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Stability and seasonal adaptability of sugarcane (*Saccharum officinarum*) clones across crop cycles revealed by AMMI analysis

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ABSTRACT

Sugarcane (*Saccharum officinarum* L.) productivity in Andhra Pradesh has declined due to seasonality and the scarcity of stable high-performing sugarcane clones. Thus, the identification of sugarcane genotypes that perform consistently in the fields across several cropping seasons and exhibit good quality parameters is of primary interest for sustainable development of sugarcane varieties. The field experiment was conducted for three years from 2022 to 2024 at the Regional Agricultural Research Station, Anakapalle, Visakhapatnam, Andhra Pradesh to assess 20 sugarcane genotypes, 14 test clones and six standard checks across three crops cycles, viz. first crop, second crop and ratoon using a randomised block design (RBD) plot arrangement with three replications. The joint analysis of seasonal variance and AMMI (Additive Main effects and Multiplicative Interaction) analysis indicated significant individual effects attributable to genotype (G), environment (E) and their interaction (GEI) for all traits examined in this investigation. Genotypic effects were predominant in variation for cane yield and sugar yield traits: cane yield (34.34%), CCS (Commercial cane sugar) yield (36.38%) and CCS% (33.72%) than environmental effects (20.58% cane yield, 10.37% CCS yield and 9.17% CCS % variation), highlighting the predominance of genetic control. Based on their mean performance, three entries 2018A 6, 2018A 157 and 2018A 88 were identified as superior clones for cane yield and sucrose accumulation. The AMMI model identified clones 2018A 157 and 2018A 88 as potential stable clones for cane yield. Additionally, clones 2018A 157 and 2018A 6 were found to be promising for CCS yield, while clone 2018A 6 was identified as the ideal clone for sucrose % and CCS % . Overall, clones 2018A 157 and 2018A 6 emerged as the most ideal genotypes, combining high performance and stability across all traits. Furthermore, the AMMI stability value indicated that clones 2018A 107 and 2018A 130 were stable across crop cycles for all evaluated traits.

Keywords: AMMI, ASV, GEI, Sugarcane, Stability

Sugarcane (*Saccharum officinarum* L.) is a vital commercial crop in India, playing a significant role in the agricultural economy and the biofuel sector. India ranks as the world's second-largest producer following Brazil, with an average output of 421.02 million tonnes cultivated over 51.16 lakh hectares from 2018 to 2023. The states of Uttar Pradesh, Maharashtra and Karnataka contribute to 80% of the national production, with an average yield of 82 t/ha. Currently, Andhra Pradesh ranks 11th in both area and production, with an average yield of 76.78 t/ha, which is below the national average (Anonymous 2024). However, Andhra Pradesh has experienced a notable decline in sugarcane cultivation, with the area planted decreasing from 1.02 lakh hectares in 2018–19 to just 0.40 lakh hectares in 2023–24. Consequently, production has dropped from 8.09 million tonnes to 2.10 million tonnes. Therefore, evaluating clonal performance across crop cycles is essential for identifying stable, high-yielding genotypes with good ratoon ability, thereby supporting sustainable sugarcane improvement in the state.

During clonal testing at the mega-environment level, the ranking of clones often varies from one location to another in terms of cane yield and sugar quality. This indicates the significant impact of genotype (G) × environment (E) interactions on their performance (Sadhu *et al.* 2024). The phenotypic expression of a clone depends on its genetic potential and the growing environment. These two factors are not always correlated due to the presence of genotype (G) × environment (E) interaction (GEI), which results in unstable performance of genotypes across different environments (Esan *et al.* 2023). A stable variety is characterised by a high average yield combined with a low magnitude of G × E interaction when grown in diverse environments. Plant breeders need to address the challenges posed by

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G × E interactions and evaluate the clones across mega-environments to ensure the selection of superior clones that demonstrate both high yield and stable performance (Kumar *et al.* 2025).

Several statistical modules have been developed for partitioning variance to measure GEI and phenotypic stability. Among these, the Additive Main Effects and Multiplicative Interaction (AMMI) module is widely used for assessing phenotype stability and GEI (Sudhagar *et al.* 2024). The AMMI method combines both multivariate and univariate approaches. It treats the main effects of genotype and environment as additive components while considering their interaction effects as multiplicative. This method produces easily interpretable results through biplots, making it a powerful tool for breeders and researchers identifying mega-environments suitable for location-specific clones in sugarcane (Sanghera *et al.* 2018). The objective of this study was to investigate 20 clones alongside six standards to identify high-yielding and stable yield clones based on cane yield, CCS yield, sucrose % and CCS % across the first and second plant crops as well as ratoon crops.

MATERIALS AND METHODS

The field experiment was conducted for three years from 2022 to 2024 at the Regional Agricultural Research Station, Anakapalle, Visakhapatnam (17.6914° N, 83.0041° E; at an elevation of 26 m amsl), Andhra Pradesh. This study involved a total of 20 sugarcane clones, which included seven early-maturing and seven mid-late maturing groups (Table 1). Additionally, six standard checks were included (87A 298, CoC 01061, 2000A 128, 83V 15, Co 86249 and 2000A 225). The experiment was designed as a randomised block design (RBD) with three replications, conducted over three crop cycles: the first plant crop (2022–23), the second plant crop (2023–24) and the ratoon crop (2023–24). Three-budded setts served as the planting material for the plant crops. After harvesting the first plant crop, the same stubble was used to establish the ratoon crop. Each clone was planted in six rows, with each row measuring six meters in length. The spacing between rows was maintained at 90 cm. All recommended agronomic practices for sugarcane cultivation were uniformly applied across all three crop cycles to ensure consistent management (Sugeerthi *et al.* 2018). Early maturing plant crops were harvested at 10 months of age during the second fortnight of October and their corresponding ratoon crops were harvested at 9 months in September. In contrast, mid-late maturing plant crops were harvested at 12 months during the second fortnight of December, while their ratoon crops were harvested at 10 months in the first fortnight of November. This schedule ensured uniformity in data collection and facilitated accurate analysis across crop cycles.

Cane yield (t/ha) was recorded by harvesting the middle four rows of each plot. The harvested cane weight was measured on a plot basis and subsequently extrapolated to a per-hectare basis. For juice quality analysis, five representative canes were randomly selected from the clumps. In the plant crop, samples were collected at the 10th month for early maturing clones and at the 12th month for mid-late maturing clones. For the ratoon crop, sampling was done at the 9th month for early maturing clones and at the 10th month for mid-late maturing clones. Commercial Cane Sugar (CCS) % and yield (Nair *et al.* 1999) were calculated using the formulae:

Table 1 List of sugarcane clones used in this experiment

Clone	Pedigree	Maturity group
2018A 6	Co87216 × CoH70	Mid-late
2018A 88	Co8371 × CoH70	Mid-late
2018A 130	CoV89101 × Co1158	Mid-late
2018A 157	CoA09321 × Co775	Mid-late
2018A 190	CoA7602PC	Mid-late
2018A 196	CoV89101PC	Mid-late
2018A 55	Co8371 × CoH70	Mid-late
83V 15	CoC671 × Co6806	Mid-late
Co 86249	-	Mid-late
2000A 225	Co85002PC	Mid-late
2018A 133	CoV89101 × ISH 69	Early
2018A 30	CoTL1153 × BO91	Early
2018A 31	CoTL1153 × BO91	Early
2018A 37	CoV89101 × ISH 69	Early
2018A 65	CoV89101 × ISH 69	Early
2018A 107	Co 89036 × CoS 88216	Early
2018A 152	Co 89036 × CoS 88216	Early
87A 298	Co7704 × CoC671	Early
CoC 01061	-	Early
2000A 128	80R41GC	Early

$$\text{CCS \%} = (\text{Sucrose \%} \times 1.022) - (\text{Brix \%} \times 0.292)$$
$$\text{CCS yield (t/ha)} = (\text{Cane yield} \times \text{CCS \%}) / 100$$

The data from plant and ratoon trials were recorded across three crop cycles and subjected to statistical analysis. Bartlett's test was performed to assess the homogeneity of error variances across the three experiments. This analysis was conducted using OPSTAT, open-source statistical software. The non-significant results of Bartlett's test for all traits confirmed the homogeneity of error variances, allowing the data from three crop cycles to be combined for further analysis. Combined analysis variance, mean performance and AMMI bi-plots and parameters were conducted using the "Metan" package (Olivoto and Lucio 2020) within the R Studio environment (Posit Team 2022).

RESULTS AND DISCUSSION

Analysis of variance and mean performance of cane yield and quality traits: The joint analysis of seasonal variance and AMMI analysis showed a significant effect ($p \leq 0.01$) of genotype, environment and their interaction for cane yield (t/ha), CCS yield (t/ha), sucrose % and CCS % (Table 2). The significant GEI effect indicated that the mean performance of the clones responded differently to variations in seasonal conditions and this variance was valuable for studying phenotypic stability and adaptability across diverse crop cycles (Vinu *et al.* 2024). Cane yield showed that 20.58% of the total variance was attributed to environmental effects, 34.34% to genotypic effects and 16% GEI effects. The total sum square of genotypic effect was higher than environment effect, which indicated that the genetic makeup (genotype) of the tested clones contributed more to the observed phenotypic variation than the environmental conditions in which they were grown (Sharifi *et al.* 2017). For CCS yield, the genotypic effect was the largest contributor to total variance (36.38%), compared to the environment (10.37%) and the genotype × environment interaction (21.16%). This indicated that genetic differences among genotypes played a dominant role in yield variation, with a moderate influence of GEI (Seife and Tena 2020). The environmental effect explained 8.45% and 9.18% of the variance in sucrose and CCS %, respectively. Genotypic effects were more pronounced, contributing 34.31% and 33.72%, while GEI accounted for 23.96% and 22.90% of the variance in these traits, respectively. Similar findings were reported by Otieno (2016) for cane yield, Tena *et al.* (2019) for sucrose and Durai *et al.* (2025) for CCS yield.

According to Gollob's F-test (1968), the first two principal components derived from the AMMI model were statistically significant for all traits. For cane yield, PC1 explained 64.1% and PC2 35.9% of the GEI variance. Similarly, in CCS yield, PC1 and PC2 accounted for 63.5% and 36.5%, respectively. For sucrose and CCS %, the variance explained by PC1 was 53.7% and 61.4%, while PC2 contributed 46.3% and 38.6%, respectively. This study highlighted that genotypic effects were the primary source of variation across all traits, surpassing environmental influences. Significant GEI further emphasised the need to evaluate clone stability and adaptability across diverse seasons.

Mean performance of clones across crop cycles: A promising clone is expected to demonstrate high mean yield performance across multiple environments or cropping seasons. Among the 20 tested clones, mean cane yield ranged from 42.53 t/ha (2000A 128 in ratoon) to 137.75 t/ha (2018A 157 in Plant I). Based on the average cane yield across the three crop cycles, clones such as 2018A 157 (112.9 t/ha), 2018A 88 (109.1 t/ha), 2018A 6 (105.8 t/ha) and 2018A 133 (101.01 t/ha) outperformed best commercial check 2000A 225 (96.6 t/ha) (Table 3).

For CCS yield, values ranged from 5.22 t/ha (2000A 128 in ratoon) to 18.63 t/ha (2018A 157 in Plant I). Clones such as 2018A 6 (14.7 t/ha), 2018A 157 (14.6 t/ha) and 2018A 88 (13.1 t/ha) exhibited superior sugar yield (SP) compared to the best performing commercial check, 2000A 225 (12.3 t/ha). Regarding sugar quality traits, sucrose % varied from 11.73% (2018A 190 in Plant I) to 21.09% (2018A 6 in Plant II), while CCS % ranged from 8.01%

Table 2 Joint analysis of variance for cane yield, CCS yield, sucrose and CCS % among 20 clones over the crop cycles

Source	Df	CY				CCSY				Sucrose %				CCS%			
		Sum Sq	Mean Sq	Pr(>F)	Variance	Sum Sq	Mean Sq	Pr(>F)	Variance	Sum Sq	Mean Sq	Pr(>F)	Variance	Sum Sq	Mean Sq	Pr(>F)	Variance
ENV	2	14803.52	7401.76	0.00	20.58	148.42	74.21	0.00	10.38	48.28	24.14	0.00	8.45	28.96	14.48	0.00	9.18
REP(ENV)	6	369.38	61.56	0.58	0.51	7.85	1.31	0.42	0.55	1.35	0.22	0.81	0.24	0.87	0.14	0.83	0.28
GEN	19	24703.71	1300.20	0.00	34.34	520.45	27.39	0.00	36.38	196.00	10.32	0.00	34.31	106.39	5.60	0.00	33.72
GEN:ENV	38	11597.03	305.18	0.00	16.12	302.76	7.97	0.00	21.17	136.89	3.60	0.00	23.96	72.25	1.90	0.00	22.90
PC1	20	7434.46	371.72	0.00	64.10	192.29	9.61	0.00	63.50	84.08	4.20	0.00	61.40	38.79	1.94	0.00	53.70
PC2	18	4162.57	231.25	0.00	35.90	110.47	6.14	0.00	36.50	52.80	2.93	0.00	38.60	33.46	1.86	0.00	46.30
Residuals	114	8878.27	77.88		12.34	148.20	1.30		10.36	51.85	0.45		9.08	34.76	0.30		11.02
Total	217	71948.93	331.56			1430.46	6.59			571.25	2.63			315.48	1.45		

Pr(>F), 0.01 significant. CY, Cane yield (t/ha); CCSY, Commercial cane sugar yield (t/ha); CCS, Commercial cane sugar (%); ENV, Environmental effects; REP(ENV), Repetitions within environment; GEN, Genotypic effects; GEN:ENV, Genotype × environment interactions effects; PC1, Principal component 1; PC2, Principal component 2.

Table 3 Mean performance of cane yield, CCS yield, sucrose and CCS % among 20 clones over the crop cycles

	Cane yield (t/ha)				CCS yield (t/ha)				Sucrose (%)				CCS (%)			
Clone	Plant I	Plant II	Ratoon	Mean	Plant I	Plant II	Ratoon	Mean	Plant I	Plant II	Ratoon	Mean	Plant I	Plant II	Ratoon	Mean
2018A 6	99.39	122.00	96.14	105.84	12.80	17.62	17.62	16.01	18.17	20.54	19.99	19.57	12.85	14.47	14.38	13.90
2018A 88	122.58	119.67	85.11	109.12	15.05	14.20	14.20	14.48	17.41	17.11	16.68	17.07	12.30	11.88	11.81	12.00
2018A 130	101.38	104.33	78.39	94.70	11.97	13.29	13.29	12.85	16.73	18.51	17.81	17.68	11.81	12.71	12.53	12.35
2018A 157	128.76	112.00	98.38	113.05	17.09	14.71	14.71	15.50	18.73	18.93	17.36	18.34	13.27	13.17	12.22	12.88
2018A 190	106.22	98.00	89.97	98.06	9.19	10.13	10.13	9.82	12.35	15.12	16.42	14.63	8.61	10.32	11.92	10.28
2018A 196	85.23	99.00	74.85	86.36	10.20	13.53	13.53	12.42	16.96	19.59	19.18	18.57	11.97	13.69	13.60	13.09
2018A 55	80.19	92.00	77.16	83.12	9.54	12.62	12.62	11.59	16.87	19.54	19.01	18.47	11.91	13.71	13.84	13.15
83V 15	108.43	84.33	85.26	92.67	13.20	11.28	11.28	11.92	17.25	19.23	19.77	18.75	12.19	13.37	14.10	13.22
Co 86249	92.46	92.33	69.45	84.75	10.64	12.71	12.71	12.02	16.27	19.74	17.70	17.90	11.48	13.76	12.44	12.56
2000A 225	107.04	103.33	79.09	96.49	12.95	14.30	14.30	13.85	17.14	19.62	17.21	17.99	12.12	13.80	12.16	12.70
2018A 133	118.45	90.15	94.38	100.99	13.55	10.23	10.23	11.34	16.25	15.97	17.27	16.50	11.43	11.36	12.01	11.60
2018A 30	75.43	93.00	80.44	82.95	8.71	12.11	12.11	10.98	16.73	18.27	16.68	17.23	11.60	13.06	12.01	12.22
2018A 31	77.32	114.35	62.20	84.62	8.29	13.83	13.83	11.98	15.61	17.09	17.73	16.81	10.76	12.09	12.63	11.83
2018A 37	100.70	97.05	73.37	90.37	11.94	10.42	10.42	10.93	16.89	15.25	18.83	16.99	11.84	10.67	13.43	11.98
2018A 65	98.15	90.49	72.36	87.00	12.56	11.20	11.20	11.65	17.87	17.39	20.40	18.55	12.84	12.34	14.60	13.26
2018A 107	85.12	92.47	64.65	80.74	9.57	11.12	11.12	10.60	16.37	16.97	18.20	17.18	11.24	12.06	12.82	12.04
2018A 152	80.55	91.60	89.03	87.06	9.07	10.52	10.52	10.03	16.00	16.23	17.10	16.44	11.29	11.48	11.98	11.58
87A 298	87.03	67.69	62.30	72.34	10.38	7.66	7.66	8.57	17.00	16.07	18.69	17.26	11.93	11.37	13.27	12.19
CoC 01061	80.08	77.00	58.10	71.73	9.79	8.77	8.77	9.11	17.59	16.21	17.76	17.18	12.23	11.39	12.42	12.01
2000A 128	83.70	79.94	43.84	69.16	10.97	9.44	9.44	9.95	18.36	16.90	17.35	17.54	13.11	11.85	12.09	12.35
Mean				89.55				11.06				17.53				12.36
SE				1.37				0.19				0.12				0.09
SD				18.31				2.5				1.55				1.16
CV				20.51				22.69				8.89				9.43

CCS, Commercial cane sugar; SE, Standard error; SD, Standard deviation; CV, Coefficient of variation; Plant I, First crop; Plant II, Second crop.

(2018A 190 in Plant I) to 15.12% (2018A 65 in ratoon). Clones such as 2018A 6, 2018A 65, 2018A 55 and 2018A 157 consistently outperformed the best standard check 83V 15 (SP: 18.7%, CCS%: 13.2%) across all three crop cycles, indicating their superior sugar quality potential. Based on cane yield and sucrose %, clones 2018A 6, 2018A 157 and 2018A 88 demonstrated superior performance across crop cycles. These clones combined high biomass productivity with excellent sugar content, making them strong candidate lines for further selection.

AMMI biplots: AMMI biplots serve as effective tools for partitioning and visualising the variance associated with genotype, environment and their interaction effects for agronomic traits. In the AMMI-1 biplot, the main effects (mean performance of clones and seasons) were displayed on the X-axis, while the first principal component axis (PCA-I scores) was plotted on the Y-axis. The PCA-I score of a clone reflects its interaction with the environment, thereby indicating its stability and adaptability across multiple crop cycles (Verma *et al.* 2023). Clones positioned close to the PCA-I = 0 line exhibited minimal genotype × environment interaction, suggesting broad adaptability. Conversely, clones located further from the zero line demonstrated greater interaction and are considered specifically adapted to certain environments (Fouladvand *et al.* 2024).

The AMMI-1 biplots for cane yield (t/ha), CCS yield (t/ha), sucrose % and CCS % effectively dissected the genotype × environment interaction, allowing assessment of both performance and stability of sugarcane clones across three crop cycles (Fig. 1). In this investigation, 20 clones and three growing seasons were categorised into four quadrants based on their adaptability as shown in the AMM-I biplot-1. For cane yield, six clones, viz. 2018A 157 (112.9 t/ha), 2018A 88 (109.1 t/ha), 2018A 6 (105.8 t/ha), 2018A 133 (101 t/ha), 2018A 130 (94.8 t/ha) and 2018A 130 (98.1 t/ha) were located on the right side of the biplot and exhibited higher yields than the grand mean for cane yield (Fig. 1A). Among these, clones 2018A 130, 2018A 88 and 2018A 190 had PC1 scores close to zero, suggesting high stability. An ideal clone combines high yield with stability, 2018A 157 and 2018A 88 were identified as ideal clones, outperforming the best standard 2000A 225 (96.0 t/ha). In the case of CCS yield, seven clones, viz. 2018A 6 (14.7 t/ha), 2018A 157 (14.6 t/ha), 2018A 88 (13.1 t/ha), 2018A 130 (11.7 t/ha), 2018A 133 (11.7 t/ha), 2018A 65 (11.4 t/ha) and 2018A 169 (11.3 t/ha) were located on right side of the biplot and exhibited higher yields than the grand mean for CCS yield (Fig. 1B.). Whereas the clones, viz. 2018A 157 and 2018A 66 surpassed the best standard (2000A 225: 123. t/ha), while 2018A 130, 2018A 65 and 2018A 88 showed high stability. Based on both yield and stability, 2018A 6 and 2018A 157 were ideal for CCS yield. In case of sucrose (%) and CCS (%), five clones, viz. 2018A 157 (SP: 18.3%, CCS: 12.9%), 2018A 6 (SP: 19.6%, CCS: 13.9%), 2018A 196 (SP: 18.6%, CCS:13.1%), 2018A 55 (SP: 18.5%, CCS: 13.2%) and 2018A 65 (SP: 18.6%, CCS: 13.3%) were located on right side of the biplot and performed above the grand mean. Among them, 2018A 157, 2018A 6, 2018A 196 and 2018A 55 had PC1

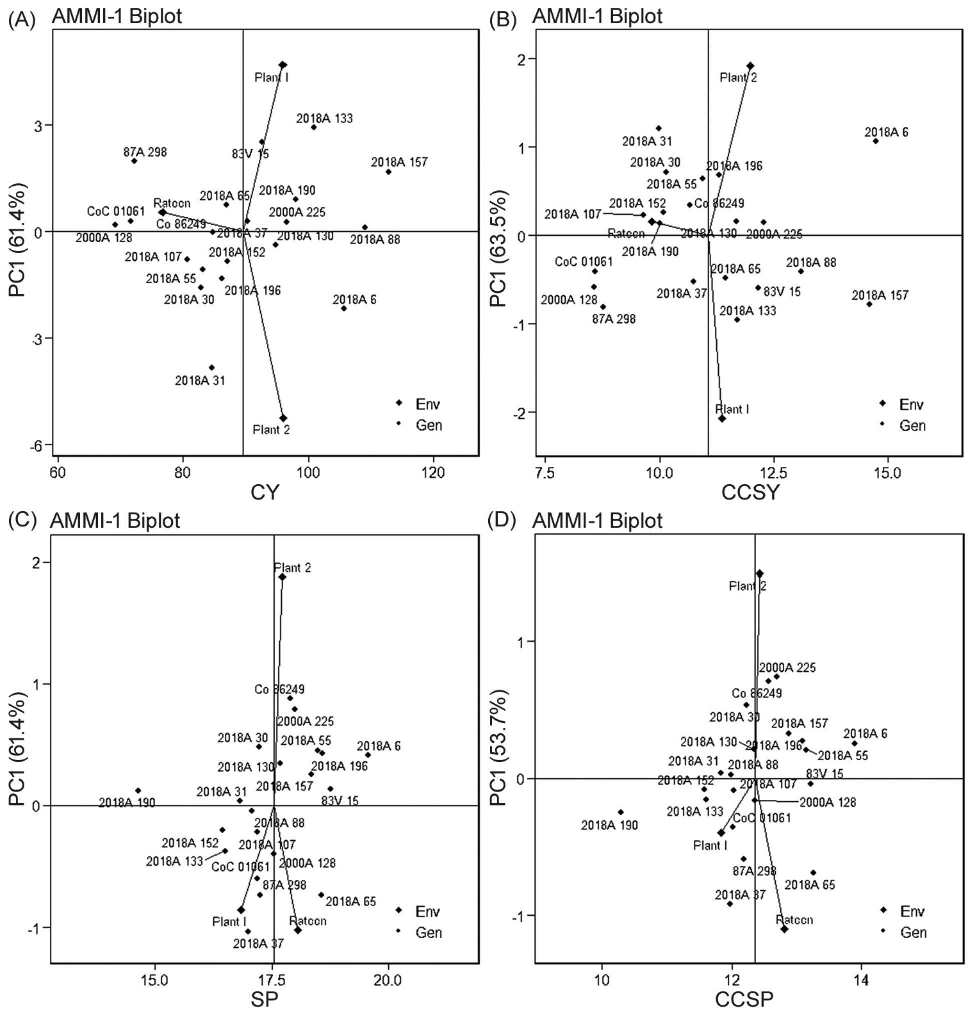

Fig. 1 AMMI-1 biplots for cane yield (A), CCS yield (B), sucrose % (C) and CCS% (D) among 20 clones over the crop cycles.
CY, Cane yield (t/ha); CCSY, Commercial cane sugar yield (t/ha); SP, Sucrose per cent; CCSP, Commercial cane sugar per cent.

scores near zero, indicating stability. Clone 2018A 6 was considered ideal for sugar quality traits and outperformed the best standard 83V 15 (18.7%, 13.2%). AMMI-1 biplot PC1 scores close to zero, suggesting high stability. The AMMI-1 biplot also revealed that the ratoon season had the shortest vector length near zero for yield traits, indicating minimal seasonal effect, while the first plant crop showed minimal seasonal variation for quality traits. Overall, clone 2018A 157 emerged as the most ideal genotype, combining high performance and stability across all traits.

The AMMI-2 biplot interprets GEI effect by plotting genotypes and environments along the first two principal components. Environmental scores are connected to the origin by lines, which represent the strength of the interaction; shorter arrows indicate weak interactions, while longer arrows signify strong interactions (Soni *et al.* 2022). Clones farther from the origin (0, 0) exhibit instability and specific adaptability across crop cycles, while those closer to the origin indicate general adaptability (Kumar *et al.* 2023). When genotypes cluster together on the biplot, it suggests that they share similar yield patterns across years. Conversely, if genotypes are spread apart, it indicates varied responses to environmental conditions. Favourable interactions occur when genotypes and environments are positioned in the same sector, suggesting compatibility, while unfavourable interactions arise when they are in opposite sectors, indicating divergence (Soni *et al.* 2022). Thus, this biplot provides valuable insights into the adaptability of genotypes and the nature of their interactions with various environments, helping to identify patterns in genotype-environment performance.

In the AMMI-2 biplot analysis, the first two principal components (PC1 and PC2) effectively captured the GEI for all traits. For cane yield, PC1 explained 64.1% and PC2 accounted for 35.9% of the total GEI variance (Fig. 2A). In CCS yield, PC1 and PC2 contributed 63.5% and 36.5%, respectively (Fig. 2B). For sucrose (%), PC1 captured 61.4% while PC2 explained 38.6% of the variation (Fig. 2C). In CCS (%), PC1 contributed 53.7% and PC2 46.3% (Fig. 2D). These results indicated that the AMMI-2 biplot provides a comprehensive visualisation of GEI patterns, supporting more accurate selection of stable and high-performing genotypes across environments (Elayaraja *et al.* 2022).

Clones positioned near the origin (0,0) of the AMMI-2 biplot were identified as stable across crop cycles due to their minimal interaction with the environment. For cane yield (t/ha), clones 2018A 65, 2018A 37, 2018A 157, 2018A 107 and 2018A 196 were close to the origin. Similarly, for CCS yield, 2018A 65, 2018A 37, 2018A 107, 2018A 6 and 2018A 196 showed high stability. For sucrose (%), clones 2018A 130, 2018A 152 and 2018A 133 were near the origin, while for CCS (%), clones 2018A 152, 2018A 30, 2018A 37 and 2018A 130 were identified as stable. Their proximity to the origin reflects low genotype × environment interaction, confirming their consistent performance across environments. Similar findings on the stability of sugarcane clones using AMMI analysis were reported by Vinu *et al.* (2024), Elayaraja *et al.* 2022 and Appunu *et al.* (2024).

AMMI stability value

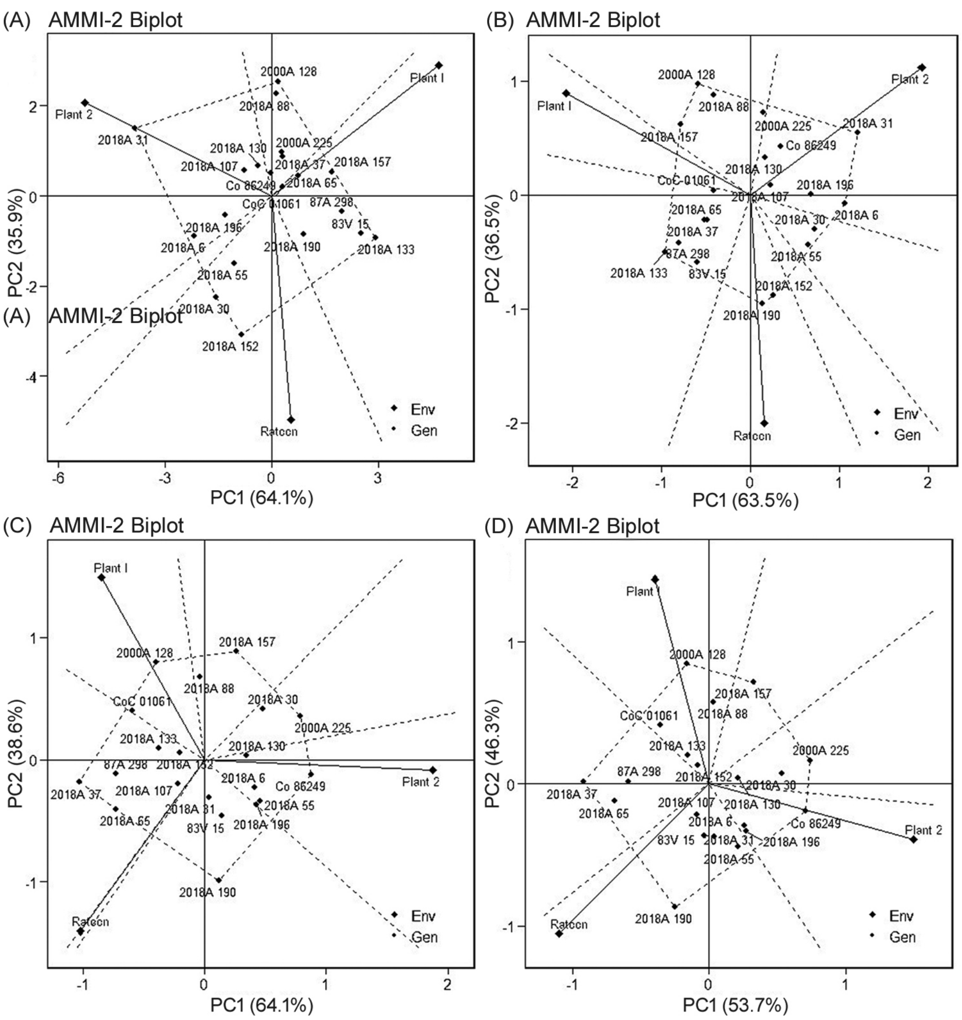

Fig. 2 AMMI-2 biplots for cane yield (A), CCS yield (B), sucrose % (C) and CCS% (D) among 20 clones over the crop cycles.
CY, Cane yield (t/ha); CCSY, Commercial cane sugar yield (t/ha); SP, Sucrose per cent; CCSP, Commercial cane sugar per cent.

Table 4 AMMI stability value of cane yield, CCS yield, sucrose and CCS % among 20 clones over the three crop cycles

	Cane yield (t/ha)		CCS yield (t/ha)		Sucrose (%)		CCS (%)	
	ASV	ASV_R	ASV	ASV_R	ASV	ASV_R	ASV	ASV_R
2000A 128	2.56	12	0.52	15	1.02	14	0.86	17
2000A 225	1.09	5	0.28	5	1.31	18	0.87	18
2018A 107	1.50	7	0.15	1	0.40	3	0.24	2
2018A 130	0.94	3	0.16	2	0.55	5	0.25	3
2018A 133	5.33	19	0.63	18	0.60	6	0.27	4
2018A 152	3.43	14	0.36	9	0.33	2	0.16	1
2018A 157	3.06	13	0.55	17	0.97	12	0.81	15
2018A 190	1.83	8	0.36	8	1.01	13	0.91	19
2018A 196	2.39	10	0.43	11	0.77	9	0.46	8
2018A 30	3.60	16	0.47	14	0.87	11	0.63	12
2018A 31	7.03	20	0.79	20	0.32	1	0.37	6
2018A 37	1.03	4	0.34	7	1.65	20	1.07	20
2018A 55	2.41	11	0.44	13	0.80	10	0.50	9
2018A 6	3.99	17	0.67	19	0.70	8	0.42	7
2018A 65	1.40	6	0.32	6	1.24	17	0.81	14
2018A 88	2.27	9	0.41	10	0.68	7	0.58	10
83V 15	4.59	18	0.44	12	0.51	4	0.37	5
87A 298	3.56	15	0.54	16	1.17	16	0.68	13
Co 86249	0.50	1	0.27	4	1.40	19	0.84	16
CoC 01061	0.58	2	0.26	3	1.03	15	0.59	11

ASV, AMMI stability value; ASV_R, AMMI stability value_Rank; CCS, Commercial cane sugar.

(ASV): The AMMI Stability Value (ASV) is a useful metric for ranking genotype stability across crop cycles. It is calculated based on the relative contributions of the first two principal component axes (PCA1 and PCA2) to the GEI sum of squares (Soni *et al.* 2022). Lower ASV values indicate higher stability, while higher values suggest greater sensitivity to environmental variation. ASV scores for 20 clones evaluated over three crop cycles revealed that clones 2018A 107 and 2018A 130 recorded the lowest ASV values for cane yield and CCS yield, indicating high stability (Table 4). Notably, the standard clone 2000A 225 also showed low ASV values among the 20 tested clones for yield traits. For sugar quality traits, clones 2018A 107, 2018A 152 and 2018A 130 exhibited the lowest ASV values, while the standard 83V15 ranked among the most stable. It is important to note that the most stable genotypes do not always produce the highest yields. Therefore, clones combining both high cane yield and low ASV values such as 2018A 107 and 2018A 130 are ideal candidates for inclusion in varietal development programmes.

The present study aimed to assess the stability and adaptability of 20 sugarcane clones across three crop cycles. This evaluation is crucial for identifying newly developed clones suitable for multi-environmental trials and wide adaptability. Among the tested clones, 2018A 157 and 2018A 6 were identified as ideal for their consistent performance in cane yield, CCS yield, sucrose (%) and CCS (%) across all three crop cycles.

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