Identification of drought tolerant *desi* cotton genotypes based on drought tolerance indices

ABSTRACT: The present experiment was conducted in two environments *viz.* irrigated and rainfed, with three replications in randomized block design at Research Area of Cotton Section, Department of Genetics & Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana) during *Kharif* 2021-22. Fifty elite *desi* cotton (*Gossypium arboreum L.*) genotypes were grown as experimental material. Five plants were randomly selected from each genotype and observations were recorded on eight morphological traits *viz.* plant height, number of monopods per plant, days to first flower, number of bolls per plant, boll weight, seed cotton yield per plant, number of seeds per boll, ginning out turn and six physiological traits *viz.* relative water content, photosynthesis rate, stomatal conductance, transpiration rate, total chlorophyll content, proline content. Under both the environments, sufficient amount of variability was present among all the genotypes for all the studied traits. The significant decrease in mean performance of all genotypes was observed for all traits except proline content under rainfed condition. Based on drought tolerance indices *viz.* YSI (Yield Stability Index) and DSI (Drought Susceptibility Index), *per se* performance and other yield contributing traits, genotypes *viz.* P 533, P 551, PAIG 129, DA-3/02 and DA-2/02 were found most drought tolerant among all the test genotypes and these may be used in future cotton breeding programs to develop higher yielding and drought tolerant varieties.

Keywords: Drought, *desi* cotton, variability, tolerant and yield

Introduction

Cotton is one of the most important sources of natural fibre worldwide. It is commonly known as "King of Fibre" and "White Gold". It is grown in tropical and subtropical regions of more than 80 countries of the world. Cotton plays a pivotal role in the agriculture-based economy of India by contributing in national and international trade, industrial activities, earning foreign exchange and generating employment at various stages during cultivation, ginning, spinning and garment making. It is grown mainly for its lint, textile raw materials, seed yields, seed oil and protein. Cotton belongs to genus "*Gossypium*" & family "Malvaceae". Out of four cultivated species of genus *Gossypium*, only two species, *Gossypium hirsutum* (2n=2x=52) and *Gossypium arboreum* (2n=2x=26) are being mostly cultivated commercially in North India. *G. arboreum* is grown under poor crop management conditions but still its yield potential is not being fully realized.

In the past few years, there has been a significant reduction in cultivated area of *G. arboreum* cotton across the country because of lower productivity and inferior fibre properties as compared to tetraploid cotton in rain fed eco-system due to different biotic and abiotic stresses. Globally, abiotic stresses such as drought, salinity, heat, soil erosion, water-logging, heavy metals toxicity etc. are serious challenges of modern farming systems under the changing climate. Drought is recognized as the most destructive cause which markedly limits the fibre yield and lint quality in cotton production (Wiggins *et al.*, 2013; Chattha *et al.*, 2018). Acute water stress occurring during flowering and boll development stage substantially affects various physiological and biochemical characters in cotton plants, such as leaf expansion, photosynthesis, carbon, nitrogen metabolism and antioxidant metabolism (Ennahli and Hugh, 2005) along with reduction in size and number of bolls per plant, plant height, seed cotton yield *etc.* (Malik and Malik, 2006). A decrease in the relative water content and chlorophyll contents under drought condition has been reported in a variety of plant species (Nayyar and Gupta, 2006; Saleem *et al*., 2015). Drought tolerance is a complex trait with multigenic components, which interact in a holistic manner in the plant system (Cushman and Bohnert, 2000). Therefore, the identification of drought tolerant genotypes is an ongoing challenge for the breeders. However, stress tolerance can be forged by identifying and characterizing those morpho-physiological traits which contribute stress tolerance and determine their relative relationship with productivity under water-deficit condition. Therefore, there is a need to breed cotton variety, which may produce relatively better yield under drought stress conditions. Thus, the objective of the present study was to identify the drought tolerant genotypes of *desi* cotton that can be further utilized in cotton improvement programmes.

MATERIAL AND METHOD

The experimental material comprised of 50 elite *desi* cotton genotypes were evaluated in Research Area of Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar (Haryana) during *Kharif* 2021-22 in two environmental conditions *i.e.*, E_1 (irrigated conditions) and E_2 (rainfed with pre-sowing irrigation). Randomized Block Design was used as a statistical layout for the present investigation. Layout plan included three replications per environment with row length 6.0 m. The spacing of 67.5 cm between rows and 30 cm between plants was maintained. Normal cultural practices recommended for *Desi* cotton were adopted throughout the crop seasons from sowing to harvesting of crop. The observations of eight morphological (plant height, number of monopods per plant, days to first flower, number of bolls per plant, boll weight, seed cotton yield per plant, number of seeds per boll, ginning out turn) and six physiological traits (relative water content, photosynthesis rate, stomatal conductance, transpiration rate, total chlorophyll content, proline content) were recorded from five randomly selected plants from each genotype in each replication.

Analysis of variance (ANOVA): An ANOVA test is a technique which is used to find out whether the experiment results are significant. Analysis of variance was carried out for different characters according to the standard procedure suggested by Fisher (1925). Following model was considered for analysis of variance of different characters:

$$\mathbf{Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}}$$

Where,

Y_{ij}= observation of i^{th} treatment and j^{th} block
μ= General mean
α_i= effect of i^{th} treatment
β_j= effect of j^{th} block
e_{ij}= random error associated with i^{th} treatment and j^{th} block

Table 1: ANOVA Table

Sources of variation	Degrees of freedom (d.f.)	Sum of squares (SS)	Mean sum of squares (MS)	Expected mean squares	F calculated value
Replications	(r-1)	SS_r	MS_r	$\sigma^2_e + g\,\sigma^2_r$	MS_r / MS_e
Genotypes	(g-1)	SS_g	MS_g	$\sigma^2_e + r\,\sigma^2_g$	MS_g/MS_e
Error	(r-1) (g-1)	SS_e	MS_e	σ^2_e	
Total	(rg-1)				

Where,

r = Number of replications

g = Number of genotypes

MS_r, MS_g and MS_e stood for mean squares due to replications, genotypes and error respectively.

σ^2_g = Variance due to genotypes

σ^2_r = Variance due to replications

σ^2_e = Variance due to error

Drought tolerance indices were calculated by using formula:

YSI (yield stability index) was calculated using formula (Bouslama and Schapaugh,1984):

$$\mathbf{YSI} = \frac{\text{Yield under stress}}{\text{Yield under non stress}} \times 100$$

Drought susceptibility index calculated by using formula (Fischer and Maurer, 1978):

$$\mathbf{DSI} = \frac{1 - \frac{\text{Yield of genotypes under stress}}{\text{Yield of genotypes under non stress}}}{1 - \frac{\text{Average yield under stress}}{\text{Average yield under non stress}}}$$

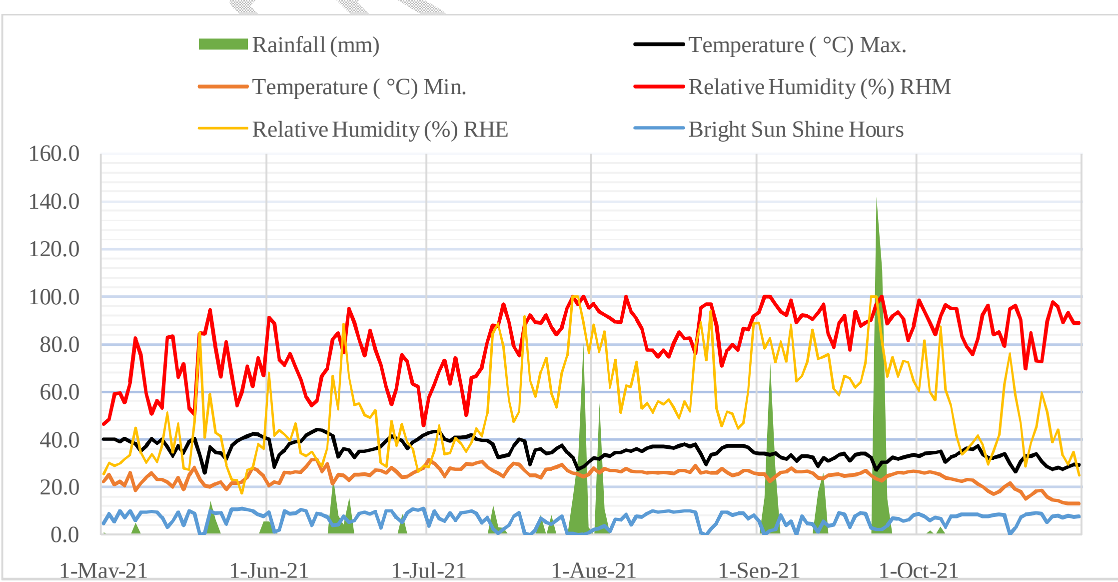


Fig. 1: Daily meteorological data during crop period

RESULT AND DISCUSSION

Analysis of variance (ANOVA): The analysis of variance was carried out for all the 14 traits among 50 elite *Desi* cotton genotypes for both environments *i.e.*, irrigated (E1) and rainfed (E2) separately and presented in Table 2. It is evident from the results that mean sum of squares due to genotypes were highly significant for all 14 traits under studied in both the environments, reflecting that sufficient genetic variability was present among the genotypes for all the traits. Similar results for analysis of variance were observed by Ahmad *et al.* (2008), Nikhil *et al.* (2018), Eldessousky *et al.* (2021), Jogender *et al.* (2023) and Kumar *et al.* (2023), for one or more traits.

Table 2. Analysis of variance of 50 *desi* cotton genotypes for various traits

Sr. No.	**Traits**	**E_1 (Irrigated)**			**E_2 (Rainfed)**		
		Source of Variation			**Source of Variation**		
		Replication [2]	**Treatments** [49]	**Error** [98]	**Replications** [2]	**Treatments** [48]	**Error** [98]
1	**PH**	64.86	73909.75**	358.78	77.69	73023.85**	488.85
2	**NM/P**	0.04	13.51**	4.57	0.06	9.68**	2.68
3	**DFF**	1.85	1004.69**	122.15	3.77	946.73**	54.89
4	**NB/P**	13.35	5958.09**	178.26	52.20	4204.30**	274.75
5	**BW**	0.01	1.34**	0.12	0.02	1.69**	0.30
6	**SCY/P**	138.09	34741.86**	1350.57	533.04	19652.02**	2405.68
7	**NS/B**	6.34	344.94**	206.14	5.44	242.44**	237.58
8	**GOT**	0.78	588.34**	120.87	2.85	371.18**	112.50
9	**RWC**	12.35	1707.31**	142.09	10.28	4851.37**	87.11
10	**PR**	0.02	352.27**	1.82	0.04	342.76**	1.40
11	**SC**	0.00	0.14**	0.00	0.00	0.11**	0.00
12	**TR**	0.01	99.44**	1.05	0.08	85.53**	0.62
13	**TCC**	7.31	624.66**	172.68	22.17	469.67**	416.59
14	**PC**	0.00	0.05**	0.01	0.00	0.06**	0.02

** Significant at 1% level of significance, [ ] Degrees of freedom

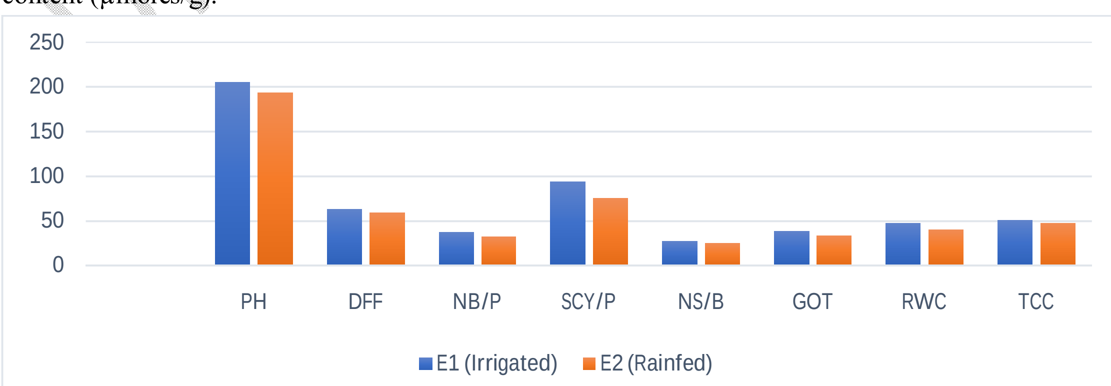
PH: Plant height (cm), **NM/P**: Number of monopods per plant, **DFF**: Days to first flower, **NB/P**: Number of bolls per plant, **BW**: Boll weight (g), **SCY/P**: Seed cotton yield per plant (g), **NS/B**: Number of seeds per boll, **GOT**: Ginning out turn (%), **RWC**: Relative water content (%), **PR**: Photosynthesis rate (µmol CO_2 $m^{-2}s^{-1}$), **SC**: Stomatal conductance (mmol H_2O $m^{-2}s^{-1}$), **TR**: Transpiration rate (mmol H_2O $m^{-2}s^{-1}$), **TCC**: Total chlorophyll content (SPAD value) and **PC**: Proline content (µmoles/g).

Mean performance and Range: The mean values of different traits observed in 50 *Desi* cotton genotypes under irrigated (E1) as well as rainfed environment (E2) along with their range are presented in the Table 3:

Table 3. Mean, maximum and minimum values for various traits of asiatic cotton

Sr. No.	Traits	E_1 (Irrigated)			E_2 (Rainfed)		
		Mean	Range		Mean	Range	
			Max.	Min.		Max.	Min.
1	**PH**	205.71	248.67	161.46	193.43	239.04	151.72
2	**NM/P**	1.87	2.56	1.44	1.39	2.00	1.00
3	**DFF**	63.43	68.00	58.33	59.47	63.67	52.67
4	**NB/P**	37.32	48.44	24.00	31.99	43.22	22.78
5	**BW**	2.51	2.75	2.24	2.36	2.70	2.10
6	**SCY/P**	93.98	121.79	61.50	75.45	102.54	52.97
7	**NS/B**	27.21	32.61	24.47	25.10	28.43	22.12
8	**GOT**	39.00	43.07	33.70	34.00	39.07	31.53
9	**RWC**	47.44	52.20	38.00	40.20	49.43	24.59
10	**PR**	6.98	10.00	3.12	5.23	8.06	3.00
11	**SC**	0.11	0.16	0.03	0.08	0.13	0.02
12	**TR**	3.67	5.10	2.07	2.80	4.02	1.94
13	**TCC**	50.91	56.52	47.85	47.63	51.60	43.33
14	**PC**	0.21	0.24	0.17	0.22	0.26	0.18

PH: Plant height (cm), **NM/P**: Number of monopods per plant, **DFF**: Days to first flower, **NB/P**: Number of bolls per plant, **BW**: Boll weight (g), **SCY/P**: Seed cotton yield per plant (g), **NS/B**: Number of seeds per boll, **GOT**: Ginning out turn (%), **RWC**: Relative water content (%), **PR**: Photosynthesis rate (µmol CO_2 $m^{-2}s^{-1}$), **SC**: Stomatal conductance (mmol H_2O $m^{-2}s^{-1}$), **TR**: Transpiration rate (mmol H_2O $m^{-2}s^{-1}$), **TCC**: Total chlorophyll content (SPAD value) and **PC**: Proline content (µmoles/g).



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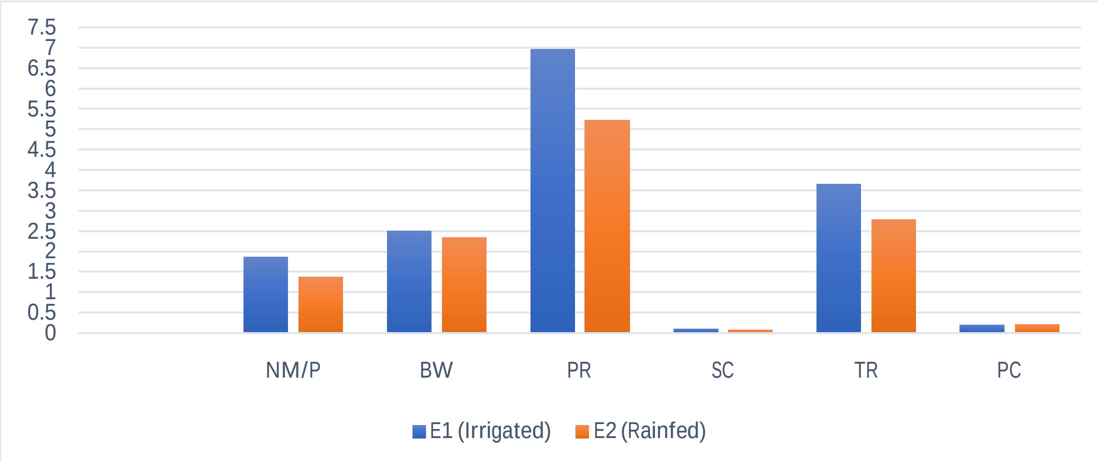


Graph 1: Comparison of different traits under irrigated and rainfed environments

Plant height (cm): The range of plant height varied from 161.46 to 248.67 cm under irrigated environment with the overall mean value of 205.71cm. The maximum and minimum plant heights were observed in genotypes FFS-6 and HD-123, respectively. On the other hand, under rainfed environment, plant height ranged from 151.72 to 239.04 cm along with an average of 193.43 cm. Maximum plant height was shown by genotype FFS-6 (239.04 cm), whereas minimum value by genotype HD-123 (151.7 cm). Rainfed conditions led to reduction in plant height of different genotypes due to water stress. Control plants were tall whereas drought stressed plants had shorter plant height (Jamal *et al*. 2014). Similar findings were reported earlier by Pettigrew (2004) and Hasan *et al*. (2018).

Number of monopods per plant: The range of number of monopods per plant varied from 1.44 to 2.56 under irrigated environment with the overall mean value of 1.87. The maximum and minimum number of monopods per plant were observed in genotypes HD 444 and PAIG 129 having 2.56 and 1.44 respectively. On the other hand, under rainfed environment, number of monopods per plant ranged from 1.00 to 2.00 along with an average of 1.39. Maximum number of monopods per plant were shown in genotypes DA-2/02 and HD 432 (2.00), whereas minimum value in genotypes P 555 and FFS-5 (1.00). Number of monopods per plants were observed more in case of irrigated environment as compared to rainfed conditions. The monopodial branches per plant were found relatively higher under five irrigations while minimum under four irrigations (Sahito *et al*. 2015).

Days to first flower: The range of days to first flower varied from 58.33 to 68.00 under irrigated environment with the overall mean value of 63.43. The maximum value of days to first flower was observed in genotypes P 397, HD 556 and HD 453 with value 68.00 and minimum value was observed in genotypes P 185, P 410 and P 530 with value 58.33. On the other hand, under rainfed environment, days to first flower ranged from 52.67 to 63.67 along with an average of 59.47. Maximum days to first flower was taken by genotype P 545 *i.e.*, 63.67 days whereas minimum days *i.e.*, 52.67 by genotype P 530. Early flowering was observed in genotypes grown under rainfed environment. The findings of days to first flower were in accordance with results obtained by Pettigrew (2004) and Ali and Ahmadikhah (2009).

Number of bolls per plant: The range of number of bolls per plant varied from 24.00 to 48.44 under irrigated environment with the overall mean value of 37.32. The maximum and minimum values of number of bolls per plant were observed for genotypes P 548 and FFS-7 having 48.44 and 24.00 respectively. On the other hand, under rainfed environment, number of bolls per plant ranged from 22.78 to 43.22 along with an average of 31.99. Maximum number of bolls per plant was shown by genotype DA-2/02 (43.22) whereas minimum value by genotype HD 399 (22.78). Rainfed conditions led to reduction in number of bolls per plant of different genotypes when compared with irrigated environment. The findings of number of bolls per plant was in accordance with Kar *et al*. (2001), Zare *et al*. (2014) and Singh *et al*. (2021).

Boll weight (g): The range of boll weight varied from 2.24 to 2.75 g under irrigated environment with the overall mean value of 2.51 g. The maximum and minimum boll weight was observed for genotypes FFS-1 and HD 556 having 2.75 g and 2.24 g respectively. On the other hand, under rainfed environment, boll weight ranged from 2.10 to 2.70 g along with an average of 2.36 g. Maximum boll weight was shown by genotype FFS-1 *i.e.,* 2.70 g whereas minimum by genotype DA-2/02 (2.10 g). Less boll weight was observed in genotypes grown under rainfed condition whereas more boll weight was observed in irrigated environment. Dahab *et al*. (2012) revealed that water stress conditions reduced the boll weight, bolls per plant and ultimately seed cotton yield per plant. Sarwar *et al*., (2012) and Wang *et al*. (2016) also reported similar results.

Seed cotton yield per plant (g): The range of seed cotton yield per plant varied from 61.50 to 121.79 g under irrigated environment with the overall mean value of 93.98 g. The maximum and minimum values of seed cotton yield per plant were observed in genotypes P 548 and FFS-7 having 121.79 g and 61.50 g respectively. On the other hand, under rainfed environment, seed cotton yield per plant ranged from 52.97 to 102.54 g along with an average of 75.45 g. Maximum seed cotton yield per plant was shown by genotype P 533 (102.54 g) whereas minimum value by genotype FFS-7 having 52.97 g. Reduction in seed cotton yield per plant was observed under rainfed environment when compared with irrigated environment due to drought stress. Seed cotton yield was reduced due to drought stress and that might be due to decrease number of bolls per plant (Zare *et al*. 2014). Similar results were also reported by Sarwar *et al.* (2012), Dahab *et al.* (2012) and Guimarães *et al*. (2017).

Number of seeds per boll: The range of number of seeds per boll varied from 24.47 to 32.61 under irrigated environment with the overall mean value of 27.21. The maximum and minimum number of seeds per boll were observed for genotypes P 547 and HD 453 having 32.61 and 24.47 respectively. On the other hand, under rainfed environment, number of seed per boll ranged from 22.12 to 28.43 along with an average of 25.10. Maximum number of seeds per boll was shown by genotype P 552 (28.43) whereas minimum value was shown by genotype CISA 6 (22.12). Rainfed conditions led to reduction in number of seeds per boll of different genotypes due to water stress as compared to irrigated environment. These finding of number of seeds per boll was in accordance with results of Wang *et al.* (2016), Shavkiev *et al.* (2020) and Shareef *et al.* (2018).

Ginning out turn (%): The range of ginning out turn varied from 33.70 to 43.07% under irrigated environment with the overall mean value of 39.00%. The maximum and minimum values of ginning out turn were observed for genotypes PAIG 129 and P 557 having 43.07% and 33.70% respectively. On the other hand, under rainfed environment, ginning out turn ranged from 31.53 to 39.07% along with an average of 34.00%. Maximum ginning out turn was observed in genotype FFS-3 (39.07%) whereas minimum in genotype P 557 (31.53%). Low percent of ginning out turn was seen in genotypes grown under rainfed conditions. Similar findings were observed by Karademir *et al.* (2011) and Veesar *et al.* (2018).

Relative water content (%): The range of relative water content varied from 38.00 to 52.20% under irrigated environment with the overall mean value of 47.44%. The maximum and minimum values of relative water content were observed for genotypes P 514 and P 397 having 52.20% and 38.00% respectively. On the other hand, under rainfed environment, relative water content ranged from 24.59 to 49.43% along with an average of 40.20%. Maximum relative water content was found in genotype HD 399 (49.43%) whereas minimum in genotype P 397 (24.59%). Leaves of the plants grown under irrigated environment retained more relative water content as compared to plants grown under rainfed environment. Relative water content is a measure of plant water status; it represents tissue metabolism and is used as index for dehydration tolerance. (Jamal *et al.* 2014). Similar findings were also reported by Nayyar and Gupta (2006) and Bogale *et al.* (2011).

Photosynthesis rate (µmol CO_2 $m^{-2}s^{-1}$): The range of photosynthesis rate varied from 3.12 to 10.00 µmol CO_2 $m^{-2}s^{-1}$ under irrigated environment with the overall mean value of 6.98 µmol CO_2 $m^{-2}s^{-1}$. The maximum and minimum values of photosynthesis rate were observed in genotypes FFS-1 and HD 534 having 10.00 µmol CO_2 $m^{-2}s^{-1}$ and 3.12 µmol CO_2 $m^{-2}s^{-1}$ respectively. On the other hand, under rainfed environment, photosynthesis rate ranged from 3.00 to 8.06 µmol CO_2 $m^{-2}s^{-1}$ along with an average of 5.23 µmol CO_2 $m^{-2}s^{-1}$. Maximum photosynthesis rate was exhibited by genotype FFS-1 (8.06 µmol CO_2 $m^{-2}s^{-1}$) whereas minimum by genotypes HD 534, P 514, DA-3/02, HD 399 and HD 123 with value 3.00 µmol CO_2 $m^{-2}s^{-1}$. Mean photosynthesis rate was reduced significantly in case of rainfed environment due to stress. Anjum *et al.* (2011) similarly determined that stomata are the entry point for water loss and CO_2 absorbability, and that stomatal closure is one of the responses against drought stress that causes a decrease in photosynthetic rate.

Stomatal conductance (mmol H_2O $m^{-2}s^{-1}$): The range of stomatal conductance varied from 0.03 to 0.16 mmol H_2O $m^{-2}s^{-1}$ under irrigated environment with the overall mean value of 0.11 mmol H_2O $m^{-2}s^{-1}$. The maximum and minimum values of stomatal conductance were observed for genotypes P 557 and P 185 having 0.16 mmol H_2O $m^{-2}s^{-1}$ and 0.03 mmol H_2O $m^{-2}s^{-1}$ respectively. On the other hand, under rainfed environment, stomatal conductance ranged from 0.02 to 0.13 mmol H_2O $m^{-2}s^{-1}$ along with an average of 0.08 mmol H_2O $m^{-2}s^{-1}$.

Maximum stomatal conductance was shown by genotype P 557 (0.13 mmol H_2O $m^{-2}s^{-1}$) whereas minimum value was shown by genotype P 185 (0.02 mmol H_2O $m^{-2}s^{-1}$). The result indicated that rainfed environment led to decrease in stomatal conductance in plants due to water stress conditions than irrigated ones. The finding of stomatal conductance was in accordance with findings of Chastain *et al.* (2014), Singh *et al.*, (2015) and Fang and Xiong (2015).

Transpiration rate (mmol H_2O $m^{-2}s^{-1}$): The range of transpiration rate varied from 2.07 to 5.10 mmol H_2O $m^{-2}s^{-1}$ under irrigated environment with the overall mean value of 3.67 mmol H_2O $m^{-2}s^{-1}$. The maximum and minimum values of transpiration rate were observed for genotypes HD 556 and P552 having 5.10 mmol H_2O $m^{-2}s^{-1}$ and 2.07 mmol H_2O $m^{-2}s^{-1}$ respectively. On the other hand, under rainfed environment, transpiration rate ranged from 1.94 to 4.02 mmol H_2O $m^{-2}s^{-1}$ along with an average of 2.80 mmol H_2O $m^{-2}s^{-1}$. Maximum transpiration rate was shown by genotype FFS-4 (4.02 mmol H_2O $m^{-2}s^{-1}$) whereas minimum by genotype P 535 (1.94 mmol H_2O $m^{-2}s^{-1}$). Plants grown under rainfed environment exhibited low transpiration rate as compared to plants grown under irrigated environment. Similar results were also reported by Meek *et al.* (2010), Hejnak *et al.* (2015) and Hasan *et al.* (2018).

Total chlorophyll content (SPAD value): The range of total chlorophyll content varied from 47.85 to 56.52 under irrigated environment with the overall mean value of 50.91. The maximum and minimum values of total chlorophyll content were found in genotypes P 478 and P 543 having 56.52 and 47.85 respectively. On the other hand, under rainfed environment, total chlorophyll content ranged from 43.33 to 51.60 along with an average of 47.63. Maximum total chlorophyll content was shown by genotype HD 442 (51.60) whereas minimum value was shown by genotype P 535 *i.e.,* 43.33. Total chlorophyll content in plants was found to be reduced in case of rainfed environment. The reduction in chlorophyll content under drought stress is a common indication of oxidative stress and is caused by pigment photo-oxidation and chlorophyll degradation (Anjum *et al.* 2011). The finding of total chlorophyll content was in accordance with Farooq *et al.* (2014).

Proline content (µmoles/g): The range of proline content varied from 0.17 to 0.24 µmoles/g under irrigated environment with the overall mean value of 0.21 µmoles/g. The maximum proline content was observed in genotype FF-4 having 0.24 µmoles/g while minimum proline content was observed in genotypes HD 324 (0.17 µmoles/g). On the other hand, under rainfed environment, proline content ranged from 0.18 to 0.26 µmoles/g along with an average of 0.22 µmoles/g. Maximum proline content was shown by genotype FFS-4 (0.26 µmoles/g) whereas minimum value by genotype HD 324 *i.e.,* 0.18 µmoles/g. Proline content was found to be increased in plants grown under rainfed conditions due to water stress. Water stress conditions induce the proline synthesis in the plant which acts as an osmolytes and create osmotic pressure in the plant cells for increasing the uptake of water (Kumar *et al.* 2013). Similar results were also reported by Pawar *et al.* (2010) and Anjum *et al.* (2011).

Drought tolerance indices

The effect of drought stress on seed cotton yield was evaluated using drought tolerance indices. These indices provide better opportunities to identify genotypes with better performance under normal and stress environment. They provide information about yield losses due to moisture deficit in rainfed environment. Two indicators *i.e.*, drought susceptibility index (DSI) and yield stability index (YSI) have been used for evaluating different genotypes for drought resistance. Both indices, DSI and YSI, were calculated using seed cotton yield in both environments (Table 4).

Yield Stability Index (YSI): It was observed that highest YSI was exhibited by genotype P 557 (92.28) followed by genotypes DA-4/02, HD 453, HD 459 and FFS-1 with YSI values 89.84, 89.00, 88.85 and 88.62, respectively. High value of YSI indicated stable performance under stress conditions. On the other hand, least YSI was observed in genotype P 546 (68.64) followed by HD 556 (70.30), FFS-4 (72.81), P 425 (73.08) and HD 328 (73.19) exhibiting poor stability under water stress conditions as compared to irrigated conditions.

Drought Susceptibility Index (DSI): Highest DSI value was observed in genotype P 546 (1.59) followed by genotypes HD 556 (1.51), FFS-4 (1.38), P 425 (1.37) and HD 328 (1.36), explaining their comparative poor performance under drought whereas lowest DSI exhibited by genotype P557 (0.39) followed by DA-4/02 (0.52), HD 459 (0.57), FFS-1 (0.58) and HD 426 (0.61).

Table 4: Table showing drought tolerance indices *i.e.*, YSI & DSI

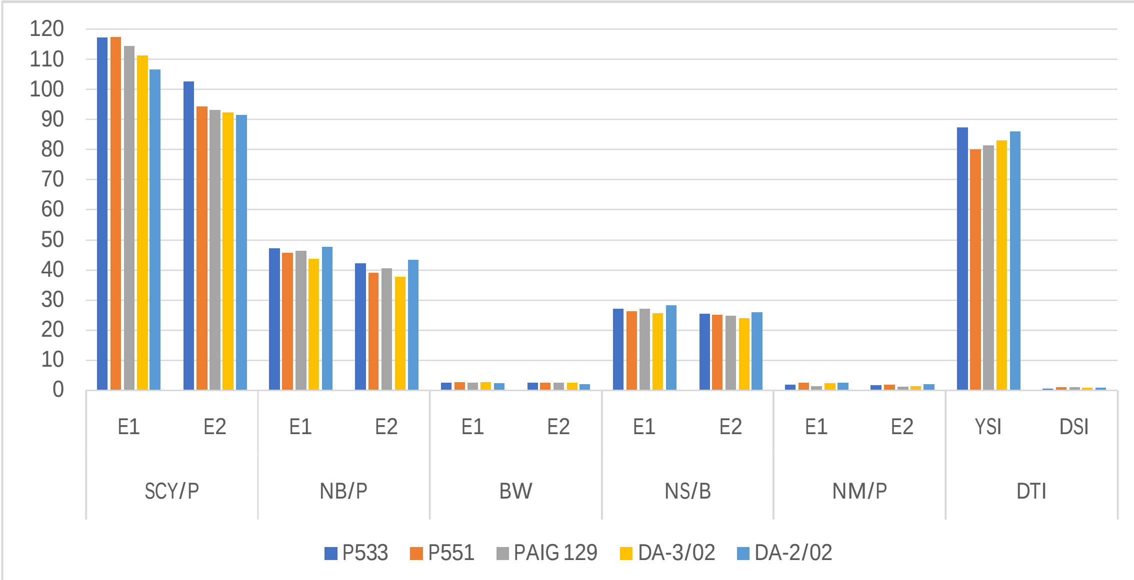
Sr. No.	Genotypes	YSI	DSI	Sr. No.	Genotypes	YSI	DSI
1	P 185	79.12	1.06	**26**	P 397	76.43	1.20
2	P 410	74.52	1.29	**27**	HD 328	73.19	1.36
3	P 425	73.08	1.37	**28**	HD 442	86.22	0.70
4	P 530	73.49	1.34	**29**	DA-2 /02	85.94	0.71
5	P 531	80.60	0.98	**30**	DA-3 /02	82.91	0.87
6	P 533	87.34	0.64	**31**	DA-4 /02	89.84	0.52
7	P536	83.20	0.85	**32**	FFS-1	88.62	0.58
8	HD 521	85.83	0.72	**33**	PAIG 129	81.38	0.94
9	P 535	74.95	1.27	**34**	HD399	73.34	1.35
10	P 540	76.28	1.20	**35**	HD 556	70.30	1.51
11	P552	77.39	1.15	**36**	FFS-2	83.60	0.83
12	HD 534	75.29	1.25	**37**	FFS-3	79.89	1.02
13	P478	79.27	1.05	**38**	FFS-4	72.81	1.38

Sr. No.	Genotypes	YSI	DSI	Sr. No.	Genotypes	YSI	DSI
14	P 514	80.07	1.01	**39**	FFS-5	74.79	1.28
15	P 543	76.35	1.20	**40**	FFS-6	82.49	0.89
16	P545	82.57	0.88	**41**	HD 444	79.10	1.06
17	P 546	68.64	1.59	**42**	HD 453	89.00	0.56
18	P 547	79.78	1.03	**43**	CINA 344	79.35	1.05
19	P 548	74.44	1.30	**44**	FFS-7	86.13	0.70
20	HD 535	80.04	1.01	**45**	FFS-8	82.21	0.90
21	P551	80.26	1.00	**46**	HD 459	88.85	0.57
22	P555	74.24	1.31	**47**	CISA 6	85.05	0.76
23	P557	92.28	0.39	**48**	HD 123	83.17	0.85
24	HD 426	88.01	0.61	**49**	HD 324	87.40	0.64
25	P 554	86.38	0.69	**50**	HD 432	86.23	0.70

Table 5: Top five drought tolerant genotypes identified on the basis of yield indices, *per se* performance for seed cotton yield and its component traits in *Desi* cotton

Sr. No.	Genotypes	SCY/P		NB/P		BW		NS/B		NM/P		DTI	
		E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	YSI	DSI
1	**P533**	117.40	102.54	47.22	42.22	2.47	2.43	27.27	25.47	1.78	1.67	87.34	0.64
2	**P551**	117.53	94.33	45.67	39.00	2.57	2.43	26.27	25.00	2.44	1.89	80.26	1.00
3	**PAIG 129**	114.61	93.27	46.11	40.55	2.50	2.31	27.20	24.80	1.44	1.11	81.38	0.94
4	**DA-3/02**	111.32	92.29	43.78	37.78	2.55	2.43	25.67	24.00	2.11	1.44	82.91	0.87
5	**DA-2/02**	106.56	91.58	47.78	43.22	2.25	2.10	28.13	25.73	2.44	2.00	85.94	0.71

SCY/P: Seed cotton yield per plant (g), **NB/P**: Number of bolls per plant, **BW**: Boll weight (g), **NS/B**: Number of seeds per boll; **NM/P**: Number of monopods per plant, **DTI**: Drought tolerance indices, **YSI:** Yield stability index, **DSI**: Drought susceptibility index



Graph 2: Comparison of top five drought tolerant genotypes identified based on yield indices, *per se* performance for seed cotton yield and its component traits

Conclusion: Yield is the final product of multiple interactions among several components because there is no separate gene system for yield *per se*. In the present investigation, efforts were made to find out the drought tolerant genotypes by comparing drought tolerance indices *i.e.*, YSI (Yield Stability Index) and DSI (Drought Susceptibility Index), *per se* performance and other yield contributing traits *viz.* seed cotton yield per plant, number of bolls per plant, boll weight, number of seeds per boll and number of monopods per plant. On the basis of these parameters, genotypes *viz.* P 533, P 551, PAIG 129, DA-3/02 and DA-2/02 were found most drought tolerant among all the test genotypes (Table 5). These genotypes showed high per se performance, more number of bolls per plant, high boll weight, more number of bolls per plant and more number of monopods per plant as well as high YSI and low DSI as compared to other genotypes.

Conference disclaimer:

Some part of this manuscript was previously presented in the conference: 3rd International Conference IAAHAS-2023 "Innovative Approaches in Agriculture, Horticulture & Allied Sciences" on March 29-31, 2023 in SGT University , Gurugram, India. Web Link of the proceeding: https://wikifarmer.com/event/iaahas-2023-innovative-approaches-in-agriculture-horticulture-allied-sciences/

Competing Interests

Authors have declared that no competing interests exist.

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