Research Article
www.ekinjournal.com
Ekin International biannual peer-reviewed journal
Ekin
Journal of Crop Breeding and Genetics
2(1):74-81, 2016

Assessment of Drought Resistance in Indian Wheat Cultivars for Morpho-Physiological Traits

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Citation:
Munjal R., Dhanda S. S., 2016. Assessment of drought resistance in Indian wheat cultivars for morpho-physiological traits. Ekin J. 2(1):74-81.

Received: 15.07.2014 ***Accepted: 19.08.2015*** ***Published Online: 29.01.2016*** ***Printed: 29.01.2016***

ABSTRACT

A set of diverse 28 wheat genotypes was evaluated for drought stress related traits, under irrigated and drought stress conditions for two years. The genotypes differed significantly for all the traits under drought stress environment, while under irrigated conditions nonsignificant differences were observed for triphenyltetrazolium chloride test, cell membrane stability, relative water content and osmotic potential. The genotypes NW 1014 and WH 1127 appeared to be drought tolerant, while C 306, HW 2004, Lok 1, NIAW 34, PBW 175, WH 1098, WH 1126, WH 1142, WH 1181 and WH 1182 indicated a combination of drought tolerance, avoidance and escape mechanisms, the genotypes HD 2858, PBW 343, WH 283 and WH 711 had tendency of escape, but susceptible and the remaining genotypes were susceptible. Correlation coefficient analysis indicated that the genotypes having better mitochondrial survival ability, membrane stability and water relation parameters under drought stress also had higher values for grain yield, drought susceptibility index (DSI) and drought response index (DRI). DRI appeared to be the most important among all the traits, because the genotypes having high DRI values also had high grain yield under drought stress conditions and high values for drought related traits.

Keywords: bread wheat, water relation parameters, cell membrane stability, drought susceptibility index, drought response index

Introduction

Drought stress is one of the major limiting factors of wheat productivity worldwide (Moayedi et al. 2011). Several drought tolerance screening methods have been developed, but their efficiency for incorporation of drought tolerance is restricted due to low heritability and a high magnitude of genotype x environmental interactions. Thus, progress for infusing drought tolerance may be achieved by using physiological characters in complement with conventional breeding for grain yield under drought stress. Cell membrane stability (CMS) measured by conductivity test and mitochondrial cell viability as measured by the reduction of tetrazoliumtriphenyl chloride test (TTC) received a considerable attention for measuring drought tolerance in wheat genotypes. Membrane disruption may result in crowding of cellular components which may be due to decrease in cellular volume resulting in protein denaturation and viscosity by increasing the permeability in plasma membranes (Kocheva et al. 2014).

Among water relation parameters relative water content was regarded as one of the reliable criteria for assessment of plant water status in mid 1980s (Arjenaki et al. 2012). Also, relative water content is related to cell volume and can reliably indicate the relation between the water absorbed by plant and the water consumed through transpiration. The use of RWC was considered for determination of water status in plant leaves to their fully turgid condition in various crops (Ibrahim et al. 2014). In addition to the maintenance of water content, solute potential (accumulation of various compatible solutes) is an important component of drought tolerance. These include amino acids (e.g., proline), sugars (e.g., fructon, sucrose), inorganic ions (e.g., potassium), organic ions (e.g., malate), ammonium compounds (e.g., glycine betaine) and polyols (e.g., manitol). These solutes help in protection of structure of membranes, proteins, oxidative damage and higher structural stabilization under drought stress and also help to maintain various metabolic and physiological functions. These may also contribute to drought avoidance with increased root growth and soil water extraction under drought stress (Boussadia et al. 2013).

Chlorophyll fluorescence also indicates drought resistance of the genotypes through carbon reduction cycle. Through the use of ATP and NADPH, metabolism of carbon influences the proton gradient, electron acceptor of PSII, and finally fluorescence yield under drought stress. Chlorophyll quenching analysis is a non-invasive and reliable method to determine the function of PS II (Batra et al. 2014). This study was planned to determine the role of traits viz., triphenyltetrazolium chloride, cell membrane stability, relative water content and osmotic potential, DSI and DRI under drought stress and their complementation with grain yield for improvement of drought tolerance.

Materials and methods

Twenty eight genotypes of wheat (*Triticum aestivum* L.) differing in their mean performance under drought stress (Table 3) were grown under normal and drought stress environments during the years 2009-2010 and 2011-2012 under field conditions at the CCS Haryana Agricultural University, Hisar, Haryana, India. The experiments were conducted in a randomized complete block design with three replications for both environments (irrigated and drought) with a plot size of two rows of 3m length and a spacing of 23 × 10cm. Both experiments were sown during the first week of November in each year. In Irrigated experiment five irrigations were provided including pre-sowing irrigation, while under drought stress conditions only pre sowing irrigation was provided in each year. Data for days to 50% heading, grain yield per plant, relative water content, osmotic potential, chlorophyll fluorescence, triphenyltetrazolium chloride and cell membrane stability were recorded at anthesis. The average of five competitive plants selected randomly from each genotype per replication.

Relative water content: The relative water content (RWC) was calculated according to Turner (1981) and evaluated from the equation: $RWC (\%) = [\{(FW - DW)/(TW - DW)\}] \times 100$, where FW is the fresh weight of the leaves, TW is the weight at full turgor and DW is the dry weight of leaves.

Cell membrane stability: CMS was measured by the method given by Blum and Ebercon (1981) for wheat. The leaf membrane stability (CMS) was determined from the following equation: $CMS (\%) = 1 - (T_1/T_2) \times 100$, where T_1 is the initial conductance and T_2 is final conductance value.

Chlorophyll fluorescence: Chlorophyll fluorescence measurements (F_v/F_m) were taken about 4 cm from the base of abaxial surface of flag leaves by using a portable handy Plant Efficiency Analyser, PEA (Hansatech, UK) at 15 days after anthesis. The florescence signals were detected as F_v/F_m. The data were analyzed using software biolyser 4.0 programme (R. Maldonado Rodriguez, Bioenergetics laboratory at the University of Geneva, Switzerland).

TTC reduction assay: Cell viability was assayed by the conversion of 2, 3, 5 triphenyltetrazolium chloride (TTC) into red formazan by dehydrogenase activity of viable cells. The level of mitochondrial viability was determined by measuring the percentage reduction of TTC to formazan using the following formula: $TTC (\%) = ODh / ODc \times 100$, Where ODh and ODc represent the optical density measured spectrophotometrically at 485 nm for second and first set respectively.

Leaf osmotic potential: Leaf osmotic potential measurements were made for samples in drought stress by the method of Blum (1988). Turgid leaf samples were frozen in liquid nitrogen samples were thawed and cell sap was pressed from leaves, which was subsequently analysed for osmolarity (C) ($mmol.kg^{-1}$) using a model 5520 Vapor Pressure Osmometer. Osmolarity of cell sap was converted from mmol/kg to osmotic potential (MPa) using the formula $MPa = - C \times 2.58 \times 10^{-3}$.

Drought susceptibility index (DSI): The drought susceptibility index of individual genotype was calculated by the method suggested by Fischer and Maurer (1978) with the following formula: $DSI = (1 - Ysi/Ypi)/D$, $D = (1 - Ys/Yp)$: where, Ys and Ysi are the mean and individual grain yields of genotypes, respectively, under a drought stress environment; Yp and Ypi are the mean and individual grain yields of genotypes, respectively, under a normal irrigated environment.

Drought response index (DRI): Drought tolerance for an individual genotype was computed using the formula given by Bidinger et al .(1987) as $DRI = (Ya - Yest)/SES$, where Yest and Ya are the yields estimated by regression and actual yields under stress for the cultivars, respectively, and SES is the standard error of the multiple regression.

Total precipitation during the season: The weekly data of precipitation during the season were obtained from the observatory, Department of Meterological Science, CCSHAU, Hisar, India. The data indicated that there was no precipitation after sowing in the month of November and December in both years. During the months of January to February there were approx. 19 mm rains in 2009-10 and 14.5 mm in 2011-12, and there were negligible rains up to second week of April and drought stress was operative. These periods coincide late jointing to boot stage of plant growth under both irrigated and rain fed environments. Drought stress experiments faced drought stress during the month of Feb onward in both years as the rains were not adequate to irrigate experiments. In addition, due to negligible rains during the months of March and April in both years severe drought stress occurred particularly during anthesis and dough stages of plant growth. The data for soil moisture content were collected gravimetrically on the depth of 0-15 cm, 15-30 cm and 30-45 cm depth at anthesis and maturity stages of plant growth throught the length of the experiment in each replication during both years. Soils of Hisar are clay loam and majority of root growth takes place between 0-15 cm depth of soil. The mean values of soil moisture content over the replications and over the years are presented in Table 1.

Results

Variability and mean performance

Significant differences among the genotypes over the environments and over the years and environments for majority of the traits revealed that the genotypes behaved differently in different environments/years (Table 2). Therefore in order to get more consistent results such types of experiments require repetition over the years and /or environments. Non-significant differences among the genotypes for triphenyltetrazolium chloride, cell membrane stability, relative water content and osmotic potential under irrigated conditions may probably due to poor expression of drought adaptive mechanisms in absence of drought stress. The data of these traits generated under irrigated conditions were excluded from further analysis. The mean performance of genotypes for grain yield under irrigated conditions was significantly higher (9.77±1.18 g) than that under drought stress (5.27±0.73 g) conditions indicating considerable impact of drought stress (Table 3). The genotypes HD 2009 (11.23^{*}), HW 2004 (11.55^{*}), WH 1098 (12.79^{*}) WH 1142 (11.45^{*}), WH 1181 (11.85^{*}) and WH 1182 (11.45^{*}) had significantly higher grain yield than their mean value (9.77±1.18) under irrigated conditions. These genotypes were also significantly higher yielder than their overall mean under drought stress conditions indicating that these genotypes may prove better under both environments. Majority of these genotypes also performed significantly better for drought related traits, namely, triphenyltetrazolium chloride test, cell membrane stability, relative water content and osmotic potential, drought susceptibility index and drought response index.

In addition, the genotypes C 306 (6.43^{*}), NIAW 34 (6.45^{*}) and PBW 175 (8.50^{*}) had significant higher grain yield over the mean (5.27±0.73) only under drought stress conditions indicating their superiority only under drought stress. Mean days to heading was significantly early under drought stress (84.38±2.40 days) than under irrigated condition (101.25±2.41 days). The genotypes HD 2858, Lok 1, PBW 175, PBW 343 and WH 711 earlier heading under both environments, while the genotypes NIAW 34 (77.35^{*}), HW 2004 (79.35^{*}), WH 1098 (78.50^{*}) and WH 1182 (77.25^{*}) escaped drought by accelerating their life cycle only under drought stress conditions. This indicated a role of developmental plasticity for days to heading in these genotypes for adaptation under drought stress conditions. But the genotypes C 306, WH 1181 and WH 1127 were very less influenced by drought stress for days to heading. Therefore, it may be assumed that early heading might have a little role in significantly higher grain yields of these genotypes under drought stress. The drought indicator traits, namely, DSI and DRI were significant for the genotypes, namely, C 306, WH 1142, HW 2004, PBW 175, WH 1181, WH 1098 and NIAW 34. This revealed that DSI and DRI were equally effective in predicting grain yields of these genotypes under drought stress, while for WH 1127 only DRI was effective (DRI= 0.75^{*}).

Correlations: Genotypes having higher grain yield under irrigated conditions also had higher grain yield under drought stress conditions ($r = 0.51^{**}$). (Table 4) indicating a complementation of high yield potential with drought resistance potential, but nonsignificant correlations of drought related traits with grain yield under irrigated conditions may be due to lack of drought hardening in absence of drought stress. Under drought stress conditions significant associations of grain yield with TTC ($r = 0.43^{*}$), CMS ($r = 0.45^{*}$), RWC ($r = 0.48^{**}$), OP ($r = 0.41^{*}$), days to heading ($r = -0.41^{*}$), DSI ($r = -0.69^{**}$) and DRI ($r = 0.82^{**}$) indicated that high grain yield was contributed by drought tolerance related traits. DRI appeared to be the most important trait as the genotypes with high score of DRI also had high values for grain yield ($r = 0.82^{**}$), TTC ($r = 0.56^{**}$), CMS ($r = 0.41^{*}$), RWC ($r = 0.65^{**}$), OP ($r = 0.38^{*}$) and low score of DSI ($r = -0.90^{**}$).

Significant correlations of TTC with CMS (r= 0.38*), RWC (r= 0.85**), OP (r= 0.63**), and DRI (r=0.56**) indicated that the genotype which had high percentage of cell viability under drought stress also had high values of membrane stability maintaining high solute potential and were better in terms of resistance parameters under drought stress. There was significant association of DSI and DRI (r = - 0.90**). DSI is an effect of all the traits contributing towards grain yield under drought stress (Fischer and Maurer, 1978), DRI can be made free from the influence of the characters relating to escape, avoidance and high yield potential through multiple regression technique (Arraudeau, 1989) as in case of present set of material.

Disscussion

Variability and mean performance

Drought stress causes disruption of water, ion and organic solute movement across the plant membranes, which affects the process of photosynthesis and transpiration and decrease the capacity of plasma-lemma to retain the solute which may be due to increased porosity and loosening of plasma membranes. Another reason for membrane disruption may be due to drought-induced denaturation of enzymes related membranes, which are responsible for maintaining chemical gradients in the cell under heat stress. (Antelmo et al. 2010). The genotypes PBW 175, WH 1181, PBW 644, UP 2425, NW 1014, Raj 3765 and WH 1098 performed were better not only for membrane stability, but also for other drought stress related traits including osmotic potential which may due to for accumulation of solutes in cells namely, sugars, sugar alcohols, amino acids, glycebetaines and protein etc. Majority of the solutes in bread wheat genotypes were K^{+} in early stages of drought stress and molecules including glycinebetaine, glucose and proline in later stages of plant growth which were involved helping maintenance of turgor and relative water conduct in leaves under drought stress (Arjenaki et al. 2012).

Resilience to phenological development also helps in adaptation to drought stress through accelerated heading and maturity. The genotypes WH 1182, WH 1142, HW 2004, NIAW 34, and WH 1098 indicated escape mechanism by completing their heading significantly early under drought stress as compared to irrigated conditions, while higher grain yields of the genotypes WH 1181, WH 1126 and WH 1127 were comparatively more influenced by drought avoidance/ tolerance mechanisms as indicated by higher values of DSI and DRI for these genotypes with stable days to heading. Involvement of these genotypes in crossing programme with that of high yielding types may provide desirable segregants under drought stress conditions.

Correlations

The genotypes with increased values of mitochondrial viability, cell membrane stability and water relation parameters, namely, RWC and OP also had high grain yield and favorable values of DRI and DSI indicating the contribution of these traits towards grain yield under drought stress conditions. This indicated that selection for CMS and or TTC under drought stress may give desirable results (Dhanda and Munjal, 2012). Grain yield is controlled by polygenes, complex inheritance, low heritability and is influenced by complex environmental interactions. Therefore, under drought stress conditions high grain yield potential should be complemented with a specific drought related trait which may buffer against severe reduction in the grain yield. Water status performs several functions in plants under drought stress. It regulates several biological reactions and maintains fliud medium which controls macromolucular structure required in operation of drought adaptive mechanisms. Recently intracellular $Ca^{2}+$ has been found to be involved in operation plant responses to drought stress and also participate in signal transduction process of plants which play an important role in accumulation of compatible solute under drought stress. (Nurit et al. 2012). Significant correlation of DSI and DRI and with grain yield and water relation traits suggested the combination of drought escape/avoidance traits with drought tolerance operating for high grain yield under drought stress.

Conclusions

A significant impact of drought stress was observed as the grain yield was reduced about 50% under drought stress conditions. All the traits under study showed significant variation particularly under drought stress conditions. Drought Response Index appeared to be the most important among all the traits studied, because the genotypes having high values for drought response index also had high grain yield under drought stress conditions. The genotypes NW 1014, and WH 1127 appeared to have tendency of drought tolerant, while C 306, HW 2004, Lok 1, NIAW 34, PBW 175, WH 1098, WH 1126, WH 1142, WH 1181 and WH 1182 indicated a combination of drought tolerance, avoidance and escape mechanisms, HD 2858, PBW 343, WH 283 and WH 711 tendency of escape, but susceptible and the remaining genotypes were susceptible. Accordingly these genotypes may be used in breeding programme as per requirement of the area of cultivation.

Table 1. Mean values for soil moisture content (%) at heading and maturity stages plant growth during the years 2009-10 and 2011-12

Soil sampling distance (m)	**Depth of soil (cm) at anthesis stage**			**Depth of soil (cm) at Maturity stage**		
	0-15	15-30	30-45	0-15	15-30	30-45
0-3	15.4	19.6	22.6	13.5	18.3	21.2
6-9	14.2	20.3	23.5	12.3	17.3	20.7
9-12	13.6	18.1	21.1	11.6	16.4	19.6
Mean	14.4	19.3	22.4	12.5	17.3	20.5

Table 2. Mean sum of squares of wheat genotypes over two years (2009-2010 and 2011-2012) and environments

Source of variation	**Degree of freedom**	**Character**		**Source of variation**	**Degree of freedom**	**Character**				
		Grain yield	**Days to heading**			**TTC**	**CMS**	**CHFL**	**RWC**	**OP**
Rep/year/env	8	3.17	0.22	Rep/year	4	166.60**	13.82	0.001	5.6	1.8**
Env (E)	1	2,579.50**	14009.10**	-	-		-	-	-	-
Year (Y)	1	723.81**	57.50**	Year (Y)	1	62.20**	826.87**	0.01**	11.3	0.9*
E xY	1	80.01**	81.03**	-	-	-	-	-	-	-
Genotype (G)	27	46.00**	62.9**	Genotype (G)	27	311.07**	195.10**	0.020**	121.5**	1.5**
GxE	27	29.11**	132.01**	-	-			-	-	-
GxY	27	1.299	15.11**	G x Y	27	205.05**	212.69**	0.001	78.5**	0.7*
GxExY	27	1.142	26.61**	-	-		-	-	-	
Error	216	5.201	5.069	Error	108	26.02	28.50	0.002	11.4	0.3
Total	335	-	-	Total	167	-	-	-	-	-

*, ** : Significant at 5% and 1% level of significance, respectively; Degree of freedom (DF), Grain yield (GY), Days to heading (DH), TriphenylTetrazolium Chloride (TTC) Cell membrane Stability(CMS), Chlorophyll Fluorescence (Fv/Fm), Relative Water Content (RWC) and Osmotic Potential (OP)

Table 3. Mean performance of wheat genotypes over two years (2009-2010 and 2011-2012) for various characters under irrigated (Irr) and drought stress (Dr) conditions

	Grain yield		**TTC**	**CMS**	**Chfl**	**RWC**	**OP**	**Days to heading**		**DSI**	**DRI**
Genotype	**Irr**	**Dr**	**Dr**	**Dr**	**Dr**	**Dr**	**Dr**	**Irr**	**Dr**		
C 306	8.12	6.43*	55.16*	55.46	0.75*	87.90*	-1.14*	97.02*	80.27	0.43*	1.36*
DBW 16	9.58	5.45	54.23*	49.58	0.70	87.90*	-2.88	100.94	81.69	0.88	0.13
DBW 17	16.23*	5.85	48.15	55.12	0.75*	75.80	-2.85	103.88	86.87	1.31	-1.01
HD 2009	11.23*	6.15*	45.18	62.85*	0.65	73.40	-3.00	96.04*	76.01	0.92	0.00
HD 2687	6.30	3.20	42.21	58.39*	0.67	70.20	-2.87	104.86	95.50	1.01	-0.35
HD 2858	9.56	5.46	46.35	52.63	0.73*	74.50	-2.45	95.06*	75.25*	0.88	-0.29
HW 2004	11.55*	6.90*	43.28	56.23	0.74*	87.50*	-1.19	98.98	79.35*	0.82*	0.81*
Lok 1	7.55	4.56	46.25	53.59	0.63	73.20	-2.75	93.10*	75.01*	0.81*	-0.64
NIAW 34	9.85	6.45*	48.15	57.64*	0.72	73.50	-2.24	98.00	77.35*	0.71*	0.76*
NW 1014	8.75	4.78	53.26*	55.16	0.73*	85.70*	-1.29	115.64	98.15	0.93	0.71*
PBW 175	9.85	8.50*	55.62*	67.29*	0.78*	89.50*	-0.56*	93.10*	77.01*	0.28*	2.74*
PBW 343	8.60	3.15	48.12	45.26	0.67	65.50	-2.32	95.45*	74.65*	1.29	-2.34
PBW 373	5.65	3.14	43.15	40.56	0.66	70.40	-2.89	112.70	94.95	0.91	-0.31
PBW 644	14.12*	5.85	52.63*	59.48*	0.68	84.20*	-2.03	106.16	92.90	1.20	-0.03
PBW550	8.45	3.48	43.26	54.65	0.61	70.10	-2.46	105.84	95.40	1.20	-0.68
Raj 3765	6.84	3.11	58.26*	59.36*	0.69	88.26*	-0.45*	98.00	83.35	1.11	-1.37
UP 2425	5.96	3.75	53.26*	62.18*	0.70	86.40*	-1.63	112.70	96.05	0.76	0.37
UP 2565	11.53*	3.05	48.56	55.21	0.61	75.60	-1.15*	107.80	88.85	1.50	-2.35
WH 1081	6.50	3.70	45.58	51.38	0.73*	81.50*	-1.52	87.22*	87.10	0.88	-0.45
WH 1098	12.79*	7.98*	59.26*	69.15*	0.73*	91.60*	-0.41*	102.90	78.50*	0.77*	1.51*
WH 1126	9.12	5.45	55.16*	51.69	0.65	88.60*	-2.39	102.90	86.98	0.82*	0.61*
WH 1127	10.25	6.13*	45.62	49.52	0.74*	71.80	-1.26*	102.90	85.05	0.82	0.75*
WH 1142	11.45*	6.98*	51.45*	47.15	0.77*	83.60*	-1.3*	101.04	81.35*	0.80*	1.07*
WH 1181	11.85*	9.30*	59.57*	61.53*	0.77*	91.60*	-0.26*	98.98	85.16	0.44*	3.50*
WH 1182	12.16*	7.26*	45.55	61.25*	0.66	73.50	-1.1*	99.30	77.25*	0.82*	0.90*
WH 283	9.23	4.26	43.18	61.85*	0.98*	69.20	-2.75	96.04*	75.35*	1.10	-1.37
WH 542	7.30	3.25	51.25*	55.48	0.66	85.40*	-2.25	100.94	93.70	1.13	-0.65
WH 711	15.23*	3.85	38.15	50.29	0.74*	65.30	-2.15	97.02*	76.90*	1.53	-3.37
Mean	**9.77**	**5.27**	**48.64**	**55.04**	**0.70**	**76.20**	**-1.84**	**101.25**	**84.38**	**0.98**	**0.00**
CD (5%)	**1.18**	**0.73**	**2.47**	**2.26**	**0.02**	**3.20**	**0.31**	**2.41**	**2.40**	**0.12**	**0.53**

*, ** : Significant at 5% and 1% level of significance, respectively; Degree of freedom (DF), Grain yield (GY), Days to heading (DH), TriphenylTetrazolium Chloride (TTC) Cell Membrane Stability (CMS), Chlorophyll Fluorescence (Fv/Fm), Relative Water Content (RWC) and Osmotic Potential (OP), Irr: Irrigated, Dr: Drought stress

Table 4. Correlation coefficients of among characters in bread wheat under irrigated (Irr) and drought stress (Dr) conditions

Character	**Env**	**Grain yield**		**TTC**	**CMS**	**Chfl**	**RWC**	**OP**	**Days to heading**		**DSI**	**DRI**
		Irr	**Dr**	**Dr**	**Dr**	**Dr**	**Dr**	**Dr**	**Irr**	**Dr**	**DSI**	**DRI**
Grain yield	Irr	1.00	0.51**	-0.02	0.20	0.18	-0.02	0.14	-0.05	-0.31	0.25	-0.01
	Dr	0.51	1.00	0.43*	0.45*	0.33	0.48**	0.41*	-0.22	-0.41*	-0.69**	0.82**
TTC	Dr	-0.02	0.43	1.00	0.38*	0.04	0.85**	0.63**	0.10	0.07	-0.47*	0.56**
CMS	Dr	0.20	0.45	0.38	1.00	0.23	0.40*	0.44*	-0.09	-0.13	-0.32	0.41*
Chfl	Dr	0.18	0.33	0.04	0.23	1.00	0.09	0.12	-0.26	-0.34	-0.24	0.19
RWC	Dr	-0.02	0.48	0.85	0.40	0.09	1.00	0.56**	0.08	0.16	-0.55**	0.65**
OP	Dr	0.14	0.41	0.63	0.44	0.12	0.56	1.00	-0.21	-0.13	-0.31	0.38*
Days to heading	Irr	-0.05	-0.22	0.10	-0.09	-0.26	0.08	-0.21	1.00	0.76**	0.20	0.01
	Dr	-0.31	-0.41	0.07	-0.13	-0.34	0.16	-0.13	0.76	1.00	0.19	0.00
Drought susceptibility index		0.25	-0.69	-0.47	-0.32	-0.24	-0.55	-0.31	0.20	0.19	1.00	-0.90**
Drought response index		-0.01	0.82	0.56	0.41	0.19	0.65	0.38	0.01	0.00	-0.90	1.00

*, ** : Significant at 5% and 1% level of significance, respectively; Degree of freedom (DF), Grain yield (GY), Days to heading (DH), TriphenylTetrazolium Chloride (TTC) Cell Membrane Stability (CMS), Chlorophyll Fluorescence (Fv/Fm), Relative Water Content (RWC) and Osmotic Potential (OP), Irr: Irrigated, Dr: Drought stress

References

Antelmo RF, Silva Cassel D, Ariano MMJ, Antanio CO and Marcos AB (2010). Chlorophyll fluorescence in rice: probing of senescence driven changes of PSII activity on rice varieties differing in grain yield capacity. Braz. J. Plant Physiol. 22:35-41.

Arjenaki GFG, Jabbari AR and Morshedi A (2012). Evaluation of drought stress on relative water content, chlorophyll content and mineral elements of wheat (*Triticum aestivum* L.) varieties. Intl. J. Agri. Crop Sci. 4(11):726-729.

Arraudeau MA (1989). Breeding strategies for drought resistance. In: Baker FWG (eds.), Drought Resistance in Cereals. CAB International, Wallingford, pp: 107-116.

Batra NG, Sharma BV and Kumari N (2014). Drought-induced changes in chlorophyll fluorescence, photosynthetic pigments, and thylakoid membrane proteins of Vigna radiate. Journal of Plant Interactions 9(1):712-721.

Bidinger FRB, Mahalakshmi and Rao GDP (1987). Assessment of drought resistance in pearl millet [*Pennisetum americanum* (L) Leeke] II: Estimation of genotypic response to stress. Aust. J. Agric. Res. 38:49-59.

Blum A (1988). Plant breeding for stresss environments. (eds.), CRC Press, Baco Raton, FL.

Blum A and Ebercon A (1981). Cell membrane stability as a measure of drought and heat tolerance in wheat. Crop Sci. 21:43-47.

Boussadia O, Steppe K, Van Labeke, Marie-Christine, Lemeur, Raoul and Braham M (2013). Active and passive osmotic adjustment in olive tree leaves during drought stress. European Scientific Journal 9:24.

Dhanda SS and Munjal R (2012). Heat tolerance in relation to acquired thermotolerance for membrane lipids in bread wheat. Field Crops Res. 135:30-37.

Fischer RA and Maurer R (1978). Drought resistance in spring wheat cultivars. I. Grain yield response. Aust. J. Agric. Res. 29:897-907.

Ibrahim A, Hashim El A, Khan P, Iqbal M, Obeid ME and Ahmed A (2014). Effect of water stress on relative water and chlorophyll contents of Juniperus Procera Hochst. Ex Endlicher in Saudi Arabia. International Conference on Chemical, Agricultural and Medical Sciences (CAMS-2014) May 2-3, Antalya (Turkey).

Kocheva K, Nenova V, Karceva T, Petrov P, Georgiev GI, Borner A and Landjeva S (2014). Changes in water status, membrane stability and antioxidant capacity of wheat seedlings carrying different Rht-B1 dwarfing alleles under drought stress. J. Agron. Crop Sci. 200(2):83-91.

Moayedi AA, Nasrulhaq Boyce A and Tavakoli H (2011). Application of physiological and biochemical indices for screening and assessment of drought tolerance in durum wheat genotypes. Aust. J. Crop Sci. 5:1014-1018.

Nurit F, Massimo N and Ettore P (2012). Water status and associated processes mark critical stages in pollen development and functioning. Annals of Botany 109:1201-1213.

Turner NC (1981). Techniques and experimental approaches for the measurement of plant water status. Plant Soil 58:339-366.