Plant Archives Vol. 21, No. 2, 2021 pp. 662-670 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no2.102

MORPHOLOGICAL RESPONSES OF SUGARCANE CULTIVARS AGAINST WATER DEFICIT STRESS IN NORTHERN KARNATAKA REGION OF INDIA

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(Date of Receiving : 13-05-2021; Date of Acceptance : 19-08-2021)

ABSTRACT

The morphological responses of sugarcane cultivars against water deficit stress were carried out in twenty-three cultivars of sugarcane grown in Yaragatti Farm of S. Nijalingappa Sugar Institute, Belagavi in Karnataka, India. Data was recorded at different time intervals, i.e., control, moderate and severe water deficit conditions. During these different time intervals, parameters such as the number of tillers, total plant height, stalk length, number of internodes and cane diameter were recorded to have a comparative study among varieties of sugarcane against water deficit stress. Thus, these distinct characters help to understand those varieties that are better suited for water deficit stress and can further be useful for selective breeding programme for commercial production of sugarcane cultivars. Therefore, cultivars which are resistant to water deficit stress such as Co 09004, Co 14011, Co 13003, Co 95020, Co 08020, Co 86032, Co 05001 and Co 671 showed increase in numbers of tillers, total plant height, stalk length, number of internodes, and cane diameter. Further, through these morphological studies, principal component analysis was done to identify the genotypes which are resistant to water deficit stress.

***Keywords* :** Morphological parameters; Principal component analysis; Sugarcane; Water deficit stress.

INTRODUCTION

Sugarcane belongs to family Poaceae, genus *Saccharum*, tribe Andropogoneae. It has four different phases of growth such as germination, formative, grand growth and maturation phase (Gasho & Shih, 1983; Endres *et al.*, 2018). It is cultivated about 19.38 million hectares in 2000 and an increase of 25.98 million hectares in 2017 was seen (Ram & Ramaiyan, 2019). It is grown in more than 120 countries among which Brazil (420,121,000 MT), India (232,320,000 MT), China (88,730,000 MT), Thailand (49,572,000 MT), Pakistan (47,244,100), Mexico (45,126,100 MT), Columbia (39,849,240 MT), Australia (38,246,100 MT), Philippines (31,000,100 MT) and USA (25,803,960 MT) are the top ten countries in production (FAO, 2005; Srivastava & Rai, 2012). Brazil ranks first in the world with 33% of global sugar cane production followed by India (23%) China (7%) and Pakistan (4%) (FNP 2009; Srivastava & Rai, 2012). Among which India occupies second position with respect to the area of 4.2 million hectares, having production of 314 million tons. Major sugarcane growing states in India which has the highest area of cultivation viz. Uttar Pradesh (47.05%) followed by Maharashtra (17.52%), Karnataka (7.76%), Tamil Nadu (7.47%), Gujarat (4.57%), Andhra Pradesh (3.76%) contributing 88% of total area (Srivastava and Rai, 2012) and remaining 12% sugarcane growing states are Bihar, Uttarakhand, Haryana, Madhya Pradesh, Chhattisgarh and Punjab (ICRISAT, 2009; Srivastava & Rai, 2012). *Saccharum barberi* Jeswiet, the sugarcane of India, and *Saccharum sinense* Roxb. of China was known through folklore and mythology from 1000 to 500 B.C. These original sugarcanes were delivered to the Americans by Columbus in 1493 and spread by human from the Orient through the Middle East, Northern Africa, and the Mediterranean (Hussain *et al.*, 2004). Interspecific crosses were done between *S. officinarum* having chromosome number ‘10’, with high sugar content and *S. spontaneum* chromosomes number ‘8’ having high plant vigor and resistance towards pest. These sugarcanes (*S. officinarum X S. spontaneum)* of distinct chromosomal organization and superiority provided the new approach in production of modern cultivars of sugarcane (Bordonal *et al.*, 2018). Different sugarcane cultivars resemble each other in their appearance but it has different morphological traits. These traits are also influenced by the environmental factors (Chidambaram and Sivasubramaniam, 2017).

One of the key factors responsible for growth of crop is a change in climate which increases the rate of transpiration in leaves. As it develops different mechanism of resistance to deal with stress by escaping drought period and by reducing their life cycle (Cia *et al.*, 2012). However, up to 60% of total loss in production may be due to drought at early growth stage and midseason. However, tillering combined with early grand growth stage which is the most important phase during which 70-80% of the cane yield takes place. Any change caused due to environmental factor during this period leads to reduction in the total plant height, stalk diameter, number of tillers, leaf area and total biomass which in turn affects the yield (Devi *et al*., 2018; Dinh *et al*., 2017; Ferreira *et al*., 2017; Hemaprabha *et al*., 2013; Misra *et al*., 2020; Ramesh, 2000). Thus, studies revealed that those sugarcane varieties susceptible to drought wilted by having lesser cane production when compared to other varieties which are tolerant to stress that remain turgid. Hence this factor helps in identification and evolution of water stress tolerant varieties from that of susceptible ones (Hemaprabha *et al*., 2006, 2013). The present study focuses on the impact of water deficit stress on morphological parameters of 23 sugarcane cultivars during the early growth period.

MATERIALS AND METHODS

Experimental Layout and Design

Twenty-three sugarcane cultivars were selectively grown in Yargatti farm of S. Nijalingappa Sugarcane Institute, Belagavi, Karnataka, India. These includes Co 09004, Co 0303, Co 14011, Co 98017, Co 13003, Co 93009, Co 95020, Co 92013, Co 07015, Co 12007, Co 08020, Co 86032, Co 85019, Co 13006, Co 90003, Co 92002, Co 92020, Co 06015, Co 98008, Co 94005, Co 10033, Co 671 and Co 05001 were selected for water deficit stress. The plot size for each cultivar represented three rows of 1.5 cm spaced. The experiment consisted of 4 data collection (2 under water stress and other 2 after stress). The irrigation was given up to 60 days and then water stress was initiated by withholding irrigation from 60-120 Days After Planting (DAP) followed by normal irrigation until harvest for recovery studies. Periodical field visits were done satisfactorily to collect data during the period of February to December 2019. Measurable morphological characters such as, the number of tillers, total plant height (cm), stalk length (cm), number of internodes and cane diameter were taken into consideration for random stalks from each row. Stalk length was taken from last visible dewlap in cm. Cane diameter was measured from middle portion of stalk by using Vernier caliper in cm (Table 1). Internodal distance of each internode was measured by the measuring scale. Thus, estimation of the growth parameters of the plant samples, was done by taking three replications which were randomly selected and average of three replicas was calculated.

Statistical Analysis

The principal component analysis (PCA) was carried out on morphological parameters of sugarcane cultivars with different time intervals. Dendrogram analysis was performed for grouping patterns of sugarcane cultivars using SPSS Statistical Software (2011).

RESULTS AND DISCUSSION

Morphological Characterization

The yield of sugarcane mainly depends upon some of the morphological traits such as number of tillers (NOT), total plant height (TPH), stalk length (SL), number of internodes (NI) and cane diameter (CD) which were considered for the present study with different time intervals such as 90^{th} (T_1), 120^{th} (T_2), 150^{th} (T_3), 270^{th} (T_4) (DAP). Where 90^{th} and 120^{th} DAP was considered as water stress period. Among the twenty-three cultivars, the tolerant cultivars showed lesser number of tillers at 120^{th} DAP in cultivars Co 09004 (25), Co 671 (25), Co 14011 (24), Co 95020 (23), Co 92013 (27), Co 93009 (26), when compared recovery 270^{th} DAP Co 09004 (88), Co 14011 (86), Co 95020 (85), Co 93009 (72), Co 92013 (71), Co 671 (89); whereas, the genotypes which are susceptible to stress showed reduction in number of tillers at 120^{th} DAP genotypes such as Co 06015 (12), Co 12007 (16), Co 13006 (15), Co 92020 (14) when compared to 270 DAP Co 06015 (63), Co 12007 (72), Co 13006 (68), Co 92020 (67). Internode length in tolerant cultivars at 120^{th} DAP in Co 09004 (3 cm), Co 14011 (4 cm) and Co 671 (4 cm), Co 08020 (4 cm), Co 10033 (3 cm) when compared to 270^{th} DAP with Co 09004 (17 cm), Co 14011 (18 cm) and Co 671 (22 cm), Co 08020 (18 cm), Co 10033 (19 cm). Whereas, no growth has been observed in susceptible genotypes Co 86032, Co 07015, Co 92020, and Co 98008 at 120^{th} DAP, when compared to 270^{th} DAP in Co 86032(19), Co 07015 (14), Co 92020(15), and Co 98008(18). The number of internodes in water deficit stress affected canes was relatively lesser than in cane after rewatering. Similarly, (Hemaprabha *et al*., 2012; Misra *et al*., 2020) showed that there is decrease in the number of internodes in drought affected canes.

At 120^{th} DAP, total plant height was high in water tolerant cultivars Co 09004 (190.5 cm), Co 14011 (186 cm), Co 671 (203 cm) and Co 10033 (223 cm) when compared to 270^{th} DAP in Co 671 (379 cm), Co 10033 (356 cm), Co 09004 (370 cm) and Co 14011 (372 cm). Reduction was seen in susceptible cultivars at 120 DAP Co 06015 (144.5 cm), Co 07015 (153 cm), Co 92020 (155 cm) and Co 86032 (145 cm) in comparison with 270^{th} DAP Co 06015 (309 cm), Co 07015 (344 cm), Co 92020 (318 cm) and Co 86032 (373 cm). Stalk length in tolerant cultivars at 120^{th} DAP in Co 09004 (18.5 cm), Co 14011 (20.5 cm), Co 671 (21 cm) and Co 10033 (17cm) when compared to 270^{th} DAP in Co 09004 (210 cm), Co 14011 (199 cm), Co 671 (231 cm) and Co 10033 (223 cm). There was no growth seen as such at 120 DAPS in susceptible genotypes Co 98008, Co 07015, Co 86032, and Co 92020 when compared to 270^{th} DAP in genotypes Co 98008(199), Co 07015(182), Co 86032(199), and Co 92020(163). The difference in the stalk length after rewatering was highest than the decrease in the stalk length at water deficit stress. Cane height was affected by water deficit stress as illustrated by (Inman-Bamber & Smith, 2005; Misra *et al*., 2020; Silva *et al*., 2008). At 120 DAP, cane diameter at 120^{th} DAP in tolerant cultivars such as Co 09004 (2.3 cm), Co 14011 (2.3 cm), Co 12007 (2.4 cm) and Co 10033 (2.4) when compared at 270^{th} DAP in Co 09004 (3.1 cm), Co 14011 (3.0 cm), Co 12007 (3.0 cm) and Co 10033(3.2 cm). Cultivar Co 06015 showed less variation of cane diameter (2.1 and 2.7 cm) at 120^{th} and 270^{th} DAP respectively, whereas, slight difference has been observed in cane diameter of cultivar Co 07015 at 120^{th} and 270^{th} (0 and 2.9) DAP, which shows that it is very susceptible to water stress conditions. Under water deficit stress the canes are relatively thinner than the cane after rewatering. Similar finding made (Lal *et al*., 1968; Misra *et al*., 2020; Silva *et al*., 2008) demonstrated the effect of drought on stalk diameter and revealed that the cultivars which has thinner stalk might flourish well than that of the thicker stalk. Further, (Gomati & Chandran, 2009) made similar finding related to sugarcane waterlogging condition. Those genotypes which were resistant to water stress showed greater number of tillers, stalk length, cane diameter, number of internodes and total plant height (Table 2 and 3).

According to the report (Silverio *et al.*, 2017) the RB073040, RB867515, RB72454, RB855536, and RB073028 variety showed higher increase in stem length with 45.83 cm, 45.50 cm, 44.66 cm, 42.50 cm, and 40.66 cm respectively. Whereas the RB073028 variety was remarkable when compared to the remaining variety with 45.50 cm stalk length. However, the variety RB073036 showed shortest stalk length of 33.33 cm. further at 60 kPa tension significant difference in stem length was noted.

Similar findings were made (Ecco *et al.*, 2014) under water deficit stress note that RB867515 had highest increase of 13.7 cm value whereas RB855536 with 14.8 cm had lowest value hence concluded that longer stress period had slower recovery rate. A study made (Endres *et al.*, 2018) on different phenophases of water deficit stress led to mean reduction in plant height of 44.5% where variety RB855113 recorded highest reduction with (54.0%) and SP79-1011 recorded lowest reduction of 34.8%.

Minimum, Maximum, Average, and Standard Deviation (SD) Analysis

A greater number of coefficients of variation were found for the traits such as TPH at T4, and TPH at T2 with 713.08, 373.29 values respectively. The average CVs varied between 0.02 and 713.08%. The standard deviation varied between 0.15% and 26.70% (Table 4). Thus, the highest variability observed for the values of CV was TPH at T4 with standard deviation of 26.70% and the trait with lowest variability was cane diameter at T4 representing the standard deviation value of 0.15%. Hence based on the maximum and minimum values, it is possible to observe within the variables indicating the influence of different factors on its measurement. Similar observation was made (Couto *et al.*, 2013) with three variables taken into consideration having an average CV of 6.46 and 13.77%. And standard deviation varied between 3.97% and 6.07%.

Pearson Correlation Coefficient

Total plant height (Table 5) was significantly positively correlated with number of tillers (r =0.548**, 0.540**, 0.562**, 0.549**. Stalk length was significantly positively correlated with number of tillers (r = 0.682**, 0.600**, 0.600**, 0.807**, 0.617**), and total plant height at 90 and 120 DAP (r = 0.611**, 0.568**, 0.642**, 0.599**). Number of internodes was positively correlated with stalk length (r=0.876**, 0.811**, 0.749**, 0.971**, 0.629**, 0.780**). A study by Gomati *et al.* (2014) reported that increase in internodal length under water logging conditions will have a better adaptation to stress. Cane diameter significantly positively correlated with number of tillers (r=0.548**, 0.576**) which indicates that the genotypes are resistant towards water deficit stress at 90 and 120 DAP. A similar observation was made by Kumar and Kumar (2014) who identified that stalk diameter had a positive association with number of internodes, cane weight, and cane yield. The positive correlation between cane diameter and stalk length (r=0.776**, 0.627**, 0.686**, 0.764**) were seen at 90 and 120 DAP. Cane diameter correlated with number of internodes (r=0.856**, 0.684**, 0.690**, 0.793**, 0.540**). A study (Smiullah *et al.*, 2013) recorded through correlation studies that cane height was positively significantly associated with cane diameter (0.345).

Principal Component Analysis

Principal component analysis (PCA) was performed for twenty treatments consisting of five traits at different developmental stages were simplified into four principal components whose cumulative variance contributes to 85.82%. PC1 and PC2 contribute 71.95% of the variance, and PC1 and PC3 exhibited a variance of 65.96%. The first principal component had a variation of 57.79% and cumulative variance of 57.79% whereas the variation for second principal component was 14.16% with cumulative variance 71.96% followed by the third principal component with a variation of 8.17% with cumulative variance 80.13% and nevertheless the fourth principal component with variance 5.68% having a cumulative variance of 85.82%. Figure 1 describes the Scree plot for twenty-three sugarcane cultivars on principal component 1-20.

It was observed from PC1 that cane diameter at T_1 and T_2 were found to be the most potent variables contributing 0.901 and 0.883% respectively. Whereas, total plant height at T_3 (0.936), and number of tillers at T4 (0.904) were best explained by PC2. Similarly, total plant height at T_1 (0.880) and cane diameter at T4 (0.700) were best explained by PC3. Further, number of tillers at T_1 (0.828) and T2 (0.832) were effective variables for PC4. Thus, the PCA analysis reduced data dimensionality by showing correlation between the traits and PCA analysis helps to characterize potential sugarcane cultivars for further development of water stress resistance in breeding programme (Table 6).

Agglomerative Hierarchical Clustering (AHC) Analysis

Figure 2 represents the dendrogram for twenty three sugarcane cultivars. AHC analysis categorized sugarcane varieties in to four main clusters as cluster I, cluster II, cluster III and cluster IV. Cluster I consisted of ten cultivars, i.e., Co 90003, Co 92002, Co 92013, Co 13006, Co 12007, Co 94005, Co 98008, Co 98017, Co 07015, and Co 0303. Whereas cluster II consists of nine genotypes, viz., Co 671, Co 08020, Co 14011, Co 09004, Co 85019, Co 86032, Co 95020, Co 05001, and Co 13003. Cluster III consists of one genotype namely Co 10033 and cluster IV comprises three genotypes, Co 06015, Co 92020, and Co 93009. (Tawadare *et al.*, 2019) found that stalk length was significantly correlated with internode length followed by plant height which was in positive correlation with internode length. Ongala *et al.* (2016) studied the genetic diversity of sugarcane clones using 19 traits, in which they observed the first three principal components showing 80.8% of total variation. Zhou *et al.* (2015) reported 111 accessions through cluster analysis based on the nine qualitative traits of principal component where they considered the first four components with a cumulative variation of 74.42% and the cluster divided 111 accessions of sugarcane into high sugar and low sugar group. Another study by Raza *et al.* (2017) based on principal component analysis concluded that stalk height, internode length, and leaf area index had a positive correlation and hence these characters can serve as a desirable tool for improving the sugarcane yield.

CONCLUSION

As the formative phase is very sensitive, water stress caused during this phase affects the crop. Thus, through morphological parameters, one can easily identify the cultivars which are tolerant to water deficit conditions as these traits are potentially reliable. The PCA identifies four principal components contributing 57.79% of the total variation which provides necessary information with multiple correlated variables. In addition, AHC also classifies twenty-three cultivars into four clusters. Based on this, the elite nine varieties such as Co 671, Co 08020, Co 14011, Co 09004, Co 85019, Co 86032, Co 13003, Co 05001 and Co 95020 have been identified as high-water stress tolerant genotypes. Hence, these sugarcane cultivars can further be considered for potential sugarcane breeding programmes under water deficit conditions for genetic improvement of sugarcane crop.

Table 1 : Morphological traits and measurement techniques used for the 23 sugarcane cultivars.

Morphological traits	Measurement technique
Number of Tiller	Total number of tillers in a row
Total Plant Height (cm)	Total Length of plant from tip of the leaf until bottom of bud
Stalk Length (cm)	Length of stalk from top to bottom
Number of Internodes	Number of internodes per stalk
Cane Diameter (cm)	Diameter of stem from top, middle, and bottom

Table 2 : Morphological responses studied (number of tillers, total plant height and stalk length) for 23 sugarcane cultivars under water stress conditions.

Genotype	**Number of Tillers***				**Total Plant Height (cm)***				**Stalk Length (cm)***			
	T1	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
Co 09004	28±1.00	25±0.58	42±2.52	88±2.52	183±2.65	190.5±4.54	254±2.65	370±11.54	9±0.58	18.5±1.15	44±3.61	210±5.29
Co 14011	29±0.58	24±1.00	43±3.21	86±6.24	171.5±1.61	186±6.03	256±4.73	372±12.86	9.5±1.04	20.5±2.05	45±3.51	199±7.00
Co 0303	23±0.58	23±1.15	39±3.46	71±1.73	151±2.52	152.5±4.44	232±5.20	357±3.51	ND	9±1.00	39±1.44	180±1.53
Co 13003	28±0.58	28±1.73	42±1.53	85±2.52	161±1.73	163.5±2.36	256±6.00	368±6.24	8±1.00	14±1.80	43±4.36	198±6.66
Co 98017	23±0.58	20±2.00	38±2.65	69±4.93	148.5±2.29	151±4.73	227±7.64	330±5.13	4.5±0.50	9±1.32	36±3.51	181±3.06
Co 95020	30±0.58	23±0.58	40±3.21	85±1.73	152±2.08	154±5.51	260±5.13	373±9.54	2±0.06	14±1.00	43±3.51	202±5.57
Co 93009	31±0.58	26±1.15	38±1.73	72±1.53	170±3.51	171±5.51	226±4.93	266±3.75	4.6±0.29	12.5±0.90	37±2.52	158±3.21
Co 92013	28±1.15	27±1.15	39±1.73	71±2.65	172.5±2.78	173±5.03	226±6.08	334±13.58	5±0.58	9±1.00	40±4.73	188±5.20
Co 12007	22±058	16±1.53	38±3.06	72±2.08	165.5±1.32	168±5.69	228±5.20	359±4.65	9.8±1.40	11.5±0.75	39±2.89	187±4.04
Co 07015	16±0.58	16±1.00	35±3.06	67±6.24	150±2.52	153±10.44	225±4.36	344±6.11	ND	ND	36±3.51	182±3.61
Co 08020	22±1.00	20±0.58	39±2.65	83±6.03	180±1.73	181±8.39	254±4.36	375±3.06	10.5±1.32	20±1.32	43±4.93	208±8.08
Co 85019	25±0.58	25±1.53	41±2.00	86±3.21	185±2.29	190±7.55	257±5.29	375±5.03	9.5±1.26	11.5±0.75	41±1.15	202±7.09
Co 86032	12±0.58	12±0.58	40±4.36	84±5.86	142±1.53	145±2.08	256±4.58	373±11.68	ND	ND	39±4.16	199±3.21
Co 90003	23±0.58	21±2.25	38±2.89	72±1.00	174±3.06	176±4.86	236±5.69	346±4.00	6±0.76	9±0.43	38±3.06	191±4.58
Co 13006	16±1.53	15±1.53	35±3.06	68±1.15	165±4.04	170±4.58	231±6.24	337±12.90	5.8±0.42	9±0.50	37±4.93	188±6.03
Co 92002	25±1.73	22±2.31	36±2.08	67±4.04	171.5±3.33	173±6.66	229±5.86	341±4.44	2.5±0.29	8±0.30	37±6.03	192±3.61
Co 06015	13±1.00	12±1.53	34±3.61	63±2.52	141±2.65	144.5±6.71	207±4.73	309±4.51	3±0.12	5.3±0.56	33±3.06	145±6.43
Co 92020	16±1.00	14±1.53	37±1.53	67±3.06	150±3.00	155±6.00	219±10.41	318±7.05	ND	ND	34±4.27	163±9.64
Co 94005	20±1.53	18±3.06	38±2.08	71±3.21	164±2.89	166.5±12.98	228±6.51	348±8.14	ND	10±0.65	36±5.69	170±8.72
Co 98008	23±0.58	22±2.08	38±3.79	70±2.31	183±1.26	188±3.12	233±7.55	351±9.29	ND	ND	35±2.31	199±14.64
Co 05001	26±2.52	22±1.00	40±5.03	82±5.51	164±3.06	166±2.52	252±3.46	371±11.56	4±0.58	8.5±0.90	43±4.16	210±9.07
Co 10033	28±2.08	24±3.06	37±2.00	73±4.51	220±5.69	223±9.39	228±7.64	356±8.54	8.5±0.76	17±1.32	44±4.04	223±10.54
Co 671	27±2.52	25±2.65	44±2.31	89±3.79	193±8.19	203±7.77	259±4.73	379±6.21	11±1.73	21±0.87	48±3.21	231±7.37

Note: 'ND' indicates not determined

$^{*}90^{th}$ (T_1), 120^{th} (T_2), 150^{th} (T_3), 270^{th} (T_4) DAP

Table 3 : Morphological responses studied (number of internodes and cane diameter) for 23 sugarcane cultivars under water stress conditions.

Genotype	Number of Internodes (cm)*				Cane Diameter (cm)*			
	T1	T2	T3	T4	T1	T2	T3	T4
Co 09004	2±0.00	3±0.58	7±0.58	17±1.00	2.2±0.15	2.3±0.06	2.6±0.06	3.1±0.10
Co 14011	2±0.58	4±0.58	7±1.00	18±1.53	2.2±0.06	2.3±0.06	2.5±0.06	3±0.06
Co 0303	ND	2±0.58	6±0.00	16±1.53	ND	2.1±0.06	2.3±0.06	2.8±0.06
Co 13003	2±0.58	3±0.58	7±1.00	17±1.00	2±0.12	2.2±0.12	2.5±0.06	2.9±0.06
Co 98017	1±0.00	2±0.00	6±0.58	14±1.15	2.2±0.06	2.3±0.06	2.6±0.10	3±0.10
Co 95020	1±0.00	2±0.00	7±0.58	18±1.00	2.1±0.06	2.2±0.06	2.5±0.06	3±0.06
Co 93009	1±0.00	2±0.00	6±0.58	16±1.53	2±0.06	2.1±0.06	2.4±0.12	2.9±0.10
Co 92013	2±0.00	2±0.00	7±1.00	18±1.53	2.1±0.06	2.3±0.06	2.6±0.06	3±0.12
Co 12007	1±0.00	2±0.00	6±0.58	17±1.00	2.2±0.06	2.4±0.06	2.5±0.06	3±0.00
Co 07015	ND	ND	5±0.58	14±0.58	ND	ND	2.2±0.10	2.9±0.10
Co 08020	2±0.00	4±0.58	7±1.15	18±1.53	2.2±0.06	2.2±0.00	2.4±0.06	2.8±0.06
Co 85019	2±0.00	2±0.00	6±0.58	18±1.53	2.1±0.15	2.2±0.06	2.5±0.10	3.1±0.10
Co 86032	ND	ND	6±1.00	19±1.53	ND	ND	2.3±0.15	3±0.15
Co 90003	2±0.00	2±0.00	6±1.00	17±1.53	2.1±0.06	2.1±0.06	2.3±0.06	2.9±0.10
Co 13006	2±0.00	2±0.00	7±1.15	16±1.53	2.1±0.10	2.2±0.06	2.4±0.06	2.9±0.15
Co 92002	1±0.00	2±0.00	7±0.58	18±1.15	2.2±0.06	2.2±0.06	2.5±0.15	3.2±0.10
Co 06015	1±0.00	1±0.00	5±0.58	14±1.53	2±0.06	2.1±0.06	2.3±0.10	2.7±0.06
Co 92020	ND	ND	6±1.00	15±1.53	ND	ND	2.1±0.06	2.8±0.10
Co 94005	ND	2±0.00	6±1.15	16±1.15	ND	2.1±0.06	2.3±0.12	2.8±0.15
Co 98008	ND	ND	6±0.58	18±1.53	ND	ND	2.2±0.10	2.9±0.15
Co 05001	1±0.00	2±0.00	7±1.00	18±1.53	2.2±0.06	2.3±0.06	2.6±0.06	3±0.15
Co 10033	2±0.00	3±0.58	7±0.58	19±1.53	2.2±0.10	2.4±0.10	2.7±0.10	3.2±0.10
Co 671	2±0.00	4±0.58	7±1.00	22±1.53	2.2±0.12	2.2±0.06	2.6±0.10	3.3±0.06

Note: 'ND' indicates Not Determined
*90th (T_1), 120th (T_2), 150th (T_3), 270th (T_4) DAP

Table 4 : Descriptive analysis for 23 sugarcane cultivars under water stress conditions.

Traits*	Range	Minimum	Maximum	Mean	Standard Error	Standard Deviation	Variance
Number of Tillers							
T1	19.00	12.00	31.00	23.22	1.14	5.48	30.00
T2	16.00	12.00	28.00	20.87	0.99	4.74	22.48
T3	10.00	34.00	44.00	38.74	0.53	2.56	6.57
T4	26.00	63.00	89.00	75.70	1.73	8.30	68.86
Total Plant Height							
T1	79.00	141.00	220.00	167.72	3.82	18.30	334.97
T2	78.50	144.50	223.00	171.46	4.03	19.32	373.29
T3	53.00	207.00	260.00	238.22	3.25	15.61	243.63
T4	113.00	266.00	379.00	350.09	5.57	26.70	713.08
Stalk Length							
T1	11.00	0.00	11.00	4.92	0.82	3.93	15.42
T2	21.00	0.00	21.00	10.32	1.35	6.49	42.10
T3	15.00	33.00	48.00	39.57	0.83	3.96	15.71
T4	86.00	145.00	231.00	191.57	4.19	20.09	403.53
Number of Internodes							
T1	2.00	0.00	2.00	1.17	0.17	0.83	0.70
T2	4.00	0.00	4.00	2.00	0.25	1.21	1.45
T3	2.00	5.00	7.00	6.39	0.14	0.66	0.43
T4	8.00	14.00	22.00	17.09	0.39	1.86	3.45
Cane Diameter							
T1	2.20	0.00	2.20	1.58	0.20	0.96	0.92
T2	2.40	0.00	2.40	1.83	0.18	0.87	0.75
T3	0.60	2.10	2.70	2.43	0.03	0.16	0.02
T4	0.60	2.70	3.30	2.97	0.03	0.15	0.02

*90th (T_1), 120th (T_2), 150th (T_3), 270th (T_4) DAP

Table 5 : Pearson's Correlation Coefficient among different morphological characters studied for twenty-three sugarcane cultivars under water stress conditions.

Traits#		**Number of Tillers**				**Total Plant Height**				**Stalk Length**				**Number of Internodes**				**Cane Diameter**			
		T1	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**	**T1**	**T2**	**T3**	**T4**
Number of Tillers	T1	1																			
	T2	.931**	1																		
	T3	.578**	.611**	1																	
	T4	.466*	.471*	.905**	1																
Total Plant Height	T1	.548**	.562**	.284	.291	1															
	T2	.540**	.549**	.353	.347	.987**	1														
	T3	.415*	.434*	.844**	.961**	.229	.278	1													
	T4	.142	.184	.614**	.716**	.258	.297	.776**	1												
Stalk Length	T1	.475*	.441*	.501*	.546**	.611**	.642**	.444*	.351	1											
	T2	.682**	.600**	.600**	.617**	.568**	.599**	.520*	.362	.820**	1										
	T3	.635**	.611**	.807**	.858**	.544**	.583**	.802**	.690**	.696**	.807**	1									
	T4	.445*	.464*	.619**	.708**	.655**	.672**	.744**	.796**	.535**	.522*	.836**	1								
Number of Internodes	T1	.509*	.523*	.384	.448*	.578**	.593**	.388	.246	.876**	.749**	.629**	.485*	1							
	T2	.640**	.596**	.574**	.559**	.540**	.567**	.490*	.374	.811**	.971**	.780**	.518*	.768**	1						
	T3	.620**	.572**	.523*	.549**	.503*	.510*	.573**	.447*	.503*	.655**	.732**	.682**	.617**	.689**	1					
	T4	.441*	.445*	.645**	.663**	.621**	.638**	.661**	.598**	.451*	.477*	.753**	.816**	.401	.467*	.642**	1				
Cane Diameter	T1	.548**	.430*	.230	.309	.390	.386	.252	.073	.776**	.686**	.495*	.324	.856**	.690**	.540**	.271	1			
	T2	.576**	.491*	.244	.228	.330	.310	.162	.098	.627**	.764**	.459*	.186	.684**	.793**	.495*	.173	.799**	1		
	T3	.670**	.594**	.447*	.458*	.513*	.505*	.381	.319	.662**	.696**	.697**	.590**	.683**	.692**	.669**	.471*	.780**	.740**	1	
	T4	.497*	.458*	.447*	.447*	.603**	.623**	.425*	.397	.462*	.417*	.615**	.733**	.424*	.386	.526**	.697**	.443*	.261	.716**	1

#90^{th} (T_1), 120^{th} (T_2), 150^{th} (T_3), 270^{th} (T_4) DAP

Table 6 : Principal component analysis of 23 sugarcane cultivars for morphological traits against water deficit stress.

Traits*	**Component**			
	1	**2**	**3**	**4**
Number of Tillers				
T1	0.400	0.192	0.279	0.828
T2	0.309	0.223	0.300	0.832
T3	0.183	0.816	0.086	0.420
T4	0.246	0.904	0.101	0.203
Total Plant Height				
T1	0.311	0.061	0.880	0.205
T2	0.315	0.123	0.867	0.185
T3	0.161	0.936	0.087	0.165
T4	0.070	0.858	0.236	-0.168
Stalk Length				
T1	0.804	0.300	0.346	-0.009
T2	0.773	0.372	0.216	0.297
T3	0.453	0.734	0.350	0.259
T4	0.183	0.690	0.645	0.052
Number of Internodes				
T1	0.839	0.187	0.321	0.073
T2	0.797	0.354	0.196	0.267
T3	0.458	0.446	0.362	0.317
T4	0.102	0.618	0.629	0.148
Cane Diameter				
T1	0.901	0.032	0.169	0.121
T2	0.883	-0.005	0.002	0.280
T3	0.679	0.237	0.362	0.306
T4	0.208	0.325	0.700	0.186
Total	11.559	2.832	1.635	1.137
% of Variance	57.799	14.162	8.175	5.686
Cumulative %	57.799	71.962	80.137	85.824

*90^{th} (T_1), 120^{th} (T_2), 150^{th} (T_3), 270^{th} (T_4) DAP

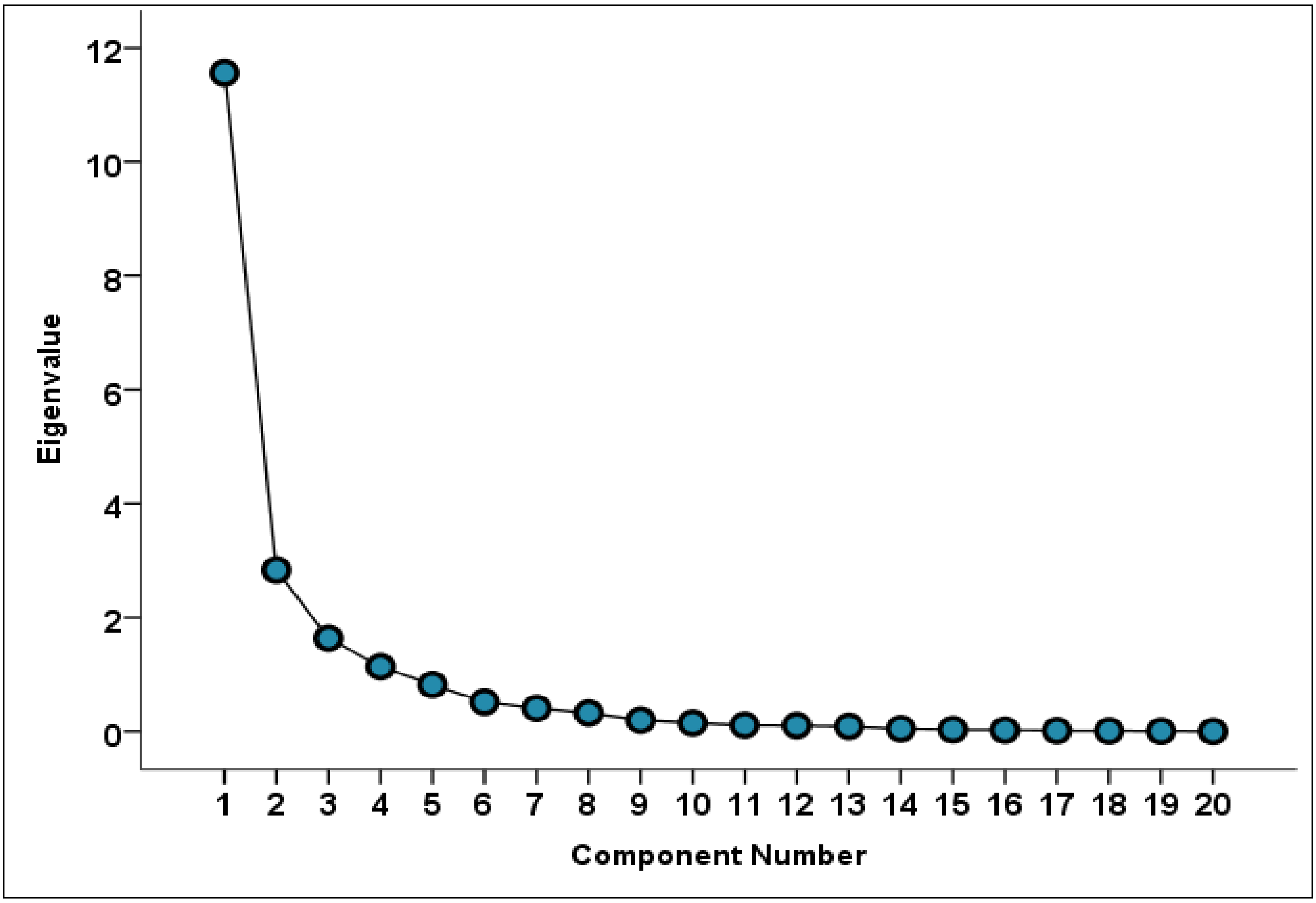

Fig. 1 : Scree plot describing the Eigen value of 23 sugarcane cultivars exposed to water deficit stress.

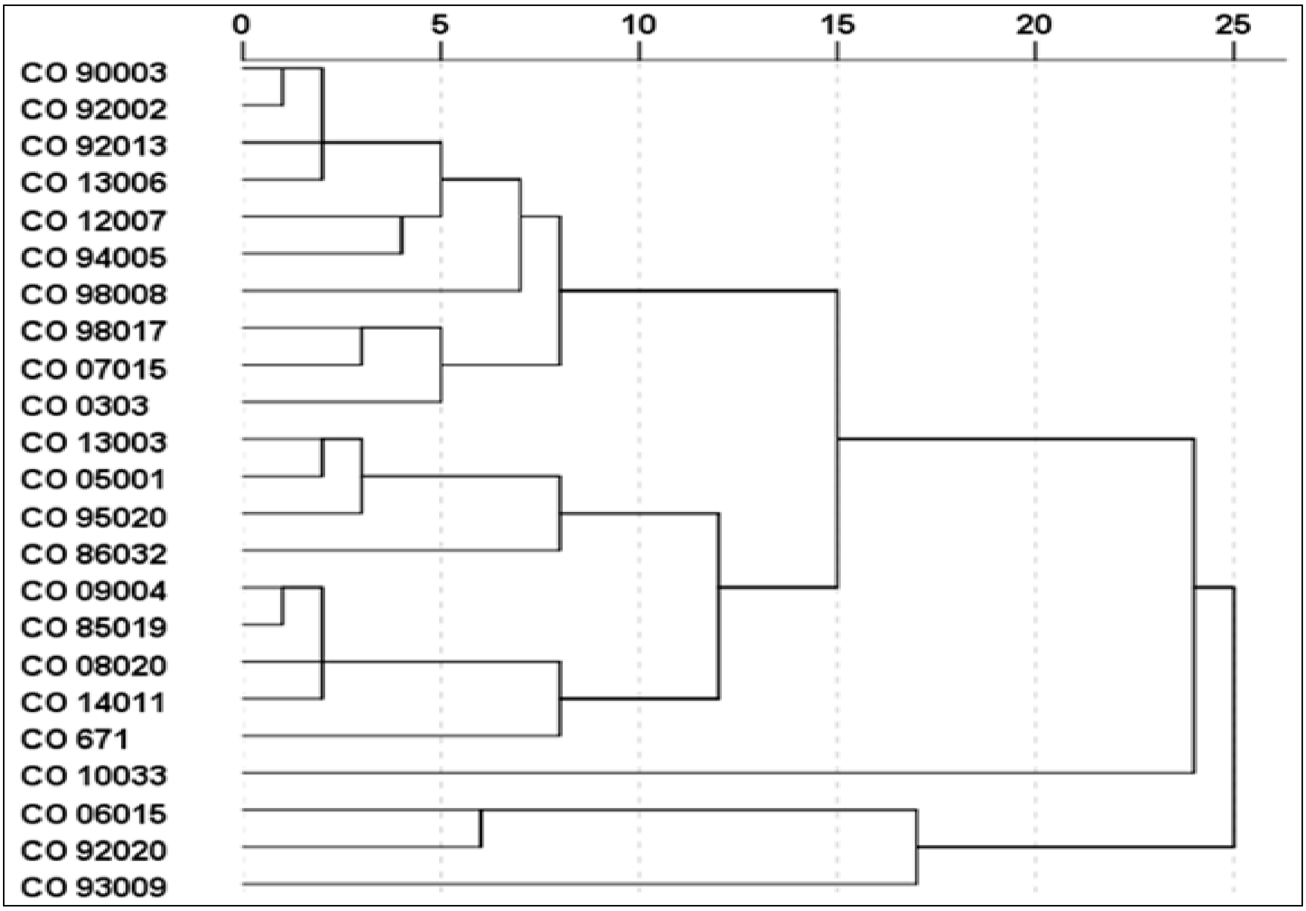

Fig. 2 : Dendrogram of cluster analysis for 23 sugarcane cultivars exposed to water deficit stress.

Acknowledgements

SJ would like to thank the Directorate of Minority, Government of Karnataka for providing financial assistance in the form of Minority Fellowship (DOM/FELLOWSHIP/ CR-21/2018-19).

Conflict of Interest

Authors have no conflict of interest.

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