STRESS INDICES BASED ON CANE AND SUGAR YIELDS: IMPLICATIONS IN SELECTION OF SUGARCANE VARIETIES FOR DROUGHT TOLERANCE

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ABSTRACT

Drought is a major cause of yield loss for many important crops including sugarcane. Due to increasing demand for sugar by a growing world population, it is needed to accelerate the selection of sugarcane clones/varieties that are resistant/tolerant and productive under water stress conditions. This study was conducted to assess the relative drought tolerance of diverse sugarcane clones/varieties evaluated under water stress (E2) and normal (E2) conditions for sugar and cane yields. Analysis of variance revealed significant differences among tested clones/ varieties under both the water regimes. Per cent cane and sugar yield reduction in comparison to normal (E1) situation was assessed that ranged from 16.66-47.89 and 25.54-62.54 per cent, respectively under stressed (E2) conditions. Since, water deficit is the single largest abiotic stress affecting sugarcane productivity and the development of water use efficient and drought tolerant cultivars is an imperative, eleven stress indices were worked out from cane and sugar yields recorded under normal and stress conditions as reported earlier to see their effectiveness in sugarcane crop. Study is suggestive that lower score values for seven stress and stability indices viz. stress susceptibility index (SSI), stress tolerance index (STI), yield stability index (YSI), yield index (YI), drought resistance index (DI), relative drought index (RDI) and modified stress tolerance index (K1STI and K2STI) higher score for stress tolerance (TOL), mean productivity and geometric mean productivity (MP and GMP) and stress susceptibility percentage index (SSPI) categorized the clones/ varieties as tolerant ones and vice versa. Further association studies showed that all the indices exhibited significant positive interaction with cane and sugar yields (CY and SY) under stress conditions except SSI and SSPI. Also inter association with different level of magnitude and significance among/between different indices were observed indicating their importance for selection of clones under drought stress situations. YI and DI had a positive correlation with RDI, GM, MP, K1 & K2 and between themselves for both cane and sugar yields indicating that they are a better predictor of potential cane and sugar yields under a stress conditions and can be useful for sugarcane researchers. Besides, clones and varieties reported in study with lowest score for SSI, STI, YSI, YI, DI, RDI and (K1STI and K2STI) and highest score for TOL, MP, GMP and SSPI be categorized for enhanced tolerance to water stress in present global warming situation in terms of their resilience to stress and production capacity to have better cane and sugar yields.

Keywords: Abiotic factors, Cane and sugar yields, Correlations, Drought, Stress indices, Sugarcane

Sugarcane is a monocotyledonous plant belonging to the family Poaceae and subfamily Andropogoneae. It is the main source of sugar (80%) globally and holds a prominent position as a cash crop. India is the largest consumer of sugar in the world and next to Brazil, second largest producer of sugar in the world. Sugarcane crop is the second important industrial crop in the country cultivated in an area of 4.90 million ha with productivity of 77.61 t/ha, its production is 350 million tones and sugar production touched to 27.42 million tonnes in India (Ram, 2021). The corresponding area in Punjab under sugarcane is 96 thousand ha with productivity of 81.3 t/ha, sugarcane production is 6.6 million tones and sugar production is 0.5 million tonnes (Anonymous, 2020). Biotic and abiotic stresses are the important factors for reducing production in agricultural

system (Mahajan and Tuteja, 2005; Lobell *et al.*, 2011; Sanghera and Kumar, 2018). Amongst abiotic stresses drought is the most important and principal factor limiting crops production in general and sugarcane as specific crop due to its long growing period (Wang *et al.*, 2003; Rampino *et al.*, 2006; Sanghera *et al.*, 2018). It is a major production constraint for this important crop worldwide due to its relatively high water requirement at its grand growth stage (Singh and Rao, 1987; Lakshmanan and Robinson, 2014; Misra *et al.*, 2020; Saini and Sanghera, 2021). However, sugarcane researchers have suggested that two stages in sugarcane at formative phase i.e. tillering and grand growth stages are the critical water demanding phases (Sanghera and Kumar, 2018) and if water deficit occurs during this period can cause upto 60 per cent losses in the productivity (Robertson *et al.*, 1999; Ramesh, 2000; Basnayake *et al.*, 2012; Gentile *et al.*, 2015). So loss of cane and sugar yield under drought stress is

of major concern which emphasized sugarcane crop improvement programs to invest in development of water stress tolerant varieties (Dhansu *et al.*, 2021; Ferreira *et al.*, 2017; Sanghera and Kumar, 2021). Due to complex nature of the plant responses to water stress, it is difficult to identify and exploit single trait that can be considered for selection of genotypes to this stress (Wang *et al.*, 2003; Hu and Xiong, 2014; Wang *et al.*, 2016; Sanghera *et al.*, 2018). This is due to the complexity of the plant responses to water deficit (Wang *et al.*, 2003; Hu and Xiong, 2014; Wang *et al.*, 2016) and difficulty to identify and exploit single trait that can be used for genotype selection (Sadeghi *et al.*, 2011; Sanghera *et al.*, 2018). The relative yield of a genotype compared to other genotypes subjected to the same drought stress has been defined as drought resistance by Hall (1993). Stress susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) whilst the values are confounded with differential yield potential of genotypes (Ramirez-Vallejo and Kelly, 1998). Various researchers have used different methods to evaluate genetic differences in drought tolerance among sugarcane clones and varieties (Lakshmanan and Robinson, 2014; Augustine *et al.*, 2016; Ramiro *et al.*, 2016; Sanghera *et al.*, 2018). In recent past, several selection criteria have been advised to select genotypes based on their performance in stress and non–stress environments.

Thus, drought indices which provide a measure of drought based on loss of cane and sugar yields under drought-conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001; Sanghera *et al.*, 2018). The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Fernandez, 1992). Stress Tolerance Index (STI) was defined as a useful tool for determining high yield and stress tolerance potential of genotypes (Fernandez, 1992). To improve the efficiency of STI a modified stress tolerance index (MSTI) was suggested by Farshadfar and Sutka (2002) which corrects the STI as a weight. Moosavi *et al.* (2008) introduced stress susceptibility percentage index (SSPI) for screening drought tolerant genotypes in stress and non-stress conditions. Fischer *et al.* (1998) suggested that relative drought index (RDI) is positive indices for indicating stress tolerance. Lan (1998) defined new indices of drought resistance index (DI), which was commonly accepted to identify genotypes producing high yield under both stress and non stress conditions. Rosielle & Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress

conditions. Fischer and Maurer (1978) suggested the stress susceptibility index (SSI) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Clarke *et al.* (1992) used SSI to evaluate drought tolerance in wheat genotypes and found year-to-year variation in SSI for genotypes and could rank their pattern. In spring wheat cultivars, Guttieri *et al.* (2001), using SSI, suggested that an SSI > 1 indicated above-average susceptibility to drought stress. The yield index (YI; suggested by Gavuzzi *et al.* (1997) and yield stability index (YSI) suggested by Bouslama and Schapaugh (1984) in order to evaluation the stability of genotypes in the both stress and non-stress conditions. Though, different strategies have been used and suggested by various researchers to identify relatively resistant genotypes under drought stress in different crops. The present study attempted to assess the suitable selection criteria for identifying drought tolerance in sugarcane clones / varieties using different stress indices calculated based on their performances for cane and sugar yields under water stress and non stress conditions and associations of the indices with cane and sugar yields, so that suitable cultivars can be identified recommended for cultivation in water stress problematic areas.

MATERIALS AND METHODS

The present investigation was carried out at experimental area of Punjab Agricultural University, Regional Research Station (RRS), Kapurthala representing the subtropical conditions of the country. The Experimental site falls at an elevation of 225 m above mean sea level and is located at 31.38°N longitude and 75.38°E latitude (Anonymous, 2021) having clay loam soils with pH of 8.3-8.7. The plant material used in the study comprised of 30 diverse clones of sugarcane consisting of nine commercial varieties (Co 0238, CoJ 88, CoS 8436, CoPb 91, CoPb 92, CoPb 93, Co 118, CoJ 85 and CoJ 64), seven local elite clones (CoPb 13181, CoPb 10181, CoPb 13182, CoPb 13183, CoPb 11214, CoPb 11211, CoPb 12181, CoPb 12182, CoPb 14212, CoPb 14211, CoPb 12212 and L 818/07, KV 2012-1, KV 2012-2, KV 2012-3, KV 2012-4 and KV 2012-5 and four ISH clones viz. ISH 148, ISH 159, ISH 135 and ISH 07 procured from different sources. All the clones/varieties were planted during spring 2017-18 in the first week of March in a randomized complete block design with two replications under two water regimes viz., normal (E1) and water stress (E2) conditions. In water stressed (E2) environment irrigation was suspended for 4 weeks interval at critical growth stages of the crop viz. germination, tillering and grand growth stage (formative stage). Each clone/variety was represented by a plot of four rows of 6 m length each with inter row spacing of 90 cm. The cane seed rate was 12 buds per

running 1 metre row length 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 under stressed condition (E2). Mean performances of different clones and varieties were recorded for cane and sugar yield at maturity under both the regimes using standard procedures. From the mean cane and sugar yields under water stress (E2) and normal conditions (E1), per cent reduction over (E1) and eleven quantitative stress tolerance/resistance indices were calculated for each clone/variety using the formulas suggested by different researchers in various crops as follow:

$SSI = (1-Ys/Yp))/(1-(\bar{Y}s)/(\bar{Y}p)))$ - (Fischer and Maurer, 1978)

$RDI = (Ys/Yp) / (\bar{Y}s)/(\bar{Y}p)$ – (Moosavi *et al.*, 2008)

$STI = (Ys \times Yp)/(\bar{Y}p^{2)})$ – (Fernandez, 1992)

$GMP = \sqrt{Ys \times Yp}$ – (Fernandez, 1992)

$TOL = Yp\text{-}Ys$ - – (Rosielle and Hamblin, 1981)

$MP = (Ys + Yp)/2$ – (Rosielle and Hamblin, 1981)

$YI = (Ys)/(\bar{Y}s)$ – (Guttieri *et al.*, 2001)

$DI = (Ys \times (Ys/Yp))/\bar{Y}s$ – (Lan, 1998)

$YSI = /Yp$ – (Bouslama and Schapaugh, 1984)

$SSPI = ((Yp-Ys/2(\bar{Y}p))\times 100$ – (Moosavi *et al.*, 2008)

$Ki\ STI,\ K_1 = Yp^2/\bar{Y}p^2\ and\ K_2 = Ys^2/\bar{Y}s^2$ – (Farshadfar and Sutka, 2002)

Where:

Ys- Mean cane/ sugar yield of clone/variety under stress condition and

Yp- Mean cane/ sugar yield of clone/variety under normal condition

To assess the impact of water stress on individual clone / variety per cent reduction of cane and sugar yield traits in E1 over E2 was calculated (Fischer and Maurer, 1978).

Statistical analysis

The mean values of cane and sugar yields of each clone/variety in each replication were used for analysis of variance as per Fisher (1935). The analysis of the experimental design was based on the linear model with the help of software CPCS1 (Cheema and Singh, 1990). Interrelationships among different indices and with cane and sugar yields under water stress environment were calculated (Al-Jibourie *et al.*, 1958). The simplest formula for computing the appropriate t value to test significance of a correlation coefficient employs the t distribution:

t= r SQRT(n-2) / (1-r^2)

Where r = correlation between the two variables

The degrees of freedom for entering the t-distribution is n – 2, where n is the number of genotypes among the traits of which correlation being tested.

RESULTS AND DISCUSSION

The minimum and maximum mean weekly temperature ranged from 2.00°C to 36.00°C and from 7.00°C to 46.00°C, respectively. The total annual rainfall during crop season (February 2016-January 2017) was 110.5 mm. Rainfall was not evenly distributed throughout the cropping season which resulted in moisture stress conditions during the critical crop growth stages. In the present investigation, the moisture stress was experienced during germination, tillering and grand growth stage (formative stage).

Analysis of variance revealed significant differences for both cane and sugar yield traits among clones/ varieties under both (E$_1$) normal and water stress (E$_2$) environments. Cane yield and sugar yield were significantly reduced under water stress conditions and ranged from 16.66-47.89 and 25.54-62.54 per cent, respectively (Table 1). Various susceptibility indices worked out and their relative significance with respect to cane and sugar yields in different clones used in this study, interrelationships between yield and different indices are discussed in the following sections:

Comparative performance of different clones/ varieties for cane and sugar yield in stress and normal environments

Perusal of Table 1 revealed that cane and sugar yield among the clone and varieties were significantly different and ranged from 48.78-110.00 (t/ha) and 5.70-13.09 (t/ha), respectively. The genotypes Co 0238, CoPb 93, KV 2012-4, CoPb 12212, ISH 159 and L 818/07 exhibited cane yield more than 90 t/ha under normal environment while in the water stress environment, clones and varieties namely Co 0238, CoPb 93, L 818/07, CoPb 13181, CoPb 13182, KV 2012-1 and ISH 159 were found promising with respect to cane yield (>60 t/ha). Differential behavior of clones and varieties in variable environments have been documented by earlier workers (Sanghera *et al.*, 2015; Sanghera *et al.*, 2018; Kashyap *et al.*, 2018; Mohammed *et al.*, 2019) suggesting the suitability of clones and varieties to different growing conditions. Similarly for sugar yield (CCS t/ha) nine clones viz; ISH 135, ISH 159, KV 2012-4, CoJ 88, CoPb 12212, L 818/07, CoPb 11211, CoPb 93, CoPb 13182 were found promising under normal conditions (Table 1) with sugar yield > 10 (t/ha). However under water limited conditions this trait was reduced to the extent of 25.54 to 62.54 per cent and clones namely L 818/07. CoPb 11212, CoPb 93 and CoPb 13182 found good with sugar yield more than

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Table 1. Comparative mean performance of different sugarcane clones/varieties for cane and sugar yield under normal (E_1) and water stress (E_2) environments

S. No	Clone/ Variety	Cane yield (ton/ha)			CCS at harvest (t/ha)		
		Mean E_1	Mean E_2	% ↓ in mean under E_2	Mean E_1	Mean E_2	% ↓ in mean under E2
1	Co 0238	110.00	64.31	41.54	13.09	6.67	49.05
2	CoJ 88	83.33	57.10	31.48	10.54	6.25	40.70
3	CoS 8436	79.69	51.39	35.51	10.04	5.18	48.41
4	CoPb 91	72.05	41.67	42.17	8.36	4.24	49.28
5	Co 118	68.75	36.46	46.97	8.74	3.31	62.13
6	CoJ 85	48.78	25.42	47.89	6.06	2.27	62.54
7	CoJ 64	54.51	38.19	29.94	6.34	3.61	43.06
8	CoPb 92	65.97	43.40	34.21	6.92	3.63	47.54
9	CoPb 11214	57.12	38.19	33.14	5.70	3.45	39.47
10	CoPb 14212	63.72	41.88	34.27	7.13	3.53	50.49
11	CoPb 14211	82.64	53.84	34.85	8.55	4.56	46.67
12	CoPb 12212	96.18	52.08	45.85	11.18	5.28	52.77
13	L 818/07	91.49	65.97	27.89	12.08	7.62	36.92
14	CoPb 11211	76.39	59.03	22.73	10.15	7.32	27.88
15	CoPb 93	100.69	76.39	24.13	13.05	8.85	32.18
16	CoPb 13181	77.43	60.76	21.53	9.78	6.79	30.57
17	CoPb 13182	86.63	64.24	25.85	10.41	7.03	32.47
18	CoPb 13183	58.33	48.61	16.66	6.50	4.84	25.54
19	CoPb 10181	61.63	50.35	18.30	6.97	5.10	26.83
20	CoPb 12181	63.02	49.65	21.22	7.59	5.11	32.67
21	CoPb 12182	61.28	47.57	22.37	7.59	5.02	33.86
22	KV 2012- 1	85.29	61.58	27.80	9.98	6.77	32.16
23	KV 2012- 2	81.21	51.26	36.88	9.73	5.33	45.22
24	KV 2012- 3	72.69	46.52	36.00	9.00	5.20	42.22
25	KV2012- 4	97.43	59.00	39.44	11.47	6.04	47.34
26	KV 2012- 5	77.00	48.61	36.87	9.09	5.26	42.13
27	ISH 148	73.82	48.00	34.98	8.08	4.78	40.84
28	ISH 07	72.65	42.00	42.19	9.19	4.39	52.23
29	ISH 135	80.56	55.00	31.73	10.86	5.94	45.30
30	ISH 159	94.33	68.25	27.65	11.25	6.22	44.71
	Mean	76.40	51.40	32.40	9.18	5.32	42.11
	Range	48.78-110.00	25.42-76.39	16.66-47.89	5.70-13.09	2.27-8.85	25.54-62.54

8.0 t/ha. Similar results regarding variable response of clones/ varieties under water stress has also been reported by Sanghera *et al.* (2018).

Attempt was made in present study to explore and compare the behavior of different stress tolerance indices for screening of sugarcane cultivars/clones under stress (drought) and non-stress (irrigated) conditions. Cane yield and sugar yield of cultivars under both irrigated and drought conditions were used for calculating different sensitivity and tolerance indices (Table 2a & b and 3a & b). Various indices worked out for cane and sugar yield traits among different clones/ varieties and their significance in screening are described below:

Stress susceptibility index (SSI)

This parameter was estimated based on mean performance of clones and varieties with respect to cane and sugar yields under normal and water stress conditions and presented in (Table 2a & 3a). For cane yield it ranged from 0.51 to 1.47 with a grand mean of 0.99 ± 0.26 (Table 2a). The corresponding values for sugar yield were 0.61 to 1.49 with grand mean 1.0 ± 0.23 (Table 3a). Based upon low SSI for cane and sugar yield four clones/varieties namely CoPb 93, CoPb 13181, CoPb 13183 and CoPb 10181 were found water stress tolerant having SSI for cane yield (SSI < 0.73) and less than 0.77 for sugar yield.

However, the frequency distribution among thirty clones /varieties categorized as tolerant, intermediate and susceptible was variable for these traits. Based on SSI for cane yield, 7 clones were found tolerant, 17 intermediate and 6 as susceptible. Similarly for sugar yield 7 were tolerant, 19 were intermediate and 4 were susceptible (Fig. 1a & b). Sanghera *et al.* (2018) studied the impact of water stress on cane and sugar yield in plant crop and reported the differential response of clones and varieties based on the mean performance for different traits and categorized them as tolerant and susceptible based on the value of stress susceptibility index (Dhansu *et al.*, 2021).

Further discretion among different indices showed that selection through SSI chooses clones/ varieties with relatively low YP but high YS. This index ranges between 0 and 1 and the greater this index, the greater susceptibility of the genotype to stress. The main disadvantage of this index is the lack of separation of different groups (Fernandez, 1992). Similarly, Clarke *et al.* (1992) showed that yield-based SSI index did not differentiate between potentially drought resistant genotypes and those that possessed low overall yield potential.

Stress tolerance index (STI)

This parameter was also calculated for cane and sugar yield as suggested by Fernandez (1992). The grand mean score of STI in respect to cane yield was 0.70 ± 0.27 with a range of 0.21-1.32 between clone/ varieties tested under two water regimes, normal and water stress (Table 2a). For sugar yield it varied from 1.47 to 3.88 with an average of 2.56 ± 0.62 (Table 3a). All the thirty clones were categorized as tolerant, intermediate and susceptible, possessing the criteria higher the value of STI index greater will be the tolerance and vice versa for both cane and sugar yield traits. Three clones namely Co 0238, CoPb 93 and L 818/07 were found ideal with respect to tolerance as these clones depicted higher STI score for cane yield (>0.96) and sugar yield (>3.19). Of thirty clones tested

6 clones were tolerant and 5 were intermediate based upon STI values worked out for cane and sugar yield (Fig. 2a & b and Fig. 3a & b). A high STI demonstrates a high tolerance and the best advantage of STI is its ability to separate group one from others (Moosavi *et al.*, 2008).

Yield stability index (YSI)

This index was worked out to assess the stability of the sugarcane clones/varieties under water stress and non stress conditions. Significant differences were found amongst the genotype with respect to YSI. The average YSI among the clones was 0.68 ± 0.09 for cane yield with a range of 0.52 to 0.83 (Table 2a). For sugar yield the corresponding values recorded were 0.58 ± 0.10 and 0.37 to 0.74, respectively (Table 3a). The clones with higher values of YSI were regarded as stable clones under both stress and non stress conditions. Based on higher value of YSI for cane and sugar yield four clone/varieties namely CoPb 11211, CoPb 13181, CoPb 13183 and CoPb 10181 were categorized as stable one and 19 clones showed intermediate stability based on YSI score calculated on cane yield and 22 clones showed similar behavior based on the YSI score worked out for sugar yield (Fig. 4a & b). This stability indices has been carried out by earlier workers in different crops (Nouri *et al.*, 2011; Farshadfar *et al.*, 2013; Kachare *et al.*, 2016; Wasae, 2021).

Yield index (YI)

The clones with high value of yield index (>1.22) was found suitable for water stress conditions. Five clones namely Co 0238, L 818/07, CoPb 93, CoPb 13182 and ISH 159 exhibited high yield index and considered suitable for water stress condition based on cane yield (Table 2a). However for sugar yield only two clones L 818/07 and CoPb 13182 were found suitable, (Fig. 5a & b). The average score of yield index amongst the clone/ varieties for cane and sugar yield was 1.0 with Standard deviation of 0.21 and 0.28, respectively. For cane yield it ranged from 0.49 to 1.49 while in case of sugar yield it varied from 0.43 to 1.66 (Table 2a and 3a). This stability indices has been carried out by earlier workers in different crops (Nouri *et al.*, 2011; Farshadfar *et al.*, 2013; Kachare *et al.*, 2016; Wasae, 2021).

Drought Tolerance Index (DI)

Data appended in Table 2a & 3a for drought tolerance index worked out based on the performance of different clones and varieties for cane and sugar yield revealed that it ranged from 0.26 to 1.13 with an average of 0.69 ± 0.19 for cane yield and 0.16 to 1.13 and 0.59 ± 0.23 for sugar yield. The categorization of clones based on DI showed that high score of Drought tolerance index is related to high water stress tolerance.

Table 2a. Stress tolerance indices score of sugarcane clones/varieties based on mean cane yield under water stress and normal conditions

Clones/varieties	SSI	STI	YSI	YI	DI	RDI	K1 STI	K2 STI
Co 0238	1.27	1.21	0.58	1.25	0.73	0.87	2.07	1.57
CoJ 88	0.97	0.82	0.69	1.11	0.76	1.02	1.19	1.23
CoS 8436	1.09	0.70	0.64	1.00	0.64	0.96	1.09	1.00
CoPb 91	1.29	0.51	0.58	0.81	0.47	0.86	0.89	0.66
Co 118	1.44	0.43	0.53	0.71	0.38	0.79	0.81	0.50
CoJ 85	1.47	0.21	0.52	0.49	0.26	0.78	0.41	0.24
CoJ 64	0.92	0.36	0.70	0.74	0.52	1.04	0.51	0.55
CoPb 92	1.05	0.49	0.66	0.84	0.56	0.98	0.75	0.71
CoPb 11214	1.02	0.37	0.67	0.74	0.50	0.99	0.56	0.55
CoPb 14212	1.05	0.46	0.66	0.81	0.54	0.98	0.70	0.66
CoPb 14211	1.07	0.76	0.65	1.05	0.68	0.97	1.17	1.10
CoPb 12212	1.41	0.86	0.54	1.01	0.55	0.81	1.58	1.03
L 818/07	0.86	1.03	0.72	1.28	0.93	1.07	1.43	1.65
CoPb 11211	0.70	0.77	0.77	1.15	0.89	1.15	1.00	1.32
CoPb 93	0.74	1.32	0.76	1.49	1.13	1.13	1.74	2.21
CoPb 13181	0.66	0.81	0.78	1.18	0.93	1.17	1.03	1.40
CoPb 13182	0.79	0.95	0.74	1.25	0.93	1.10	1.29	1.56
CoPb 13183	0.51	0.49	0.83	0.95	0.79	1.24	0.58	0.89
CoPb 10181	0.56	0.53	0.82	0.98	0.80	1.22	0.65	0.96
CoPb 12181	0.65	0.54	0.79	0.97	0.76	1.17	0.68	0.93
CoPb 12182	0.69	0.50	0.78	0.93	0.72	1.16	0.64	0.86
KV 2012- 1	0.85	0.90	0.72	1.20	0.87	1.07	1.25	1.44
KV 2012- 2	1.13	0.71	0.63	1.00	0.63	0.94	1.13	0.99
KV 2012- 3	1.10	0.58	0.64	0.91	0.58	0.95	0.91	0.82
KV2012- 4	1.21	0.98	0.61	1.15	0.70	0.90	1.63	1.32
KV 2012- 5	1.13	0.64	0.63	0.95	0.60	0.94	1.02	0.89
ISH 148	1.07	0.61	0.65	0.93	0.61	0.97	0.93	0.87
ISH 07	1.29	0.52	0.58	0.82	0.47	0.86	0.90	0.67
ISH 135	0.97	0.76	0.68	1.07	0.73	1.02	1.11	1.14
ISH 159	0.85	1.10	0.72	1.33	0.96	1.08	1.52	1.76
Grand Mean	0.99 ± 0.26	0.70 ± 0.27	0.68 ± 0.09	1.00 ± 0.21	0.69 ± 0.19	1.01 ± 0.13	1.04 ± 0.40	1.05 ± 0.43
Range	0.51-1.47	0.21-1.32	0.52-0.83	0.49-1.49	0.26-1.13	0.78-1.24	0.41-2.07	0.24-2.21

SSI= Stress Susceptibility Index; STI= Stress Tolerance Index; YSI= Yield Stability Index; YI= Yield Index; DI= Drought Tolerance Index; RDI= Relative Drought Tolerance Index; K1 STI & K2 STI= Modified Stress Tolerance Index

Five clones/varieties as per their DI score viz. L 818/07, CoPb 11211, CoPb 93, CoPb 13181 and CoPb 13182 are found to be tolerant to water stress in respect to both cane and sugar yield. Four clones behaved as susceptible and 20 were grouped under intermediate category showing moderate tolerance towards water stress (Fig. 6a & b). Khalili *et al*. (2012) also used this index for categorization of different genotypes in Spring Canola as drought tolerant and susceptible suggesting higher the DI score more is the stress tolerance in the cultivar/genotype.

Relative Drought Tolerance Index (RDI)

The relative drought tolerance index (RDI) in present study was worked out for different sugarcane clone/varieties for cane and sugar yield based on the performance of clones using cane and sugar yield under stress condition relative to their performance under normal condition to categorize them as stress tolerant and susceptible. As suggested by earlier researchers

Table 2b. Stress tolerance indices score of sugarcane clones/varieties based on mean cane yield under water stress and normal conditions

Clones/varieties	TOL	GMP	MP	SSPI
Co 0238	45.69	84.11	87.16	29.90
CoJ 88	26.23	68.98	70.22	17.17
CoS 8436	28.30	63.99	65.54	18.52
CoPb 91	30.38	54.79	56.86	19.88
Co 118	32.29	50.07	52.61	21.13
CoJ 85	23.36	35.21	37.10	15.29
CoJ 64	16.32	45.63	46.35	10.68
CoPb 92	22.57	53.51	54.69	14.77
CoPb 11214	18.93	46.71	47.66	12.39
CoPb 14212	21.84	51.66	52.80	14.29
CoPb 14211	28.80	66.70	68.24	18.85
CoPb 12212	44.10	70.77	74.13	28.86
L 818/07	25.52	77.69	78.73	16.70
CoPb 11211	17.36	67.15	67.71	11.36
CoPb 93	24.30	87.70	88.54	15.90
CoPb 13181	16.67	68.59	69.10	10.91
CoPb 13182	22.39	74.60	75.44	14.65
CoPb 13183	9.72	53.25	53.47	6.36
CoPb 10181	11.28	55.71	55.99	7.38
CoPb 12181	13.37	55.94	56.34	8.75
CoPb 12182	13.71	53.99	54.43	8.97
KV 2012- 1	23.71	72.47	73.44	15.52
KV 2012- 2	29.95	64.52	66.24	19.60
KV 2012- 3	26.17	58.15	59.61	17.13
KV2012- 4	38.43	75.82	78.22	25.15
KV 2012- 5	28.39	61.18	62.81	18.58
ISH 148	25.82	59.53	60.91	16.90
ISH 07	30.65	55.24	57.33	20.06
ISH 135	25.56	66.56	67.78	16.73
ISH 159	26.08	80.24	81.29	17.07
Grand Mean	24.93 ± 8.52	62.68 ±12.18	64.02 ± 12.31	16.32 ± 5.58
Range	9.72-45.69	35.21-87.70	37.10-88.54	6.36-29.90

TOL= Stress Tolerance; GMP= Geometric Mean Productivity; MP= Mean Productivity; SSPI= Stress Susceptibility Percentage Index

and observed in drought tolerance index (DI) it was found that clones/ varieties possessing higher values of RDI indicated better tolerance towards water restricted environment. This index recorded significant differences amongst the clone/varieties. For cane yield, the average RDI score among the clones was 1.01 ± 0.13 with a range of 0.78 to 1.24 (Table 2a). However, corresponding values for sugar yield trait were 1.0 ± 0.17 and 0.65 to 1.29, respectively (Table 3a). Based on higher value of RDI for cane and sugar yield; four clones/varieties namely CoPb 11211, CoPb 13181, CoPb 13183 and CoPb 10181 were categorized as tolerant and 19 clones with respect to cane yield and 24 clones with respect to sugar yield showed intermediate behavior for water stress tolerance. Based on high score of both DI and RDI indices, 2 clones namely CoPb 11211 and CoPb 13181 were found drought tolerant while others showed a variable behavior (Fig. 7a and

Table 3a. Stress tolerance indices score of sugarcane clones/varieties based on mean sugar yield under water stress and normal conditions

Clones/varieties	SSI	STI	YSI	YI	DI	RDI	K1 STI	K2 STI
Co 0238	1.17	3.88	0.51	1.25	0.64	0.88	2.03	1.57
CoJ 88	0.97	3.02	0.59	1.17	0.70	1.02	1.32	1.38
CoS 8436	1.15	2.98	0.52	0.97	0.50	0.89	1.20	0.95
CoPb 91	1.17	2.48	0.51	0.80	0.40	0.88	0.83	0.64
Co 118	1.48	2.44	0.38	0.62	0.24	0.65	0.91	0.39
CoJ 85	1.49	1.68	0.37	0.43	0.16	0.65	0.44	0.18
CoJ 64	1.02	1.84	0.57	0.68	0.39	0.98	0.48	0.46
CoPb 92	1.13	2.05	0.52	0.68	0.36	0.91	0.57	0.47
CoPb 11214	0.94	1.62	0.61	0.65	0.39	1.05	0.39	0.42
CoPb 14212	1.20	2.11	0.50	0.66	0.33	0.86	0.60	0.44
CoPb 14211	1.11	2.53	0.53	0.86	0.46	0.92	0.87	0.73
CoPb 12212	1.26	3.31	0.47	0.99	0.47	0.82	1.48	0.99
L 818/07	0.88	3.34	0.63	1.43	0.90	1.09	1.73	2.05
CoPb 11211	0.66	2.42	0.72	1.38	0.99	1.25	1.22	1.89
CoPb 93	0.77	3.38	0.68	1.66	1.13	1.17	2.02	2.77
CoPb 13181	0.73	2.46	0.69	1.28	0.89	1.20	1.13	1.63
CoPb 13182	0.77	2.71	0.68	1.32	0.89	1.17	1.29	1.75
CoPb 13183	0.61	1.47	0.74	0.91	0.68	1.29	0.50	0.83
CoPb 10181	0.64	1.62	0.73	0.96	0.70	1.26	0.58	0.92
CoPb 12181	0.78	1.98	0.67	0.96	0.65	1.16	0.68	0.92
CoPb 12182	0.81	2.02	0.66	0.94	0.62	1.14	0.68	0.89
KV 2012- 1	0.76	2.58	0.68	1.27	0.86	1.17	1.18	1.62
KV 2012- 2	1.08	2.86	0.55	1.00	0.55	0.95	1.12	1.00
KV 2012- 3	1.00	2.61	0.58	0.98	0.56	1.00	0.96	0.96
KV2012- 4	1.13	3.39	0.53	1.14	0.60	0.91	1.56	1.29
KV 2012- 5	1.00	2.63	0.58	0.99	0.57	1.00	0.98	0.98
ISH 148	0.97	2.32	0.59	0.90	0.53	1.02	0.77	0.81
ISH 07	1.24	2.72	0.48	0.83	0.39	0.83	1.00	0.68
ISH 135	1.08	3.19	0.55	1.12	0.61	0.94	1.40	1.25
ISH 159	1.06	3.30	0.55	1.17	0.65	0.95	1.50	1.37
Grand Mean	1.00 ± 0.23	2.56 ±0.62	0.58 ± 0.10	1.00 ± 0.28	0.59 ± 0.23	1.00 ± 0.17	1.04 ± 0.45	1.07 ± 0.58
Range	0.61-1.49	1.47-3.88	0.37-0.74	0.43-1.66	0.16-1.13	0.65-1.29	0.39-2.03	0.18-2.77

SSI= Stress Susceptibility Index; STI= Stress Tolerance Index; YSI= Yield Stability Index; YI= Yield Index; DI= Drought Tolerance Index; RDI= Relative Drought Tolerance Index; K1 STI & K2 STI= Modified Stress Tolerance Index

b). These results are in agreement with the finding of Khalili *et.al*. (2012), who reported such differential behavior of canola genotypes for this index. The higher relative tolerance of the clone/variety observed if RDI>1, the genotype is relatively drought tolerant.

Modified stress tolerance index (K1 STI & K2 STI)

These indices are modified and improved version of Stress tolerance index (STI). K1 index represents behavior of clones/varieties under water stress environment where as K2 index is representative of normal environment. Maximum values of these indices are congruent to maximum tolerance for stress conditions. K1 and K2 index average score for cane yield is 1.04 ± 0.40 and 1.05 ± 0.43 respectively (Table 2a). For sugar yield the average K1 and K2 index average score is 1.04 ± 0.45 and 1.07 ± 0.58 (Table

Table 3b. Stress tolerance indices score of sugarcane clones/varieties based on mean sugar yield under water stress and normal conditions

Clones/varieties	TOL	GMP	MP	SSPI
Co 0238	6.42	9.34	9.88	34.97
CoJ 88	4.29	8.12	8.40	23.37
CoS 8436	4.86	7.21	7.61	26.47
CoPb 91	4.12	5.95	6.30	22.44
Co 118	5.43	5.38	6.03	29.58
CoJ 85	3.79	3.71	4.17	20.64
CoJ 64	2.73	4.78	4.98	14.87
CoPb 92	3.29	5.01	5.28	17.92
CoPb 11214	2.25	4.43	4.58	12.25
CoPb 14212	3.60	5.02	5.33	19.61
CoPb 14211	3.99	6.24	6.56	21.73
CoPb 12212	5.90	7.68	8.23	32.14
L 818/07	4.46	9.59	9.85	24.29
CoPb 11211	2.83	8.62	8.74	15.41
CoPb 93	4.20	10.75	10.95	22.88
CoPb 13181	2.99	8.15	8.29	16.29
CoPb 13182	3.38	8.55	8.72	18.41
CoPb 13183	1.66	5.61	5.67	9.04
CoPb 10181	1.87	5.96	6.04	10.19
CoPb 12181	2.48	6.23	6.35	13.51
CoPb 12182	2.57	6.17	6.31	14.00
KV 2012- 1	3.21	8.22	8.38	17.48
KV 2012- 2	4.40	7.20	7.53	23.97
KV 2012- 3	3.80	6.84	7.10	20.70
KV2012- 4	5.43	8.32	8.76	29.58
KV 2012- 5	3.83	6.91	7.18	20.86
ISH 148	3.30	6.21	6.43	17.97
ISH 07	4.80	6.35	6.79	26.14
ISH 135	4.92	8.03	8.40	26.80
ISH 159	5.03	8.37	8.74	27.40
Grand Mean	3.86 ± 1.18	6.97 ± 1.67	7.25 ± 1.67	21.03 ± 6.44
Range	1.66-6.42	3.71-10.75	4.17-10.95	9.04-34.97

TOL= Stress Tolerance; GMP= Geometric Mean Productivity; MP= Mean Productivity; SSPI= Stress Susceptibility Percentage Index

3a). Range of index score k1 corresponding to cane and sugar yield is 0.41 to 2.07 and 0.39 to 2.03 whereas K2 range for cane and sugar yield is 0.24 to 2.21 and 0.18 to 2.77 respectively. As per the K1 index score Co 0238, CoPb 93 and ISH 159 exhibit maximum values and thus inferred as most tolerant for water stress conditions whereas CoPb 85, CoJ 64 and CoPb 11212 were grouped as susceptible due to least index values and categorizing the rest genotypes as intermediate due to intermediate score in respect to both cane and sugar yield (Fig. 7a & b). K2 index score categorize Co 0238 and CoPb 93 as tolerant genotypes and Co 118, CoJ 85 and CoJ 64 as susceptible genotypes when taken in account the cane and sugar yield (Fig. 8 a & b).

Stress tolerance (TOL)

Least index value of this parameter signifies better tolerance of the clones/varieties in the water stressed conditions. Clones/varieties recorded significant variability for TOL. TOL index ranged from 9.72 - 45.69
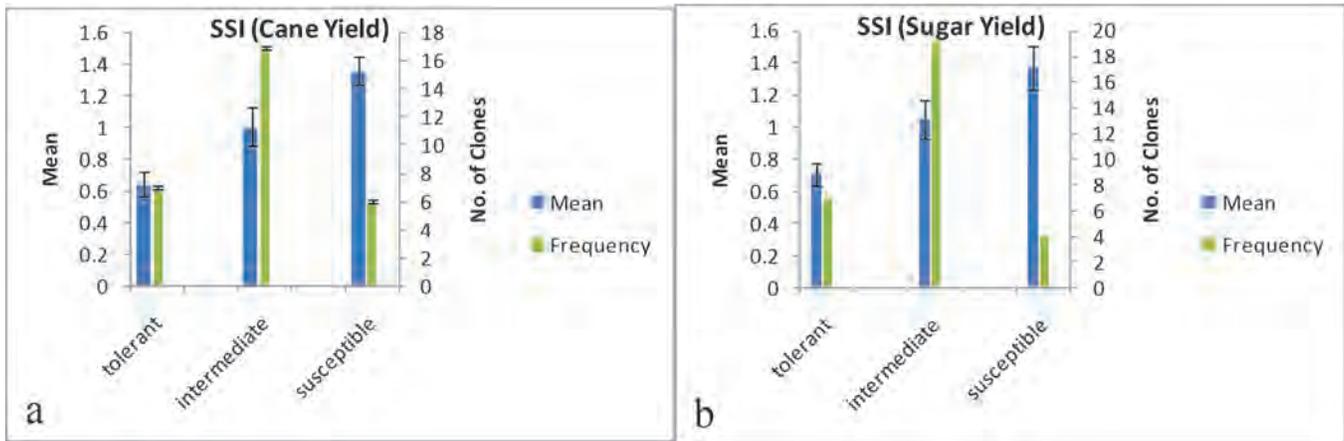
Fig. 1a and b. Characterization of sugarcane clones/ varieties based on SSI calculated from mean cane and sugar yields under water stress and non -stress conditions
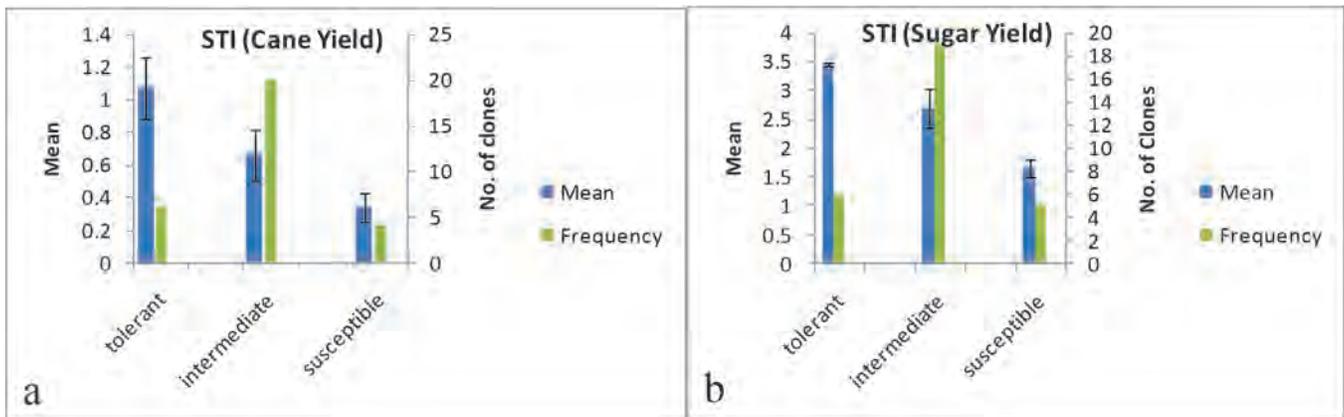
Fig. 2a and b. Characterization of sugarcane clones/ varieties based on STI calculated from mean cane and sugar yields under water stress and non -stress conditions
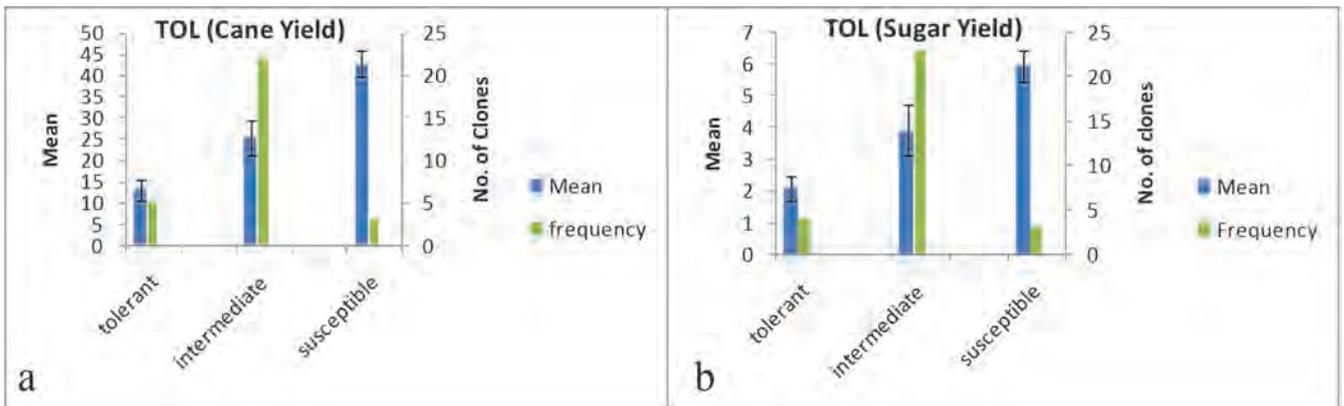
Fig. 3a and b. Characterization of sugarcane clones/ varieties based on TOL calculated from mean cane and sugar yields under water stress and non -stress conditions

with a grand mean of 24.93 ± 8.52 for cane yield (Table 2b). For sugar yield the TOL index grand mean comes out to be 3.86 ± 1.18 which falls within the range of 1.66 - 6.42 (Table 3b). 3 clones namely CoPb 10181, CoPb 12181 and CoPb 13183 are tolerant to stressed conditions based on the TOL index for both cane and sugar yield whereas 2 clones viz: Co 0238 and CoPb 12212 recorded susceptible behavior and the rest fall in intermediate semitolerant group (Fig. 9a & b). Selection through TOL chooses genotype with low YP but with high YS. MP is mean yield for a genotype in two stress and non-stress conditions. MP can select genotypes

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with high YP but with relatively low YS and it fails to distinguish groups. By decreasing TOL and increasing MP, the relative tolerance increases (Rosielle and Hamblin, 1981; Fernandez, 1992).

Mean and Geometric Mean productivity

Based upon high GMP four clones/varieties namely Co 0238, CoPb 93, KV 2012-4, ISH 159 were found water stress tolerant having GMP with grand mean score of 62.68 ± 12.18 for cane yield (Table 2b) and 6.97 ± 1.67 for sugar yield (Table 3b). Co 0238 and CoPb 93 are high yielders and common clones which showed tolerant behavior in relation to both cane and sugar yield as per the GMP score. However, the frequency distribution among thirty clones /varieties categorized as tolerant, intermediate and susceptible was variable for these traits. Based on GMP for cane yield, 4 clones were found tolerant, 22 intermediate and 4 as susceptible. Similarly for sugar yield 3 were tolerant, 22 were intermediate and 5 were susceptible (Fig. 10a & b).

MP score range is 37.10 to 88.54 with a grand mean of 64.02 ± 12.31 for cane yield (Table 2b) and 4.17 to 10.95 with grand mean of 7.25 ± 1.67 for sugar yield (Table 3b). Significant variability was found among the genotypes in mean productivity index. Higher the MP score higher is the tolerance ability. 5 clones recorded relatively tolerant behavior, 22 clones showed relatively semitolerant behavior whereas 2 clones are found to be susceptible in stressed conditions in respect to both cane and sugar yield as per the MP score (Fig. 11a & b).

Mean productivity index MP and Geometric mean productivity GMP categorized the common 3 clones/ varieties namely L 818/07, CoPb 93 and Co 0238 as tolerant cutivars for cane yield and common 4 clones namely Co 0238, CoPb 93, KV 2012-4 and ISH 159 as tolerant cultivars for sugar yield. GMP is more powerful than MP in separating clones and has a lower susceptibility to different amounts of YS and YP so; MP, which is based on arithmetic mean, will be bias when the difference between YS and YP is high. Therefore, higher GMP value, the greater the degree of tolerance. Geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environments and over years (Fernandez, 1992).

Stress susceptibility percentage index (SSPI)

To compare the relative efficiency of various stress indices, SSPI as suggested by Moosavi *et al*. (2008) was worked out to assess the relative drought tolerance of sugarcane clone/varieties that is grown under water stress and non stressed conditions. The SSPI score ranged from 6.36 -29.90 with a grand mean of 16.32 ± 5.58 for cane yield and 9.04 - 34.97 with grand mean of 21.03 ± 6.44 for sugar yield (Table 2b and 3b). SSPI score was inversely proportional to the stress tolerance behavior of the clones/varieties. Based on low SSPI score amongst the clones calculated for cane and sugar yields, four clones/varieties namely CoPb 12181, CoPb 12182, CoPb 13183 and CoPb 10181 were found water stress tolerant (SSPI for cane yield< 10.74 and < 14.59 for sugar yield). Of the clones tested for SSPI in respect to cane and sugar yield, 22 clones showed relatively semi-tolerant behavior in stressed conditions suggesting the significance of this index for screening crop genotypes under stress conditions (Fig. 12a & b). Moosavi *et al*. (2008) used this index in wheat genotypes for their screening to relative drought tolerance. SSPI reveal the tolerance of a cultivar to drought stress as the nature of SSPI is such that it rely on the survival mechanisms of crops in stress conditions although such clones may have either high or low yields in two water conditions. The yield stability is of more importance than high yield for this index.

Correlation matrix among different indices, cane and sugar yields

Further, to determine the most desirable drought tolerant criteria, the correlation coefficients between Yp, Ys and other quantitative indices of drought tolerance were calculated (Table 4). In other words, correlation analysis between cane and sugar yield and drought tolerance indices can be a good criterion for screening the best cultivars and indices used. Cane yield in stress (Ys) condition was significantly and positively correlated with STI, GMP, MP, TOL, YI, YSI, indicating that these criteria were more effective in identifying high yielding cultivars under different water stress conditions. Sugar yield in stressed conditions was found to be positively correlated with all the decisive indices for the best cultivars screening.

Perusal of correlation tables (4a and 4b) delineating relation between cane and sugar yield with different stress indexes revealed that cane yield under water stressed (E_2) condition was significantly correlated with stress susceptibility index, yield index, drought resistant index, geometric mean productivity, mean production. It was also positively and significantly correlated with yield stability index. Higher the values of these indexes under E_2 environment, higher will be the respected cane yield and thus the better land productivity. Cane yield reported to be have significant positive correlation with all the indices at 0.01 level except yield stability index and relative drought index, which reported to have a significant negatively correlation. However, tolerance reported to be having non-significant effect on the cane yield. Therefore, yield might be reduced
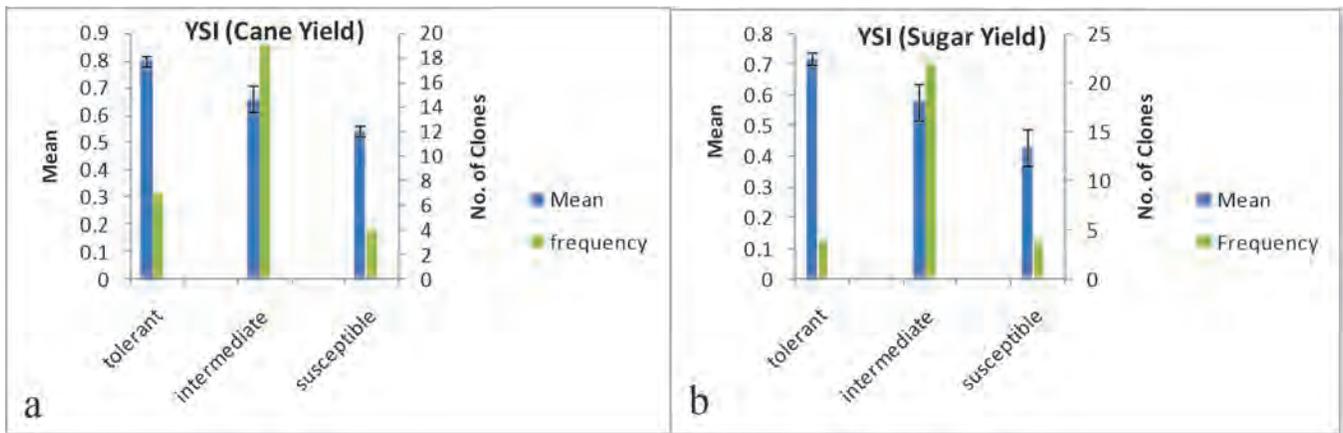
Fig. 4a &b. Characterization of sugarcane clones/ varieties based on YSI calculated from mean of cane and sugar yields under water stress and non -stress conditions
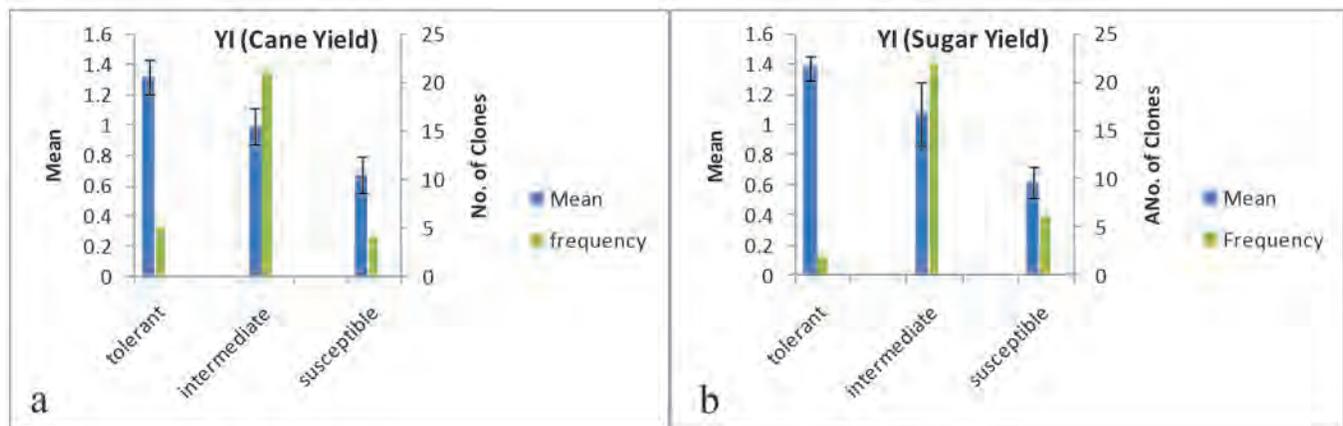
Fig. 5a and b. Characterization of sugarcane clones/ varieties based on YI calculated from mean cane and sugar yields under water stress and non -stress conditions
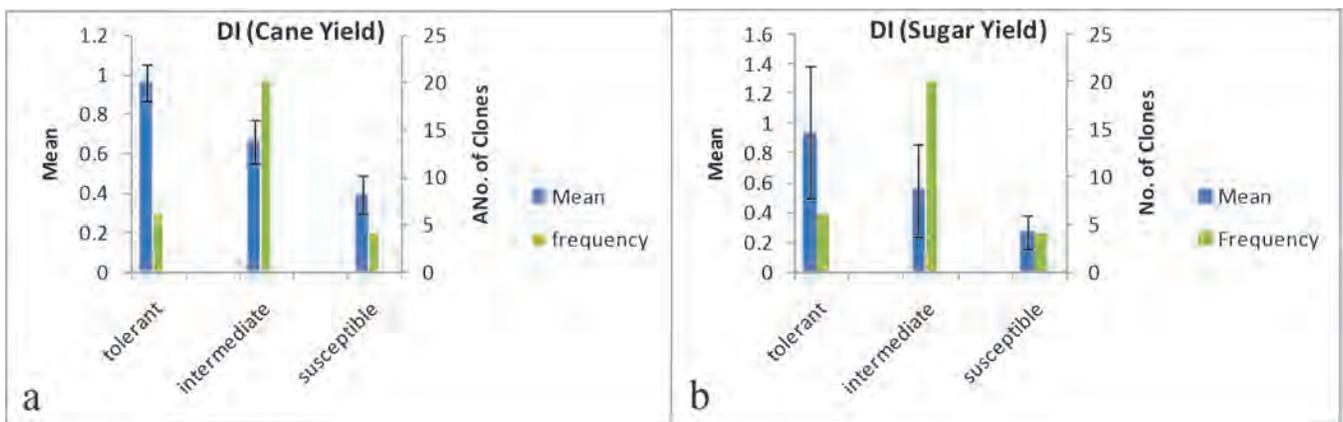
Fig. 6a and b. Characterization of sugarcane clones/ varieties based on DI calculated from mean cane and sugar yields under water stress and non -stress conditions
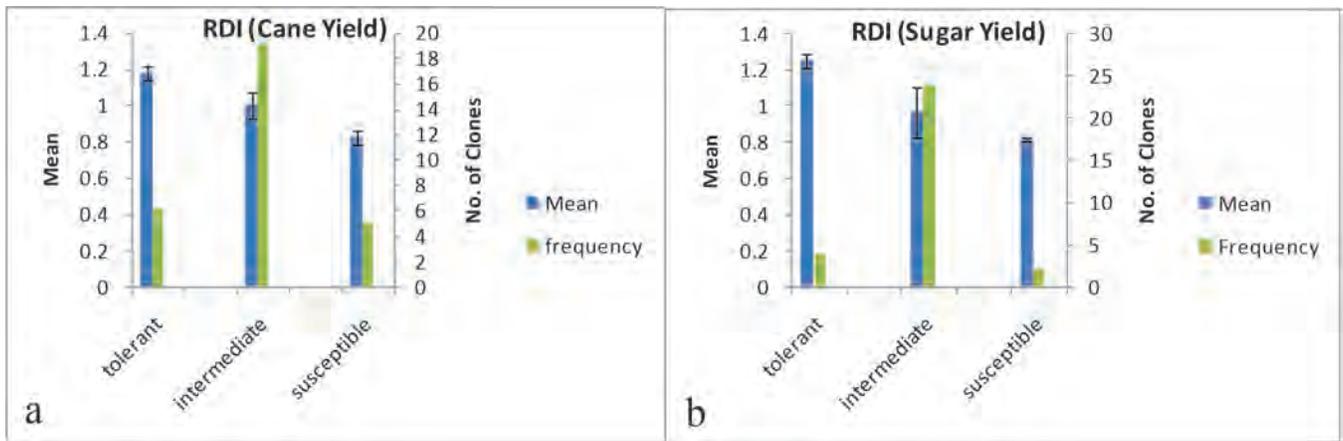
Fig. 7a and b. Characterization of sugarcane clones/ varieties based on RDI calculated from mean cane and sugar yields under water stress and non -stress conditions
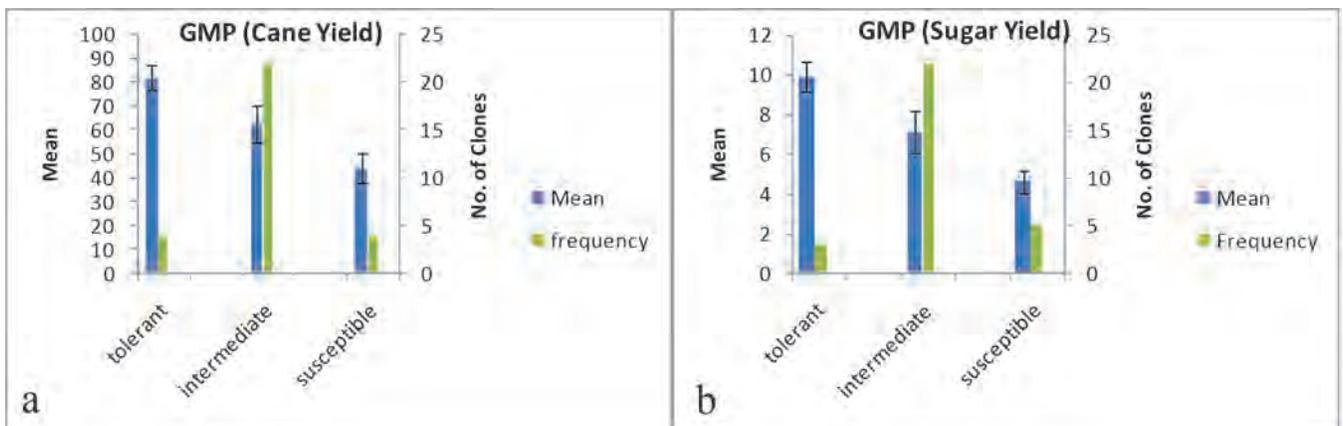

Fig. 8a and b. Characterization of sugarcane clones/ varieties based on GMP calculated from mean cane and sugar yields under water stress and non -stress conditions
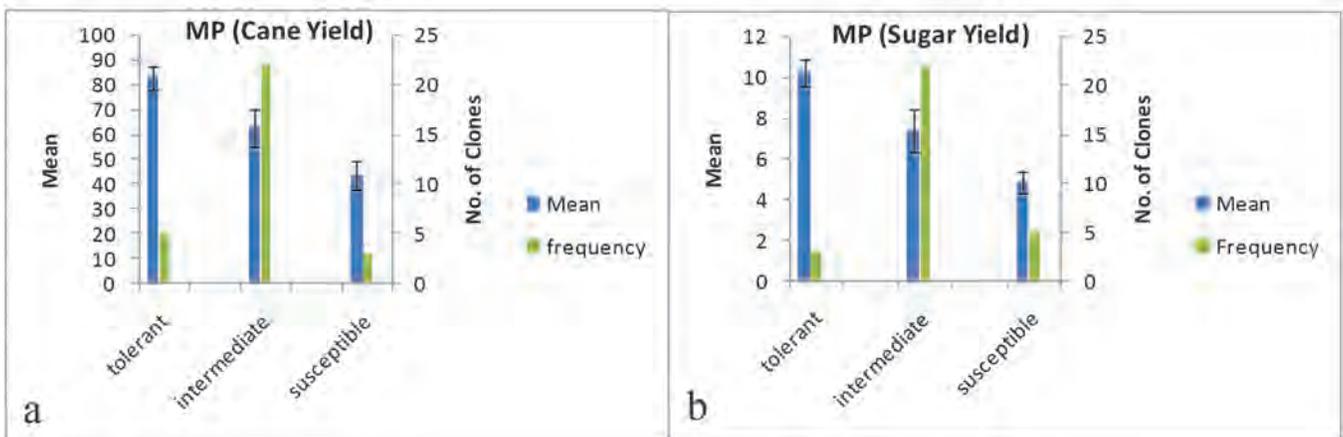

Fig. 9a and b. Characterization of sugarcane clones/ varieties based on MP calculated from mean cane and sugar yields under water stress and non -stress conditions

Fig. 10a and b. Characterization of sugarcane clones/ varieties based on SSPI calculated from mean cane and sugar yields under water stress and non -stress conditions
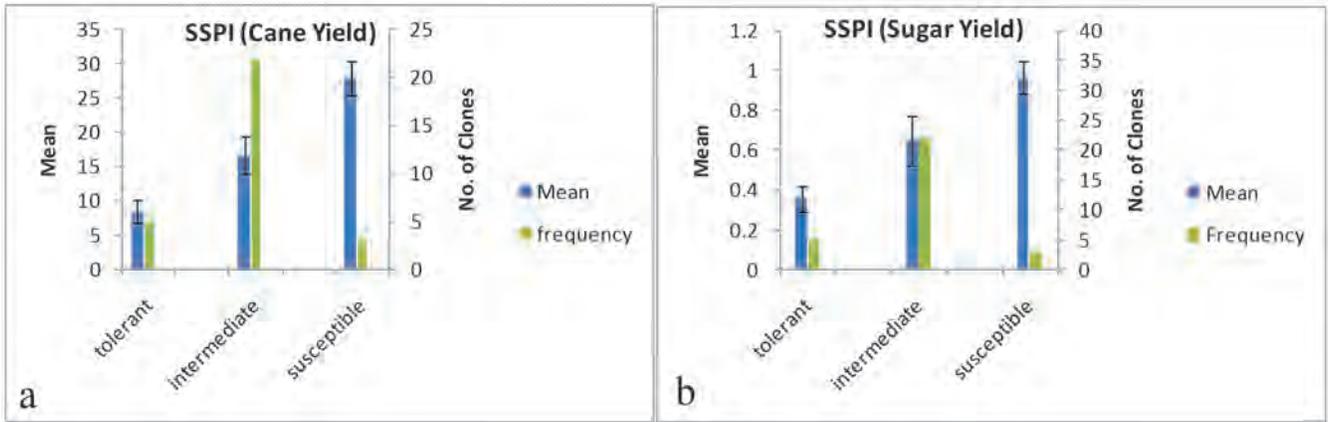
Fig. 11a and b. Characterization of sugarcane clones/ varieties based on K1 STI calculated from mean cane and sugar yields under water stress and non -stress conditions

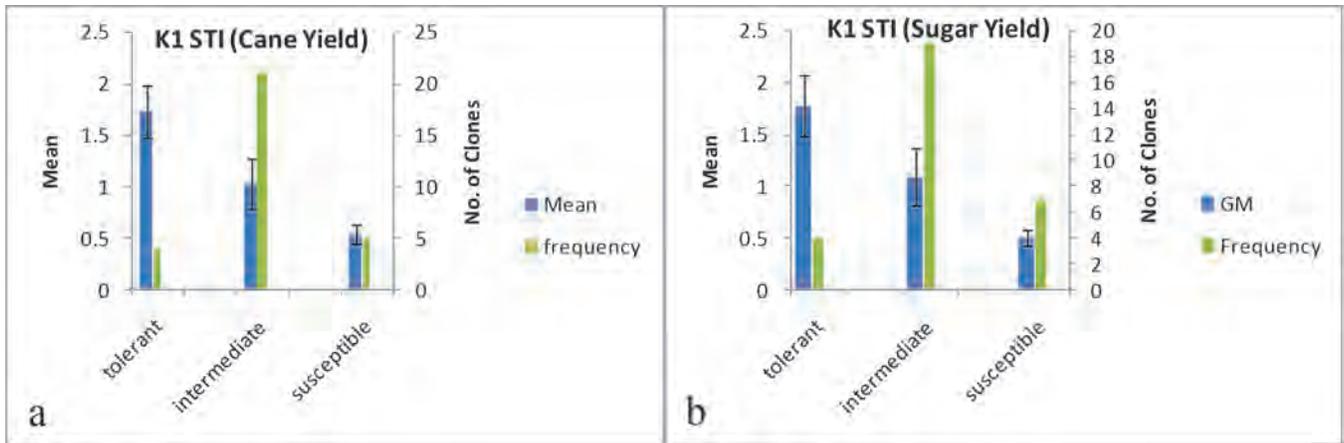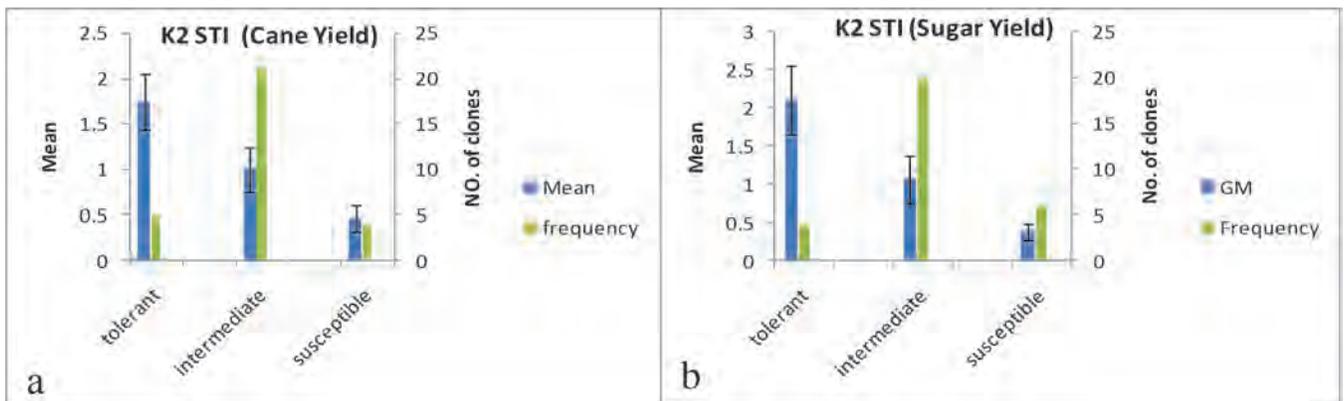**Fig. 12a and b. Characterization of sugarcane clones/ varieties based on K2 STI calculated from mean cane and sugar yields under water stress and non -stress conditions**

significantly proportionately with proportionate increase in these parameters while the yields will be significantly increased with significant increase in all the other indices. Under, E_1 environment, except YSI and RDI, all the indexes reported to be significantly positively correlated with cane yield.

Further, as far as sugar yields is concerned, it is delineated from the Table 3b that under E_1 environment, the sugar yields significantly affected with stress susceptibility index, tolerance, yield index, drought resistant index, geometric mean productivity, mean production and stress susceptibility percentage while the relation observed to be non-significant with yield stability index and relative drought index. However, under E_2 environment, sugar yields significantly affected with stress susceptibility index, yield stability index, yield index, drought resistance index, relative drought index, geometric mean productivity, mean production, while relation observed to be non-significant with tolerance and stress susceptibility percentage. Under E_2 environment, yield stability index and tolerance, relative drought index and tolerance and stress susceptibility percentage and yield stability index significantly negatively correlated to each other while the correlation between yield stability index and stress susceptibility index, drought resistance index and tolerance, relative drought index and stress susceptibility index observed to be negative which means that with the increase in one indexes, other indexes will be proportionately decreased which will certainly have relationship with the sugar yield. Similarly, under E_1 environment, stress susceptibility index has negative correlation with yield stability index and relative drought index while tolerance and yield stability index, tolerance and relative drought index, yield stability index and stress susceptibility percentage and relative drought index and stress susceptibility percentage has negative correlation with each other. Toorchi *et al.* (2012) showed that correlation between MP, GMP, Ys and Yp was positive. Dehghani *et al.* (2009) reported that GMP, MP and STI were significantly and positively correlated with stress yield. Farshadfar *et al.* (2001) believed that most appropriate index for selecting stress tolerant cultivars is an index which has partly high correlation with cane yield under stress and non-stress conditions. The observed relations were consistent with those reported by Toorchi *et al.* (2012) in canola and Golabadi *et al.* (2006) in durum wheat. Ehdaie and Shakiba (1996) in wheat found that there was no correlation between stress susceptibility and yield under optimum condition.

Further, it could also be concluded that STI, YI, DI, GMP and MP might be used for evaluating/screening different sugarcane cultivars for the water stressed regions as far as cane yield is concerned while STI, YI,

DI, GMP and MP are the indexes which might be used for screening sugarcane cultivars for the water stressed regions as far as sugar yield is concerned.

However, in an all STI, YI, DI, GMP and MP are the indexes which could be used for screening out sugarcane cultivars for the water stressed region for both cane and sugar yields.

Sugarcane is an industrial crop and of vital importance to India, in the production of sugar and jaggery, ethanol, power generation and raw materials for different purposes. In Indian agriculture, drought is by far the most important environmental stress that constrains crop yield (Blum *et al.*, 1988). In addition, increasing temperature is an important component of climate change and its negative impact on cane yield is expected to increase in the future. Indeed, it has been demonstrated that growing sugarcane crop under water stress can lead to a 30–35 per cent reduction in cane yield, when compared with controls (well irrigated conditions). Many efforts have been made to improve sugarcane productivity under water-limiting conditions. While breeding activity has directed selection towards increasing the economic yield of cultivated varieties, natural selection has favoured mechanisms of adaptation and survival. Decades of breeding activities have focused on the increase of cane yield under drought environments for this crop. Meanwhile, significant gains in understanding the physiological and molecular responses of plants to water deficits have been provided by fundamental researches. However, in both conventional breeding and biotechnology the drought-resistant ideotype is not always well defined and traits that might deliver high drought productivity are not always clear. Further, a little progress had been made in identifying key mechanisms involved in delivering a combination of high cane productivity and stress resilience. The concepts of drought tolerance as set out in the literature can differ significantly. Effectively, the ecological definition of drought resistance is the ability to stay alive during periods of low water supply. Alternatively, for crops, drought tolerance is defined as the ability of plants to grow and reproduce satisfactorily to produce harvestable yield with limited water supply or when under periodic water deficit (Fleury *et al.*, 2010). It has been suggested that cane and sugar yield stability is a better indicator of genotypic drought resistance compared with cane yield under stress. In this context, present study revealed that lower score values for seven stress and stability indices viz. stress susceptibility index (SSI), stress tolerance index (STI), yield stability index (YSI), yield index (YI), drought resistance index (DI), relative drought index (RDI) and modified stress tolerance index (K1STI and K2STI) higher score for stress tolerance (TOL), mean productivity and

Table 4a. Correlation coefficients among cane yield and different indices in sugarcane under water stress conditions

	CY	SSI	STI	TOL	YSI	YI	DI	RDI	GMP	MP	SSPI	K1	K2
CY	1												
SSI	-0.451	1											
STI	0.949**	-0.163	1										
TOL	0.148	0.788**	0.430**	1									
YSI	0.451**	-1.000	0.163	-0.788	1								
YI	1.000**	-0.451	0.949**	0.148	0.451**	1							
DI	0.922**	-0.751	0.764**	-0.243	0.751**	0.922**	1						
RDI	0.451**	-1.000	0.163	-0.788	1.000**	0.451**	0.751**	1					
GMP	0.959**	-0.188	0.993**	0.422**	0.188	0.959**	0.775**	0.188	1				
MP	0.940**	-0.128	0.992**	0.478**	0.128	0.940**	0.735**	0.128	0.998**	1			
SSPI	0.148	0.788**	0.430**	1.000**	-0.788	0.148	-0.243	-0.788	0.422**	0.478**	1		
K1	0.807**	0.135	0.946**	0.693**	-0.135	0.807**	0.523**	-0.135	0.938**	0.957**	0.693**	1	
K2	0.989**	-0.421	0.956**	0.150	0.421**	0.989**	0.912**	0.421**	0.950**	0.931**	0.150	0.810**	1

CY= Cane Yield; SSI= Stress Susceptibility Index; STI= Stress Tolerance Index; TOL= Stress Tolerance; YSI= Yield Stability Index; YI= Yield Index; DI= Drought Tolerance Index; RDI= Relative Drought Tolerance Index; GMP= Geometric Mean Productivity; MP= Mean Productivity; SSPI= Stress Susceptibility Percentage Index; K1 & K2 STI= Modified Stress Tolerance Index

Table 4b. Correlation coefficients among sugar yield and different indices in sugarcane under water stress conditions

	CY	SSI	STI	TOL	YSI	YI	DI	RDI	GMP	MP	SSPI	K1	K2
CY	1												
SSI	-0.577	1											
STI	0.643**	0.209	1										
TOL	0.171	0.674**	0.848**	1									
YSI	0.577**	-1.000	-0.209	-0.674	1								
YI	1.000**	-0.577	0.643**	0.171	0.577**	1							
DI	0.943**	-0.797	0.350**	-0.160	0.797**	0.943**	1						
RDI	0.577**	-1.000	-0.209	-0.674	1.000**	0.577**	0.797**	1					
GMP	0.964**	-0.350	0.820**	0.426**	0.350**	0.964**	0.821**	0.350**	1				
MP	0.938**	-0.268	0.863**	0.503**	0.268	0.938**	0.770**	0.268	0.996**	1			
SSPI	0.171	0.674**	0.848**	1.000**	-0.674	0.171	-0.160	-0.674	0.426**	0.503**	1		
K1	0.817**	-0.027	0.947**	0.696**	0.027	0.817**	0.587**	0.027	0.937**	0.963**	0.696**	1	
K2	0.985**	-0.540	0.618**	0.165	0.540**	0.985**	0.935**	0.540**	0.947**	0.922**	0.165	0.814**	1

CY= Cane Yield; SSI= Stress Susceptibility Index; STI= Stress Tolerance Index; TOL= Stress Tolerance; YSI= Yield Stability Index; YI= Yield Index; DI= Drought Tolerance Index; RDI= Relative Drought Tolerance Index; GMP= Geometric Mean Productivity; MP= Mean Productivity; SSPI= Stress Susceptibility Percentage Index; K1 & K2 STI= Modified Stress Tolerance Index

geometric mean productivity (MP and GMP) and stress susceptibility percentage index (SSPI) categorized the clones/ varieties as tolerant ones. Further association studies showed that all the indices exhibited significant positive interaction with cane and sugar yields (CY and SY) under stress conditions except SSI and SSPI, indicating that they are a better predictor of potential cane and sugar yields under stress conditions and can be useful for sugarcane researchers. Differential behaviour of clones/ varieties (Table 5) reported in study with lowest score for SSI, STI, YSI, YI, DI, RDI and (K1STI and K2STI) and highest score for TOL, MP, GMP and SSPI were categorized for enhanced tolerance to water stress in terms of their resilience and production capacity to have better cane and sugar yields.

Authors' contribution

Conceptualization of research work and designing of experiments (GSS); Execution of field/lab experiments

Table 5. Differential response of sugarcane clones/varieties with respect to different stress susceptiblity/stability indices

S.No	Stress Tolerance Indices	Promising Clones/varieties for cane yield	Promising Clones/varieties for sugar yield
1	SSI	CoPb 11211, CoPb 93, CoPb 13181, CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182	CoPb 11211, CoPb 93, CoPb 13181, CoPb 13182, CoPb 13183, CoPb 10181, KV 2012-1
2	STI	Co 0238, L 818/07, CoPb 93, KV 2012-4, ISH 135, ISH 159	Co 0238, CoPb 12212, L 8818/07, CoPb 93, KV 2012-4, ISH 159
3	YSI	CoPb 11211, CoPb 13181, CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182, ISH 159	CoPb 11211, CoPb 13181, CoPb 13183, CoPb 10181
4	YI	Co 0238, L 818/07, CoPb 93, CoPb 13182, ISH 159	L 818/07, CoPb 13182
5	DI	L 818/07, CoPb 11211, CoPb 93, CoPb 13181, CoPb 13182, ISH 159	L 818/07, CoPb 11211, CoPb 93, CoPb 13181, CoPb 13182, KV 2012-1
6	RDI	CoPb 11211, CoPb 13181, CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182	CoPb 11211, CoPb 13181, CoPb 13183, CoPb 10181
7	K1 STI	Co 0238, CoPb 12212, CoPb 93, ISH 159	Co 0238, CoPb 93, KV 2012-4, ISH 159
8	K2 STI	Co 0238, L 818/07, CoPb 93, CoPb 13182, ISH 159	L 818/07, CoPb 11211, CoPb 93, CoPb 13181
9	TOL	CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182	CoPb 11214, CoPb 13183, CoPb 10181, CoPb 12181
10	GMP	Co 0238, CoPb 93, KV 2012-4, ISH 159	Co 0238, L 818/07, CoPb 93
11	MP	Co 0238, L 818/07, CoPb 93, KV 2012-4, ISH 159	Co 0238, L 818/07, CoPb 93
12	SSPI	CoJ 64, CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182	CoPb 11214, CoPb 13183, CoPb 10181, CoPb 12181, CoPb 12182

and data collection (GSS, LK); Analysis of data and interpretation (GSS, LK, A); Preparation of manuscript (GSS, LK, A).

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