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Mean performance of yield and quality traits of sugarcane at north coastal zone of Andhra Pradesh

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Abstract

Sugarcane is a globally commodity crop and plays significant role in world sugar production. Developing high-yielding sugarcane elite lines can be achieved by leveraging the genetic variance present within the population. Hence, the present study was aimed to evaluate the genetic variance and mean performance of eleven sugarcane genotypes across 14 yield and quality traits were evaluated in two plant crops and one ratoon crop using a Randomized Block design with three replications at Regional Agricultural Research Station, Anakapalle, India. The combined analysis of variance revealed significant variation for all the parameters under study except stalk diameter. Based on the overall mean performance, two clones viz., 2017A236 and 2017A65 were demonstrated superior performance in terms of cane yield and related traits during the plant crop, as well as quality traits in the ratoon crop. Therefore, these two clones are recommended for further genetic improvement.

Keywords: Plant crop, ratoon, cane yield, genetic variance, sucrose (%) and jaggery yield

Introduction

Sugarcane is a major cash crop and plays significant role in agricultural industry across globe. It serves as the primary source of sugar and jaggery production worldwide. Additionally, it provides valuable by-products, including bagasse, molasses, and ethanol^[1]. Sugarcane accounts for 80% of the world's sugar production and 20-25% of bioethanol production. Sugarcane is a highly polyploidy and C₄ plant widely cultivated in tropical and subtropical regions^[2]. Brazil is the largest sugarcane-producing country, cultivating 1.92 billion tonnes, which accounts for 38% of global sugarcane production. Following Brazil, India produces 376.90 million tonnes of sugarcane from 4.73 million hectares. In India, Andhra Pradesh produces 7.95 million tonnes of sugarcane from 0.10 million hectares, with the major sugarcane-growing districts located in the north coastal zone of the state^[3].

The development of hybrids in sugarcane is limited due to the crop's predominant mode of asexual propagation. Therefore, sugarcane breeding programs should prioritize identifying superior variants from existing clones through systematic selection^[4]. One of the primary challenges in sugarcane improvement lies in simultaneously enhancing cane yield potential and increasing sucrose content, both of which are critical for the crop's economic value^[5]. A thorough study of genetic variability within the existing population serves as the foundation of any effective plant breeding program aimed at developing new varieties^[5].

Mean values of phenotypes are crucial in plant breeding, offering insights into the average performance of traits such as yield, quality, and stress resistance across environments^[6]. They aid in identifying superior genotypes, estimating genetic potential, and assessing trait stability and adaptability^[7]. These values guide selection decisions, enabling breeders to prioritize genotypes with desirable traits and align breeding efforts with specific goals, ultimately enhancing genetic gain and crop improvement.

The genetic enhancement of sugarcane clones is a critical aspect of improving cane yield per unit area, sucrose content, and other quality traits. In India, farmers prefer sugarcane varieties with early maturity and high productivity, while the sugar industry demands varieties with elevated sucrose content. Therefore, the development of sugarcane varieties that cater to both

plantation and ratooning crops, combining high yield and superior quality traits, is essential. Such varieties not only provide economic benefits to farmers but also reduce cultivation costs and optimize agronomic practices. In this context, the present study was conducted on eleven sugarcane clones to characterize their performance, and assess genetic variance. The goal was to identify superior clones that exhibit a combination of high cane yield and sucrose levels, addressing the dual requirements of farmers and the sugar industry effectively.

Materials and Methods

The study was carried out with eleven sugarcane clones (2017A36, 2017A65, 2017A236, 2017A253, 2017A340, 2017A396, 2017A408, 2017A457, 2017A405, 2017A553 and 87A298 (S) under the Main Yield Trials to assess their performance and potential for further genetic improvement. The trial was conducted using a Randomized Block Design (RBD) with three replications during 2020–22 cropping season (first plant and ratoon) and 2021–22 season (second plant crop) at the Regional Agricultural Research Station, Anakapalle, India. Each clone was planted in six rows, each row measuring six meters in length, with a row spacing of 90 centimeters. The recommended agronomic packages of practices were followed consistently throughout the crop's growth across all three seasons. After harvesting the first plant crop, a ratoon crop was established using the same set of clones and second plant crop also planted in the same season. All plant and ratoon crops were harvested at 300 days of age to ensure uniformity in data collection and analysis.

The study focused on 14 quantitative and qualitative traits of sugarcane, selected based on the descriptors and guidelines outlined by the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FR, 2001) under the DUS (Distinctiveness, Uniformity, and Stability) criteria (Blakeney, 2001). Observations encompassed yield and quality parameters, including germination percentage at 30 days after planting (DAP), number of tillers ($\times 1000/\text{ha}$) at 120 and 240 DAP, stalk length (cm), stalk diameter (cm), single cane weight (kg), number of millable canes (NMC) was recorded and expressed as thousands per hectare ($'000/\text{ha}$), CCS yield (tonnes/hectare) was estimated using the formula $(\text{Cane yield} \times \text{CCS} \%) / 100$, and cane yield (tons) was recorded on a per-plot basis and subsequently calculated per hectare. Jaggery yield (t/ha), brix (%), sucrose (%) and fiber (%) were recorded at the harvest stage. Commercial Cane Sugar (CCS) percentage was determined as $(\text{Sucrose} \% \times 1.022) - (\text{Brix} \% \times 0.292)$.

The data analysis was carried out using the R Studio environment and R version 4.1.2 [8]. Combined analysis of variance and mean performance was conducted using the "metan" package within the R Studio environment [9].

Results and Discussion

Analysis of variance

The mean squares obtained from the combined analysis of variance for cane yield and other quality, yield traits among eleven clones were evaluated in two plant crops and one ratoon crop was presented in Table 1. The results indicate significance variance ($P < 0.05$) was observed among the eleven clones for all traits except stalk diameter. These significant differences suggest that there is a substantial amount of genetic variation presented among clones and all traits are affected by the growing seasons. Similar studies were reported [7,10].

Mean performance

The mean performance of eleven sugarcane clones was assessed across 14 yield and quality traits in two plant crops and one ratoon crop were presented in Table 2.

Germination percentage (at 30 DAP): The germination percentage directly impacts the sugarcane crop stand, as higher germination leads to a denser and more uniform stand, resulting in better yield potential. The clone 2017A553 shows the highest germination potential at 89.59% in the plant II crop, while the germination potential for the ratoon crop has not been considered. Over three seasons, clone 2017A553 demonstrates a higher mean performance of 47.97%, whereas clone 2017A408 shows a lower performance at 37.85%. Overall, the plant II crop exhibits higher germination potential.

Number of tillers (in thousands per hectare) at 120 DAP: The tillering ability of a clone is positively correlated to cane yield. The clone 2017A36 demonstrated the highest tillering capacity (180.62) in the plant II crop, while the clone 2017A408 exhibited the lowest (44.44) in the ratoon crop. Overall, clone 2017A36 has the highest tillering potential across all three seasons, with the plant II crop showing the greatest tillering capacity.

Number of shoots (in thousands per hectare) at 240 DAP: indicates that clone 2017A236 demonstrates a high tillering ability of 144.08 in the plant II crop, while clone 2017A553 shows the lowest tillering ability at 66.9 in the ratoon crop. Overall, clone 2017A236 from the plant I crop season had the highest tillering ability at 240 DAP across the three seasons

Stalk length (cm): Cane length is positively correlated with cane yield, indicating that longer canes contribute to higher yields. The clone 2017A253 was identified as the longest clone with 409.88 cm in the ratoon crop, while clone 2017A408 was the shortest at 186 cm in the plant II crop. Overall, clone 2017A253 longer cane among three seasons and the ratoon crop clones exhibited longer canes compared to the two plant crops.

Stalk diameter (cm): Tall clones with thick-stalked canes that are resistant to lodging show promise as high-yielding varieties. A large stalk diameter is a crucial trait for enhancing commercial acceptability. The clone 2017A340 has the thickest stem at 2.99 cm in the plant II crop, while 2017A36 has the thinnest at 2.07 cm in the plant I crop. Overall, ratoon crop clones exhibited thinner stalks compared to the two plant crops.

Single cane weight (kg): Single cane weight, influenced by its length and girth, plays a significant role in contributing to the final cane yield. The clone 2017A553 exhibited the highest cane weight at 1.36 kg in the plant II crop, while clone 2017A457 had the lowest at 0.73 kg in the ratoon crop. The overall standard variety 87A298 (S) demonstrated the highest mean performance at 1.11 kg across three seasons, with plant II crop clones showing a higher mean cane weight

Number of Millable Canes ($\times 1000/\text{ha}$) at Maturity: This metric is directly influenced by the combined interaction of germination and tillering, highlighting their critical roles in productivity. The clone 2017A236 exhibited significant performance (131.72) in the plant II crop, while clone 2017A408 showed the lowest performance at (61.11) in the ratoon crop. Overall, the plant I crop displayed significant performance in terms of the number of millable canes.

Cane yield (t/ha): Cane yield is a key indicator of a variety's economic potential, reflecting the interaction of genetic potential

and environmental response. Developing high-yielding clones is essential for enhancing both cane and sugar yield per unit area.

The clone 2017A236 exhibited superior performance with 137.4 t/ha in the plant I crop, while the clone 2017A457 showed poor performance at 64.19 t/ha in the ratoon crop. Overall, the clone 2017A236 demonstrated superior performance across three seasons, with plant I crop clones exhibiting a higher yield.

CCS Yield (t/ha): Identifying sugarcane varieties with desirable traits and high sugar content is a crucial focus in breeding programs, as sugar recovery is vital for both millers and breeders. The clone 2017A236 exhibited superior performance with a CCS yield of 19.18 t/ha in the plant I crop, while clone 2017A457 showed poor performance at 7.41 t/ha in the ratoon crop. Overall, the clone 2017A236 demonstrated superior performance among three seasons, and plant I crop clones exhibited higher yields.

Jaggery yield (t/ha): Analysis results indicate that clone 2017A65 exhibited a high recovery percentage of 15.76 kg in the plant I crop, while the lowest recovery was recorded for clone 2017A396 at 5.32 kg in the same season. Overall, clone 2017A65 showed the highest recovery among three seasons, and ratoon crops exhibited a high jaggery recovery percentage.

Brix % at 10th Month: Total Soluble Solids (TSS) significantly influences sugar recovery percentage, making it a critical parameter in sugarcane evaluation. The clone 2017A405 showed the maximum sugar recovery percentage at 21.47% in the ratoon crop, while 2017A340 exhibited the lowest at 15.62% in the plant I crop. Overall, clone 2017A553 demonstrated the highest sugar recovery percentage (19.72%) among three seasons, with the ratoon crop recording the highest recovery percentage.

Sucrose % at 10th Month: Sucrose percentage is a key indicator of sugarcane quality, directly affecting sugar recovery and production efficiency in sugar mills. The clone 2017A408 recorded the highest sucrose percentage at 19.84% in the ratoon crop, while clone 2017A405 had the lowest at 14.39% in the plant II crop. Overall, clone 2017A236 exhibited the highest sucrose percentage over three seasons, and ratoon crops showcased high sucrose content clones.

CCS % at 10th Month: Commercial Cane Sugar (CCS) percentage is a critical measure of sugarcane quality, reflecting the recoverable sugar content that directly impacts mill efficiency and profitability. The clone 2017A253 recorded the highest CCS percentage at 14.33% in the ratoon crop, while clone 2017A405 had the lowest at 9.93% in plant II crop. Overall, clone 2017A553 demonstrated the highest CCS percentage over three seasons, with ratoon crops exhibiting high CCS percentage clones.

Fiber (%) at maturity: Fiber percentage in sugarcane is a vital trait affecting milling efficiency, as higher fiber content can hinder juice extraction. It is also crucial for selecting varieties suitable for dual-purpose uses such as biofuel and paper production. The clone 2017A553 exhibited a high fiber percentage of 19.75% in the plant I crop, while the same genotype showed the lowest fiber percentage at 6.15% in the ratoon crop. Overall, clone 2017A65 exhibited the highest fiber percentage across three seasons, with plant I crops showing higher fiber percentage clones.

Table 1: Analysis of variance for 14 yield and quality traits among eleven genotypes

Source	Df	GP	NT(120DAP)	NT(240DAP)	SL	SD	SCW	NMC	CY	CCSY	JY	BP	SC	CCSP	FP
ENV	2	45436.21	11018.61*	3579.51*	343.50*	0.03	0.02	5814.35*	5928.35	10.18*	19.15*	10.18*	11.33*	8.64*	423.62*
REP(ENV)	6	40.59	72.76	49.30	56.49	0.04	0.00	54.63	8.09	3.55	4.07	3.55	2.97	3.29	3.28
GEN	10	86.38*	3380.14*	1634.03*	21327.23*	0.04*	0.09	1258.18*	1994.71*	4.26*	20.55*	4.26*	4.17*	2.81*	3.20*
GEN:ENV	20	124.58	868.01*	346.64*	2772.02*	0.04	0.02	209.81*	454.84*	2.82*	11.85*	2.82*	2.03*	1.15*	12.90*
Residuals	60	0.28	0.32	0.39	0.25	0.05	0.00	0.46	0.09	0.07	0.07	0.07	0.06	0.05	0.05

$P < 0.05$, GP=Germination percentage, NT(120DAP)= Number of tillers (x 1000/ha) at 120 DAP, NT(240DAP)= No. of shoots (x 1000/ha) at 240

DAP, SL= Stalk length (cm), SD= Stalk diameter (cm), SCW= Single cane weight (kg), NMC= Number of Millable Canes (x 1000/ha), CY= Cane yield (t/ha), CCSY= CCS Yield (t/ha), JY= Jaggery yield (t/ha), BP= Brix % at 10th Month, SC= Sucrose % at 10th Month, CCSP= CCS % at 10th Month and FP= Fiber (%) at maturity.

Table 2: The mean performance of 14 yield and quality traits among eleven clones over two plant crops and one ratoon crop.

Parameters	GP	NT (120DAP)	NT(240DAP)	SL	SB	SCW	NMC
Mean	42.73	118.53	103.41	284.83	2.62	0.94	93.9
SE	3.12	2.76	1.78	5.27	0.02	0.01	1.72
SD	30.89	27.28	17.62	52.2	0.22	0.12	17.04
CV	72.67	23.13	17.13	18.42	8.33	13.04	18.24
Min	0 (2017A36 in E3)	44.44 (2017A408 in E3)	66.9 (2017A553 in E3)	186 (2017A408 in E2)	2.07 (2017A36 in E2)	0.71 (2017A408 in E3)	61.11 (2017A408 in E3)
Max	89.59 (2017A553 in E2)	180.62 (2017A36 in E2)	144.08 (2017A236 in E2)	409.88 (2017A253 in E3)	2.99 (2017A340 in E1)	1.36 (2017A553 in E2)	131.72 (2017A236 in E2)
MinENV	E3 (0)	E3 (97.5)	E3 (91.49)	E2 (281.21)	E2 (2.6)	E3 (0.91)	E3 (78.6)
MaxENV	E2 (66.83)	E2 (130.53)	E1 (110.75)	E3 (287.4)	E3 (2.66)	E2 (0.96)	E1 (102.41)
MinGEN	2017A408 (37.85)	2017A396 (88.71)	2017A405 (85.65)	2017A408(192.79)	87A298 (S) (2.48)	2017A253 (0.81)	2017A405 (79.11)
MaxGEN	2017A553 (47.97)	2017A36 (150.77)	2017A236 (126.82)	2017A253 (372.71)	2017A253 (2.72)	87A298 (S) (1.11)	2017A236 (115.46)
	CY	CCSY	JY	BP	SC	CCSP	FP
Mean	96.44	11.83	10.58	18.45	16.97	12.01	12.4
SE	2.05	0.25	0.23	0.12	0.11	0.1	0.35
SD	20.34	2.48	2.27	1.21	1.13	0.96	3.42
CV	21.2	21.06	21.55	6.59	6.68	8.04	27.74
Min	64.19 (2017A408 in E3)	7.41 (2017A457 in E3)	5.32 (2017A396 in E1)	15.62 (2017A340 in E1)	14.39 (2017A405 in E2)	9.93 (2017A405 in E2)	6.15 (2017A553 in E3)
Max	137.47 (2017A236 in E1)	19.18 (2017A236 in E1)	15.76 (2017A65 in E1)	21.47 (2017A405 in E3)	19.84 (2017A408 in E3)	14.33 (2017A253 in E3)	19.75 (2017A553 in E1)
MinENV	E3 (84.49)	E3 (10.9)	E1 (10.08)	E1 (18.01)	E1 (16.41)	E1 (11.5)	E3 (9.68)
MaxENV	E1 (110.93)	E1 (13)	E3 (11.46)	E3 (19.07)	E3 (17.58)	E3 (12.52)	E1 (16.46)
MinGEN	2017A408 (77.83)	2017A457(9.61)	2017A405 (8.54)	2017A340 (17.19)	2017A405 (16.09)	2017A405 (11.37)	2017A396 (11.65)
MaxGEN	2017A236 (123.6)	2017A236 (16.13)	2017A65 (13.68)	2017A553 (19.72)	2017A236 (18.14)	2017A553 (13.04)	2017A65 (13.4)

E1= First plant crop, E2= second plant crop, E3= Ratoon crop GP=Germination percentage, NT(120DAP)= Number of tillers (x 1000/ha) at 120 DAP, NT(240DAP)= No. of shoots (x 1000/ha) at 240 DAP, SL= Stalk length (cm), SD= Stalk diameter (cm), SCW= Single cane weight (kg), NMC= Number of Millable Canes (x 1000/ha), CY= Cane yield (t/ha), CCCY= CCS Yield (t/ha), JY= Jaggery yield (Kg), BRI= Brix % at 10th Month, SC= Sucrose % at 10th Month, CCSP= CCS % at 10th Month and FP= Fiber (%) at maturity.

Conclusion

In summary, clone 2017A236 exhibits exceptional performance across multiple traits and cane yield over three seasons. Hence, this clone was recommended for further genetic enhancement. The plantation crop demonstrates the highest yield performance, while the ratoon crop showcases superior quality performance. Similar findings for mean performance of yield and quality traits in sugarcane were reported by [7, 10, 1, 11].

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