Indian Journal of Agricultural Sciences **83** (10): 1079–85, October 2013/Article

Analyzing the performance of sugarcane (*Saccharum* spp) clones under abiotic stresses using ANOM as a tool

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Received: 27 April 2013; Revised accepted: 2 September 2013

ABSTRACT

Thirty sugarcane (*Saccharum* spp) clones were evaluated for stalk yield, CCS yield and sucrose% in two plant and one ratoon crops under four environmental conditions, viz. water stress, waterlogging, saline and normal. The statistical tool ANOM and GGE-Biplot was employed to quantify the performance of clones across and within environments. Stalk yield decreased by 20.41% under water stress, 14.07% under waterlogging and 5.45% in saline conditions. The CCS yield decreased to the tune of 20.93% under water stress, 15.28% under waterlogging and 5.65% in saline conditions. Irrespective of abiotic stresses, plant crops recorded 25.25% higher stalk yield and 29.31% higher CCS yield than the ratoon crop. Based on ANOM tools, five top ranking clones for stalk yield (Co 97016, ISH 148, CoLk 8102, Co 98016 and Co 97015) and CCS yield (Co 97016, Co 98014, CoLk 8102, Co 97015 and Co 98016) were identified which could be used as commercial varieties for planting under abiotic stresses or as parents in abiotic stresses resistance breeding programmes.

Key word: ANOM, Stability, Salinity, Sugarcane, Waterlogging, Water stress

Sugarcane grown under sub-tropical conditions of India is subjected to the extreme weather conditions, viz. high temperature during May-June and low temperature during December-January. The negative effects of the climatic factors on sugarcane productivity are further aggravated by the edaphic factors such as salinity, alkalinity, water stress and water logging. To overcome these stresses, sugarcane breeders are searching clones possessing adaptive advantages under these conditions. Such clones can be exploited directly as commercial varieties or can be used as parents for further improvement. Generally, a large number of clonal selections are screened under different abiotic stress environments for a minimum duration of two years. These data are difficult to comprehend unless a suitable statistical tool is available to visualize the result. Nelson *et al*. (2005) described a graphical tool called ANOM (analysis of means), for multiple comparisons of means involving single and two factor experiments. In this paper, we present the performance of Co and allied canes under normal, water stress, waterlogging, and saline environments using ANOM tools and stability parameters.

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MATERIALS AND METHODS

The experiment was conducted at Sugarcane Breeding Institute, Regional Centre, Karnal (Haryana) during 2007-09 in factorial RBD replicated thrice. Twenty one improved 'Co clones' namely, Co 6415 (clone no 1), Co 6806 (2), Co 7915 (3), Co 7717 (4), Co 85286 (5), Co 87028 (6), Co 87033 (7), Co 89035 (8), Co 91020 (9), Co 93026 (10), Co 95021 (11), Co 97014 (12), Co 97015 (13), Co 97016 (14), Co 97017 (15), Co 98014 (16), Co 98015 (17), Co 98016 (18), CoLk 8102 (19), CoS 94267 (20) and BO 91 (21), two clones of *Saccharum barberi* [Dhaur Aligarh (clone no. 22) and Praria Shahjahanpur (23)], six inter-specific hybrids of *Saccharum* spp, viz. ISH 7 (clone no. 24), ISH 135 (25), ISH 148 (26), ISH 175 (27), ISH 261 (28) and ISH 273 (29) along with a standard Co 1148 (clone no. 30) were evaluated for two years (plant crop-I during 1st year and plant crop II and ratoon of plant crop I in the 2nd year) under four environmental conditions namely, water stress, waterlogging, saline and normal environmental conditions. The plot size per clone was six m^2 (4 m long row at 75 cm row spacing × 2 rows per clone). In the normal environmental condition, irrigation was given at an interval of ten days as recommended for sugarcane crop in the Haryana State. Water stress environment was created by withholding irrigations during pre-monsoon period (April–June) till 50% of the clones showed permanent leaf rolling at the time of sunrise. Waterlogging condition was created during monsoon period (July-September) by flooding experimental plot to a depth of 1½ feet. Saline condition was created before planting by applying saline solutions in quantities sufficient to salinize 60 cm of top soil. Salts like NaCl, $CaCl_2$ and $MgSO_4$ were used to have Na:Ca:Mg ratio as 6:2:2 and Cl:SO_4 as 8:2 on milli-equivalent basis which is typical of chloride type saline conditions in the sub-tropical India. Data on stalk yield, and pol in juice (sucrose%) at harvest (12 month after planting) were recorded. The commercial cane sugar yield {CCS t/ha= (CCS% × cane yield/ha)/100} was estimated from CCS% as per the formula 1.022 × Pol% - 0.292 × Brix%. The variability among the clones in relation to plant type (1st plant, 2nd plant and ratoon) and environment (normal, drought, saline and waterlogging) were analyzed through the univariate general linear model using SPSS software. The analysis of means (ANOM) was carried out as detailed by Nelson *et al*. (2005) to graphically visualize the patterns of variation across environment and plant type. To ascertain the performance of the clones over environments and years *vis-à-vis* stability for cane yield, CCS yield and pol %. GGE biplot analysis was carried out as per the method of Yan and Tinker (2006).

RESULTS AND DISCUSSION

Analysis of variance

The ANOVA for the year-wise pooled mean of cane yield, CCS yield and pol% in juice showed significant mean sum of square for these traits (data not shown), indicating variability among the clones, environments as well as differential response of the clones in plant and ratoon crop for the above traits. The mean sum of squares due to clones × environment and clones × crop type were significant for all the traits. It signifies that the clones have interacted with environments and responded differently under normal, saline, water stress and waterlogging conditions. The interaction effects between clones × environments × crop types was significant for CCS yield and cane yield but sucrose% was least affected by crop type × environment interaction. The difference in CCS and cane yields between plant and ratoon crops was further influenced by the abiotic stresses. This result corroborate with the earlier studies by Bora and Singh (2001) and Bhatnagar *et al.* (2003) who reported differences for single cane weight and NMC between plant and ratoon crops.

Analysis of mean (ANOM)

The ANOVA for cane yield and CCS yield showed significance of main effects and interaction effects but the magnitude and direction of the effects could not be discernible easily. This drawback however, could be overcome by ANOM tools as it allows one to easily draw conclusions and interpret the results statistically. The overall mean of all the clones ± the level of significance at α=0.05 was taken as the criterion, the individual clones were compared with these limits and the clones were segregated into very high or very poor performer (Fig 1). The average cane yield per plot was 47.72 kg. Eight clones namely, Co 97014, Co 97015, Co 97016, Co 98014, Co 98016, CoLk 8102, ISH 148 and Co 1148 have recorded above average yield (56.57 kg), whereas 7 clones

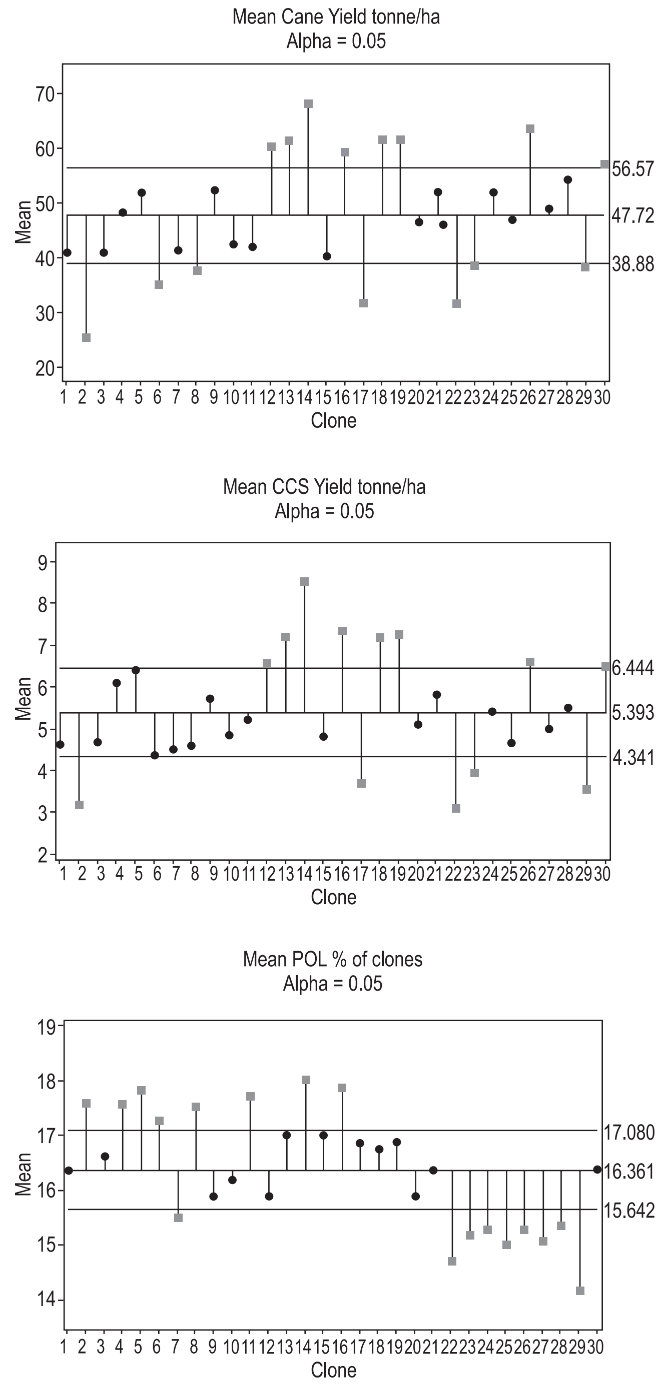


Fig 1 Analysis of Means (ANOM) showing the performance of 30 clones across 4 environments

Co 6806, Co 87028, Co 89035, Co 98015, Dhaur Aligarh, Praria Shahjahanpur and ISH 273 have registered below average yield (38.88 kg/plot). The CCS yield in the clone Co 97014, Co 97015, Co 97016, Co 98014, Co 98016, CoLk 8102, ISH 148 and Co 1148 were above the average (6.44 kg/plot) while it was below the average (4.34 kg/plot) in the clone Co 6806, Co 98015, Dhaur Aligarh, Praria Shahjahanpur and ISH 273. The results thus indicate the correlated response in the above clones for stalk yield and CCS yield. Eight clones have shown above average performer (17.08%) for pol % in juice; they were Co 6806, Co 7717, Co 85286, Co 87028, Co 89035, Co 95021, Co 97016 and Co 98014. Nine clones were below average performance (15.64%) for pol % in juice; they were from the species *S. barberi* (Dhaur Aligarh, Praria Shahjahanpur) and inter-specific hybrids (ISH 7, 135, 148, 175, 261 and 273) derived from commercial hybrids × *Saccharum* spp. Thus, on the basis of ANOM, seven test clones Co 97014, Co 97015, Co 97016, Co 98014, Co 98016, CoLk 8102, ISH 148 and a standard Co 1148 could be selected as the best clones for subtropical condition.

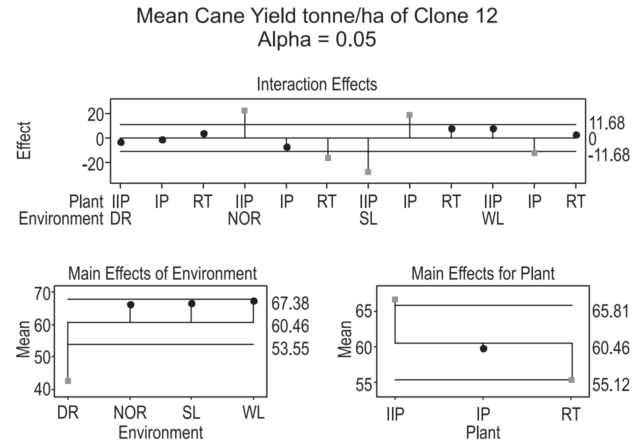
The mean performance of clones for cane yield, CCS yield and pol% and their ranking based on high mean and stability criteria using GGE-Biplot analysis (Col B-I) is presented in Table 1. The top five ranked entries are highlighted in shades in Table 1 to easily identify clones that performed consistently well under normal and abiotic stresses. Clones Co 97016, ISH 148, CoLk 8102, Co 98016 and Co 97015 occupied top five position as per ANOM analysis, while, clones Co 97016, ISH 148, CoLk 8102, Co 98016 and Co 97015 were at the top five positions as per GGE-biplot analysis.

With regard to CCS yield, based on simple ranking clones Co 97016, Co 98014, CoLk 8102, Co 97015 and Co 98016 occupied top five ranks (Table 2). These clones were also at top five positions as per GGE-biplot stability analysis. The inter-specific hybrid, ISH 148 has shown remarkable vegetative growth and stood second for cane yield but ranked 6th for CCS yield because of low pol in juice (15.27%).

The top ranking clones for pol% were Co 97016, Co 98014, Co 85286, Co 95021 and Co 6806. The pooled ranking of these clones across crop types and environments were also within top five positions, indicating their stable performance for the trait across environments. On the basis of ANOM and stability criterion for stalk yield, sugar yield and to some extent on pol % in juice, five clones namely, Co 97016, Co 98016, Co 97015, Co 98014 and CoLk 8102 could be pinpointed for utilization as parent or as commercial cultivar in abiotic stress prone areas.

Main and interaction effects of clones based on ANOM graphical analysis

To illustrate the main and interaction effects of individual clones using ANOM tools, Co 97014 was taken as example and its performance is given in Fig 2, 3 and 4. The stalk yield



Note: IP-I plant, IIP- II plant, RT-Ratoon, NOR-Normal, DR-Water stress, SC-Saline envt, WL-Water logging.

Fig 2 ANOM indicating the main effects and interaction effects of crop types (Plant crop I, II and Ratoon) and environments (normal, water stress, saline and water logging conditions) in clone 12 (Co 97014) for stalk yield. Note: IP-I plant, IIP- II plant, RT-Ratoon, NOR-Normal, DR-Water stress, SC-Saline envt, WL-Waterlogging.

of Co 97014 under drought condition was significantly lower (41.41 kg/plot) than its average stalk yield across all environments (60.46 kg/plot). The II plant stalk yield of this variety was significantly higher (66.60 kg/plot) than the mean (60.47 kg/plot), whereas its ratoon yield was significantly lower (55.02 kg/plot) than the mean (Fig 2). The interaction effect of this clone was significant and positive with respect to II plant × normal environment (95.67 kg) and I plant × saline environment (85.77 kg), whereas significant negative interaction was observed between ratoon × normal

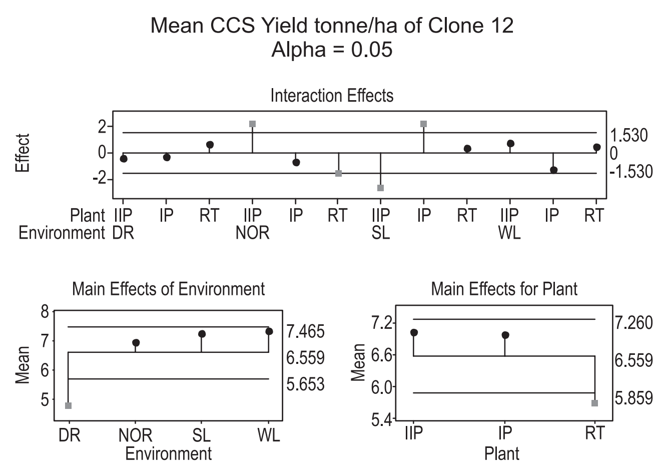


Fig 3 ANOM indicating the main effects and interaction effects of crop types (Plant crop I, II and Ratoon) and environments (normal, water stress, saline and water logging conditions) in clone 12 (Co 97014) for CCS yield.

Table 1 Mean cane yield and CCS yield (tonnes/ha) of clones and their ranking based on high mean & Stability criterion using GGE-Biplot analysis (Col B-I)

Clone	Cane Yield	A SR	B PE	C IP	D IIP	E RT	F NC	G WS	H SC	I WL	CCS yield	A SR	B PE	C IP	D IIP	E RT	F NC	G WS	H SC	I WL	Pol %	A SR	B PE	C IP	D IIP	E RT	F NC	G WS	H SC	I WL
Co 6415	40.89	22	21	18	22	20	22	25	11	23	4.62	22	22	18	19	20	23	22	11	22	16.35	17	15	19	12	19	19	14	16	11
Co 6806	25.28	30	30	30	27	30	30	29	30	30	3.17	29	29	28	24	30	29	27	30	30	17.59	5	4	3	2	12	12	3	5	8
Co 7915	40.94	21	23	26	9	26	8	26	24	24	4.67	20	23	24	6	26	9	24	22	25	16.62	14	13	15	13	11	13	7	15	20
Co 7717	48.28	15	14	8	2	27	17	12	8	20	6.08	10	12	5	2	27	14	10	8	19	17.56	6	6	1	1	18	11	11	4	6
Co 85286	52.02	11	11	14	13	11	5	8	17	19	6.39	9	8	8	9	8	3	6	13	12	17.83	3	5	7	3	2	6	4	7	2
Co 87028	35.02	27	26	25	14	29	24	22	26	27	4.37	25	25	22	8	29	18	19	26	26	17.27	8	7	10	7	16	4	10	8	15
Co 87033	41.29	20	19	10	23	24	21	18	22	9	4.50	24	21	12	22	25	22	20	23	14	15.49	22	22	20	15	27	22	21	24	25
Co 89035	37.53	26	24	22	18	25	25	24	21	25	4.58	23	20	19	16	23	19	17	19	24	17.52	7	8	11	8	4	2	2	6	12
Co 91020	52.35	10	16	24	21	3	16	16	15	14	5.73	12	17	25	23	3	15	15	18	16	15.89	19	20	22	23	14	20	20	20	18
Co 93026	42.27	18	20	11	19	22	23	19	16	17	4.83	18	18	10	20	21	20	18	17	15	16.18	18	18	12	16	23	15	23	19	10
Co 95021	42.04	19	17	16	16	21	18	13	19	22	5.21	15	13	13	12	19	13	9	14	20	17.72	4	2	2	6	5	3	5	3	7
Co 97014	60.46	6	3	4	10	6	4	14	6	1	6.56	7	7	7	7	9	7	12	7	1	15.87	21	19	16	21	21	21	16	21	17
Co 97015	61.48	5	1	7	3	10	6	3	7	5	7.20	4	3	9	3	10	4	4	6	7	17.00	9	11	18	10	6	7	9	11	19
Co 97016	68.15	1	4	1	1	12	2	5	1	12	8.52	1	1	2	1	11	2	3	1	11	18.03	1	3	4	5	1	1	1	1	3
Co 97017	40.17	23	22	17	20	23	14	27	25	10	4.80	19	19	14	18	24	11	25	25	10	17.00	10	9	8	9	17	16	8	9	9
Co 98014	59.24	7	5	6	6	9	1	1	14	11	7.34	2	2	3	4	6	1	1	9	5	17.87	2	1	6	4	3	5	6	2	1
Co 98015	31.64	28	28	20	29	28	28	30	23	29	3.69	27	27	20	27	28	26	29	21	29	16.85	12	14	25	11	7	8	12	10	24
Co 98016	61.67	4	2	2	8	7	7	7	3	2	7.18	5	4	1	10	5	5	7	3	2	16.75	13	12	5	19	9	9	17	13	5
CoLk8102	61.75	3	6	12	5	1	10	6	5	8	7.25	3	5	11	5	1	8	5	2	6	16.87	11	10	9	14	10	10	13	12	4
CoS94267	46.49	17	15	13	24	13	11	23	13	13	5.11	16	15	17	25	13	12	21	16	13	15.88	20	21	23	22	15	18	19	25	16
BO 91	52.00	12	13	27	12	4	19	15	18	4	5.80	11	14	26	13	4	17	14	20	4	16.35	16	17	14	17	13	17	18	14	13
Dhaur A	31.54	29	29	28	30	19	29	28	27	28	3.10	30	30	29	30	22	30	30	28	27	14.69	29	29	26	28	28	29	29	30	23
Praria S	38.54	24	26	21	28	18	20	17	28	21	3.93	26	26	23	28	18	24	23	27	23	15.18	26	25	24	27	24	23	25	23	29
ISH 7	51.94	13	10	9	7	17	9	9	12	3	5.41	14	10	15	11	17	16	11	15	3	15.29	24	26	28	20	25	26	22	26	28
ISH 135	46.89	16	18	23	25	5	27	11	20	18	4.65	21	24	27	26	12	27	16	24	21	14.99	28	28	30	24	26	28	26	27	26
ISH 148	63.55	2	7	3	17	2	3	4	10	7	6.58	6	9	4	21	2	6	8	10	9	15.28	25	24	27	26	20	25	24	22	27
ISH 175	48.84	14	12	19	11	15	13	20	9	6	4.98	17	16	21	15	16	21	26	12	8	15.07	27	27	21	25	30	24	28	28	22
ISH 261	54.33	9	9	15	4	16	12	10	4	16	5.50	13	11	16	17	14	25	13	5	18	15.35	23	23	13	29	22	27	27	17	21
ISH 273	38.06	25	27	29	26	14	26	21	29	26	3.53	28	28	30	29	15	28	28	29	28	14.16	30	30	29	30	29	30	30	29	30
Co 1148	57.04	8	8	5	15	8	15	2	2	15	6.49	8	6	6	14	7	10	2	4	17	16.37	15	16	17	18	8	14	15	18	14

SR, PR-simple ranking or pooled ranking across all environments, IP-I plant, IIP-II plant, RT-ratoon, NC-normal, WS-Water stress, SC-saline, WL-waterlogging

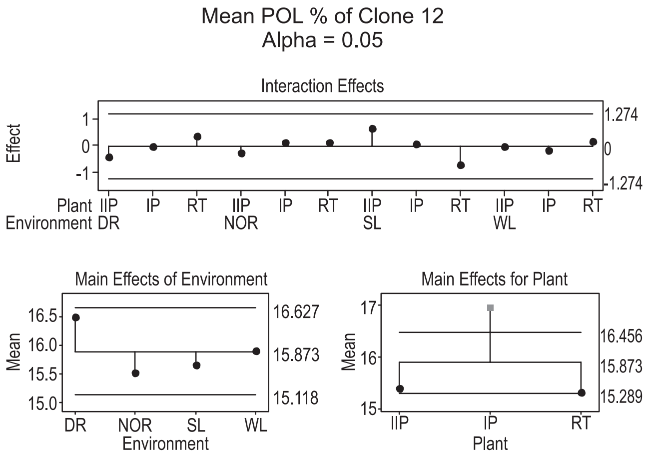


Fig 4 Fig 3 ANOM indicating the main effects and interaction effects of crop types (Plant crop I, II and Ratoon) and environments (normal, water stress, saline and water logging conditions) in clone 12 (Co 97014) for pol % in juice.

environment (44 kg), II plant × saline environment (43.73 kg) and I plant × waterlogging environment (54.55) (Fig 2). The CCS yield of Co 97014 under water stress was significantly lower (4.75 kg/plot) than its across the environments average (6.56 kg/plot). Similary, its ratoon CCS yield was significantly lower (5.67 kg) than its overall mean. The interaction effect for CCS yield was significant and positive with respect to II plant × normal (9.65 kg) and I plant × saline environment (9.93 kg) (Fig 3), whereas significant negative interaction was discernible for ratoon × normal (4.46 kg) and II plant × saline environment (5.09 kg). Co 97014 did not show significant improvement for pol% in any of the environments in comparison to its average pol% across all environments (15.87%). The pol% of first plant crop was significantly higher (16.92 %) than its overall mean (15.87%) (Fig 4). The interaction effects between environment and crop types was found to be non-significant.

The mean stalk yield of Co 97015, across all environments was 61.48 kg/plot. Stalk yield under normal, water stress, water logging and salinity environment did not deviate significantly from the overall mean (Table 2). The second plant stalk yield was significantly higher (76.96 kg/plot) than the overall mean, whereas ratoon yield was significantly lower (50.46 kg/plot) than the overall mean. Co 97015 showed significant positive interaction between I plant × saline, II plant × normal and ratoon × saline environments (Table 3). The CCS yield under water logging condition was significantly lower (6.20 kg/plot) than its overall mean (7.20 kg/plot) (Table 2) which may be due to its poor ratoon yield (5.79 kg CCS yield in ratoon vs. 7.90 kg in plant crop), significant negative interaction under normal and saline environments (*e.g.* I plant × normal environment (5.70 kg/plot) and II plant × saline conditions (6.03 kg) and low pol%

Table 2 Significant deviations (+/-) in the mean stalk yield, CCS yield and Pol % of selected clones from overall performance across environments and crop types

Character	Envts./crops	Co 97014	Co 97015	Co 97016	Co 98014	Co 98016	CoLk 8102	ISH 148
Cane yield (kg/plot)	Average	60.46	61.48	68.15	59.24	61.67	61.75	63.55
	Normal				+ *		+ *	
	Water stress	- *		- *		- *		
	Water logging			- *	- *			- *
	Salinity			+ *	- *	+ *	+ *	
	I Plant						- *	
	Ratoon	- *	- *	- *			+ *	+ *
	II Plant	+ *	+ *	+ *	+ *			- *
CCS yield (kg/plot)	Average	6.56	7.20	8.52	7.34	7.18	7.25	6.58
	Normal				+ *			
	Water stress	- *		- *		- *		
	Water logging		- *	- *	- *		- *	
	Salinity			+ *	- *		+ *	
	I Plant					+ *	- *	
	Ratoon	- *	- *	- *		- *		+ *
	II Plant		+ *	+ *				- *
Pol %	Average	15.87	17.00	18.03	17.87	16.75	16.87	15.27
	Water logging		- *					
	I Plant	+ *			+ *	+ *	+ *	+ *
	II Plant			- *		- *	- *	- *

+ * or - * Positive or Negative but significant deviation from general mean

Table 3 Significant interaction effects (+/-) for stalk and CCS yields of selected clones

Character	Interaction	Co 97014	Co 97015	Co 97016	Co 98014	Co 98016	CoLk 8102	ISH 148
Cane yield	I P x N					- *	- *	
	I P x WS							- *
	I P x WL	- *					+ *	
	I P x SL	+ *	+ *		+ *	+ *		
	II P x N	+ *	+ *		+ *	+ *	+ *	
	II P x SL	- *	- *			- *		
	R x N	- *						
	R x SL		+ *					
CCS yield	I P x N		- *			- *	- *	
	I P x WL	- *		- *			+ *	
	I P x SL	+ *	+ *		+ *	+ *		
	II P x N	+ *	+ *		+ *	+ *	+ *	
	II P x WL			+ *				
	II P x SL	- *	- *			- *		
	R x N	- *						

IP, IIP refers to plant crop I & II, R-Ratoon crop, N-Normal environment, SL-Saline, WS-Water stress, WL-Waterlogging environment + * or - * Positive or Negative but significant deviation from general mean

in juice under waterlogging condition (15.96 % under waterlogging vs. 17.59% under normal environment (Table 3).

Co 97016 was one among the best clones, recorded 68.15 kg/plot average stalk yield and 8.52 kg/plot CCS yield (Table 2). The ratoon stalk yield and CCS yield of this clone were significantly lower but plant crop yield (II-Plant) was significantly higher than the average yield. The CCS yield was significantly lower under water stress (7.07 kg/plot) and waterlogging (7.11 kg/plot) environment in comparison to normal environment (9.27 kg/plot). The stalk yield was also lower under water stress (54.97 kg/plot) and waterlogging (58.10 kg/plot) environments in comparison to normal environment (74.59 kg/plot). The interaction between plant type × environments was non-significant for stalk yield. However, for CCS yield the interaction effect between plant crop × waterlogging environment was significant.

The stalk yield and CCS yield of Co 98014 was significantly higher under normal environment (75.06 kg stalk/plot and 9.17 kg CCS/plot) than the overall mean across three crop types and four environments (52.24 kg stalk/plot and 7.34 kg CCS/plot). Its performance under saline environment (49.13 kg cane yield/plot and 6.14 kg CCS yield/plot) and waterlogging environment (48.41 kg cane yield/plot and 6.19 kg CCS yield/plot) was poor. Significant and positive interaction between II plant × normal environment and I plant × saline environment were discernible for stalk and CCS yields. Clone Co 98016 registered significantly higher cane yield under saline environment (62.31 kg/plot) as compared to its average cane yield (61.67 kg/plot) across environments and crop types. Nonetheless, its stalk yield was poor under water stress condition (51.46 kg/plot). The deviation of stalk yield of I plant, II plant and ratoon from its overall mean were non-significant which is an indication of its stability. The interaction effects between plant crop × saline environment was negative for stalk and CCS yields.

The stalk yield of CoLk 8102 was significantly higher under normal (68.48 kg/plot) and saline (69.73 kg/plot) environments than its overall mean (61.75 kg). Ratoon yield of this variety (68.36 kg/plot) was significantly higher whereas I plant crop yield was poor (52.36 kg/plot). CoLk 8102 also registered higher CCS yield (8.47 kg/plot) under saline environment than the overall mean (7.25 kg). The average stalk yield of ISH 148, a derivative of inter-specific cross "CoC 671 × *Saccharum spontaneum* (SES108B)" was (63.55 kg/plot). This clone registered poor stalk yield under water logging condition (56.34 kg/plot) but not under normal, water stress and saline environments. Stalk and CCS yields in the ratoon crop was significantly higher (72.90 kg cane yield/plot and 7.49 kg CCS yield/plot), a favourable trait inherited from *S. spontaneum.* Only the main effects (plant crops vs. ratoon) alone was significant for CCS yield but not the interaction effect between crop types × environments.

Effect on environments

The results of the study showed that the stalk yield and sugar yield have decreased under water deficient, waterlogging, and salinity stress conditions. The stalk yield per plot was 53.01 kg under normal, 19 kg under water deficient, 45.55 kg under waterlogging and 50.12 kg under saline stress conditions. In comparison to the cane yield under normal environment, yield decline was higher (20.41%) under water stress, followed by waterlogging condition (14.07%) and least under saline environment (5.45%). The CCS yield per plot was 6.02 kg under normal condition, 4.76 kg under water stress, 5.10 kg under waterlogging and 5.68 kg under saline water irrigated condition. The CCS yield decreased 20.93% under water stress, 15.28% under waterlogging and only 5.65% in saline condition. From the above results, it also appears that the effect of water stress and waterlogging on stalk yield and sugar yield was more or less similar but more severe than the effects of salinity. Notably, the saline water irrigated condition did not significantly affect the CCS yield of ratoon crop. These results corroborate with the earlier findings of Ramesh and Mahadevaswamy (1999) who reported that drought caused 18.1-29.2% reduction in stalk yield, Ram *et al.* (2003) who reported reduction of stalk and sugar yields under waterlogging condition, and Rietz and Haynes (2002) who opined that sodicity was a more limiting factor for sugarcane growth than salinity. The effect of abiotic stresses on pol% in juice was at low scale. The pol% has decreased just about 1.58% under waterlogging, 0.73% under saline water irrigation whereas it increased 0.43% under water stress. This finding is similar to the earlier study by Hemaprabha *et al.* (2004) who reported increase in sucrose content in some Co clones under water stress. Water stress did not adversely affect the stalk and CCS yield in variety like Co 98014. Therefore, this variety can be recommended under normal as well as water stress environments. Under waterlogging condition, clone Co 97014, Co 98016 and BO 91 would be the best choice since their stalk yield and CCS yield in plant and ratoon crop was higher. The clone Co 97016 recorded higher stalk and CCS yield under saline water irrigated condition hence it is proposed to evaluate this clone in large scale trials under saline water irrigated condition.

CONCLUSION

The ANOM tools have enabled to quantify the performance of sugarcane clones under four abiotic stresses and three crop types. The interaction effects of individual clones and its stability could be studied conveniently across environments using the graphical tools of ANOM and GGE-Biplot. Varieties such as Co 7717 showed good stalk yield, pol%, and CCS yield in plant crop alone however, varieties such as Co 98014, CoLk 8102 and Co 97016 showed good performance both in plant and ratoon crop. Water stress has not adversely affected the stalk and CCS yields of Co 98014. Under waterlogging condition, the clone Co 97014, Co 98016 and BO 91 gave satisfactory stalk and CCS yields in plant as well as ratoon crops. ISH 148, Co 97016 and Co 98014 exhibited favorable pattern of high mean and stability for stalk yield, pol% and CCS yield. These clones are expected to perform better over a wide range of environmental conditions. Utilization of such clones, with fewer interaction effects, as parents would be advantageous for achieving quick gains.

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