RESEARCH ARTICLE

EVALUATION OF SUGARCANE GERMPLASM FOR DROUGHT AND SALINITY TOLERANCE

S.Vasantha*, R. Gomathi, S. Venkataramana and R. Arunkumar

Abstract

Sugarcane (*Saccharum officinarum* L) belongs to the family Poaceace and comprises of five species *viz*., *Saccharum officinarum* L., *Saccharum spontaneum* L. *Saccharum robustum*Brandes et Jeswiet ex Grassl., *S. barberi* Jeswiet and *S. sinense* Roxb. Amend Jeswiet. The cultivated crop is the product of inter specific hybridization involving these species. *Saccharum* species clones have wider habitat and possess tolerance/ resistance to varied abiotic stress conditions. In this context evaluating the germplasm types for the major stresses i.e., drought and salinity, presumes importance for locating tolerance traits. ICAR – Sugarcane Breeding Institute, Coimbatore houses about 3000 germplasm clones and evaluation of these clones would present valuable information for future utilization. Ninety five clones comprising of different species of *Saccharum* (*S. officinarum*:6, *S. barberi*:13, *S. sinense*:11, *S.spontaneum*:46, *S. robustum*: 12) and 17 ISH clones were screened for drought tolerance and forty types were identified as tolerant to drought. A total of 637 clones belonging to different species of *Saccharum viz*., *S. officinarum* (391), *S. robustum* (58), *S. barberi* (39) and IND clones (78) were screened for salinity tolerance. One hundred and eighty clones were found to be tolerant to salinity suggesting large germplasm pool available for exploitation.

Key Words: *Saccharum* species, drought, salinity, photosynthetic rate, transpiration rate

Introduction

Sugarcane has wider adaptability and grows in varied agro-climatic zones of the country. Mining the gene pool collections from different ecological habitat for tolerance to abiotic stresses holds promise for incorporation of desired traits for future breeding endeavours. ICAR – Sugarcane Breeding Institute, Coimbatore maintains a large collection of more than 3000 germplasm including *Saccharum officinarum, S. sinense, S. barberi, S. robustum and S.spontaneum,* and interspecific hybrids which are known to possess an extremely greater tolerance potential to different stresses. All improved sugarcane varieties grown throughoutthe world are products of inter specific hybridization involving *S. officinarum*, *S. barberi*, *S.sinense* and wild species of *S. spontaneum and S. robustum*. In particular, *S. spontaneum* has played a major role in the adaptation to varied climatic conditions and tolerance to various biotic and abiotic stresses (Sreenivasan and Amalraj 2004).

Water stress remains an ever growing problem and it is the major limiting factor in crop production worldwide (Jones and Corlett 1992). Water stress of varying degrees is experienced at one stage or the other of the crop growth in all most all the sugarcane growing regions of the country. A wide range of morphological traits, physiological, biochemical and molecular processes are influenced by water stress. At the beginning of the stress, stomatal closure occurs

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which reduces transpiration rates and a decrease in leaf water potential which collectively influence the photosynthesis and productivity. Drought during the vegetative period tends to slow down the leaf development and canopy expansion. The major attribute is the drying off of older leaves and stunted growth of stem resulting in a dwarf canopy. The occurrence of physiological and morphological responses which may lead to some adaptations to stress may vary considerably among species (Souza et al. 2004).

Soil root zone EC below 2 dSm^{-1} has no effect on growth and yield of sugarcane. Between EC levels 5 to 7 dSm^{-1}, the yield decreases by 50% and at EC of 8.0 dSm^{-1}, stools of some cultivars may be killed. The salinity effects are aggravated when irrigation water becomes scanty and EC of irrigation water is high (>3.0 dSm^{-1}) Mass and Hoffman 1977. Higher reduction in germination of setts with increasing salinity levels were reported for sugarcane. Varieties showed significant difference in germination. Kumar and Naidu (1993) observed that soil salinity as more damaging for germination of setts at low temperature (below 25º C). The germination of buds decreased with increasing salinity. The rate and percent emergence of sprouts, length of roots, shoot dry matter and number of roots decreased under salinity and the effect was relatively less in tolerant variety as compared to a susceptible one (Abdul etal.1997, Akhtar etal.2003). A decrease in cane yields of the order of 5.45tha^{-1} for every 1$mmohsha^{-1}$ (from an EC of 5mmhos) is experienced due to soil salinity. Yield reduction from 20% (Co 86011) to 45%(Co 7219) has been recorded in popular genotypes.

Materials and Methods

The selected *Saccharum* species (*S. officinarum, S. sinense, S. barberi, S. spontaneum, and S. robustum*) were obtained from sugarcane germplasm collection (ICAR-Sugarcane Breeding Institute Research Centre, Kannur, Kerala) and planted and evaluated at ICAR-Sugarcane Breeding Institute, Coimbatore. The trial comprised of planting two bud setts (40/ row of 6.06m length (spaced at 0.9 m) adopting a RBD replicated thrice. The normal crop received 42 irrigations (5 acre cm each): 8 during the germination (0-60 days), 12 during formative phase (60 to 150 days), 12 during the grand growth (150 to 240 days) and 10 during the maturity and ripening phase (240 to 360 days). The moisture stress treatment comprised of withholding twelve irrigations during the grand growth. The treatment was terminated at 150 days age and thereafter the irrigation schedule was identical for both normal and drought treated plots. The experiment was spread over two cropping seasons that comprised of screening *Saccharum* species and ISH clones for drought tolerance under field condition.

Screening for drought

Sugarcane germplasm types were screened based on morphological, physiological and yield data generated following standard protocol. Leaf water potential was measured in the 1st TVD leaf lamina using the Pressure Chamber (PMS, USA). The relative water content was measured in controlled and water stressed leaf samples. Osmotic potential was estimated during stress and at post stress periods utilizing the Vapour Pressure Osmometer (Wescor, USA). The osmotic potential was quantified against standard and expressed in -MPa. Photosynthetic measurements were made during the formative and at grand growth phase on the mid portion of the adaxial surface of the leaf lamina utilizing ADC photosynthetic system LCA-4 (ADC-Analytical Development Corporation, Hoddesdon, Hertfordshire, U.K)

Screening for Salinity Tolerance

A total of 637 clones belonging to different species of *Saccharum* viz., *S. officinarum* (391), *S. robustum* (132), *S. barberi* (36) and IND clones (78) were screened for salinity tolerance. Screening of germplasm clones was carried out in pot culture experiments. Ten single bud setts of the germplasm materials were planted in the pots (45×45cm) filled with 40 kg of soil, 58g urea, 16.5g potash and 62g of super phosphate were added per pot as basal dose. Salinity treatment was given by adding sodium chloride and calcium chloride (1:1) to raise the electrical conductivity of the soil to 10 dS m^{-1}.Soil pH was between 7.5 to 8.0. Control pots received normal watering (EC 2.4 dS m^{-1} and pH 7.0 to 7.5) while treatment pots received watering with salt water. Five pots were maintained for each treatment and clone.

Results and Discussion

Photosynthesis in S.*spontaneum*

The photosynthetic rate showed extreme variation in *S.spontaneum* clones. About 29 types exhibited moderately high (>10 µmol Co_2m s^2) $^{-1}$ photosynthetic rate and the drought treatment caused 73.78% reduction. The transpiration rate varied from 0.380 to 1.057m mol $H_2Om^{-2}s^{-1}$ under normal and from 0.100 to 0.740 m mol $H_2Om^{-2}s^{-1}$ under drought. Certain types such as SES 32A, SES 91, SES 103, SES 151 B, SES 155 A, Glagah, Hasuda, IMP 238 which maintained identical levels of transpiration in both normal and drought might possess inherent capability of drought tolerance (Table 1)

Table 1.Photosynthesis and transpiration in *S.spontaneum* L. clones under drought stress

S.No.	Genotype	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})		Transpiration rate (mmol H_2O m^{-2} s^{-1})	
		Normal	Drought	Normal	Drought
1	SES 021	12.29	1.58	0.413	0.180
2	SES 32 A	17.56	2.50	0.463	0.517
3	SES 55 A	9.23	2.23	0.680	0.407
4	SES 09 1	7.77	9.96	0.783	0.657
5	SES 093	12.42	0.45	0.690	0.053
6	SES 103	15.10	3.04	0.680	0.503
7	SES 108 B	15.46	2.25	0.877	0.297
8	SES 115 B	12.00	3.61	0.580	0.263
9	IND 90-812	12.61	1.93	0.630	0.470
10	IND 89-688	9.63	1.38	0.803	0.513
11	SES 119	12.75	1.65	0.933	0.403
12	SES 132 A	11.47	1.59	1.033	0.403
13	SES 151 B	15.71	9.39	0.787	0.670
14	SES 155A	10.19	6.13	0.693	0.740
15	IND 90-805	19.50	0.15	1.057	0.460

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S.No.	Genotype	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})		Transpiration rate (mmol H_2O m^{-2} s^{-1})	
		Normal	Drought	Normal	Drought
16	SES 189	14.12	5.81	0.940	0.297
17	SES 205 B	8.29	6.48	0.773	0.433
18	SES 235	7.33	4.33	0.633	0.257
19	SES 236	7.56	3.07	0.547	0.410
20	SES 256	11.15	3.18	0.737	0.473
21	SES 341	10.07	3.07	0.693	0.340
22	IND 90-796	14.15	2.08	0.910	0.243
23	Burma	9.34	3.71	0.550	0.287
24	Glagah	10.65	3.18	0.390	0.347
25	Hasuda	8.15	3.25	0.380	0.300
26	Imp 238	11.67	1.70	0.410	0.400
27	Imp 564	11.57	6.61	0.483	0.290
28	Imp 1544	12.92	0.99	0.637	0.227
29	S.spont	21.19	3.50	0.567	0.257
30	Tabongo	18.85	0.65	0.650	0.180
31	US 4641	14.66	3.52	0.667	0.220
32	IND 81-200	9.76	2.87	0.540	0.260
33	IND 84-351	16.01	3.94	0.733	0.310
34	IND 84-395	13.65	4.16	0.727	0.313
35	IND 84-438	14.91	2.98	0.640	0.137
36	IND 84-461	13.70	0.85	0.603	0.100
37	IND 84-476	11.25	2.29	0.983	0.193
38	IND 85-503	21.02	4.20	0.853	0.163
	Mean	12.78	3.35	0.691	0.341
CD@5	T	0.362		0.043	
	G	1.578		0.187	
	T	2.232		0.254	

T and G denote Treatment and Genotype, respectively.

Selection for drought tolerance

Leaf area defined the canopy and moisture stress influences LAI negatively (Vasantha et al 2005). The mean leaf area reduction was 61% and the clones retaining better leaf area index include ISH 69, 100, 175 & 269 at peak stress period (Table 2). At the same time the leaf water potential a measure of leaf turgidity indicated less reduction in clones 110, 41,176, 58, 50, 43. Corresponding increase in osmotic potential in clones 41, 58, 50, 110, 43 suggested the strong osmoregulation features operating in these clones. However, the leaf area was moderate in these clones under stress. The ISH clones with higher LAI under stress also had

Table 2. Growth attributes of ISH clones during formative phase

S.No.	ISH clone	Main shoot height (cm)		No. of leaves		LAI (150 DAP)		Total dry matter (kg m^{-2})	
		Normal	**Drought**	**Normal**	**Drought**	**Normal**	**Drought**	**Normal**	**Drought**
1	ISH 1	128.6	78.6	10.3	9.3	3.27	0.79	1.239	0.387
2	ISH 9	131.6	73.3	7.6	6.3	2.55	0.67	1.550	0.681
3	ISH	130.0	82.3	8.6	5.6	4.33	1.02	2.695	0.421
4	ISH	127.6	97.6	7.0	5.3	2.33	1.12	1.402	0.541
5	ISH	131.3	74.3	8.3	6.3	3.21	1.02	1.499	0.553
6	ISH	155.3	104.0	8.3	6.6	2.74	0.86	1.237	0.435
7	ISH	108.6	77.0	7.0	5.6	2.79	0.82	1.633	0.585
8	ISH	132.3	93.6	9.6	6.6	3.10	1.13	1.550	0.513
9	ISH	144.6	100.0	8.6	5.0	2.73	1.85	1.421	0.860
1	ISH	149.3	111.3	7.6	5.6	2.43	1.74	1.359	1.065
1	ISH	92.6	72.6	6.0	5.0	1.86	1.14	0.863	0.315
1	ISH	108.0	90.6	6.0	5.3	1.50	0.59	1.077	0.485
1	ISH	119.6	73.0	8.6	5.0	1.73	1.09	0.963	0.461
1	ISH	113.3	96.3	7.0	6.0	1.57	0.54	0.684	0.254
1	ISH	133.0	100.0	8.6	6.6	1.96	0.50	0.803	0.432
1	ISH	133.3	106.3	6.3	6.0	2.53	1.12	2.211	0.839
1	ISH	145.6	100.3	6.0	5.6	4.88	1.51	1.922	0.801
1	ISH	139.6	104.0	6.6	5.3	3.89	1.38	1.768	0.598
1	ISH	157.0	104.3	6.6	5.3	4.39	1.19	1.545	0.697
2	ISH	162.6	106.3	6.6	5.6	3.14	1.35	2.633	0.747
	Mean	132.2	92.3	7.6	5.9	2.85	1.1	1.503	0.583
C	T	3.21		0.44		0.121		0.072	
@	G	10.17		1.42		0.383		0.227	
5	T×G	14.38		2.01		0.542		0.321	

T and G denote Treatment and Genotype, respectively.

moderately low water potential (more negative values) registered high main shoot height at grand growth phase i.e., post stress relief stage. The revival growth after stress termination is a key factor, which has not been much attended to. The revival growth is a compensation mechanism for the loss of growth experienced during stress.

Photosynthesis and transpiration was reduced by 77% and 62% in drought stress (Table.3). Change in leaf water potential was significant. Leaf water potential, representing the relative turgidity was appreciable in ISH 110, 41, 176, 23, 43, 50 and 58. A corresponding high osmotic potential was recorded in these clones suggesting a possible osmoregulation system operating under stress. Relative water content varied from 61% to 78% in drought and clones with least RWC also had very high osmotic potential. Turgour maintenance

Table 3. Physiological traits in ISH clones subjected to drought at formative phase

S.No.	**ISH Clone**	**Photosynthetic rate (µmol CO m^{-2}s^{-1})**		**Transpiration rate (mmol H O m^{-2}s^{-1})**		**Leaf water potential (MPa)**		**Osmotic potential (MPa)**		**RWC (%)**	
		N	D	N	D	N	D	N	D	N	D
1	ISH 1	21.4	11.52	0.640	0.283	-	-2.19	-	-1.35	86.2	63.5
2	ISH 9	20.9	0.91	0.787	0.073	-	-2.10	-	-1.15	87.4	70.6
3	ISH	17.9	3.80	0.450	0.153	-	-2.69	-	-1.71	89.2	70.0
4	ISH	20.1	3.46	0.683	0.083	-	-1.92	-	-1.27	88.8	75.8
5	ISH	19.0	8.07	0.727	0.323	-	-1.82	-	-1.09	87.7	70.2
6	ISH	20.3	5.17	0.697	0.280	-	-1.96	-	-1.23	85.4	65.1
7	ISH	22.5	2.94	0.723	0.217	-	-1.94	-	-1.15	79.7	73.1
8	ISH	22.4	2.40	0.713	0.403	-	-1.95	-	-1.21	87.9	72.8
9	ISH	22.3	4.24	0.643	0.307	-	-2.08	-	-1.35	80.2	71.5
10	ISH	17.4	6.36	0.650	0.363	-	-2.18	-	-1.31	84.3	69.3
11	ISH	17.4	7.51	0.423	0.303	-	-2.10	-	-1.13	84.2	68.9
12	ISH	14.3	5.14	0.350	0.270	-	-1.77	-	-1.19	85.1	78.5
13	ISH	18.4	4.86	0.513	0.237	-	-2.11	-	-1.35	81.5	64.6
14	ISH	18.3	4.92	0.490	0.327	-	-2.48	-	-1.46	85.4	67.8
15	ISH	16.9	5.30	0.583	0.243	-	-2.99	-	-1.84	85.5	61.5
16	ISH	21.5	3.89	0.610	0.200	-	-2.88	-	-1.19	-	-
17	ISH	21.7	2.51	0.503	0.183	-	-2.28	-	-1.32	85.3	63.0
18	ISH	21.6	4.47	0.677	0.190	-	-1.83	-	-1.33	85.8	62.6
19	ISH	22.1	1.16	0.517	0.043	-	-2.14	-	-1.36	-	-
20	ISH	21.2	0.33	0.573	0.010	-	-2.34	-	-1.46	86.6	64.5
	Mean	19.9	4.46	0.598	0.225	-	-2.18	-	-1.32	85.3	68.5
C	T	0.29		0.025		0.0		0.01		3.199	
@	G	0.91		0.080		0.0		0.03		1.012	
5	T×G	1.29		0.113		0.0		0.04		4.525	

N and D denote Normal and Drought treatments, respectively. T and G denote reatment and Genotype, respectively.

is controlled by accumulated cell compatible solutes leading to osmotic adjustment or by cell wall bio-physical traits, which can be regulated under stress. Osmotic adjustment can be driven by the uptake of ions from soil such as potassium or by metabolically derived cell compatible solutes. These are not very complex functions (Blum 2009). Main shoot height, No. of leaves and dry matter production during stress differed significantly among the ISH clones and G×T interaction was also significant, implying the strong influence of moisture stress at formative phase on the productive physiological processes of the crop.

Relatively simple heritable constitutive plant morphological and developmental traits can have a decisive effect on crop performance and productivity under drought stress. Most constitutive traits that impact drought resistance, again, operate mainly through dehydration avoidance and effective use of water (EUW). Examples are root depth, plant leaf area as determined by leaf size or tillering, early flowering, leaf surface properties and even certain morphological features of the reproductive system, which influence fertility under stress (Blum 2011). When drought resistance is probed by functional genomics through the study of stress-responsive genes, such simple albeit effective constitutive traits are ignored (Blum 2011). In practical terms the leaf area index, leaf rolling (quantifiable), leaf blooms are some valuable traits in this regard.

Cane yield and juice quality data, depicts no specific trend (Table 4). ISH 23 and ISH 41, had severe impact on cane yield under stress, while in ISH100, ISH 110 and ISH175 the yield reduction was meagre and in ISH43 and ISH118 the yield was stable in both normal and stress condition. Selection based on yield alone might eliminate

Table 4. Cane yield and juice quality traits of ISH clones under drought stress

S.No	Variety	Sucrose %		Purity %		NMC		Cane yield	
ISH clones		Normal	Droug	Normal	Drought	Normal	Droug	Normal	Drought
1	ISH 1	20.50	17.00	89.68	84.70	93.98	69.91	97.18	49.37
2	ISH 9	16.65	17.36	85.82	87.27	108.33	83.79	89.65	63.52
3	ISH 12	16.27	13.95	86.96	83.79	112.96	68.98	69.28	29.63
4	ISH 23	17.85	16.55	89.01	87.49	93.52	62.03	60.94	46.26
5	ISH 41	21.29	18.27	90.20	89.13	78.70	64.81	72.44	39.74
6	ISH 43	18.23	17.63	87.05	86.82	92.59	67.31	79.68	56.13
7	ISH 50	18.85	18.06	89.10	86.01	86.11	60.18	72.00	29.76
8	ISH 58	17.71	18.76	90.08	89.78	93.98	85.74	84.48	76.30
9	ISH 69	17.48	18.65	89.41	90.78	62.50	43.05	59.31	34.35
10	ISH 100	19.21	16.83	88.95	86.22	78.24	65.74	72.02	54.59
11	ISH 101	14.37	15.36	84.21	84.41	72.22	48.14	55.96	30.67
12	ISH 110	19.83	17.82	91.85	90.03	110.18	87.13	102.44	76.85
13	ISH 111	11.88	10.64	57.21	74.86	55.55	49.07	69.68	53.63
14	ISH 118	12.57	13.83	80.13	83.90	76.38	51.39	63.80	39.06
15	ISH 129	16.99	15.69	84.27	84.02	99.53	74.53	94.87	52.00
16	ISH 175	10.04	9.87	76.94	73.89	121.76	84.35	81.04	54.63
17	ISH 176	15.44	13.70	83.38	79.86	94.44	63.51	103.07	46.67
18	ISH 269	20.50	17.00	89.68	84.70	93.98	69.91	97.18	49.37
CD @	Mean	16.74	15.84	84.86	84.78	92.69	67.11	80.42	50.30
	T	0.70		NS		10.57		10.81	
	G	2.10		8.22		31.74		NS	
	TxG	NS		NS		NS		NS	

T and G denote Treatment and Genotype, respectively.

genuine tolerant gene pool as ISH types represent crosses involving different species. Various physiological traits indicated the similarity of ISH clones with species clones, in expression of several adaptive features like osmoregulation and conductance behaviour under drought stress. Despite having significant G×T interaction, many of the traits studied did not show appreciable association with yield attributes but for alone association of juice sucrose with relative water content in drought stress (Fig.1).

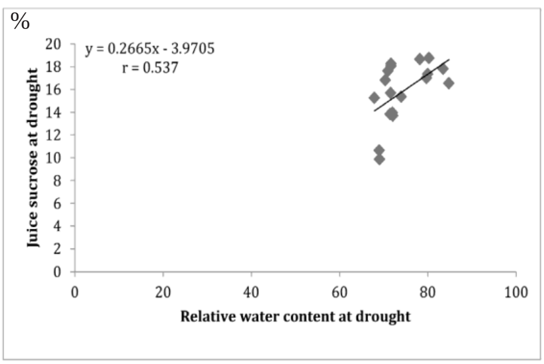

Fig.1. Association of relative water content with juice sucrose percentage under drought stress

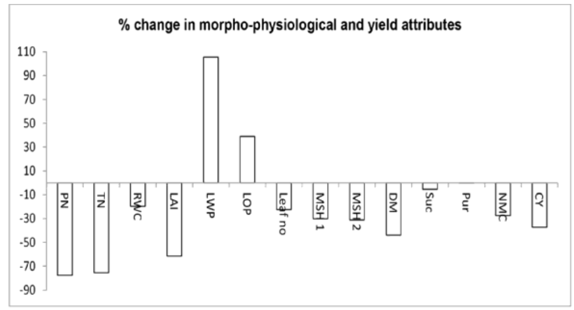

Fig.2. Influence of formative phase drought on growth, physiology and yield traits. PN: photosynthetic rate, TN: transpiration rate, RWC: relative water content, LAI: leaf area index, LWP: leaf water potential, LOP: leaf osmotic potential, Leaf no: leaf number, MSH1: main shoot heightat 150 DAP , MSH2: main shoot height at 210 DAP, DM: dry matter, Suc: juice sucrose%, Pur: juice purity%, NMC: number of millable canes, CY: cane yield

Statistically significant data pertaining to different traits under stress indicate the usefulness of these parameters for identifying tolerant types (Table 5 a, b and Fig.2). Many of the alterations exist as transient expression and are returned to normalcy with the relief of stress. Only few traits like LAI, dry matter production ultimately decides the successes

Table 5a.Results of two-way ANOVA (F-value) showing the effects of drought on physiological and morphological traits in ISH genotypes

Source	RWC	MSI	LAI	WP	OP	Pn	Tn	Leaf no.	Leaf area	Dry matter
Treatment (T)	1.012**	108.97**	99.64**	47022.37**	23227.15**	290.96**	692.64**	524.21**	560.17**	649.32**
Genotype (G)	3.199**	-	11.98**	289.24**	677.02**	0.474	5.85**	13.75**	12.96**	16.86**
TxG	4.525**	-	4.98**	267.36**	200.97**		11.63**	7.31**	7.22**	9.34**
Error										
Total										

** denotes significance at 0.05 probability level. RWC: relative water content, MSI: membrane stability index, LAI: leaf area index, WP: water potential, OP: osmotic potential, Pn: photosynthetic rate, Tn: transpiration rate, Leaf no:

Table 5b.Results of two-way ANOVA (F-value) showing the effects of drought on morphological traits and juice quality in ISH genotypes

Source	Main Shoot height (1)	Main shoot height (2)	NMC	Single cane weight	Inter- node / Cane length crose cane Cane yield Su- %				Puri- ty %	CCS Yield
Treat ment (T)	608.65**	640.36**	24.12*	4.19**	62.	207.77**	32.0	6.75*	0.00	2.174
Gen- otyp (G)	15.61**	18.41**	2.18**	32.77**	1.6	6.96**	1.77	13.7	4.44*	42.07
TxG	3.30**	4.33**	0.33	-	4.6	5.28**	0.34	1.02	0.74	-
Error										
Total										

** denotes significance at 0.05 probability level.

of a genotype under stress condition. Drought impacted several traits studied and screening the wild/ wide germplasm pool requires judicious application of these tools to identify mechanisms of drought tolerance apart from their impact on yield. However, screening commercial hybrids (Co canes) where minimum economic loss can be allowed, yield stability assumes importance and therefore different yardstick needs to be applied for screening different sets of sugarcane material.

Based upon the physiological characteristics, genotypes: Gungera, 57 NG 73, IJ 76-412, IJ 76-564 and Caledonia Ribbon among *S. officinarum*; Nargori, Lalri, Mangasic, MatnaShaj and ParariaShaj among *S. barberi*, NG 77-79, 57 NG 19, NG 77-146, NG 77-23, 57 NG 27 and NG 77-38 among *S. robustum*, Mcilkrum, Reha, Lalkhadi, Kalkya and Kheli among. *S. sinense*, TS 76-216, US 56-20-1, Taiwan 96, Pamba, Ponape-1, SES 32A, IND 90-805, IND 90-796, IND 85-503, S.spont, Tabongo and IND 84-351 among *S. spontaneum*, ISH 9, 23, 41, 58, 100, 110, 118 and 175 among ISH types were found to be typical drought resistant types (Table 6a). The

Table6a. *Saccharum* species clones tolerant to drought stress

S.No. *Saccharum*	Genotypes tolerant to drought stress
1 *S. officinarum* L. (5)	Gungera, 57 NG 73, IJ 76-412, IJ 76-564, Caledonia Ribbon
2. *S. robustum*(6)	NG 77-79, 57 NG - 19, NG 77-146, NG 77-23, 57 NG - 27, NG 77-
3.*S. barberi* (5)	Nargori, Lalri, Manga sic, MatnaShaj, PararíaShaj
4.*S. spontaneum* (12)	Ts 76-216, Us 56-20-1, Taiwan 96, Pamba, Ponape-1, SES 32A, IND 90-805,IND 90-796, IND 85-503, S.spont, Tabongo, IND 84-351
5.*S. sinense* (5)	Mcilkrum, Reha, Lalkhadi, Kalkya, Kheli
6.ISH clones (8)	ISH 9, ISH 23, ISH 41, ISH 58, ISH 100, ISH 110, ISH 118, ISH 175

Table 6b. *Saccharum* species clones tolerant to salinity stress

S.No.	*Saccharum* stress species	Genotypes tolerant to salinity
1.	*S. officinarum* L. (140)	Blanche reunion, Chapina, Fiji -28, Tjiing Bali, Green german, Horne,Hawaii-original -24,Hina Hina-18, IJ 76- 315, IJ 76- 316, IJ 76- 422, IJ 76- 470, Keong, Koelz 1132, Kaludaiboothan, Luzon white, Manteiga 1295, Manteiga 1585, Manjiri red, Maxwell, Mogali, Miavoi, Mikokio- 44, Maur-55 str, Mongetgayam, NC -15, NC -33, NG 21 -12, Local red, Waxy red, NG 77-67, NG 77-70, NG 77- 92, NG 21-42, 21 NG – 2, 21 NG - 5, 21 NG - 6, 21 NG - 21, 28 NG 12, 28 NG 13, 28 NG 21, 28 NG 32, 28 NG 54, 28 NG 68, 28 NG 72, 28 NG 80, 28 NG 87, 28 NG 110, 28 NG 206 , 28 NG 210, 28 NG 211, 28 NG 273, 28 NG 287, 51 NG 11, 51 NG 12, 51 NG 14, 51 NG 53, 51 NG 59, 51 NG 77, 51 NG 147, 51 NG 159, 51 NG 287, 57 NG 26, 57 NG 57, 57 NG 67, 57 NG 68, 57 NG 100, 57 NG 126, 57 NG 71, 57 NG 159, 57 NG 166, 57 NG 172, 57 NG 184, 57 NG 191, 57 NG 196, 57 NG 198, 57 NG 199, 57 NG 203, 57 NG 237, 57 NG 241, 57 NG 272, 77 NG 15, 77 NG 18, 77 NG 31, 77 NG 32, 77 NG 65, 77 NG 66, 77 NG 117, Old Jamaica, Ogle's selection,Oramboo, Otaheite, Pynmana ribbon, Pattacheruku, Pakaweli -2, Patta Patti, Pohina -51, Selemibali, Shamsara, Sinense, Sarawak unknown, Tahiti -3, Tibbomird, UB – I, UB – 14, White transparent, Zwart manila, Tjerpering, Koelz 11132, 57 NG 78, 57 NG 215, 57 NG 50, 57 NG 212, 57 NG 110, Poona, Caledonia, Fiji -10, IM 76 - 360, IM 76- 252, Katha, Uba white, Ansali, 77 NG 242, Rayada, IJ 76 543, IJ 76 522, IJ 76 556, IJ 76 470, IJ 76 418, IJ 76 316, IJ 76 315, IM 76- 507, IM 76 – 253, IM 76 - 232, Black Fiji, IK 76- 31, 77 NG 1, 77 NG 221, ZwartCheribon
2.	*S. robustum*(15)	28 NG 219, 28 NG 251, 57 NG 6, 57 NG 201, 77 NG- 10, 77 NG- 26, 77 NG-34,77 NG - 55, 77 NG - 136, 77 NG - 160, 77 NG - 167, 77 NG - 170, 77 NG - 221, 77 NG - 237, 57 NG 231
3.	*S. barberi*(12)	Khakai, Khatuia -124, Kewali 14G, Kuswarottur, Lalri,Nargori, Pansahi, Path- ri , Uba seedling, Reha
4.	IND clones(14)	IND 81- 46, IND 81- 202, IND 81- 93, IND 81- 95, IND 82- 247,IND 82- 254, IND 82-260, IND 82-319, IND 82-325, IND 84- 406,IND 84- 450, IND 84-400, IND 84- 404, IND 84- 405

present study has demonstrated and documented various physiological attributes related to drought tolerance in sugarcane and identified variations among species of sugarcane that possess inherent tolerant features to drought. The selected types from this study have potential to serve as the best parental stocks/ breeding materials for evolving drought resistant sugarcane varieties.

Selection for salinity tolerance

Data on germination percentage for assessing the crop establishment, cane weight, length and cane yield were utilised for short listing the genotypes. Percent germination, cane yield under saline condition and relative cane yield were considered to rate clones for tolerance to salinity. The clones with higher reduction in germination cane yield and relative cane yield (>50%) were rated as susceptible, while the clones with <50% reduction were rated as tolerant to salinity in on drought. In the world collection of sugarcane germplasm several *Saccharum* species were reported to be tolerant to salinity (Ramana Rao et al. 1985). The present report can serve as preliminary screening based on very few traits, to shortlist the large germplasm lines. Further detailed evaluation can be carried out with these shortlisted types to locate tolerant genotypes useful as parental stock and also useful traits for screening purpose.

Out of 391 clones of *S. officinarum* L., 140 types were found to be tolerant to salinity. Out of 58 types tested from *S. robustum*, 15 were found to be tolerant and out of 39 *S. barberi* types, 12 were identified as salinity tolerant clones (Table. 6b).

Three of the germplasm types*viz*., Nargori, Lalri and Caledonia ribbon showed tolerant reaction to both drought and salinity. Four clones tolerant to drought viz., 57NG73, Gungera, Matnashaj and Parariashaj, were found to be sensitive to salinity, implying complex mechanisms operating for tolerance behaviour are available in the germplasm for commercial exploitation.

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