.6	MR
5	C 32016	23.45	MS	9.75	LS	2.1	MR
6	C 32023	28.35	MS	11.62	LS	2.4	MR
7	C 32027	24.15	MS	10.35	LS	2.6	MR
8	C 32028	19.25	MS	22.35	LS	3.2	MR
9	C 33004	18.07	MS	11.83	LS	3.6	MR
10	C 33024	45.83	HS	12.50	LS	4.4	MS
11	C 33025	25.67	MS	15.61	LS	5.1	MS
12	C 33035	54.31	HS	20.10	LS	9.0	HS
13	C 33042	19.25	MS	10.92	LS	9.0	HS
14	C 33046	20.84	MS	14.56	LS	9.0	HS
15	C 33056	18.22	MS	25.15	LS	3.6	MR
16	C 33060	21.86	MS	21.80	LS	3.4	MR
17	C 33074	18.55	MS	17.91	LS	2.8	MR
18	C 33075	22.75	MS	10.85	LS	3.7	MR
19	C 33108	21.71	MS	11.61	LS	8.0	S
20	C 33114	22.35	MS	12.05	LS	7.6	S
21	C 33122	35.25	HS	17.75	LS	2.9	MR
22	C 33123	20.50	MS	22.54	LS	3.1	MR
23	C 33206	12.35	LS	9.85	LS	6.9	S
24	C 33232	42.35	HS	15.65	LS	9.0	HS
25	C 33237	47.54	HS	14.41	LS	5.3	MS
26	C 33245	35.45	HS	13.65	LS	9.0	HS
27	C 33250	55.15	HS	25.82	LS	4.9	MS
28	C 33260	52.32	HS	18.75	LS	9.0	HS
29	C 33267	18.68	MS	10.31	LS	7.5	S
30	C 33273	51.25	HS	8.55	LS	5.1	S
31	C 33276	28.33	MS	23.66	LS	2.8	MR
	Checks						
1	CoC (Sc) 22	12.77	LS	7.95	LS	3.1	MR
2	Co 86032	37.45	MS	11.82	LS	5.3	MS
3	CoC (Sc) 24	27.63	MS	17.53	LS	7.8	S

Borer : LS - Less Susceptible; MS - Moderately Susceptible; HS - Highly Susceptible

Red rot: R-Resistant; MR- Moderately Resistant; MS- Moderately Susceptible, S-Susceptible; HS-Highly Susceptible

Inter-node borer screening: The results on the incidence of inter-node borer in different clones were recorded at 185 days after planting and presented in Table 5. The damage level (mean) of the inter-node borer ranged from 7.95 (CoC (Sc) 22) to 25.82% (C 33250). All the clones were found less susceptible (LS) to inter-node borer, indicating a relatively low level of damage across the evaluated genotypes. In sugarcane borer screening, clones rated as moderately susceptible (MS) for early shoot borer and less susceptible (LS) for inter-node borer are considered ideal for variety release. In the present investigation, the promising five clones *viz*., C 32028, C 32016, C 33114, C 33075 and C 33276 expressed moderately susceptible (MS) for early shoot borer and less susceptible (LS) to internode borers along with superior performance in yield and quality traits. The study on borer incidence in sugarcane clones has already been reported (38, 39). The sugarcane pests and losses instigated by the sugarcane crop in West Bengal, India were already reported in an earlier research paper (40).

***Resistance to red rot*:** The results on the resistance to red rot in clones were scored two months after inoculation with the red rot pathogen and presented in Table 5. Among the 31 clones screened, 14 clones were found to have moderately resistant reactions to red rot disease including the promising clones C 32028, C 32016, C 33075 and C 33276. Due to the changing dynamics of the epidemics of red rot disease, the identification of clones with high yield potential and quality traits coupled with resistance is essential in the development of varieties. Similar reports of clones with high quality and red rot resistance were earlier reported (41).

Conclusion

Based on the overall performance of sugarcane clones, it was concluded that, among 31 clones evaluated, four clones, *viz*., C 32028, C 32016, C 33075 and C 33276, are the top performed clones. They exhibited better performance over checks for yield and yield-related characters and quality traits along with borer resistance (moderately susceptible to early shoot borer and less susceptible to intern-node borers). Among the characters studied, the number of tillers and millable canes are the major yield contributing characters. Hence, it was decided that these four promising clones might be advanced for imminent yield trials for variety release.

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Authors' contributions

VR performed data analysis, red rot screening, coordination, summarizing and revising the manuscript. SG executed the experiments, collected the data and drafted the manuscript. JJ screening clones for major pest (Borer complex). PV carried out analysis of data and interpretation of the findings. All the authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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