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Effect of moisture stress on morpho-physiological traits of wheat (*Triticum aestivum* L.) genotypes

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Abstract
Research experiment was carried out on twelve wheat genotypes viz. DBW-88, DBW-93, GW-322, K-1006, K-8027, MACS-6222, MACS-6478, NW-2036, NW-5054, PBW-590, UAS-428 and C-306 which were grown in two swing conditions non-moisture stress condition (Irrigated) and moisture stress condition (Rainfed) of Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during 2016-2017 *rabi* season. Sowing of wheat crop under (nin-moisture stress) condition was found to be most economical and out of twelve genotypes tested under experiment, GW-322 was found superior over others in respect of number of grains per spike, spike weight, test weight, grain yield, chlorophyll content index (at anthesis), relative water content.

Keywords: Drought, water requirement, chlorophylls, growth, photosynthesis, drought stress, physiological processes

Introduction
Wheat (*Triticum aestivum* L.) is the most widely grown and consumed food grain of the world. It competes well with other important cereals in their nutritive value. It meets 20 percent of total food calories for human being (Khichar and Niwas, 2007) [5]. It contains 7-12% protein. Wheat proteins have special significance in nutrition; they are principally concerned in providing characteristic substance 'gluten' which is very essential for bakers.

Drought is a polygenic stress and is considered as one of the most important factors limiting crop yields around the world. As climate change leads to increasingly hotter and drier summers, the importance of drought constraints on yield and yield components has increased in India. Wheat is an important crop where high temperatures and water stress often reduce plant growth and crop yields. Therefore, wheat yield is lowered. The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important. The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and cultivar genetics. The moisture stress adversely affects the various physiological and morphological processes of the crop. Water stress not only affects plant growth and development but ultimately productivity in almost all cereals, thus it is one of the most serious threats to The World Agriculture.

In case of wheat, there is need to improve yield gain under moisture stress using reliable physiological and morphological traits, which may be dependable for selecting genotype having higher tolerance to moisture stress. Based on better morpho-physiological basis this study was conducted for the identification of genotype responsible for moisture stress condition.

Materials and methods
The experiment was conducted at the farm of Wheat Research Unit, Mission School Block, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season 2016-17. The climate of Akola is subtropical semi-arid. Average annual precipitation is 750 mm and the major amount is received during the period June to September. Field experiments was laid out in Spilt Plot Design, with three replications, two treatments and twelve genotypes. Out of two treatments in one treatment irrigation was scheduled at critical growth stages after sowing and another treatment is moisture stress (rainfed) condition. Seed material of wheat varieties viz., DBW 88, DBW 93, GW 322, K 1006, K 8027, MACS 6222, MACS 6478, NW 2036, NW 5054, PBW 590, UAS 428, C 306 was obtained from the Senior Research Scientist (Wheat), Dr. P. D. K. V, Akola. Field experiment sowing was undertaken on 12th Nov 2016 utilizing 100 kg/ha seed rate. Gross plot size adopted was 2.5 m x 0.90 m and fertilizer dose was applied @ 120 kg/ha + 60 kg P_2O_5/ha and 60 kg K_2O/ha.

All plots were irrigated with pipeline system installed and volume of irrigation waves for each plot was controlled by adjustable counter, wheat crop harvesting was done on dated March 15, 2016. Grain yield was recorded after harvesting of the crop at maturity. Also, some parameters such as test weight, spike length, no. of effective tillers per meter at maturity, no. of grains per spike, spike length, spike weight, chlorophyll content index (at anthesis), canopy temperature (at anthesis), leaf area per plant(at grain filling stage) leaf area index (at grain filling stage), relative water content (at grain filling stage)were determined. Meanwhile the number of days to heading, number of days to anthesis, the number of days maturity were recorded during the growing season for each genotype. Data obtained was subjected to Analysis of varianceas per the standard procedure.

Results and Discussion

Significant differences are observed for grain yield, test weight, spike length, no. of effective tillers at maturity, no. of grains per spike, spike length, spike weight, chlorophyll content index (at anthesis), canopy temperature (at anthesis),leaf area per plant (at grain filling stage), leaf area index (at grain filling stage), relative water content (at grain filling stage) in both the conditions viz., rainfed and irrigated.

Wheat crop sown under irrigated condition has registered significantly higher days to heading (69 days) than wheat crop grown under moisture stress (rainfed) condition (66 days). Ear head emergence was occurred earlier due to moisture stress condition as compared to irrigated one. Significantly maximum days for heading, anthesis and maturity was observed in genotype K-8027 (Table 1). However, minimum days were required for heading and anthesis in PBW-590 (62 days). It was evident that, anthesis occurred 3 days earlier due to moisture stress (rainfed) condition (70 days) in comparison to irrigated condition (73 days), Similarly maximum significantly days were recorded for days to maturity under irrigated condition of wheat crop (121 days) relative to moisture stress (rainfed) condition (116 days). High moisture stress induced by rainfed sowing caused reduction by 5 days for days to maturity as compared to irrigated condition. Similar results were reported by Mekkei *et al.* (2014) [6].

The crop sown on under irrigated condition recorded significantly higher plant height at all the growth stages as compared to the crop sown on under moisture stress (rainfed) condition. The reason for consistently increased plant height in irrigated condition might be the enhanced vegetative development of crop due to the favorable moisture condition. Similar results were reported by Sarwar *et al.* (2010), Akbari *et al.* (2011) [4, 1]. Genotype C-306 exhibited maximum plant height (128.80 cm), which was statistically significant over rest of the genotypes and DBW-93 recorded the lowest plant height 104.12 cm at harvest.

Moisture stress induced by rainfed sowing condition (63.81) significantly decreased the number of effective tillers per meter at maturity as compared to irrigated condition (83.00) in wheat crop. Highly significantly effective tillers were recorded in genotypes DBW-93 (80.50) followed by GW-322 (80.00). However, significantly lower effective tillers were noted in genotypes DBW-88 (65.83), K-8027 (68.33) and NW-2036 (68.67) respectively. Number of grains spike^{-1} were significantly reduced under moisture stress (rainfed) condition (43.39) as compared to irrigated condition (53.33). It might be due to favorable moisture regime helped in proper growth and development of crop that reflected in higher number of grains per spike. Similar results were reported by Khan *et al*. (2007), Akbari *et al*. (2011) [4, 1]. The early maturing genotype GW-322 recorded significantly highest grains spike^{-1} i.e. 55.67 and was found on par with C-306 (53.67), NW-5054 (52.17) and K-1006 (50.83). Whereas, lowest grains per spike (41.67) were observed in genotypes UAS-428, MACS-647(42.00), DBW-88 (46.83) presented.

The data shown in Table 1 indicated that, length of spike was significantly higher in case of irrigated condition of wheat (8.86 cm) over moisture stress (rainfed) condition (7.47 cm). The high moisture stress condition caused reduction in spike length over irrigated sown wheat crop. Similar results were reported by Amiri *et al.* (2013) [2].

Among the genotypes, C-306 (8.77 cm) and K-8027 (8.75 cm) recorded significantly highest spike length followed by GW-322 (8.66 cm), MACS-6478 (8.60 cm), K-1006 (8.57 cm). While lowest values of spike length were observed in UAS-428 (6.55 cm), NW-2036 (7.40 cm), DBW-93 (7.72 cm).

The data pertaining to the character, revealed thatspike weight (g) was maximum under irrigated condition (4.47 g) relative to moisture stress (rainfed) condition (2.55 g) in wheat. The reduction in spike weight was caused due to high moisture stress induced by moisture stress (rainfed) condition. Among the wheat genotypes tested, genotype GW-322 for spike weight (g) it has recorded significantly highest spike weight (3.84 g) over all the genotypes, and it was followed by K-8027 (3.68 g). However, lowest (3.26 g) spike weight was recorded in UAS-428.

In case of parameter grain spike^{-1}. Significantly maximum value recorded by irrigated treatment (53.33) as compared to moisture stress treatment (43.93). Amongst the genotypes the differences for grain spike^{-1} were statistically significant and maximum grain spike^{-1} were recorded by GW-322 (55.67), followed by C-306 (53.67) and NW-5054 (52.17) whereas K-8027 was recorded lowest grain spike^{-1} i.e. 40.50 followed by UAS-428 (41.67).

Wheat crop sown under irrigated condition recorded (50.65 g) higher test weight as compared to moisture stress (rainfed) condition (42.65 g) and among the genotypes for test weight MACS-6478 (49.95 g) was recorded significantly highest test weight followed by GW-322 (49.82 g)and NW-2036 (49.38 g).Lowest test weight was recorded by DBW-93 (39.70 g), DBW-88 (42.85 g), K-1006 (43.73 g) in that order.

Maximum biological yield was recorded in irrigated sown condition (910 g plot $^{-1}$) and minimum in moisture stress (rainfed) sown condition (530 g plot $^{-1}$) in wheat crop. Similar results were reported by Akbari *et al.* (2011) [1]. Significantly highest biological yield was recorded in genotype K-1006 (840 g plot $^{-1}$) and remained on at par with NW-5054 (790 g plot $^{-1}$). However, significantly lowest biological yield was recorded in PBW-590 (600 g plot^{-1}).

The data shown in Table 1 indicated that, grain yield (g plot^{-1}) was found significantly higher in case of irrigated condition wheat (410 g plot^{-1}) than moisture stress (rainfed) condition (210 g plot^{-1}). The high moisture stress induced by moisture stress (rainfed) condition caused 50 per cent reduction in grain yield over normal irrigated sown wheat crop. Similar results were reported by Guttieri *et al*. (2001) [3]. Among the genotypes GW-322 recorded the significantly highest grain yield of 400 g plot^{-1} than all the wheat genotypes and followed by NW-5054 (390 g plot^{-1}), MACS-6478(340 g plot^{-1}) and C-306 (320 g plot^{-1}).The significantly lowest grain yield was recorded in DBW-93 (160 g plot^{-1}) and NW-2036 (160 g plot^{-1}) followed by NW-2036(260 g plot^{-1}), PBW-590 (270 g plot^{-1}), MACS-6222 (170 g plot^{-1}).

Irrigated sowing (45.05%) significantly increased harvest index relative to moisture stress (rainfed) sowing (39.62%) in wheat crop. It might be due to favorable moisture rigime helped in proper growth and development of grain that reflected in higher harvest index. Similar results were reported by Reynolds *et al*. (2009) [7]. Significantly highest harvest index was recorded in genotype NW-5054 (49.65%) over all the genotypes and followed by GW-322 (44.12%). Whereas, lowest harvest index was found in genotype K-1006 (37.25%).

Table 1: Effect of sowing environment and genotypes on days to anthesis, days to heading, days to maturity, plant height (cm), no. of effective tillers per meter, spike length, spike weight of wheat crop

Treatments	Days to heading	Days to anthesis	Days to maturity	Plant height	No. of effective tillers per meter	Spike length	Spike weight	No. of grains spike-1	Test weight (g)	Grain yield (g/plot)
Sowing environment										
T1	69	73	121	116.26	83.00	8.86	4.47	53.33	50.65	410
T2	66	70	116	107.28	63.81	7.47	2.55	43.39	42.65	210
SE (m) ±	0.32	0.30	0.05	0.04	0.12	0.01	0.001	0.30	0.08	0.30
CD at 5%	1.97	1.86	0.32	0.25	0.75	0.09	0.009	1.81	0.54	1.00
Genotypes										
G1-DBW 88	68	71	119	111.12	65.83	7.82	3.43	46.83	42.85	320
G2-DBW 93	69	72	118	104.12	80.50	7.72	3.27	50.50	39.70	260
G3-GW 322	66	71	118	108.82	80.00	8.66	3.84	55.67	49.82	400
G4-K1006	67	70	117	109.57	75.33	8.57	3.67	50.83	43.73	310
G5-K 8027	72	75	120	118.42	68.33	8.75	3.68	40.50	48.08	310
G6-MACS 6222	68	73	118	109.90	71.33	8.44	3.47	50.00	48.83	280
G7-MACS 6478	68	72	118	112.82	75.17	8.60	3.39	42.00	49.95	340
G8-NW 2036	63	68	116	116.03	68.67	7.40	3.35	49.00	49.38	260
G9-NW 5054	68	72	118	109.85	76.17	8.42	3.82	52.17	47.74	390
G10-PBW 590	62	66	117	106.35	71.00	8.10	3.36	47.50	47.98	270
G11-UAS 428	69	73	119	110.45	73.17	6.70	3.26	41.67	45.14	260
G12-C 306	70	73	118	123.80	75.33	8.77	3.63	53.67	46.60	320
SE (m) ±	0.78	0.70	0.51	0.42	0.90	0.09	0.02	0.74	0.37	0.30
CD at 5%	2.21	2.00	NS	1.22	2.58	0.27	0.06	2.11	1.07	1.00
Interaction (TXG)										
SE (m) ±	1.09	0.99	0.72	0.85	1.81	0.19	0.04	1.04	0.75	7.0
CD at 5%	NS	NS	NS	NS	5.16	NS	0.12	2.98	2.14	2.00
GM	67.5	71.33	118	111.77	73.40	8.16	3.51	48.36	46.65	0.31

Data recorded on chlorophyll content index are presented in Table 2. It was evident that CCI was significantly increased under irrigated condition (29.61) in comparison to moisture stress (rainfed) condition (25.21). It might be due to loss of chlorophyll index under water stress is considered a main cause of inactivation of photosynthesis. Similar results were reported by Taiz and Zeiger (2006), Tas and Tas (2007) [9, 10]. Among the genotypes significantly highest CCI was found in GW-322 (30.08) over all the genotypes and significantly lowest CCI values are observed in genotypes PBW-590 (24.28), C-306 (25.97) and DBW-93 (26.15).

Table 2: Effect of sowing environment and genotypes Biological yield (Kg/plot), Harvest index (%),Chlorophyll index at anthesis, Canopy temperature (°C) at anthesis, Leaf area per plant (dm2), Leaf area index, Relative water content (%)of wheat crop

Treatments	Biological yield (Kg/plot)	Harvest index (%)	Chlorophyll index at anthesis	Canopy temperature (°C) at anthesis	Leaf area per plant (dm2)	Leaf area index	Relative water content (%)
Sowing environment							
T1	910	45.05	29.61	19.58	1.51	6.54	61.47
T2	530	39.62	25.21	22.01	0.84	3.61	48.30
SE (m) ±	1.0	0.06	0.05	0.01	0.0006	0.003	0.03
CD at 5%	3.0	0.37	0.32	0.06	0.004	0.01	0.22
Genotypes							
G1-DBW 88	710	45.07	26.88	20.97	1.11	4.80	55.63
G2-DBW 93	690	37.36	26.15	20.88	1.14	4.94	54.28
G3-GW 322	780	44.12	30.08	21.13	1.15	4.98	56.00
G4-K1006	840	37.25	26.60	21.87	1.17	5.10	55.43
G5-K 8027	720	42.09	27.27	20.88	1.17	5.10	55.45
G6-MACS 6222	720	38.34	27.82	20.62	1.18	5.13	55.67
G7-MACS 6478	740	42.76	28.13	20.02	1.18	5.13	54.55
G8-NW 2036	620	43.65	28.70	20.67	1.20	5.20	54.97
G9-NW 5054	790	49.65	28.28	21.35	1.20	5.21	55.90
G10-PBW 590	600	43.25	24.28	20.67	1.20	5.21	53.63
G11-UAS 428	670	39.48	28.75	20.75	1.22	5.30	53.45
G12-C 306	790	39.29	25.97	19.72	1.13	4.92	53.68
SE (m) ±	1.0	0.82	0.29	0.19	0.003	0.01	0.20
CD at 5%	3.0	2.34	0.84	0.42	0.01	0.04	0.59

Interaction (TXG)							
SE (m) ±	2.0	1.64	0.59	0.30	0.007	0.03	0.41
CD at 5%	6.0	4.68	1.69	NS	0.02	0.09	1.18
GM	0.72	41.72	27.41	20.79	1.07	5.08	54.89

From the data, it was revealed that, increase in canopy temperature was observed in moisture stress (rainfed) condition (22.01 ^{0}C) relative to irrigated condition (19.58 ^{0}C) at anthesis. Similar results were reported by Siddique *et al*. (2000) [8]. Among the genotypes, highest canopy temperature was exhibited by genotype K-1006 (21.87 ^{0}C), followed by NW-5054 (21.35 ^{0}C), GW-322 (21.13 ^{0}C) and lowest canopy temperature exhibited byC-306 (19.72 ^{0}C) followed by MACS-6478 (20.02 ^{0}C), PBW-590 (20.67 ^{0}C).

Data pertaining to leaf area plant^{-1}(dm^{2}) at grain filling stage is presented in Table 2. The significantly highest leaf area plant^{-1} was recorded in irrigated condition (1.51 dm^{2}) as compared to moisture stress (rainfed) condition (0.84 dm^{2}).Response of genotypes to leaf area plant^{-1} showed greater variation. The general mean value was 1.07 dm^{2}. The genotype UAS-428 (1.22 dm^{2}) recorded significantly highest leaf area plant^{-1} followed by NW-5054 (1.20 dm^{2}), NW-2036 (1.20 dm^{2}), PBW-590 (1.20 dm^{2}) and MACS-6478 (1.18 dm^{2}).While significantly lowest in C-306 (1.13 dm^{2}). As regards the leaf area index, it was found significantly increased under irrigated condition (6.54) as compared to moisture stress (rainfed) condition (3.61) in wheat crop. Wheat genotypes exhibited higher UAS-428 (5.30)LAI followed by NW-5054 (5.21), PBW-590 (5.21), whereas lowest LAI was found in genotypes DBW-88 (4.80), C-306 (4.92), DBW-93 (4.94).

It was revealed that RWC was drastically reduced under moisture stress (rainfed) condition (48.30%) as compared to irrigated condition (61.47%) and significantly highest RWC was recorded in genotype GW-322 (56.00%) and followed by NW-5054 (55.90%), MACS-6222 (55.67%) and DBW-88(55.63%). whereas, significantly lowest RWC was recorded in genotype UAS-428 (53.45%) followed by PBW-590 (53.63%), C-306 (53.68%)

Conclusion

Sowing of wheat crop under irrigated condition significantly improved all the morpho-physiological characters viz. no. of effective tillers per meter at maturity, no. of grains spike^{-1}, spike weight, test weight, biological yield, grain yield, harvest index, chlorophyll content index (at anthesis), canopy temperature (at anthesis), leaf area per plant, leaf area index, relative water content (at grain filling stage) as compare to sowing of wheat under moisture stress (rainfed). Out of twelve genotypes tested under both condition, genotype GW-322 was superior over other in respect of number of grains per spike, spike weight, test weight, grain yield, chlorophyll content index (at anthesis), relative water content as compared to the other genotypes in moisture stress condition.

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