

MORPHO-PHYSIOLOGICAL AND BIOCHEMICAL CHARACTERIZATION OF WHEAT UNDER THE WATER DEFICIT CONDITIONS

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Abstract: In present study the 10 wheat genotypes were evaluated for their morphological, physiological and biochemical characters under drought stress. Drought is one of the most important phenomena which limit crop production and yield. Analysis of variance for morpho-physiological and biochemical traits and yield revealed highly significant differences among the entries under irrigated and non irrigated condition. In this study parameter like plant height, leaf length, number of tiller, spike length, spikelets per spike, seeds per spike, chlorophyll content, RWC, MSI and proline content was recorded. Analysis of the data showed that under water stress condition HD 2733 showed highest no. of tiller (4.37), Spikeletes per spike (17.20) and seeds per spike (21.20). While highest chlorophyll content genotype DBW 71 (34.37). RWC and MSI under the stress condition genotype HD 2733 performance better. Proline accumulation is believed to play adaptive roles in plant stress tolerance. Accumulation of proline has been advocated as a parameter of selection for stress tolerance. Therefore, the objective of the present investigation was to find out suitable morpho-physiological and biochemical traits that could be invariably used for the yield improvement of wheat grown under drought stress condition, responses to drought is essential for a holistic perception of plant resistance mechanisms to water-limited conditions. Crops demonstrate biochemical responses to tackle drought stress. All these parameters were found to greatly affect under imposed drought condition. Almost all the parameters were showed decline under imposed drought condition except proline content which is known as a stress tolerant indicator.

Keywords: Wheat, Morpho-physiological character, Proline, Drought Stress

INTRODUCTION

Wheat (*Triticum aestivum* L.), the world's most important and widely adopted crop in terms of area and production and contributes more calories and proteins to the world's diet than any other food crop (Hanson *et al.*, 1982). Three types of wheat are grown in India, 1) *Triticum aestivum* (bread wheat), 2) *Triticum durum* (durum wheat) and 3) *Triticum dicoccum* (dicoccum wheat). The green revolution, which was initiated in the country in the late 1960s, has had a very significant effect in increasing the yield of wheat. At present Uttar Pradesh, Punjab and Haryana are the three major wheat producing states. They account for nearly 70 % of the total wheat produced in the country. Though Uttar Pradesh the highest production in India, it lags behind Punjab and Haryana in terms of productivity. Drought is one of the most common environmental stresses that affect growth and development of plants. Drought stress, which is the most serious environmental problem limiting crop production in rainfed agriculture (Bahieldin *et al.*, 2005), can severely impact plant growth and development, limit plant production and the crop performance (Shao *et al.*, 2009). Drought and its effects on wheat productivity Drought stress affects the plant growth, development and productivity in all the cereal crops which is the major threat to world's agriculture (Hamayun *et al.*, 2010

and Subhani *et al.*, 2011). The circumstances thus demand breeding of crop for drought stressed areas using modern and traditional techniques. Signal transduction and stress response trigger physiological events that help the plant to withstand drought stress (Zhou *et al.*, 2010). Simane *et al.*, (1993) and Solomon *et al.*, (2003) observed the effect of water stress on the yield and yield components of durum wheat at different growth stages. Water stress leads to closure of stomata which in turn reduces the transpiration rate and diffusion of CO₂. Stomata of leaf close in response to light (generated by pigment zeaxanthin) and CO₂ concentration in the leaves (dehydrating roots send abscisic acid to the leaves signaling them to close stomata). The major driving force of water from the soil to the leaves is difference in the water potential between outside and inside of the leaf. As water vapour diffuses from the inside of the leaf it passes through the stomata into the atmosphere. This diffusion generates a negative pressure through the xylem down to the roots. With declining soil water reserves the plant closes the stomata in a response to water loss and maintains the continuous column of water from the root hairs to the leaf mesophyll. The surroundings under which plants are grown will affect the expression of certain physiological and morphological characters based on which they can be selected. Blum *et al.*, (1999) reported that osmotic adjustments were specifically

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and positively related with plant production under drought stress but not with plant production under irrigated conditions.

MATERIAL AND METHOD

The experiment was conducted in 2015-16 at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. The experiment was designed in pot with 10 wheat varieties PBW 533, UP 2425, PBW 226, DBW 17, PBW 590, DBW 71, DBW 16, K 802, K 9107 and HD 2733. Wheat genotypes selected on the basis of diverse backgrounds were grown in pots. The crop was exposed to partial drought (at different growth stages) with re-watering after produced a specific drought. The experiment was conducted in three replications having drought condition and another was raised under irrigated conditions. Irrigation water was supplied by sprinklers to provide two water regimes during plant growth. Drought was created in this rain free environment by with-holding irrigation after 15 days from sowing and giving supplementary irrigations every three weeks during 90 days post-sowing. Wheat genotypes were evaluated for morphological, physiological and biochemical traits (irrigated conditions) and for drought tolerance (water stressed conditions) at different growth stages.

Plant height

The plant height was measured from bottom of the plant i.e. from soil level to the base of the spike and (five selected plants) at reproductive stage of crop and average plant height was worked out.

Number of Tillers

Wheat seedling of different cultivars in their in early stages of growth show marked difference in their growth habit. The number of tillers per plant was counted of five selected plants at reproductive stage of plant and an average tiller per plant was worked out.

Flag leaf length

Flag leaf length measured from the base of ligula to the tip of leaf in cm.

Spike length

The average spike length of five plants on the main culm from the base of the spike to the top of the last spikelet excluding awns was recorded in centimeter.

Number of spikelet's per spike

Total numbers of spikelet's on main spike of all five plants were counted at the time of maturity and average was recorded.

Seeds per spike

Mean number of seeds counted from 5 randomly sampled spikes at maturity is recorded as seed per spike.

Chlorophyll content

The chlorophyll content in the flag leaf was determined using a SPAD meter. Five flag leaves of each genotype grown in rainfed condition were measured after anthesis stage. Three measurements

in the middle of the flag leaf were made randomly for each plant and the average sample was used for analysis.

Relative Water Content (%)

Relative water content of leaf was determined by method developed by Barrs and Weatherly (1962). Completely extended leaves were removed and fresh weight of leaf was taken immediately. The leaves were soaked in distilled water for 4 hrs under a constant light at room temperature. The turgid weight of leaf was calculated. The sample was dried at 80 °C for 24 hrs. The total dry mass of the sample was recorded. Finally, the relative water content of the leaf was calculated by employing following formula: Relative water content (RWC) = $\left[\frac{(FW-DW)}{(TW-DW)} \right] \times 100$

Where, FW = Fresh weight, DW = Dry weight, TW = Turgid weight

Leaf membrane stability

Membrane stability index of leaf during temperature induction was determined according to the method of Sairam (1994). Leaf section of 2 cm length was taken from the flag and penultimate leaves from drought stressed and irrigated plants. Leaf of (0.2g) of uniform size was taken in to test tubes containing 10mL of double distilled water in two sets. Test tube in one set were kept at 40°C in water bath for 30min. Test tubes were cooled under running water and electric conductivity of the water containing samples was measured (C1) using conductivity bridge. Test tube in the other set incubated at 100 °C in the boiling water bath for 15 minute and after cooling the test tube their EC was measured as above (C2). The leaf tissues were then killed by autoclaving all the samples for desiccation (T) and control (C) treatments. Leaf membrane stability of leaf tissues was calculated as percentage of injury using the equation: Injury (%) = $1 - \frac{(T1-T2)}{1-(C1-C2)} \times 100$ Where, T1 and T2 are the first and second conductivity measurement for the desiccation treatment, respectively. C1 and C2 are the first and second measurement of the control.

Proline concentration (PC)

The PC was determined according to the method of (Bates *et al.*, 1973). Plant material (0.5 g) after anthesis stage was grinded with 10 ml of 3% sulfosalicylic acid. The homogenate was filtered, and 1 ml of glacial acetic acid and 1 ml of acid ninhydrin reagent were added to a 1 ml of filtrate. Then the mixture was shaken by hand and incubated in boiling water bath for 1 h. After that, it was transferred to ice bath and warmed to room temperature. Toluene (2 ml) was added to the mixture and the upper toluene layer was measured at 520 nm using UV spectrophotometer.

Proline ($\mu\text{g/g}$ fresh weight) = $36.2311 \times \text{OD} \times \text{V} / 2 \times \text{F}$

Where, OD = Optical density at 520 nm, V = total volume of extract in ml, f = Milligram of fresh weight of leaf taken for one proline estimation.

RESULT AND DISCUSSION

Plant height

Plant height in wheat it is an important growth parameter, which is affected by genetic as well as environmental factors. Plant height is measured in centimetres from bases of the plant to the tip of the spike at the time of maturity. All the wheat genotype showed wide range of variation for plant height i.e. 63.40-69.00 (in irrigated condition) and 61.23-65.97 (in non-irrigated condition). The genotype K 802 showed the highest plant height (69.00) and the genotype PBW 590 showed lowest plant height (63.40) in irrigated condition. The genotype PBW 533 showed the highest plant height (65.97) and the genotype DBW 17 showed lowest plant height (61.23) in non-irrigated condition. The total mean of plant height (66.65) under irrigated condition and (62.58) non-irrigated condition. plant height is decrease due to water stress and Less reduction in plant height in stress conditions may be an important adaptive mechanism for environments characterized as drought tolerant at anthesis in moisture stress observed by Mirbahar *et al.*, 2009 ; Singh *et al.* 2001.

Number of tillers

All the wheat genotype showed wide range of variation for number of tillers i.e. 3.30-5.40 (in irrigated condition) and 2.63-4.37 (in non-irrigated condition). The genotype HD 2733 showed the highest number of tillers (5.40) and the genotype DBW 71 showed lowest number of tillers (3.30) in irrigated condition. The genotype HD 2733 also showed the highest number of tillers (4.37) and the genotype DBW 71 showed lowest number of tillers (2.63) in non-irrigated condition. The total mean of number of tillers (4.45) under irrigated condition and (3.41) non-irrigated condition similar result was reported by (Khakwani *et al.*, 2011). They observed higher number of tillers in range 2.67 to 4.83.

Flag Leaf Length

Flag leaf measured from the bases of ligula to the tip of leaf in cm. All the wheat genotypes showed wide range of variation for flag leaf length i.e. (20.57-29.37cm) in irrigated condition) and (16.57-24.77cm) in non-irrigated condition. The genotype PBW 533 showed the maximum flag leaf length (29.37 cm) and the genotype K 802 showed minimum flag leaf length (20.57cm) in irrigated condition. The genotype PBW 533 showed the maximum flag leaf length (24.77cm) and the genotype K 802 showed minimum flag leaf length (16.57cm) in non-irrigated conditions. The total mean of flag leaf length (25.39 cm) under irrigated condition and (21.56 cm) non-irrigated condition). Similar results were also reported by (khakwani *et al.*, 2011 and khakwani *et al.*, 2012). They observed higher leaf area in range 12.48 to 41.91 cm. In general all genotypes showed reduced leaf area under drought condition, it may be due to decrease in the

photosynthetic activity of plant leaves due to water stress. In many research, it was observed that due to water shortage cell sap of leaves decreases so volume of cell and parenchymatous cell size decreased.

Spike length

Wide range of variation also showed by all the genotypes with the range (7.50-9.57) in irrigated condition and (5.50-8.60 cm) in non-irrigated condition. The genotype HD 2733 showed the maximum spike length (9.57 cm) and the genotype DBW71 showed minimum spike length (7.50 cm) in irrigated condition. The genotype K 9107 showed the maximum (8.60 cm) and the genotype UP 2425 showed minimum spike length (5.50 cm) in non-irrigated condition. The total mean of spike length (8.44 cm) under irrigated condition and (7.30 cm) non-irrigated condition. Similar result observed Abassi *et al.*, (2014) reported that length of spike also affected by the drought stress and decreases grain yield is associated with reduction in spike length

Number of Spikelets /spike

Number of spikelets per spike directly play important role in wheat productivity. Water deficit condition also affects the number of spikelets per spike. All the wheat genotype showed a wide range of variation for spikelets per spike i.e. 16.20-20.03 (in irrigated condition) and 14.10-17.20 (in non-irrigated condition). The genotype HD 2733 showed the highest spikelets per spike (20.03) and the genotype PBW 226 showed lowest spikelets per spike (16.20) in irrigated condition. The genotype HD 2733 also showed the highest spikelets per spike (17.20) and the genotype PBW 226 showed lowest spikelets per spike (14.10) in non-irrigated condition. The total mean of spikelets per spike (17.82) under irrigated condition and (16.03) non-irrigated condition. similar result find Zhao *et al.*, (2013) reported in our study that spikelets per spike show positive agronomic performance under well water condition and reduce in drought stress condition Water deficit condition that limits the area under cultivation and yield of crops and show negative role against spikelets per spike specially yield more sensitive to drought stress, while in the landraces traits not differ under stress as compare to optimum conditions observed by Dencis *et al.* (2000).

Seeds per spike

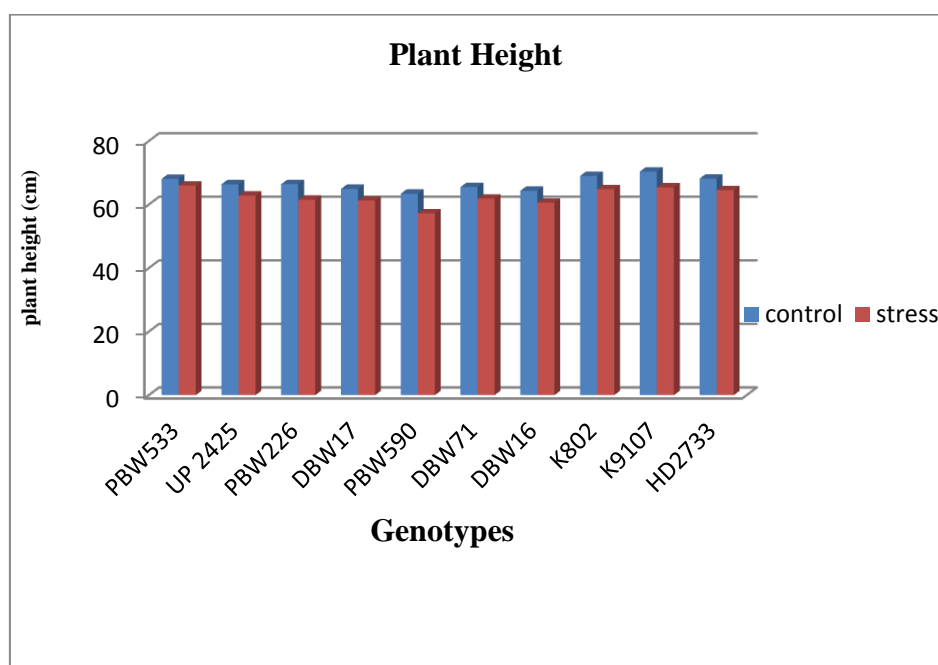
Measurement of seeds the number of seed counted from spike at maturity is recorded as seeds per spike. It is evident from the present data that wide range of variation existing among the genotypes with respect to number of seed per spike. All the wheat genotypes showed wide range of variation for seed per spike i.e. 19.30-25.00 (in irrigated condition) and 13.83-21.20 (in non-irrigated condition). The genotype HD 2733 showed the maximum seed per spike (25.00) and the genotype K 9107 showed minimum seed per spike (19.30) in irrigated condition. The genotype HD 2733 also showed the maximum seed per spike

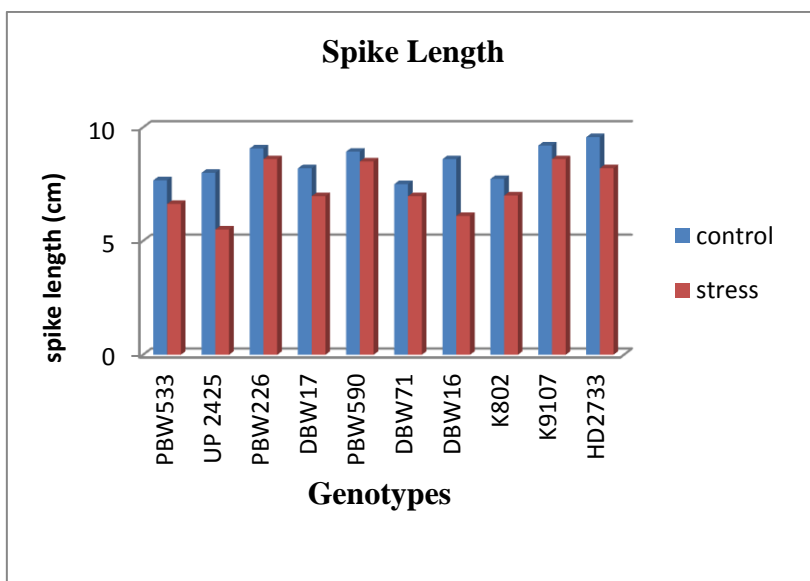
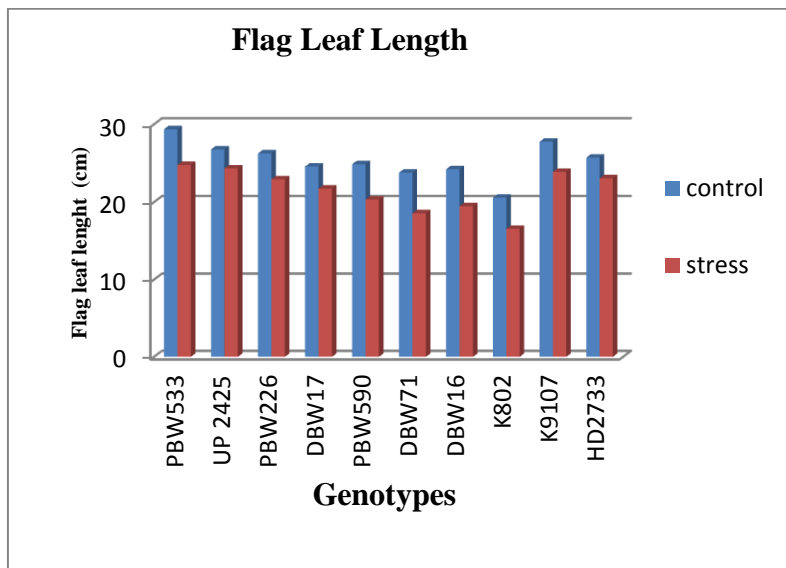
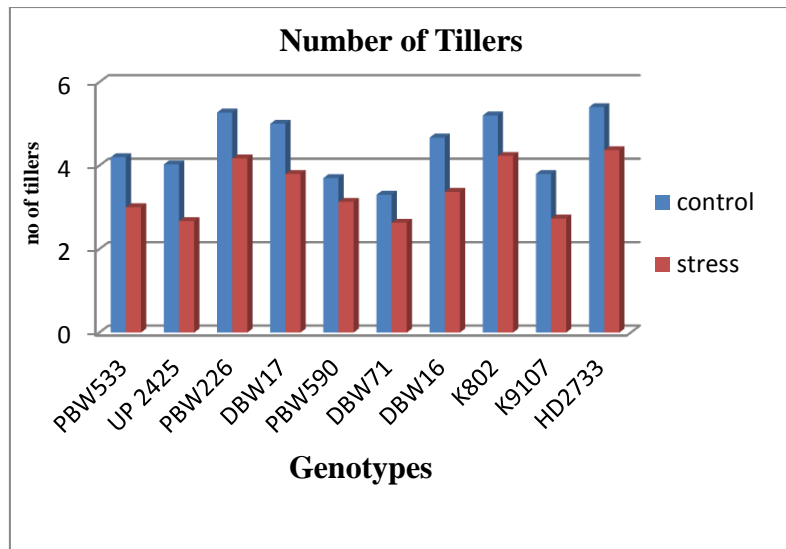
(21.20) and the genotype K 9107 also showed minimum seed per spike (13.83) in non-irrigated condition. The total mean of seed per spike (22.70) under irrigated conditions and (18.21) in non-

irrigated condition. Similar result find Sokoto *et al.*, (2013) reported that the effect of drought on grains per spike which resulted in reduction of yield.

Table 1. Morphological characterization of wheat under the water deficit conditions.

Genotypes	Plant height (cm)		No. Of tillers/plant		Flag leaf length (cm)		Spike length (cm)		Spikelets/spike		Seeds per spike	
	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated
PBW533	68.10	65.97	4.20	3.00	29.37	24.77	7.67	6.63	18.23	16.40	24.40	20.47
UP 2425	66.37	62.80	4.03	2.67	26.77	24.33	8.00	5.50	16.43	14.17	22.93	19.17
PBW226	66.40	61.50	5.27	4.17	26.27	22.93	9.07	8.60	16.20	14.10	22.03	18.07
DBW17	64.93	61.23	5.00	3.80	24.57	21.73	8.20	6.97	17.40	16.07	22.43	17.30
PBW590	63.40	57.23	3.70	3.13	24.87	20.33	8.93	8.50	18.33	16.60	24.23	19.43
DBW71	65.50	61.83	3.30	2.63	23.80	18.57	7.50	6.97	18.03	16.57	22.73	17.67
DBW16	64.33	60.57	4.67	3.37	24.23	19.47	8.60	6.10	18.20	16.63	22.90	20.03
K802	69.00	64.83	5.20	4.23	20.57	16.57	7.73	7.00	17.33	16.43	21.13	18.00
K9107	70.37	65.37	3.80	2.73	27.77	23.90	9.20	8.60	18.03	16.13	19.30	13.83
HD2733	68.17	64.53	5.40	4.37	25.73	23.07	9.57	8.20	20.03	17.20	25.00	21.20
Mean	66.65	62.58	4.45	3.41	25.39	21.56	8.44	7.30	17.82	16.03	22.70	18.51
CD	0.80	2.35	0.23	0.15	1.46	1.00	0.22	0.21	0.36	0.22	0.73	0.44
SE (m)	0.27	0.79	0.07	0.05	0.49	0.33	0.07	0.07	0.12	0.07	0.24	0.15
SE (d)	0.38	1.12	0.11	0.07	0.69	0.47	0.10	0.10	0.17	0.10	0.35	0.21
C.V.	0.70	2.19	3.01	2.56	3.36	2.70	1.52	1.73	1.20	0.81	1.89	1.40





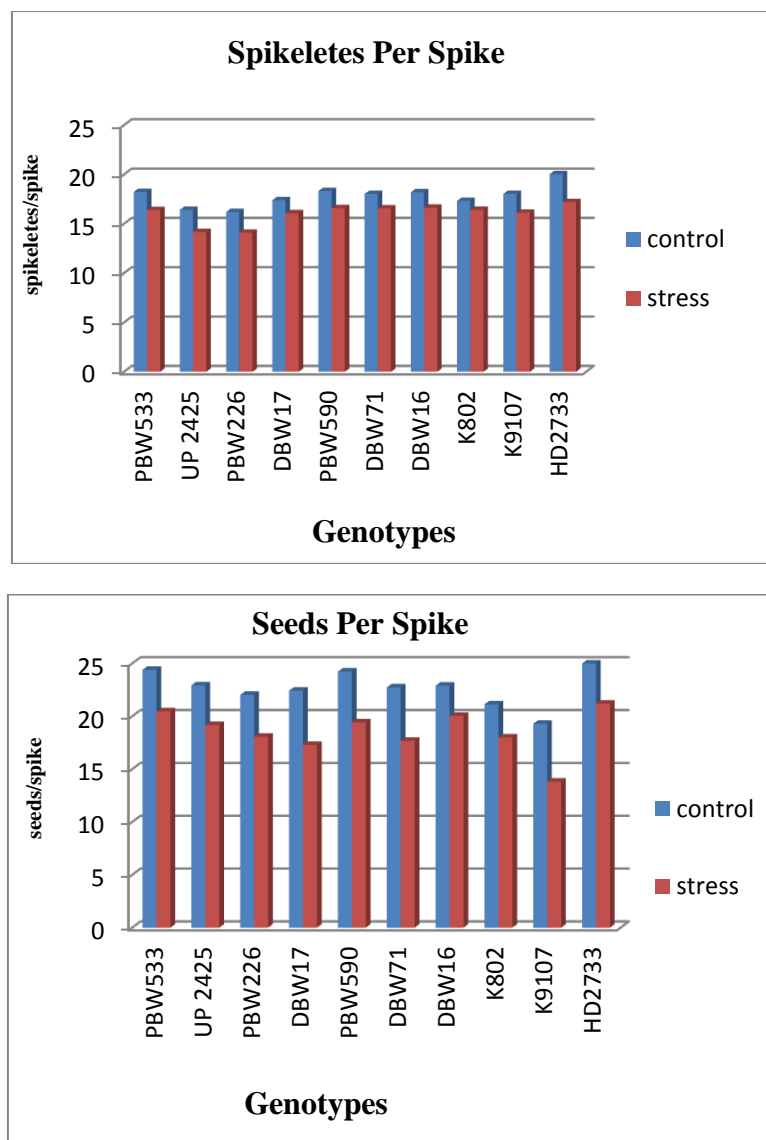


Fig. 1. Morphological character viz: plant height (cm), no of tillers, flag leaf length (cm), spike length (cm), spike length (cm), Spikeletes per spike and seeds per spike of wheat under the water deficit conditions.

2 Physiological and biochemical characterization of wheat genotypes under the water deficit conditions.

Chlorophyll content

Chlorophyll content was measured using a portable Minolta chlorophyll SPAD meter. The result showed that the chlorophyll content under control condition and water deficit condition. In water deficit condition show less chlorophyll content in wheat genotypes. The chlorophyll content ranged from 41.10-52.57 (in irrigated condition) and 34.37-45.40 (in non-irrigated condition). The higher chlorophyll content observed in genotype HD2733 (52.59) and the genotype DBW 71 showed lower chlorophyll value (41.10) in irrigated condition. The genotype PBW 533 showed the higher value of chlorophyll (45.40) and the genotype DBW 71 showed lower value of chlorophyll (34.37) in non-irrigated condition. The total mean of chlorophyll content (46.88) under irrigated condition and (39.73) in non-irrigated

condition. Similar results were reported by (Sibomana *et al.*, 2013) The lower chlorophyll content was recorded under drought condition means a genotype may be a drought tolerant in nature. Our results are in agreement with the study of (Nyachiro *et al.*, 2001).

Relative water content

All the wheat genotypes showed wide range of relative water content i.e. 69.23-82.37 % (in irrigated condition) and 61.77-73.23 % (in non-irrigated condition). The highest value of relative water content observed in genotype HD 2733 (82.37%) and lowest value relative water content observed in genotype K 9107 (69.23%) under irrigated condition. Genotype HD 2733 showed highest value (73.23%) and genotype K 9107 showed lowest value (61.77%) under non irrigated condition. The total mean of relative water content (76.15%) under irrigated condition and (67.40%) (in non-irrigated condition.). Mationn *et al.*, (1989) presented similar result as

regards drop in the amount of relative water content in sensitive and tolerant genotype of barley similar result was reported by (Bajji *et al.*, 2001. and khakwani *et al.*, 2011) in wheat. They observed higher relative water content in range 69.3% to 81.1%, 75.67% to 90% and 52.44% to 96.87%, respectively.

Leaf membrane stability

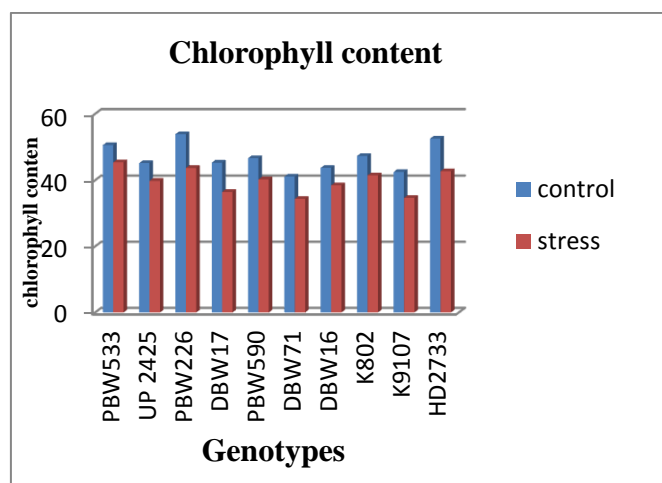
All the wheat genotypes showed wide range of Cell membrane stability i.e. 47.60-64.13% (in irrigated condition) and 39.27-56.20 % (in non-irrigated condition). The highest value of leaf membrane stability observed in genotype DBW 71 (64.13%). and lowest value of leaf membrane stability observed in genotype PBW 226 (47.60%) under irrigated condition. Genotype HD 2733 showed highest value (56.20%) and genotype PBW 226 showed lowest value (39.27%) under non irrigated condition (Table 4.2 a). The total mean of leaf membrane stability (55.77%) in irrigated condition and (47.09%) in non-irrigated condition). Similar results were also discussed by Bayoumi *et al.*, (2008).

Proline content

Proline accumulation is believed to play adaptive roles in plant stress tolerance. Accumulation of proline has been advocated as a parameter of selection for stress tolerance. All wheat genotypes showed wide range of proline content observed (0.218 -0.413 $\mu\text{g g}^{-1}$ fresh wt.) irrigated condition and (0.313-0.493 $\mu\text{g g}^{-1}$ fresh wt.) non-irrigated condition. The highest proline content observed in genotype HD 2733 (0.413 $\mu\text{g g}^{-1}$ fresh wt.) and lowest amount proline accumulated in genotype K 802 (0.218 $\mu\text{g g}^{-1}$ fresh wt.) under irrigated condition. Genotype HD 2733 showed highest proline content (0.493 $\mu\text{g g}^{-1}$ fresh wt.) and genotype PBW 533 showed lowest proline content (0.313 $\mu\text{g g}^{-1}$ fresh wt.) under non irrigated condition (Table 2). The total mean of proline content (0.303 $\mu\text{g g}^{-1}$ fresh wt.) under irrigated condition and (0.380 $\mu\text{g g}^{-1}$ $\mu\text{g g}^{-1}$) in non-irrigated condition. Proline, generally, functions through counteracting the injury exerted by water stress by accumulation in the main plant organs (Heikal and Shaddad 1982). Similar results were obtained by some other authors (Chen *et al.*, 2001, Claussen 2005; Hassanein *et al.*, 2009; Kadam *et al.*, 2017.)

Table 2. Physiological and biochemical characterization of wheat genotypes under the water deficit conditions.

Genotypes	Chlorophyll content		Relative water content %		Membrane stability index %		Proline content $\mu\text{g g}^{-1}$ fresh wt.	
	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated	irrigated	Non-irrigated
PBW533	50.60	45.40	77.37	71.63	52.47	41.37	0.220	0.313
UP 2425	45.17	39.83	75.50	67.60	57.57	47.53	0.318	0.377
PBW226	53.90	43.70	76.27	69.67	47.60	39.27	0.319	0.425
DBW17	45.30	36.47	70.63	66.43	61.23	54.20	0.245	0.331
PBW590	46.63	40.27	79.00	70.63	48.47	42.37	0.285	0.345
DBW71	41.10	34.37	77.43	72.47	64.13	52.53	0.369	0.411
DBW16	43.73	38.47	75.63	68.23	62.27	55.23	0.321	0.401
K802	47.33	41.47	78.10	70.43	48.27	41.43	0.218	0.321
K9107	42.50	34.67	69.23	61.77	52.53	40.77	0.326	0.383
HD2733	52.57	42.73	82.37	73.23	63.20	56.20	0.413	0.493
Mean	46.88	39.73	76.15	67.40	55.77	47.09	0.303	0.380
CD	6.45	3.95	3.87	3.27	3.24	4.05	0.007	0.007
SE (m)	2.17	1.33	1.30	1.10	1.09	1.36	0.002	0.002
SE (d)	3.07	1.88	1.84	1.55	1.54	1.93	0.003	0.003
C.V.	8.02	5.80	2.96	2.75	3.38	5.02	1.302	1.124



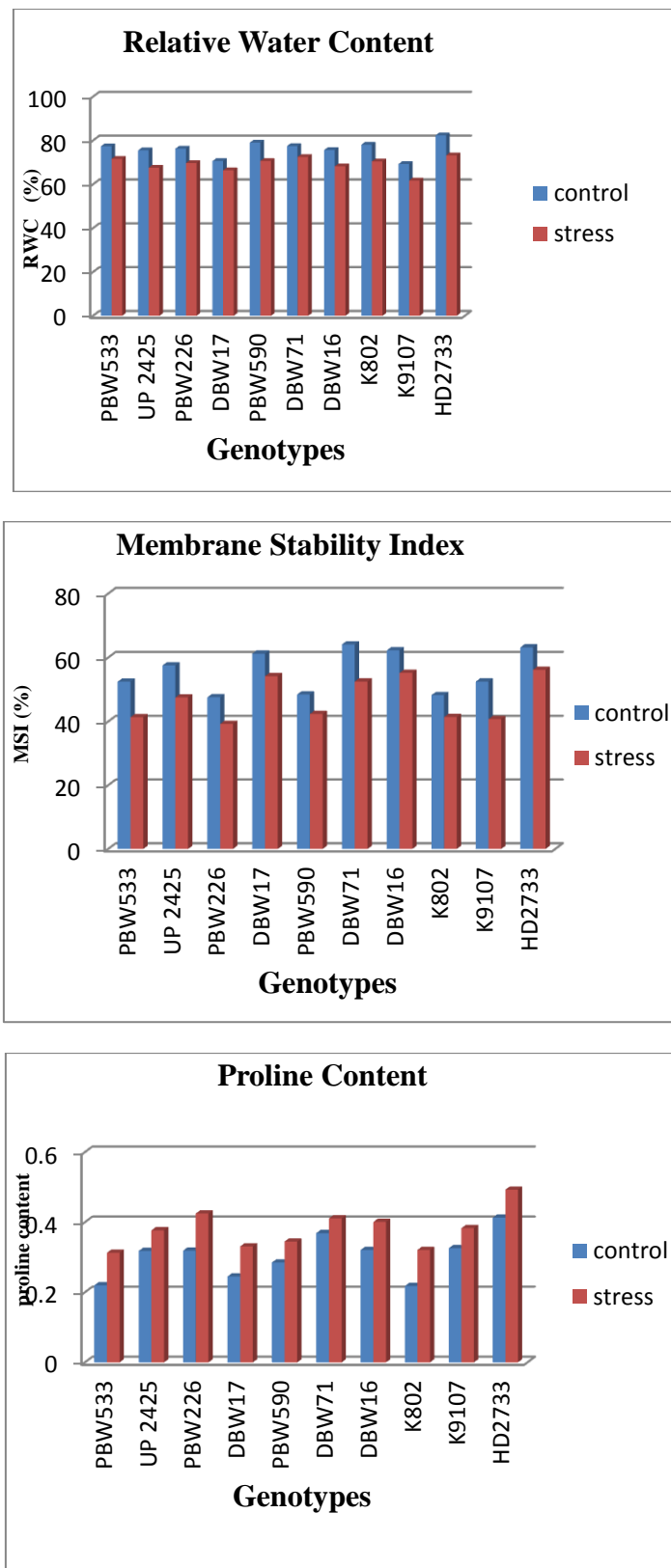


Fig. 2. Physio-biochemical character viz: chlorophyll content ,relative water content , membrane stability index and proline content of wheat under the water deficit conditions.

CONCLUSION

In the present investigation a continuous range of variability for morphological, physiological and

biochemical traits indicate the presence of several minor genes having small but additive effect for drought tolerance among wheat genotypes. Substantial variability is present among wheat

genotypes for morphological traits *viz.* Plant height, tiller per plant, flag leaf length, spike length, number of spikelets/spike and Seeds/spike are efficient parameters to evaluate germplasm for drought tolerance. Physio-biochemical traits chlorophyll content, relative water content, membrane stability index and proline content were affected by water stress. Different genotypes were showed variable response to drought stress we observed that HD 2733 tolerant variety under water deficit condition. So we can say for the production of wheat yield RWC, MSI and proline content used for the screening of drought tolerant cultivars.

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REFERENCES

- Abbasi, T., Premalatha, M., Abbasi, T. N. and Abbasi, S. A. (2014). Wind energy: Increasing deployment, rising environmental concerns. *Renewable and Sustainable Energy Reviews* **31**: 270–288
- Bayoumi, T. Y., Eid, M. H. and Metwali, E. M. (2008). Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes. *African J. Biotech.* **7**: 2341-2352.
- Bahieldin, A, Hesham, H.T., Eissa, H.F., Saleh, O.M., Ramadan, A.M., Ahmed, I.A., Dyer, W.E., El-Itriby, H.A. and Madkour, M.A. (2005). Field evaluation of transgenic wheat plants stably expressing the HVA1 gene for drought tolerance. *Physiol Plant* **123**:421–427.
- Bates, L. S., Waldran, R. P. and Teare, I. D. (1973). Rapid determination of free proline for water stress studies. *Plant Soil.* **39**: 205-208.
- Bajji, M., Lutts, S. and Kinet, J. M. (2001). Water deficit affect on solute contribution to osmotic adjustment as a function of leaf ageing in three duration wheat (*Triticum durum* Desf.) cultivars performing differently in arid conditions. *Plant Science.* **160**:669-681.
- Blum, A. (1999). Drought resistance of a doubled-haploid line population of rice in the field. Workshop on Genetic Improvement of Rice for Water Limited Environments. *IRRI, Los Baños, Philippines*, 1-3.
- Chen, C. T., Chen, L. M., Lin, C. and Kao, C. H. (2001). Regulation of proline accumulation in detached rice leaves exposed to excess copper. *Plant Sci.* **160**:283–290.
- Claussen, W. (2005). Proline as a measure of stress in tomato plants. *Plant Sci.* **168**:241–248.
- Dencic, S., Kastori, R., Kobiljski, B. and Duggan, B. (2000). Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. *Euphytica* **113** (1):43-52
- Heikal, M. M. and Shaddad, M. A. (1982). Alleviation of osmotic stress on seed germination and seedling growth of cotton, pea and wheat by proline. *Phyton (Aust)* **22**:275-287.
- Hassanein, R. A., Hassanein, A. A., Haider, A. S. and Hashem, H. A. (2009). Improving salt tolerance of *Zea mays* L. Plants by presoaking their grains in glycine betaine. *Aust J Basic Appl Sci.* **3**(2): 928-942.
- Mationn, M. A., Brown, J. H. and Ferguon, H. (1989). Leaf water potential, relative water content and diffusive resistance as screening techniques for droughtresistance in barley. *Agron. J.***81**:100-105.
- Mirbahar, A. A., Markhand, G. S., Mahar, A. R., Abro, S. A. and Kanhar, N. A. (2009). Effect of water stress on yield and yield components of wheat (*Triticum aestivum* L.) Varieties. *Pak. J. Bot.*, **41**(3): 1303-1310.
- Hanson, H., Borlang, N.E. and Anderson, R.G. (1982). Wheat in the third world. *West View Press*, Boulder, Colorado.
- Hamayun, M., Khan, S.A., Khan, A.L., Shinwari, Z.K., Iqbal, I., Sohn, E-Y., Khan, M.A. and Lee, I.J. (2010). Effect of salt stress on growth attributes and endogenous growth hormones of soybean cultivar Hwang keum kong. *Pakistan Journal of Botany*, **42**(5): 3103-3112.
- Sairam, R.K. and Saxena, D.C. (2000). Oxidative stress and antioxidants in wheat genotypes: possible mechanism of water stress tolerance. *J. Agro. Crop. Sci.***184**:55-61.
- Khakwani, A.A., Dennett, M., Munir, M. (2011). Drought tolerance screening of wheat varieties by inducing water stress conditions. *Songklanakarin Journal of Science and Technology*, **33**:135–142.
- Khakwani, A.A., Dennett, M., Munir, M., Abid, M. (2012). Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development. *Pakistan Journal of Botany*, **44**:879–886.
- Kadam, Sukshala, Shukla, Yogesh, Narayan, Subhash, Chandrakant, Singh and Kiran, Suthar (2017). Screening of Wheat Genotypes (*Triticum durum* L.) in Response to Drought Stress by Some Physiological and Biochemical Indices. *Int. J. Pure App. Biosci.* **5** (3): 969-977.
- Sibomana, I.C., Aguyoh, J.N. and Opiyo, A.M. (2013). Water stress affects growth and yield of container grown tomato (*Lycopersicon esculentum* Mill) plants. *Global Journal of Biochemistry and Biotechnology* **2**(4), 461- 466.
- Singh, R.P., Rajara, S., Miranda, A., Huerto-Espino, J. and Crossa, J. (2001). Grain yield and other traits of tall and dwarf isolines of modern bread and durum wheats. (In: Z. Bedo and L. Lang, eds). *Wheat in Global Envir.* 579-584.
- Subhani, G.M., Hussain, M., Ahmad, J., Anwar, J. (2011). Response of exotic wheat genotypes to

drought stress. *Journal of Agricultural Research*, **49**(3): 293-305.

Shao, H. B., Chu, L. Y., Jaleel, C. A., Manivannan, P., Panneerselvam, R. and M. A. Shao (2009). Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. *Crit. Rev. Biotechnol.* **29**: 131-151.

Simane, B. (1993). Durum wheat drought resistance. PhD. Thesis. Wageningen University, *The Netherlands*.

Mirzaei, A., Naseri, R. and Soleimani, R. (2011). Response of different growth stages of wheat to moisture tension in a semiarid land. *World Appl Sci J.* **12**(1):83-89.

Nyachiro, J.M., Briggs, K.G., Hoddinott, J. and Johnson Flanagan, A.M. (2001). Chlorophyll

content, chlorophyll fluorescence and water deficit in spring wheat. *Cereal Res. Comm.*, **29**(1-2):135-142.

Solomon, K.F., Labuschangne, M.T. and Bennie, T.P. (2003). Response of Ethiopian durum wheat (*Triticum turgidum* var durum L.) genotypes to drought stress. *South Africa J. Plant Soil*, **20**: 54-58.

Sokoto, M. B. and Singh A. (2013). Yield and Yield Components of Bread Wheat as Influenced by Water Stress, Sowing Date and Cultivar in Sokoto, Sudan Savannah, Nigeria. *American Journal of Plant Sciences*, **4**: 122-130.

Zhou, G.A., Chang R.Z. and Qiu L.J., (2010). Overexpression of soybean ubiquitin-conjugating enzyme gene GmUBC2 confers enhanced drought and salt tolerance through modulating abiotic stress-responsive gene expression in Arabidopsis. *Plant Mol. Biol.*, **72**: 357-369.