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Research Article

IMPACT OF WATER STRESS ON MANIFESTATION OF CANE YIELD COMPONENTS AND PHYSIOLOGICAL TRAITS IN SUGARCANE (*Saccharum* Spp. HYBRID COMPLEX)

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Abstract- Thirty sugarcane (*Saccharum* spp. hybrid complex) elite clones/varieties were evaluated for different cane yield components and physiological traits under normal (E_1) and water stressed (E_2) conditions. Analysis of variance revealed significant difference for traits studied in both the environments. Water stress imposed led to significant reduction in cane yield and component traits. Germination (%) in E_2 environment exhibited a mean reduction of 34.19 % with a range of (19.10-48.98%) among different varieties and clones. However, number of millable canes, stalk length, stalk diameter and single cane weight showed the variable pattern for drought susceptibility index (DSI) worked out among different cultivars of sugarcane. For physiological traits, the mean percent decrease in relative water content (RWC) at 120 days, specific leaf weight, total chlorophyll content delineate different indices with respect to different clones/varieties. Based on cane yield, minimum DSI was exhibited by the clone ISH 148 (0.51) closely followed by ISH07 (0.56), ISH 135 (0. 58), KV2012-4 (0.66), ISH159 (0.69), KV2012-2 (0.70) and KV2012-3 (0.74) and all these clones/varieties were categorized as drought tolerant while KV2012-5, CoPb93, Co238, KV2012-2, CoPb12181 and CoPb94 had DSI (0.75-1.00) were categorized as intermediate and rest were droughts susceptible in terms of cane yield. The clones with desirable agro-physiological traits with low DSI needs to be evaluated on large scale under target environments for their specific adaptation.

Key words- Sugarcane, water stress, germination, stomatal frequency, cane yield, Chlorophyll content.

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Introduction

Water stress is a principal environmental limitation of sugarcane production. It occurs due to the consequence of either contagious water resource or transitory rainless periods cause significant yield reductions and greatly restrict the cultivation of sugarcane. Drought is the most important limiting factor for crop production and it is becoming an increasingly severe problem in many regions of the world [1] and it is also important environmental stress factors limiting sugarcane production worldwide [2]. One of the main problems associated with the development of drought tolerant varieties is the difficulty to identify single traits that can be used for genotype selection [3]. Apart from that, the information on drought response among cultivars is generally gained after they have been released for commercial production [4]. To overcome this barrier selection of drought tolerant cultivar is an important task. Therefore, for sugarcane crop, efforts have to be concentrated on agronomic and physiological traits, which could be suited to water stress conditions or be correlated to drought tolerance and could be used for development of new varieties [5]. Further, in sugarcane physiological and morphological traits responsible for improved cane yield, sucrose content and resource use have remained poorly understood [6, 7]. Researchers have also linked various physiological responses of plants to drought with their tolerance with a few genotypes [5] like drying of older leaves, stunted growth of culm resulting in dwarf canopy and ultimately the lower cane yields [2]. Therefore, the present study was aimed to assess the manifestation of some agro-physiological traits of sugarcane under water stress conditions that can be used as selection criteria for identification/development of sugarcane varieties for water stress conditions.

Materials and Methods

The present investigation was carried out at experimental area of Punjab Agricultural University, Regional Research Station (RRS) Kapurthala, located at of 31.38°N longitude and 75.38°E latitude at an elevation of 225 m above mean sea level. It is having clay loam soils with pH of 8.3-8.7 representing sub-tropical conditions of the country. During the study period a total rainfall of 63.17 mm was received with mean maximum and minimum temperatures of 30.72°C and 16.36, respectively [Fig-1]. The experimental plant material consisted of 30 diverse clones of sugarcane comprising nine commercial varieties (Co 0238, CoJ 88, CoS 8436, CoPb 91, CoPb 92, CoPb 93, Co 0118, CoJ 85 and CoJ 64), twelve local elite clones (CoPb 13181, CoPb 10181, CoPb 13182, CoPb 11214, CoPb 11211, CoPb 12181, CoPb 12182, CoPb 14212, CoPb 14211, CoPb12212 and L818/07), five new introductions (KV2012-1, KV2012-2, KV2012-3, KV2012-4 and KV2012-5) and four ISH clones *viz.* ISH148, ISH159, ISH135 and ISH07 procured from different sources. All the clones/varieties were planted during spring 2016-17 in the first week of March in a randomized complete block design with two replications under two water regimes *viz.,* normal (E_1) and water stress (E_2) conditions. In water stressed (E_2) environment, irrigation was suspended for 3 weeks interval at critical growth stages of sugarcane *viz.* germination, tillering and grand growth stage (formative stage). Each genotype was represented by a plot of four rows of 6m length each with inter row spacing of 90 cm. The cane seed rate was 12 buds per running metre row in both the environments. The standard agronomic practices as per package of practices of the PAU for kharif field crops were followed to raise the ideal crop stand except irrigation in stressed condition (E_2). Data were recorded for different cane yield components traits like

germination (%), tillers at 240 DAP ('000/ha), no. of millable canes at maturity (NMC, '000/ha), stalk length (cm), stalk diameter (cm), single cane weight (kg), cane yield (t/ha) following standard procedures. Physiological traits namely relative water content (RWC) (%) at 120 DAP as per Turner [8], total chlorophyll (mg/l) as suggested by [9], stomatal frequency (no.), specific leaf weight (g) following standard procedures under both the environments as follow:

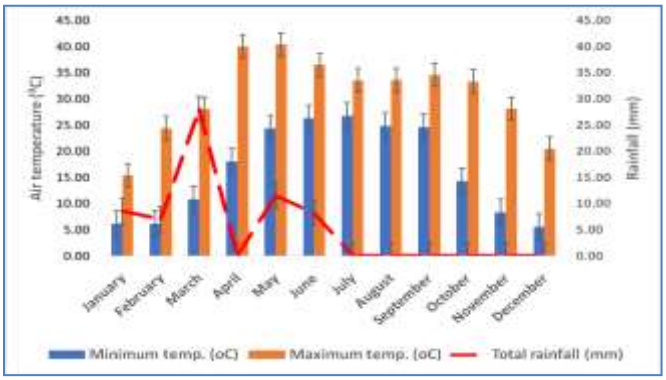

Fig-1 Mean monthly maximum and minimum air temperatures along with rainfall (mm) recorded during crop season at the site

Relative water content (%)

Leaves (120 DAP) were collected from five randomly selected plants from each clone in each replication. 10g leaf discs (fresh weight) from each sample were submerged in test tubes for 6 hrs. Excess water removed without putting any pressure and then saturated weight recorded. Dry weight recorded after drying the discs at 70°C for 72 hr. From these data, RWC was calculated as follows:

$$RLWC = \frac{\text{Fresh weight - Dry weight}}{\text{Saturated weight - Dry weight}} \times 100$$

Total chlorophyll content (mg/l)

Total chlorophyll content was estimated using five leaves (seven month old plant) by following dimethyl sulphoxide (DMSO) method and readings were taken using spectrophotometer at 665 nm and 648 nm wavelengths along with blank. Total Chlorophyll concentration was calculated as mg /g fresh weight by the following formulae (Barnes et al., [10] and expressed as mg/l.

Total chlorophyll (mg/g F.W) = (7.49 A665 + 20.34 A648)

Where: A665 = absorption value at 665 nm, A648= absorption value at 648 nm.

Stomatal frequency (no.):

Stomatal frequency (five samples leaves) of peeled off leaf membrane (by applying thinner followed by cello tape) was calculated by counting the number of stomata per microscopic field of the compound microscope. The mean of four microscopic fields considered as stomatal frequency of the genotype under study in both the environments and expressed as number of stomata per microscopic field.

Specific leaf weight (SLW) (g)

For SLW, all the leaves of a genotype from each plot (at 120 days after planting) were counted in field and kept in oven at 50°C for 24 hours. The dry weight of oven dried leaves was taken and specific leaf weight (SLW) was calculated using the following formula:

$$\text{Specific leaf weight (g)} = \frac{\text{Dry weight of total leaves per plant (g)}}{\text{Total no. of leaves per plant}}$$

Drought susceptible index (DSI)

DSI for cane yield was worked out from average performance of clone/ varieties for a trait in water stress (E_2) and normal (E_1) environments as per Fischer and Maurer [11] used to categorize the test clones as tolerant (DSI <0.75), intermediate (DSI 0.75-1.00) and sensitive (DSI >1.00) under water stress environment (E_2).

Drought susceptibility index (DSI) was calculated as follow:

$$S = \frac{1 - Y/Yp}{D}$$

Where,

Y - Performance of a trait of a given genotype under stress,

Yp - Performance of a trait of the same genotype under normal

D- Drought intensity which is calculated as

$$D = 1 - \frac{Xd}{Xp}$$

Xd - Mean performance of a trait for all genotypes under stress, and

Xp -Mean performance of a trait for all genotypes under normal.

Statistical analysis

The mean values of all the traits from each genotype in each replication were used for analysis of variance as per Fisher [12]. The analysis of the experimental design was carried out with CPCS1 software [13] and interpretations were made accordingly.

Result and Discussion

Analysis of variance (ANOVA)

The analysis of variance under normal (E_1) and water stressed (E_2) conditions was carried out for seven cane yield component traits and four physiological parameters [Table-1]. Mean sum of squares for genotypes were found significant for all cane yield component traits recorded in this study under both the environments, except for stalk length under normal (E_1) environment. It also revealed significant difference among clones and varieties used in the study for different traits [Table-1]. Significant variability for cane and component traits has also been documented [14]. Sanghera *et al* [15] reported highly significant differences among 13 sugarcane clones for the characters (germination (%) at 45 days, number of tillers at 120 days, stalk length, stalk diameter, NMC and cane yield) under normal environment. Similarly, Khan *et al* [16] reported that the mean performance of the genotypes for cane yield and its components showed significant ($p \leq 0.05$) differences among the clones. Significant differences have also been observed among the sugarcane genotypes for single stalk weight and cane yield under prolonged drought stress [17].

Manifestation of cane yield component traits and their drought susceptibility indices

Mean germination percentage was 43.53 (%) under normal (E_1) environment and 28.44 (%) under water stress (E_2) environment. The per cent decrease in germination in E_2 environment was 34.19 % with maximum reduction for the L818/07 (48.98%) and minimum for the genotype ISH135 (19.10%). The DSI values worked out for different genotypes in study ranged from 0.55 to 1.41 with prevailed drought intensity (D =0.35). Seven genotypes namely ISH135, ISH148, KV2012-2, ISH07, ISH159, KV2012-5, KV202-4 were found drought tolerant (S<0.75), whereas 8 genotypes KV2012-1, KV2012-3, CoJ64, CoPb93, CoPb12181, CoPb12182, CoPb14212 and CoPb14211 were intermediate (S = 0.75-1.00). The remaining genotypes were found to be drought susceptible (S>1.00) [Table-2]. Number of shoots at 240 days in the present study had a mean value of 127.00 (000/ha) under normal (E_1) environment and 84.00 (000/ha) under water stress (E_2) environment. The reduction percentage under E_2 was 33.79 % for this trait. Highest DSI for it was recorded for the genotypes CoPb12212 and L818/07 (1.43) and lowest for ISH135 (0.54) [Table-2]. About 3 genotypes were found least affected, 12 intermediate and remaining 15 were most affected by drought for this trait. Sugarcane clones/varieties under study exhibited mean percentage decrease of 33.86% under water stress (E_2) environment for number of tillers at 240 days. DSI values were ranged from 0.59 to 1.41 with the prevailed drought intensity of 0.34. The genotype ISH148 and ISH07 (0.59) had

minimum DSI value followed by ISH135 (0.60), ISH159 (0.65), KV2012-2 (0.70) and KV2012-5 (0.74). The genotypes KV2012-1, KV2012-3, KV2012-4, Co238 and CoPb14211 were intermediate in their reaction to water stress [Table-2]. These results were similar as reported by Wagih *et al* [18], who reported significant reduction in the number of tillers under water stress conditions among sugarcane clones. In case of NMC, clone ISH148 (0.50) exhibited minimum DSI value followed by ISH159 (0.54), ISH135 (0.57), ISH07 (0.62), KV2012-2 (0.62), KV2012-5 (0.69) and KV2012-4 (0.70). The percent reduction under E_2 for this trait ranged from 17.54 to 50.00 with mean value of 34.79 %. The maximum percent reduction under E_2 was recorded for the clone L818/07 (50.00 %) followed by CoPb13182 (49.22 %), CoPb12212 (48.85 %) and CoJ88 (48.62) and minimum for the ISH148 (17.54 %) followed by ISH159 (18.75 %), ISH135 (19.83 %) and KV2012-2 (21.59 %) [Table-2]. On the basis of DSI values and percent reduction in mean under E_2 clones ISH148, ISH135, ISH159, ISH07, KV2012-2 and KV2012-5 were categorized as drought tolerant for this trait. Pawar *et al* [19] found high number of millable canes under moisture stress conditions and proved these genotypes to withstand moisture stress. Stalk length is a very important trait that directly effects cane yield. Under normal (E_1) environment, this trait ranged from 192.50 to 308.33 cm and from 120 .00 to 240.00 cm under water stress (E_2) environment. Percent reduction under E_2 for this trait was ranged from 17.72 to 47.06 with, maximum value exhibited by clone CoPb10181 (47.06 %) and minimum value was recorded for the clone ISH148 (17.72 %). DSI values were ranged from 0.53 to 1.42 for this trait. Maximum DSI value was exhibited by the clone CoPb10181 (1.42) followed by clone L818/07 (1.36), CoJ88 (1.26) and CoPb13182 (1.26) while the minimum DSI values were recorded for the clone ISH148 (0.53) followed by ISH07 (0.59), KV2012-4 (0.62) and KV2012-5 (0.67) [Table-2].

Table-1 *Analysis of variance for different cane yield components and physiological traits in sugarcane under normal (E_1) and water stress (E_2) environments*

S. No.	Traits	Mean Squares					
	S.V.	Replications		Varieties/Clones		Error	
	Df	1		29		29	
	Env.	E_1	E_2	E_1	E_2	E_1	E_2
	Cane yield and component traits						
1	Germination (%)	2.59	60.11	220.15*	100.64*	45.23	17.30
2	No. of tillers at 240 days (000/ha)	248.07	3226.65	738.14*	368.78*	206.48	68.32
3	No. of millable canes (000/ha)	1075.27	170.02	628.00*	357.33*	166.27	107.02
4	Stalk length (cm)	400.53	11070.36	1417.5	1485.66*	482.93	186.59
5	Stalk diameter (cm)	0.01	0.81	0.17*	0.10*	0.04	0.02
6	Single cane weight (kg)	0.16	0.03	0.30*	0.22*	0.05	0.02
7	Cane yield (t/ha)	32.27	240	433.6*	238.45*	50.47	10.76
	Physiological traits						
1	Relative water content (%) at 120 DAP	0.04	136.68	110.32*	136.01*	30.57	69.65
2	Total chlorophyll (mg/l)	0.99	1.11	1.78*	1.45*	0.84	0.57
3	Stomatal frequency (no.)	0.27	35.27	25.12	22.92	5.68	4.44
4	Specific leaf weight (g)	0.25	2.74	2.25*	1.76*	1.19	0.28

* Significant at 5% level of significance

Table-2 *Drought Susceptibility index (DSI), mean and percent decrease under E_2 of sugarcane genotypes for cane yield components under normal (E_1) and water stress (E_2) environments*

Sr. No.	Genotype	Germination (%)				No. of tillers at 240 days (000/ha)				NMC (000/ha)			
		Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI
1	CoPb10181	58.00	30.00	48.28	1.39	132.00	91.00	31.06	0.90	119.00	69.00	42.02	1.21
2	CoPb13181	55.00	33.74	38.65	1.12	120.00	81.00	32.50	0.94	111.00	69.00	37.84	1.09
3	CoPb13182	27.36	17.62	35.60	1.03	134.00	74.00	44.78	1.30	128.00	65.00	49.22	1.41
4	CoPb13183	65.00	40.50	37.69	1.09	141.00	94.00	33.33	0.97	122.00	73.00	40.16	1.15
5	CoPb11214	54.67	32.00	41.47	1.20	139.00	80.00	42.45	1.23	116.00	65.00	43.97	1.26
6	CoPb11211	38.25	21.00	45.10	1.30	83.00	51.00	38.55	1.12	77.00	47.00	38.96	1.12
7	CoPb12181	32.22	22.32	30.73	0.89	113.00	72.00	36.28	1.05	100.00	68.00	32.00	0.92
8	CoPb12182	29.03	19.97	31.21	0.90	120.00	79.00	34.17	0.99	104.00	69.00	33.65	0.97
9	CoPb14212	33.00	23.00	30.30	0.87	111.00	72.00	35.14	1.02	107.00	69.00	35.51	1.02
10	CoPb14211	40.55	27.80	31.44	0.91	116.00	85.00	26.72	0.78	114.00	75.00	34.21	0.98
11	CoPb12212	38.06	22.19	41.70	1.20	150.00	80.00	46.67	1.36	131.00	67.00	48.85	1.40
12	L 818/07	51.80	26.43	48.98	1.41	148.00	76.00	48.65	1.41	144.00	72.00	50.00	1.44
13	KV2012- 1	28.33	21.00	25.87	0.75	107.00	74.00	30.84	0.90	97.00	69.00	28.87	0.83
14	KV2012- 2	36.39	28.00	23.06	0.67	95.00	72.00	24.21	0.70	88.00	69.00	21.59	0.62
15	KV2012- 3	39.44	29.00	26.47	0.76	131.00	94.00	28.24	0.82	127.00	93.00	26.77	0.77
16	KV2012-4	37.64	28.00	25.61	0.74	92.00	65.00	29.35	0.85	86.00	65.00	24.42	0.70
17	KV2012- 5	52.08	39.00	25.12	0.72	129.00	96.00	25.58	0.74	120.00	91.00	24.17	0.69
18	ISH 148	41.00	33.00	19.51	0.56	124.00	99.00	20.16	0.59	114.00	94.00	17.54	0.50
19	ISH 07	43.91	34.00	22.57	0.65	108.00	86.00	20.37	0.59	106.00	83.00	21.70	0.62
20	ISH 135	46.97	38.00	19.10	0.55	121.00	96.00	20.66	0.60	116.00	93.00	19.83	0.57
21	ISH 159	45.14	35.00	22.46	0.65	120.00	93.00	22.50	0.65	112.00	91.00	18.75	0.54
22	Co 238	42.78	31.00	27.54	0.79	129.00	92.00	28.68	0.83	125.00	88.00	29.60	0.85
23	CoJ88	32.64	17.50	46.38	1.34	110.00	58.00	47.27	1.37	109.00	56.00	48.62	1.40
24	CoS8436	47.02	28.00	40.45	1.17	118.00	65.00	44.92	1.30	108.00	63.00	41.67	1.20
25	CoPb91	39.53	21.00	46.88	1.35	99.00	62.00	37.37	1.09	81.00	48.00	40.74	1.17
26	Co 118	50.97	28.00	45.07	1.30	121.00	69.00	42.98	1.25	120.00	67.00	44.17	1.27
27	CoJ85	32.78	19.36	40.94	1.18	106.00	70.00	33.96	0.99	94.00	58.00	38.30	1.10
28	CoJ64	67.91	45.00	33.74	0.97	161.00	104.00	35.40	1.12	146.00	94.00	35.62	1.02
29	CoPb92	51.80	28.60	44.79	1.29	152.00	94.00	38.16	1.11	146.00	89.00	39.04	1.12
30	CoPb93	46.86	33.28	28.98	0.84	106.00	69.00	34.91	1.01	100.00	67.00	33.00	0.95
	GM	43.53	28.44	34.19	0.98	122.00	80.00	33.86	0.98	112.13	72.88	34.79	0.99
	Range	27.36-67.91	17.50-45.00	19.10-48.98	0.50-1.41	83.00-161.00	51.00-104.00	20.16-48.65	0.59-1.41	77.00-146.00	47.00-94.00	17.54-50.00	0.50-1.44

Table-2 *contd.*

Sr. No.	Genotype	Stalk length (cm)				Stalk diameter (cm)				Single cane weight (kg)				Cane yield (t/ha)			
		Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI
1	CoPb10181	283.33	150.00	47.06	1.42	2.90	1.64	43.45	1.31	2.02	1.23	39.11	1.22	110.00	64.31	41.54	1.27
2	CoPb13181	296.67	193.17	34.89	1.05	2.43	1.64	32.51	0.98	1.71	1.12	34.50	1.08	83.33	57.10	31.48	0.97
3	CoPb13182	303.33	176.20	41.91	1.26	2.50	1.60	36.00	1.09	1.52	0.98	35.53	1.11	79.69	51.39	35.51	1.09
4	CoPb13183	283.33	173.59	38.73	1.17	2.33	1.61	30.90	0.93	1.26	0.80	36.51	1.14	72.05	41.67	42.17	1.29
5	CoPb11214	246.67	140.00	43.24	1.30	2.17	1.21	44.24	1.34	0.99	0.52	47.47	1.48	68.75	36.46	46.97	1.44
6	CoPb11211	263.33	156.00	40.76	1.23	2.63	1.59	39.54	1.20	1.57	0.89	43.31	1.35	48.78	25.42	47.89	1.47
7	CoPb12181	259.17	174.90	32.52	0.98	2.25	1.57	30.22	0.91	1.07	0.67	37.38	1.17	54.51	38.19	29.94	0.92
8	CoPb12182	277.50	180.12	35.09	1.06	2.38	1.66	30.25	0.92	1.24	0.92	25.81	0.81	65.97	43.40	34.21	1.05
9	CoPb14212	240.83	176.20	26.84	0.81	2.08	1.50	27.88	0.84	0.75	0.51	32.00	1.00	57.12	38.19	33.14	1.02
10	CoPb14211	263.33	189.26	28.13	0.85	2.17	1.39	35.94	1.09	0.91	0.60	34.07	1.07	63.72	41.88	34.27	1.05
11	CoPb12212	292.50	180.12	38.42	1.16	2.52	1.54	38.89	1.18	1.54	1.01	34.42	1.08	82.64	53.84	34.85	1.07
12	L 818/07	255.50	140.00	45.21	1.36	2.00	1.02	49.00	1.48	0.92	0.48	47.83	1.50	96.18	52.08	45.85	1.41
13	KV2012- 1	296.83	220.00	25.88	0.78	2.67	1.93	27.72	0.84	1.84	1.40	23.91	0.75	91.49	65.97	27.89	0.86
14	KV2012- 2	278.33	210.00	24.55	0.74	2.75	1.96	28.73	0.87	1.74	1.35	22.41	0.70	76.39	59.03	22.73	0.70
15	KV2012- 3	253.50	190.00	25.05	0.75	2.43	1.85	23.87	0.72	1.99	1.52	23.62	0.74	100.69	76.39	24.13	0.74
16	KV2012-4	266.67	212.00	20.50	0.62	2.58	1.96	24.03	0.73	1.55	1.16	25.16	0.79	77.43	60.76	21.53	0.66
17	KV2012- 5	308.33	240.00	22.16	0.67	2.53	1.89	25.30	0.77	1.65	1.25	24.24	0.76	86.63	64.24	25.85	0.79
18	ISH 148	237.00	195.00	17.72	0.53	1.88	1.53	18.62	0.56	1.68	1.36	19.05	0.60	58.33	48.61	16.66	0.51
19	ISH 07	269.17	216.00	19.75	0.59	2.23	1.72	22.87	0.69	1.78	1.42	20.22	0.63	61.63	50.35	18.30	0.56
20	ISH 135	251.67	195.00	22.52	0.68	1.83	1.48	19.13	0.58	1.79	1.46	18.44	0.58	63.02	49.65	21.22	0.65
21	ISH 159	242.50	185.00	23.71	0.71	2.45	1.95	20.41	0.62	1.64	1.32	19.51	0.61	61.28	47.57	22.37	0.69
22	Co 238	283.33	193.17	31.82	0.96	2.53	1.82	28.06	0.85	1.71	1.25	26.90	0.84	85.29	61.58	27.80	0.85
23	CoJ88	206.67	120.00	41.94	1.26	2.43	1.40	42.39	1.28	1.02	0.59	42.16	1.32	81.21	51.26	36.88	1.13
24	CoS8436	192.50	126.00	34.55	1.04	2.63	1.58	39.92	1.21	0.96	0.54	43.75	1.37	72.69	46.52	36.00	1.10
25	CoPb91	290.00	160.00	44.83	1.35	3.10	1.72	44.52	1.35	2.24	1.31	41.52	1.30	97.43	59.00	39.44	1.21
26	Co 118	271.67	168.37	38.02	1.14	2.67	1.56	41.57	1.26	1.63	0.98	39.88	1.25	77.00	48.61	36.87	1.13
27	CoJ85	282.50	170.00	39.82	1.20	2.82	1.77	37.23	1.13	1.76	1.15	34.66	1.08	73.82	48.00	34.98	1.07
28	CoJ64	260.83	165.00	36.74	1.11	2.25	1.57	30.22	0.91	1.03	0.68	33.98	1.06	72.65	42.00	42.19	1.29
29	CoPb92	293.33	180.00	38.64	1.16	2.17	1.32	39.17	1.18	1.25	0.72	42.40	1.33	80.56	55.00	31.73	0.97
30	CoPb93	278.33	185.00	33.53	1.01	2.22	1.50	32.43	0.98	1.36	0.96	29.41	0.92	94.33	68.25	27.65	0.85
	GM	267.48	178.65	33.15	0.99	2.41	1.61	32.83	0.99	1.47	1.00	32.64	1.02	76.40	51.40	32.40	0.99
	Range	192.50-308.33	120-240	17.72-47.06	0.53-1.42	1.83-3.10	1.02-1.96	18.62-49.00	0.56-1.48	0.75-2.24	0.48-1.52	18.44-47.83	0.58-1.50	48.78-110.00	25.42-76.39	16.66-47.89	0.51-1.47

Based on minimum DSI values and minimum percent reduction under E_2, seven clones were categorized as droughts tolerant, seven clones were intermediate, and rest were sensitive to drought reaction for stalk length. Higher reduction in drought in relation to the normal condition was observed for internode length and cane length [20]. Stalk diameter under normal (E_1) environment ranged from 1.83 to 3.10 cm with a mean value of 2.41 and from 1.02 to 1.96 cm with a mean value of 1.61 under water stress (E_2) environment. The percent reduction under E_2 for this trait varied from 18.62 to 49.00 with maximum reduction exhibited by the clone L818/07 (49.00 %) followed by variety CoPb91 (44.52 %) and CoPb11214 (44.24 %). Minimum percent reduction under E_2 was recorded for the clone ISH148 (18.62 %) followed by ISH135 (19.13 %) and ISH159 (20.41 %). DSI for stalk diameter ranged from 0.56 to 1.48 with a mean value of 0.99. The highest DSI recorded for the clone L818/07 (1.48) followed by CoPb91 (1.35), CoPb11214 (1.34) and CoPb10181 (1.31) while lowest DSI exhibited by the clone ISH148 (0.56) followed by ISH135 (0.58) and ISH159 (0.62) [Table-2]. Based on DSI clones namely ISH148, ISH07, ISH135, ISH159, KV2012-3 and KV2012-4 were categorized as drought tolerant for this trait (S <0.75). These results are in accordance Singh and Reddy [21] who revealed that thin stalked varieties with more number of millable canes in general appeared to more drought tolerant.

Single cane weight recorded percent reduction in mean under E_2 with a range of 18.44 to 47.83 % with a mean reduction of 32.64 (%). Maximum percent reduction under E_2 was exhibited by clone L818/07 (47.83%) while minimum value was recorded for the clone ISH135 (18.44%). DSI for this trait varied from 0.58 to 1.50 with highest value exhibited by clone L818/07 (1.50) and lowest by clone ISH135 (0.58) [Table-2]. Based on DSI values, six clones were categorized as drought tolerant (S<0.75), six clones were intermediate (S = 0.75 -1.00) and rest were categorized as drought susceptible (S> 1.00) for this trait. Similar findings were reported [19] who also found high single cane weight among sugarcane clones under moisture stress conditions.

Sugarcane cane yield is the product for which all selections and improvements are made. Genotypes in the present study exhibited a range of 48.78 to 110.00 (t/ha) with a mean value of 76.40 (t/ha) for cane yield under normal (E_1) environment and from 25.42 to 76.39 t/ha with a mean value of 51.40 t/ha under water stress (E_2) environment. Cane yield percent reduction under E_2 ranged from 16.66 to 47.89% with a maximum reduction percent for the genotype CoPb11211 (47.89 %) followed by CoPb11214 (46.97), CoPb13183 (42.17) and L818/07 (45.85) and minimum for the genotype ISH148 (16.66) followed by ISH07 (18.30), ISH135 (21.22), KV2012-4 (21.53) and KV2012-2 (22.73) [Table-2]. DSI for cane yield (t/ha) was ranged from 0.51 to 1.47 showing a differential behaviour of clones/varieties to water stress. Of the clones/varieties tested minimum DSI value was exhibited by the clone ISH148 (0.51) followed by ISH07 (0.56), ISH135 (0.35), KV2012-4 (0.66), ISH159 (0.69), KV2012-2 (0.70) and KV2012-3 (0.74) and all these clones/varieties were categorized as drought tolerant with the prevailed drought intensity (D=0.35). The genotypes/clones KV2012-5, CoPb93, Co238, KV2012-2, CoPb12181 and CoPb94 had DSI (0.75 -1.00) were categorized as intermediate and rest were drought susceptible in terms of cane yield [Table-2].Variable extent of cane yield reduction in sugarcane genotypes had been reported by earlier workers up to 70-80% [2] and 16.00% [19]. Basnayake *et al* [22] reported cane yield reduction (17.52%) under water stressed conditions and concluded that the genotypes with minimum cane yield reduction under water stress conditions can be considered drought tolerant.

Manifestation of physiological traits and Drought susceptibility indices

Relative water content (RWC) at 120 days after planting ranged from 47.35 to 77.30 %, under normal (E_1) environment. This value varied from 29.00 to 58.00 %, under water stress (E_2) environment [Table-3]. The mean percent decrease in RWC at 120 days after planting under E_2 was 34.58. The clones ISH148, ISH07, ISH135, ISH 159, KV2012-1 and KV2012-2 showed less decrease in this trait under E_2 environment. Mean DSI value for RWC at 120 days after planting was 1.00 with drought intensity (D) of 0.33. The genotypes ISH148, ISH07, ISH135,

ISH 159, KV2012-1 and KV2012-2 were found drought tolerant (S < 0.75) in terms of this trait [Table-3]. These results agree with the earlier findings [23] who also concluded that the genotypes that maintain higher leaf sheath moisture in their leaves appeared to be more drought tolerant. Similarly, Venkataramana *et al* [2] also documented that varieties Co 312, Co 1148 and Co 6806 maintained relatively higher leaf water potential possessed some drought tolerance. Silva *et al* [24] also reported that the tolerant group of genotypes had relatively high RWC values compared to those in the susceptible group thus confirming their empirical classification as drought tolerant. Relatively high RWC during mild drought is indicative of drought tolerance [25, 26].

Total chlorophyll recorded mean values 7.23 (mg/l), under E_1 environment and 4.81, under E_2 environment. The mean percentage reduction of total chlorophyll content under water stress (E_2) environment was 31.50 [Table-3]. The clone ISH135 showed minimum percentage reduction (17.08 %) in total chlorophyll content under water stress (E_2) environment. About 7 clones/varieties in terms of 5 in terms of total chlorophyll content had a DSI value of < 0.75 that indicates all these clones/varieties have same degree of drought tolerance in terms of chlorophyll content [Table-3]. The above results are in accordance with [24] who reported that Chlorophyll content declined progressively with exposure to drought, but the decline was more severe in genotypes from the susceptible group. Zhao *et al* [27] concluded that the measurement physiological traits *viz.* stomatal conductance, photochemical efficiency and leaf photosynthesis rate during the formative stage may be useful for early detection of water stress in sugarcane.

DSI for stomatal frequency ranged from 0.70 to 1.34 that shows variation in expression of clones/varieties to water stress. Among the tested genotypes, CoPb12182 (0.70) showed minimum value of DSI followed by the genotype CoPb14211 (0.71) and CoPb11211 (0.74). These genotypes had minimum decrease percentage under E_2 environment. The clones KV2012-4 (48.89), ISH159 (46.34), ISH07 (42.86), KV2012-1 (42.86), ISH148 (41.18), KV2012-5 (39.02), KV2012-3 (36.84) and KV2012-2 (34.88) had maximum reduction percentage in terms of stomatal frequency [Table-3] under water stress (E_2) environment which means these genotypes had minimum number of stomata in their leaves that reduces transpiration rate from the leaves of these genotypes under water scarcity so, these genotypes performed better under water stress conditions. Graca *et al* [28] showed the photosynthetic rate and stomatal conductance decreased significantly in all cultivars exposed to water deficit. As a whole, the tolerant cultivars exhibited a better photosynthetic performance lesser transpiration loss than the sensitive cultivar. Silva *et al* [29] considered TCP02-4587 as a drought tolerant cultivar of sugarcane because of its high capacity to economize water in its leaves, higher leaf water potential, a higher efficiency of stomatal control and a higher photosynthetic capacity. In case of specific leaf weight, the percent reduction under water stress (E_2) varied from 20.08 to 4.88 (%) with the mean value of 32.45 (%). Maximum per cent reduction under E2 was exhibited by clone CoJ88 (44.88) while minimum was recorded for the clone ISH135 (20.08). Among the clones/varieties tested the lowest DSI was exhibited by the clones ISH07 and ISH135 (0.63) closely followed by ISH159 (0.64), KV2012-5 (0.64) and ISH148 (0.67) [Table-3]. These clones/ varieties were categorized as drought tolerant (S<0.75). The clones/varieties that exhibited medium DSI values i.e.Co238, KV2012-1, KV2012-2, KV2012-3, KV2012-4, CoPb11214 and CoPb93 and these were categorized as intermediate (S = 0.75-1.00). Remaining all were drought susceptible(S>1.00). Agarwal and Sinha [30] and Misra [31] revealed that specific leaf weight had been widely used as selection parameter contributing towards drought tolerance for various crop plants in addition to economic yield. Of the different traits taken in present study, it was found that comparison of different traits for DSI vs reduction in water stressed suggest that stomatal frequency observed with maximum percent reduction and cane yield minimum percent reduction under water stressed conditions over the irrigated conditions while DSI reported to be within the intermediate range [Fig-2]

Table-3 *Drought Susceptibility index (DSI), mean and percent decrease under E_2 of sugarcane genotypes for physiological traits under normal (E_1) and water stress (E_2) environments*

Sr. No.	Genotype	RWC at 120 DAP (%)				Total chlorophyll (mg/l)			
		Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI
1	CoPb10181	65	34	47.69	1.38	7.46	4.2	43.7	1.3o
2	CoPb13181	73.96	45.41	38.6	1.11	7.34	5.06	31.06	0.93
3	CoPb13182	65	40.17	38.2	1.10	7.18	4.48	37.6	1.12
4	CoPb13183	53.29	29	45.58	1.32	6.95	4.23	39.14	1.17
5	CoPb11214	67.25	35	47.96	1.38	5.59	3.12	44.19	1.32
6	CoPb11211	77.3	43	44.37	1.28	6.71	4.02	40.09	1.19
7	CoPb12181	57.32	40.68	29.03	0.84	7.87	4.98	36.72	1.09
8	CoPb12182	64.58	46.5	28	0.81	6.3	4.19	33.49	1
9	CoPb14212	76.38	49	35.85	1.04	7.6	4.95	34.87	1.04
10	CoPb14211	60.13	30	50.11	1.45	6.36	4.32	32.08	0.96
11	CoPb12212	67.51	34	49.64	1.43	7.39	4.65	37.08	1.1
12	L 818/07	66.25	34	48.68	1.41	6.29	3.5	44.36	1.32
13	KV2012- 1	47.35	34.18	27.81	0.80	6.82	4.97	27.13	0.81
14	KV2012- 2	77.19	58	24.86	0.72	7.16	5.36	25.14	0.75
15	KV2012- 3	73.33	55	25	0.72	8.35	6.18	25.99	0.77
16	KV2012-4	55.58	41.11	26.03	0.75	8.62	6.5	24.59	0.73
17	KV2012- 5	61.67	48	22.17	0.64	7.46	5.54	25.74	0.77
18	ISH 148	63.14	52	17.64	0.51	8.18	6.38	22	0.66
19	ISH 07	64.1	53	17.32	0.50	6.54	5.26	19.57	0.58
20	ISH 135	67.55	55	18.58	0.54	6.38	5.29	17.08	0.51
21	ISH 159	61.89	51	17.6	0.51	6.09	4.9	19.54	0.58
22	Co 238	63.1	45	28.68	0.83	8.77	6.1	30.44	0.91
23	CoJ88	62.5	34	45.6	1.32	5.22	3.2	38.7	1.15
24	CoS8436	57.5	35	39.13	1.13	8.47	4.71	44.39	1.32
25	CoPb91	55.36	32	42.2	1.22	7.27	4.48	38.38	1.14
26	Co 118	76.67	46.63	39.18	1.13	7.98	4.69	41.23	1.23
27	CoJ85	70	45.52	34.97	1.01	7.07	4.38	38.05	1.13
28	CoJ64	68.81	46.33	32.67	0.94	6.55	4.11	37.25	1.11
29	CoPb92	67.26	37	44.99	1.30	8.87	5.05	43.07	1.28
30	CoPb93	69.18	49	29.17	0.84	8.27	5.6	32.29	0.96
	GM	65.2	42.61	34.58	0.99	7.23	4.81	33.5	0.99

Table-3 *contd.*

Sr. No.	Genotype	Stomatal frequency (no.)				Specific leaf weight (g)			
		Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI	Mean E_1	Mean E_2	% ↓ in mean under E_2	DSI
1	CoPb10181	45.00	27.00	40.00	1.10	4.64	2.69	42.03	1.31
2	CoPb13181	44.00	28.00	36.36	1.00	5.28	3.13	40.72	1.27
3	CoPb13182	44.00	28.00	36.36	1.00	6.96	4.20	39.66	1.24
4	CoPb13183	47.00	32.00	31.91	0.88	4.48	2.98	33.48	1.05
5	CoPb11214	47.00	32.00	31.91	0.88	7.48	5.60	25.13	0.79
6	CoPb11211	48.00	35.00	27.08	0.74	5.83	3.40	41.68	1.30
7	CoPb12181	45.00	31.00	31.11	0.86	4.36	2.88	33.94	1.06
8	CoPb12182	47.00	35.00	25.53	0.70	4.94	3.34	32.39	1.01
9	CoPb14212	37.00	25.00	32.43	0.89	3.23	2.15	33.44	1.04
10	CoPb14211	41.00	29.00	29.27	0.80	4.25	2.75	35.29	1.10
11	CoPb12212	39.00	29.00	25.64	0.71	3.81	2.19	42.52	1.33
12	L 818/07	47.00	27.00	42.55	1.17	4.64	2.83	39.01	1.22
13	KV2012- 1	42.00.	24.00	42.86	1.18	6.61	4.86	26.48	0.83
14	KV2012- 2	43.00	28.00	34.88	0.96	5.69	4.29	24.60	0.77
15	KV2012- 3	38.00	24.00	36.84	1.01	6.65	4.89	26.47	0.83
16	KV2012-4	45.00	23.00	48.89	1.34	6.75	5.10	24.44	0.76
17	KV2012- 5	41.00	25.00	39.02	1.07	5.39	4.28	20.59	0.64
18	ISH 148	51.00	30.00	41.18	1.13	5.25	4.12	21.52	0.67
19	ISH 07	42.00	24.00	42.86	1.18	4.68	3.73	20.30	0.63
20	ISH 135	52.00	31.00	40.38	1.11	4.98	3.98	20.08	0.63
21	ISH 159	41.00	22.00	46.34	1.27	4.64	3.69	20.47	0.64
22	Co 238	44.00	31.00	29.55	0.81	5.00	3.80	24.00	0.75
23	CoJ88	46.00	32.00	30.43	0.84	3.81	2.10	44.88	1.40
24	CoS8436	45.00	28.00	37.78	1.04	4.33	2.80	35.33	1.10
25	CoPb91	45.00	29.00	35.56	0.98	3.89	2.15	44.73	1.40
26	Co 118	43.00	26.00	39.53	1.09	5.00	3.02	39.60	1.24
27	CoJ85	38.00	27.00	28.95	0.80	5.35	3.26	39.07	1.22
28	CoJ64	41.00	28.00	31.71	0.87	3.54	2.39	32.49	1.01
29	CoPb92	47.00	33.00	29.79	0.82	5.42	3.31	38.93	1.22
30	CoPb93	42.00	28.00	33.33	0.92	4.01	2.80	30.17	0.94
	GM	44.00	28.3	35.34	0.99	5.02	3.42	32.45	1.01
	Range	37.00-52.00	22.00-35.00	25.53-48.89	0.70-1.34	3.23-7.48	2.10-5.60	20.08-44.88	0.63-1.40

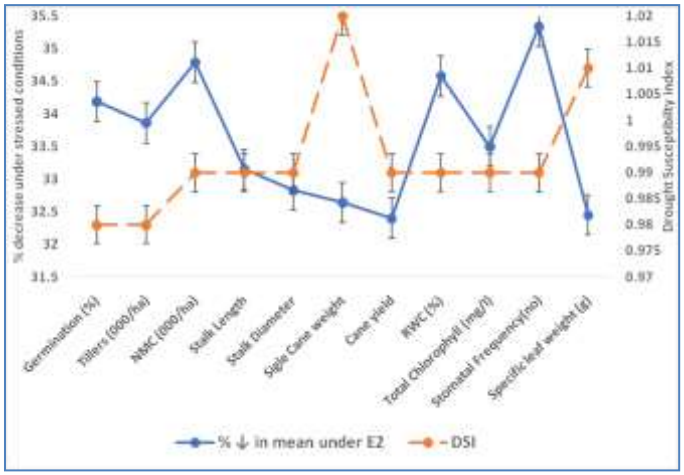

Fig-2 Drought susceptible indices and percent reduction in mean for different agro-physiological traits under water stress condition in sugarcane

Conclusions

This study concludes that cane yield is an important trait in sugarcane and the minimum DSI values for it were exhibited by the clone ISH148 (0.51) followed by ISH07 (0.56), ISH135 (0.65), KV2012-4 (0.66), ISH159 (0.69), KV2012-2 (0.70) and KV2012-3 (0.74) and these clones/varieties were categorized as drought tolerant with the prevailed drought intensity (D=0.35). The genotypes/clones KV2012-5, CoPb93, Co 0238, KV2012-2, CoPb12181 and CoPb94 had DSI (0.75 -1.00) were categorized as intermediate that can be evaluated on large scale in the target environment for their better adaptability and higher cane yields.

Application of research: Clones / varieties identified should be useful for commercial cultivation for water stressed conditions after testing on large scale and protocols/traits mentioned are useful for future screening of sugarcane germplasm to develop genetic stocks for breeding programme.

Research Category: This is research based for assessment of sugarcane clone/varieties to develop climate resilient varieties in the different agro-climatic condition of state.

Abbreviations:
SLW : Specific leaf weight
DSI : Drought susceptibility index
RRS : Regional Research Station

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