

Screening and evaluation of elite sugarcane (*Saccharum Officinarum*) L. clones for yield, juice quality parameters with resistance to Early Shoot Borer and Red Rot Disease

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Abstract

The present study was carried out at Regional Agricultural Research Station, Anakapalle (2018-19 to 2019-20) in RCBD with two replications in a gross plot size of 8mtx0.8mx8R=51.20m² and net plot size of 8mx0.8mx6R=38.40m². All recommended package of practices were followed. The clone 2009A252 recorded significantly higher tiller population at 120DAP(141.28 thousands/ha, number of millable canes(132.00thousands/ha),cane yield(143.67t/ha) and sugar yield(24.59t/ha) followed by 2014A210(135.70thousands/ha,128.33 thousands/ha,131.33 t/ha and 22.32t/ha respectively) and 2015A222 (133.00 thousands/ha,120.00 thousands/ha,126.00 t/ha and 22.27t/ha respectively) and found to be significantly superior over the standard,87A298(118.30 thousands/ha,105.33 thousands/ha,110.67 t/ha and 17.34t/ha respectively). The clone,2015A152 recorded significantly higher brix per cent(24.00),sucrose(22.50%),CCS (18.67%),juice extraction per cent(66.23) and fibre per cent(14.22) followed by 2015A199 (23.05%,21.60%,17.72%,62.33% and 14.30% respectively) and 2015A187(23.02%,21.57%,17.69%,60.33% and 14.30% respectively) when compared to standard,87A298(21.05%,19.55%,15.67%,58.67% and 13.96% respectively). Five clones viz., 87A298,2006A64, 2009A107, 2014A210 and 2015A183 were rated as less susceptible (LS) to early shoot borer with mean percent damage. A biplot describing the traits projection on the first three principal components describing the traits in Sugarcane of 71.93% of total variation represented that yield and quality contributing characters were positively associated among themselves. Similarly, characters such as brix %, CCS% and Sucrose % showed a positive correlation since the angle between vectors is less than 90°. All the traits had positive vectors on PC1. The biplot ordination in two or three dimensions highlighted the relations among the traits. Identification of clones with high yield potential and quality traits coupled with resistance to pests and diseases is essential in the development of varieties. The promising genotypes represent valuable genetic resources for future varietal improvement in sugarcane breeding programs through targeted breeding approach

Keywords: Sugarcane clones-cane and sugar yields-resistance to shoot borer and red rot incidence

Introduction

Sugarcane (*Saccharum* spp. hybrids) is an essential industrial cash crop, cultivated in different agro-climatic conditions of the world (Kandel *et al*, 2018) [10] in terms of both production (376.91million 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 (<https://www.statista.com>). 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 (Mian, 2006) [14]. At present there is an urgent need to develop better-performing high-yield varieties (Chattha and Ehsanullah,2003) [3]. Sugarcane productivity was greatly influenced by the selection of variety, season, timely practice of agronomic methods and application of adequate essential nutrients (Ganapathy *et al*, 2024) [8]. Over 200 insect pest species affect sugarcane crops, with borer causing the most substantial financial losses for farmers (Mukunthan and Nirmala, 2002) [15]. Borer infestations lead to economic losses of 22% in cane yield and 15% in sugar recovery (Weng *et al*, 2011) [32]. In India, *Chilo*

infuscatellus is one of these borers that cause significant losses in the early stages of sugarcane growth, particularly in the summer (Nagalakshmi *et al*, 2009). In various regions of India, it has been identified as a significant pest of sugarcane, reducing yield (up to 45%) and sugar recovery (2.0units) (Madan *et al*,1999) [11]. Hence, the present study was carried out to screen the sugarcane clones for yield, juice quality and resistance to early shoot borer under natural environmental conditions and red rot under artificial conditions.

Materials And Methods

The study was conducted at the Regional Agricultural Research Station (RARS), Anakapalle, during 2018–19 to 2019–20. Thirty-one elite genotypes developed from breeding programme were tested against a standard 87A298. The experiment was carried out in Randomized Block Design with three replications. Gross plot size adopted was 8mt X0.8mtX8R=51.20m² and Net plot size is 8mt X 0.8mt X 6R= 38.40 m² 40,000 three budded setts. per hectare seed rate was adopted and 80 cm between rows. Fertilizers applied 100 kg P2O5+ 120 kg K2O /ha at the time of planting are applied as basal dressing. Nitrogen@112 kg

N/ha in the form of urea will be applied in two split doses, 30% at ten days after transplanting and the remaining 70% at 60 days after transplanting. Data on NMC, Cane yield and yield components were recorded during the crop growth period. 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 (1000ha⁻¹) was documented at 120 DAP 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 Juice sucrose was determined at harvest following the standard procedure Maide & Chen (1977). The sugar yield was worked out by Commercial Cane Sugar percent (CCS%) and cane yield (t ha⁻¹). Estimated CCS yield was determined based on CCS percent and cane yield. Statistical analysis was performed as per procedure of Panse and Sukhatme (1978)

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 component vectors (Singh and Narayanan,1993) [25]. The PCA was analyzed using the R software version4.4.1

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 categorized based on the classification (Venugopal Ravichandran *et al.*,2025).

0-15%incidence; Less Susceptible (LS)

15.1-30%incidence: Moderately Susceptible (MS)

>30% Highly Susceptible (HS)

2. Assessment of red rot resistance: Screening for red rot resistance was done in the selected adopting the plug inoculation method (Prakasam *et al.*, 1971) [19]. At seven months of crop age, ten canes per clone were inoculated

at the third internode with a spore suspension containing 6×10^5 spores/mL prepared from three predominant red rot pathotypes (*Cf*419, *Cf* 671, and *Cf* 997) as per Satyanarayana *et al.*, (1984) [24]. The inoculation site was sealed with plasticine, and disease assessment was done 60 days post-inoculation by recording lesion width, nodal transgression, presence of white spots, and nature of tops. Disease severity was rated on a 0–9 scale following Srinivasan and Bhat (1961) [29].

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 (Memon *et al.*,2005) [13].

Growth parameters

The results pertaining to yield and its contributing traits in the present study were presented in Table 1. The study revealed that maximum germination percent was recorded by the clone 2014A224 (79.55) followed by 2009A 252 (75.84) and 2010A 229 (74.72). The clone 2009A252 recorded significantly higher tiller population at 120DAP(141.28 thousands/ha, cane yield(143.67t/ha) and sugar yield(24.59t/ha) followed by 2014A210(135.70thousands/ha,128.33 thousands/ha,131.33 t/ha and 22.32t/ha respectively) and 2015A222 (133.00 thousands/ha,120.00 thousands/ha,126.00 t/ha and 22.27t/ha respectively) and found to be significantly superior over the standard,87A298(118.30 thousands/ha,105.33 thousands/ha,110.67 t/ha and 17.34t/ha respectively present findings were in agreement with similar studies of patel *et al.*, and Saranraj *et al.*, (2023) [23]. For yield components the clone 2009A252 recorded numerically higher single cane weight(1.32Kg),Stalk girth(3.00 cm) and Stalk length(2.60m) followed by 2014A210(1.30Kg,2.90cm,2.50m respectively) and 2015A222(1.28Kg,2.85cm and 2.42m respectively) and were found to be superior over the standard,87A298(1.20Kg,2.26cm,2.35m respectively) when tested in the trial (Table 1) These results were in accordance with the findings of Bhavana *et al.*, (2002) and Singh *et al.*, (2015) [15] in Sugarcane

Table1: Mean performance of sugarcane clones for cane yield and its contributing traits

S.No.	Genotype	Name of Genotype	Genotype germination (%)	Tiller population at120 DAP (000s/ha)	NMC (000s/ha)	SCW (Kg)	Stalk girth (m)	Stalk length (m)	Cane yield (t/ha)	CCS yield (t/ha)
1	G1	2005A128	68.55	116.70	99.45	1.18	1.90	2.00	101.36	12.89
2	G2	2006A64	74.66	124.23	107.65	1.20	3.00	2.20	132.00	19.06
3	G3	2006A223	68.32	128.35	104.64	1.20	3.10	2.30	101.36	15.42
4	G4	2006A102	69.51	131.06	110.54	1.21	2.30	2.11	118.36	17.61
5	G5	2007A81	58.14	122.15	110.32	1.22	2.20	2.06	114.33	15.56
6	G6	2008A120	70.14	119.90	105.64	1.20	2.50	2.12	102.33	14.20
7	G7	2008A210	68.32	121.10	109.28	1.18	2.60	2.10	103.67	16.47
8	G8	2009A107	69.81	131.62	105.32	1.16	2.60	2.10	116.67	19.27
9	G9	2009A252	75.84	141.28	132.00	1.32	3.00	2.60	143.67	24.59
10	G10	2009A234	69.66	125.14	100.89	1.00	2.70	2.02	113.36	16.70
11	G11	2010A229	74.12	126.32	108.33	1.03	2.60	2.16	114.35	15.09
12	G12	2012A249	70.32	127.90	111.33	1.28	2.80	2.12	101.33	15.20
13	G13	2012A224	70.00	122.10	101.03	0.80	2.60	2.13	117.36	16.84

14	G14	2014A224	79.55	128.26	102.67	1.16	2.90	2.30	104.56	14.27
15	G15	2014A142	68.15	131.30	105.96	1.20	2.30	2.20	123.35	19.40
16	G16	2014A210	65.33	135.70	128.33	1.30	2.40	2.50	131.33	22.32
17	G17	2014A56	70.33	121.65	120.33	1.00	2.30	2.20	122.36	20.43
18	G18	2015A311	71.23	122.62	116.33	1.20	2.55	3.50	114.35	20.54
19	G19	2015A228	64.32	131.65	114.32	1.10	2.70	2.00	122.35	20.25
20	G20	2015A199	58.36	128.60	115.33	1.05	2.60	2.00	120.33	20.13
21	G21	2015A222	61.32	133.00	120.00	1.28	2.85	2.42	126.00	22.27
22	G22	2015A152	64.33	125.00	101.33	1.20	2.60	2.10	118.33	22.09
23	G23	2015A183	65.33	118.22	106.67	1.00	2.80	2.10	102.36	21.18
24	G24	2015A187	58.33	115.23	112.36	1.26	3.00	2.40	119.33	21.10
25	G25	2015A137	62.33	131.22	114.33	1.20	3.00	2.50	111.22	19.68
26	G26	2015A233	58.68	122.28	102.36	1.10	2.90	2.30	118.33	18.58
27	G27	2015A59	60.33	118.22	101.36	1.18	2.40	2.30	112.33	19.85
28	G28	21015A51	61.02	122.34	108.33	1.20	2.20	1.90	112.33	19.57
29	G29	2015A230	60.33	128.22	100.33	1.20	2.60	2.40	116.55	21.20
30	G30	2015A 199	62.33	126.33	101.33	1.02	3.00	2.50	117.33	20.79
31	G31	87A298(C)	64.32	118.30	105.33	1.20	2.26	2.35	110.67	17.34
		C D (0.05)	18.32	18.33	23.67	2.32	1.97	2.67	33.37	10.22
		CV (%)	8.33	6.58	8.67	4.65	5.67	6.67	10.23	9.87

Juice quality and its components traits

Mean performance of juice quality and its components traits for sugarcane clones in the current study were presented in Table 2. Brix percent and sucrose percent plays a vital role in determining the quality of the sugarcane genotype. If higher fibre percent present in the genotypes means the clones were with stands to lodging of severe cyclonic winds. Juice extraction percent is a highly desirable character in extraction of juice from cane. If the cane is soft, extraction percent is higher in the clones. The clone, 2015A152

recorded significantly higher brix per cent(24.00), sucrose(2.50%), CCS (18.67%), juice extraction per cent(66.23) and fibre per cent(14.22) followed by 2015A199 (23.05%, 21.60%, 17.72%, 62.33% and 14.30% respectively) and 2015A187(23.02%, 21.57%, 17.69%, 60.33% and 14.30% respectively) when compared to standard, 87A298(21.05%, 19.55%, 15.67%, 58.67% and 13.96% respectively) These findings were in agreement with the present findings of Singh *et al.*, (2023) [27] and Roohi *et al.*, (2021) [22] in Sugarcane.

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

S.No.	Genotype	Genotype	Brix (%)	Sucrose (%)	CCS (%)	Purity (%)	POL (%)	Extraction (%)	Fibre (%)
1	G1	2005A128	18.05	16.60	12.72	91.97	14.37	55.86	13.44
2	G2	2006A164	19.77	18.32	14.44	92.67	16.04	58.32	12.45
3	G3	2006A223	20.54	19.09	15.21	92.94	16.14	53.84	15.43
4	G4	2006A102	20.21	18.76	14.88	92.83	16.73	49.18	10.82
5	G5	2007A81	18.94	17.49	13.61	92.34	15.14	56.02	13.45
6	G6	2008A120	19.21	17.76	13.88	92.45	15.32	52.61	13.75
7	G7	2008A210	21.22	19.77	15.89	93.17	16.64	56.34	15.84
8	G8	2009A107	20.54	19.09	15.21	92.94	16.71	49.15	12.45
9	G9	2009A252	22.45	21.00	17.12	93.54	18.18	58.88	13.45
10	G10	2009A234	20.06	18.61	14.73	92.77	16.11	56.33	13.44
11	G11	2010A229	18.53	17.08	13.20	92.17	14.95	59.09	12.45
12	G12	2012A249	20.33	18.88	15.00	92.87	16.15	50.85	14.45
13	G13	2012A224	19.68	18.23	14.35	92.63	15.74	51.22	13.65
14	G14	2014A224	18.98	17.53	13.65	92.36	15.02	53.25	14.33
15	G15	2014A142	19.88	18.43	14.55	92.71	15.59	49.84	15.43
16	G16	2014A210	21.36	19.91	16.03	93.21	17.08	52.33	14.23
17	G17	2014A56	22.03	20.58	16.70	93.42	17.76	54.21	13.69
18	G18	2015A311	19.56	18.11	14.23	92.59	15.39	49.88	15.02
19	G19	2015A228	21.88	20.43	16.55	93.37	17.52	57.23	14.22
20	G20	2015A199	22.06	20.61	16.73	93.43	17.89	54.33	13.22
21	G21	2015A222	23.01	21.56	17.68	93.70	18.54	52.33	13.99
22	G22	2015A152	24.00	22.55	18.67	93.96	19.34	66.23	14.22
23	G23	2015A183	21.33	19.88	16.00	93.20	17.03	55.32	14.32
24	G24	2015A187	23.02	21.57	17.69	93.70	18.49	60.33	14.30
25	G25	2015A137	20.33	18.88	15.00	92.87	16.20	58.22	14.22
26	G26	2015A233	21.03	19.58	15.70	93.11	16.80	58.33	14.20
27	G27	2015A59	20.33	18.88	15.02	92.87	16.24	52.33	13.96
28	G28	21015A51	21.33	19.88	16.23	93.20	17.05	54.33	14.23
29	G29	2015A230	22.08	20.63	16.75	93.43	17.62	56.33	14.58
30	G30	2015A 199	23.05	21.60	17.72	93.71	18.36	62.33	14.98
31	G31	87A298 (C)	21.05	19.55	15.67	93.10	16.82	58.67	13.96
		CD(0.05)	2.32	1.33	1.67	2.32	1.97	12.67	2.96
		CV (%)	0.33	1.58	1.03	3.65	5.67	9.67	1.23

Principal component analysis was executed for nine quantitative traits to assess the extent of variance in sugarcane clones and the results were depicted in Table 3. The pictorial representation (Scree plot) was generated with X axis with nine dimensions and Y with variation percent (Fig. 1). On the basis of Eigen values, a total of 71.93% of the total cumulative variance was contributed by the first three components as shown in table 3. PC1 explained 40.95 of the total cumulative variance, while PC2 explained 17.10% and PC3 explained 13.88% of the total variation. The present findings were in accordance with the

studies in sugarcane (Aamer *et al.*, 2018) [1] and Singh *et al.*, (2020) [28] A bi plot describing the traits projection on the first three principal components describing the traits in Sugarcane of 71.93% of total variation is given in Fig 2. The Bi plot ordination represented that yield and quality contributing characters were positively associated among themselves. Similarly, characters such as brix %, CCS% and Sucrose % showed a positive correlation since the angle between vectors is less than 90°. The biplot ordination in two or three dimensions highlighted the relations among the traits (Crovello,1970) [4]

Table 3: Eigen values(λ), variance (%) and cumulative variance (%) for nine principal components in Sugarcane

PC	Eigen value(λ)	Percentage of variance (%)	Cumulative per cent of variance (%)
PC1	2.86	40.95	40.95
PC2	1.13	17.10	58.05
PC3	0.95	13.88	71.93
PC4	0.74	12.69	84.62
PC5	0.65	9.88	94.50
PC6	0.41	3.22	97.72
PC7	0.26	2.10	99.82
PC8	0.092	0.092	99.91
PC9	0.088	0.088	100.00

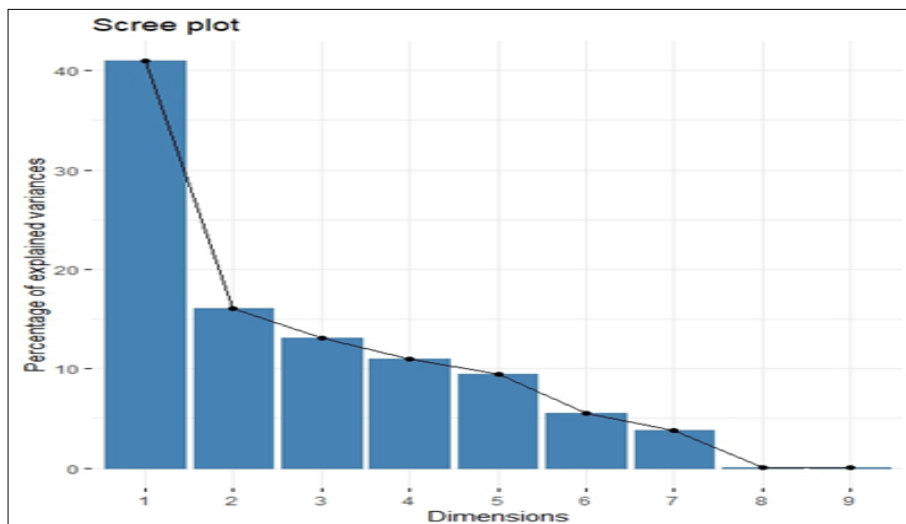


Fig 1: Screen plot depicting all nine dimensions with the percentage of variances

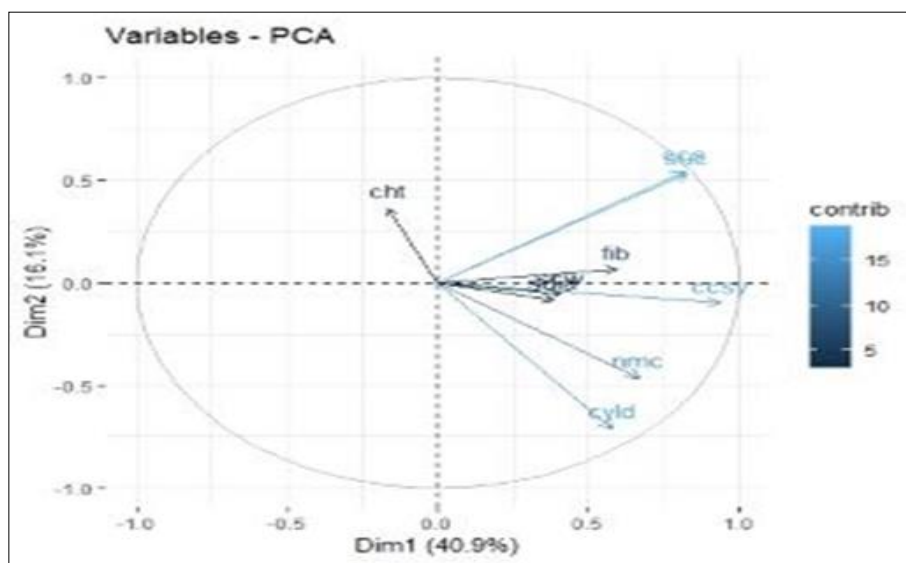


Fig 2: PCA-Biplot depict in two-dimensional ordination for nine quantitative traits on two-component axes

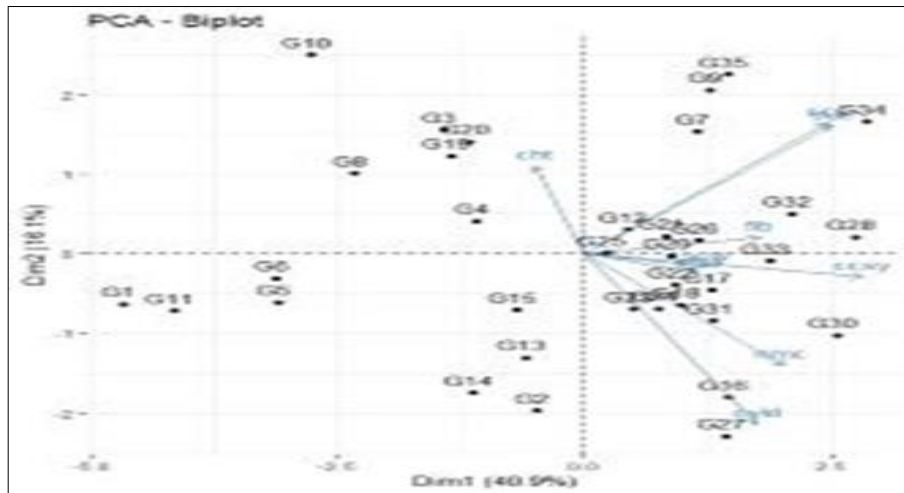


Fig 2: PCA-Biplot depict in two-dimensional Ordination for nine quantitative traits on two-component

Resistance to Early Shoot borer

Early shoot borer incidence of 31 sugarcane clones was recorded and the mean cumulative percentage of incidence is depicted in Table 4. The larvae bore into the mother shoot and destroy the apical meristem resulting in the drying of shoots. 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 (Rao,1954) [21]. The results pertaining to the mean per cent damage level of early shoot borer in different sugar cane clones ranged from 12.35 (2009A107) to 55.15(2015AA59) The results indicated that seven clones were classified as highly susceptible to early shoot borer damage, while 19 clones were rated as moderately susceptible (MS). Five clones viz., 87A298,2006A64, 2009A107, 2014A210 and 2015A183 were rated as less susceptible (LS) to early shoot borer with mean percent damage. The least susceptible nature of the clones may be due to their inherent capacity to

produce more tillers. The results were in agreement with earlier findings (Swathi *et al*, 2022 and Umasankar *et al*, 2017) [30]

Resistance to red rot reaction

The results of the resistance to red rot in clones were scored two months after inoculation with the red rot pathogen and presented in Table 4. Among 31 clones screened, three promising Clones viz, 87A298, 2008A210 and 2014A210 were found to be resistant, 17 clones moderately resistant and eleven clones recorded as moderately susceptible reaction to red rot disease. Identification of clones with high yield potential and quality traits coupled with resistance to pests and diseases is essential in the development of varieties. Similar reports of clones with high quality and red rot resistance were reported earlier in sugarcane (Ganapathy *et al*,2022) [5, 7, 9].

Table 4: Damage level of early shoot and resistance to red rot disease in sugarcane clones

S.No	Clone(S)	Early Shoot Borer (ESB)		Red rot	
		Cumulative mean %damage	Damage rating	Score	Reaction
1	2005A128	21.35	MS	4.0	MR
2	2006A164	14.85	LS	2.2	MR
3	2006A223	22.75	MS	2.8	MR
4	2006A102	30.52	HS	3.6	MR
5	2007A81	23.45	MS	2.1	MR
6	2008A120	28.35	MS	2.4	MR
7	2008A210	24.15	MS	2.6	R
8	2009A107	12.35	LS	3.2	MR
9	2009A252	18.07	MS	3.6	MR
10	2009A234	45.83	HS	4.4	MS
11	2010A229	25.67	MS	3.1	MR
12	2012A249	54.31	HS	6.0	MS
13	2012A224	19.25	MS	5.0	MS
14	2014A224	20.84	MS	6.0	MS
15	2014A142	18.22	MS	3.6	MR
16	2014A210	12.86	LS	1.4	R
17	2014A56	18.55	MS	2.8	MR
18	2015A311	22.75	MS	3.7	MR
19	2015A228	21.71	MS	4.0	MR
20	2015A199	22.35	MS	4.6	MS
21	2015A222	35.25	HS	2.9	MR
22	2015A152	20.50	MS	3.1	MR
23	2015A183	12.35	MS	6.0	MS
24	2015A187	42.35	HS	6.0	MS

25	2015A137	47.54	HS	5.3	MS
26	2015A233	35.45	HS	6.0	MS
27	2015A59	55.15	HS	5.9	MS
28	21015A51	22.32	MS	4.0	MR
29	2015A230	18.68	MS	3.5	MR
30	2015A 199	30.00	MS	5.1	MS
31	87A298 (C)	13.22	LS	1.8	R

Conclusion

The clone 2009A252 recorded significantly higher tiller population at 120DAP(141.28 thousands/ha, number of millable canes(132.00 thousands/ha),cane yield(143.67t/ha) and sugar yield(24.59t/ha) followed by 2014A210(135.70thousands/ha,128.33 thousands/ha,131.33 t/ha and 22.32t/ha respectively) and 2015A222 (133.00 thousands/ha,120.00 thousands/ha,126.00 t/ha and 22.27t/ha respectively) and found to be significantly superior over the standard,87A298(118.30 thousands/ha,105.33 thousands/ha,110.67 t/ha and 17.34t/ha respectively. The clone,2015A152 recorded significantly higher brix per cent(24.00),sucrose(22.50%),CCS (18.67%),juice extraction per cent(66.23) and fibre per cent(14.22) followed by 2015A199 (23.05%,21.60%,17.72%,62.33% and 14.30% respectively) and 2015A187(23.02%,21.57%,17.69%,60.33% and 14.30% respectively) when compared to standard,87A298(21.05%,19.55%,15.67%,58.67% and 13.96% respectively). Five clones viz., 87A298,2006A64, 2009A107, 2014A210 and 2015A183were rated as less susceptible (LS) to early shoot borer with mean percent damage. The least susceptible nature of the clones may be due to their inherent capacity to produce more tillers. Three promising Clones viz, 87A298, 2008A210 and 2014A210 were found to be resistant, 17 clones moderately resistant and eleven clones recorded as moderately susceptible reaction to red rot disease. A biplot describing the traits projection on the first three principal components describing the traits in Sugarcane of 71.93% of total variation represented that yield and quality contributing characters were positively associated among themselves. Similarly, characters such as brix %, CCS% and Sucrose % showed a positive correlation since the angle between vectors is less than 90°. All the traits had positive vectors on PC 1. The biplot ordination in two or three dimensions highlighted the relations among the traits. Identification of clones with high yield potential and quality traits coupled with resistance to pests and diseases is essential in the development of new varieties. Identification of red rot-resistant genotypes against predominant pathotypes under artificial inoculation, highlights the potential of pathological screening with selection strategies. The elite clones identified (e.g., 87A298, 2008A210 and 2014A210) can serve as valuable genetic resources for developing climate resilient and disease-resistant sugarcane varieties through targeted breeding efforts.

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