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Field Screening for Morpho-Physiological Traits in Bread Wheat (*Triticum aestivum* L. em. Thell) Genotypes under Moisture Stress

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ABSTRACT: Moisture stress is one of the main limiting factors for reducing yield in the wheat crop. Therefore, for the development of moisture stress tolerant cultivars, morpho-physiological attributes are an effective tool to screen genotypes with a large adaptation to a range of environments, namely irrigated and rainfed conditions. An experiment was conducted for the identification of moisture stress tolerant wheat genotypes by field screening of sixteen genotypes under irrigated and rainfed conditions. The tolerant genotypes were identified by percent decrease in performance for the morpho-physiological traits under rainfed conditions. In the present investigation, the morphological traits, *i.e.*, 1000 grain weight, grains/spike, grain weight/spike (g) and grain yield/plant (g), were taken into account for the identification of moisture stress-tolerant wheat genotypes. The tolerant genotypes, *i.e.*, BOW/VEE/5/ND/VG9144//KAL/BBB/YACO/4/CHIL/6/CASKOR/3/…, PBW660, HD3086, WH1080, FRANCOLIN#1/BAJ#1, VL3001, BECARD/KACHU were identified on the basis of morphological traits. Whereas, on the basis of a percent decrease in performance in physiological traits, *i.e.*, NDVI at anthesis, NDVI at 15 days after anthesis, canopy temperature depression at anthesis and 15 days after anthesis, chlorophyll content at anthesis and 15 days after anthesis, relative water content and quantum yield were accounted and tolerant genotypes, *i.e.*, BECARD/KACHU, PBW644, PBW660 and FRANCOLIN#1/BAJ#1 were identified. Therefore, these identified genotypes based on morpho-physiological traits can be used in future wheat breeding programmes to develop high-yielding and moisture-stress tolerant cultivars.

Keywords: Wheat, moisture stress, Morphological traits, Physiological traits, Percent decrease.

INTRODUCTION

Wheat is one of the first domesticated food crops, with evidence indicating that it was initially cultivated approximately 9600 BCE in the Fertile Crescent regions of south-western Asia. Wheat is currently only second to rice in terms of dietary consumption, with 67 percent of wheat produced being used for food, 21% for feed, and the remainder for other purposes such as industrial biofuels (FAO, 2021). Drought stress is one of the most main factors limiting wheat yield in semi-arid regions around the world. Crop varieties that are well adapted to dry conditions are needed to feed an ever-increasing population with declining water supplies (Foley *et al.,* 2011). Drought clearly has a negative impact on crop growth, development, dry matter production, and yield potential (Ayed *et al.,* 2021). In most moisture stress tolerance breeding programmes, grain yield is used to make selections. Aside from moisture stress, several other factors influence grain yield. Water scarcity impacts many stages of growth and development (vegetative, reproductive, and grain development) and has a detrimental impact on the plant's physiological processes, lowering yield (Mursalova *et al.,* 2015). Rao *et al.,* (2021) assessed effect of water stress on grain quality traits in wheat varieties. The plant morpho-physiological features are particularly important for selection in a breeding programme to improve moisture stress tolerance (Ashfaq *et al*., 2022). According to a recent review (Khadka *et al.,* 2020), a breeding programme that selects for morpho-physiological features has the potential to contribute to moisture stress tolerance in wheat. Several studies were done regarding the selection of tolerant genotypes for water stress by morphologic as well as physiological attributes. Ayed *et al.,* 2021; Soares *et al.*, 2020; Rabieyan *et al.,* 2022 identified drought-tolerant wheat genotypes by evaluation under irrigated and rainfed conditions for different yield components. Din *et al.,* (2020) used various physiological parameters, *viz*., chlorophyll content, canopy temperature, proline content, osmotic adjustment, excised leaf water retention, relative water content and cell membrane stability, for screening thirty wheat genotypes. Zubair *et al.,* (2021) used quality parameters for evaluation of wheat genotypes under irrigated and rainfed condition. Othmani *et al.,* (2021) used PEG-8000 for early-stage drought stress and screened durum wheat genotypes for water stress tolerance by different morphological traits. The various stress indices were used by researchers to identify tolerant cultivars (Banerjee *et al.,* 2020; Ayed *et al.,* 2021; Roostaei *et al.,* 2021); these indices can be used in the future for the assessment of wheat genotypes. Ashfaq *et al.,* (2022) used morpho-physiological parameters for selection of high yielding drought-tolerant winter bread wheat genotypes. Morphological traits, such as the number of grains/spikes, grain weight/spike, and 1000 grain weight, influence the tolerance of wheat to moisture stress conditions (Sattar *et al*., 2018). As a result, in arid regions, grain yield and its components are two key selection criteria. The chlorophyll content (Rahman *et al.,* 2016), Normalized Difference Vegetative Index (NDVI) (Singh *et al.*, 2016), canopy temperature depression (Rahman *et al*., 2016), relative water content (Arjenaki *et al*., 2012) and quantum yield (Huseynova, 2012; Romena and Najaphy 2012) have been used as a physiological screening technique for moisture stress tolerance. The photosynthetic efficiency is also an important physiological parameter, Koua *et al.,* (2022) revealed Chromosome 3A exhibits several pleiotropic and drought-responsive alleles for photosynthetic efficiency, so for the selection of these alleles can increase grain yield in future wheat breeding programme. Larouk *et al.,* (2021) estimated genetic variability in recombinant inbreed lines of wheat for yield and chlorophyll fluorescence parameters. Photosystem II (PSII) is a key component of plant photosynthesis that is especially sensitive to water scarcity (Lu *et al.,* 1999). PSII fluorescence can thus be used to detect stress in plants as a biosensing device. The highest photochemical efficiency of PSII is determined by the quantum yield. Environmental stresses affecting PSII efficiency result in a typical reduction in quantum yield (Khamssi and Najaphy 2012).

MATERIAL AND METHODS

The proposed research work was carried out at the N. E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar, India, during the rabi season, 2018-19. Fourteen wheat genotypes namely, BECARD/KACHU (Gi1), BOW/VEE/5/ND/VG9144//KAL/BBB/YACO/4/CHIL/6/CASKOR/3/… (Gi2), 92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA//TSI/VEE#5/… (Gi3), FRANCOLIN#1/BAJ#1 (Gi4), KACHU*2//WHEAR/SOKOLL (Gi5), PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/4/BERKUT//… (Gi6), UP2572 (Gi7), VL3001 (Gi8), NW5054 (Gi9), PBW644 (Gi10), C306 (Gi11), WH1080 (Gi12), WH1142 (Gi13), HD3086 (Gi14), HD2967 (Gi15), PBW660 (Gi16) were planted in three replications, in a randomized block design (RBD) in two environments i.e., Environment 1 (irrigated) and Environment 2 (Rainfed). The morpho-physiological screening was carried out in the above wheat genotypes under two different water regimes. Data on 1000 grain weight, grain weight/spike, number of grains/spike, grain yield/plant, chlorophyll content at anthesis (CC) and 15 days after anthesis (CC 15DAA), NDVI at anthesis (NDVI) and 15 days after anthesis (NDVI 15DAA), canopy temperature depression at anthesis (CTD) and 15 days after anthesis (CTD 15DAA), relative water content (RWC) and Quantum yield during grain filling were collected for this purpose. The decreased performance of the trait will be used as per the formula mentioned below:

Decrease performance of the trait (%) =

$$\frac{\text{Performance in E1 - performance in E2}}{\text{Performance in E1 condition}} \times 100$$

The drought susceptibility index for yield character per genotype was computed using Fischer and Maurer's formula (1978).

DSI = (1-Xi/X) / (1-Yi/Y)

Where, Xi represents phenotypic means for each genotype under a stressed condition, X represents phenotypic means for each genotype under a control condition, Yi represents phenotypic means for all the genotypes under a stressed condition, Y represents phenotypic means for all the genotype under control condition.

NDVI value was recorded using the "Green seeker Crop sensing system". Data is recorded in two stages at anthesis and during the grain filling stage (15 days after anthesis). The canopy temperature depression was measured using a handheld infrared thermometer (model AG-42, Tele temp crop, Fullerton CA). The data was taken at anthesis and 15 days after anthesis. Using a "SPAD chlorophyll metre", another physiological property, chlorophyll content, was measured in the flag leaves after calibration. The data was collected during anthesis and 15 days later. In order to calculate RWC, fresh weight, dry weight and turgid weight of leaves were estimated. For the estimation of fresh leaf weight, samples were weighed after excision and then were submerged in distilled water for estimation of turgid weight. After that, they were finally direct at 70ºC for 48 h and weighed again for estimation of dry weight.

$$RWC = (FW\text{-}DW/TW\text{-}DW) \times 100$$

Where FW stands for fresh weight, DW for dry weight, and TW for leaf turgor weight.

Using a hand-held photosynthetic efficiency analyser (PEA metre, Fluor Pen 100), the maximal photochemical efficiency of PSII (quantum yield) of the leaves was determined. The photochemical efficiency of PSII was measured on flag leaves immediately after dark-adapted the leaves for 10 min using leaf clips provided with FP100. The data were recorded during the grain-filling period.

RESULTS AND DISCUSSION

The studied morpho-physiological traits were used to identify the tolerant wheat genotypes based on the percent decrease in performance under moisture stress (ranifed) conditions. In physiological traits, the percent decrease in NDVI at anthesis (Table 1) ranged from 1.90 to 16.37, whereas at 15DAA, it ranged from -10.49 to 77.03. Seven wheat genotypes *viz*., Gi1, Gi2, Gi4, Gi12, Gi13, Gi14 and Gi16 showed a marginal decrease (<5%) in NDVI at anthesis, can be classified as tolerant or moderately tolerant for trait.

Table 1: Increase/decrease % in different morpho-physiological attributes over control under rainfed condition with Drought Susceptibility index (DSI).

Sr. No.	Genotypes	NDVI		CTD		Chlorophyll content		RWC	QY during grain filling	Thousand grain weight	Grains per spike	Grain weight per spike	Grain yield/plant	Drought Susceptibility index
		At anthesis	At 15DAA	At anthesis	At 15DAA	At Anthesis	At 15DAA							
1	BECARD/KACHU	3.18	-0.53	30.30	-7.14	-11.68	-13.00	22.47	-7.04	-28.76	20.32	-14.13	39.19	0.93
2	BOW/VEE/5/ND/VG9144//KAL/BBB/YACO/4/CHIL/6/CASKOR/3/…	1.90	0.00	-10.81	33.01	11.93	10.67	5.79	5.24	-10.77	25.84	15.98	51.60	1.00
3	92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA//TSI/VEE#5/…	10.23	77.03	10.92	12.22	-1.73	-11.70	4.37	-0.64	-0.14	-8.90	-31.73	24.75	0.96
4	FRANCOLIN#1/BAJ#1	2.09	-1.80	2.96	18.45	-31.18	-32.27	4.79	0.66	-17.24	-16.18	-29.50	-57.36	1.00
5	KACHU*2//WHEAR/SOKOLL	11.21	9.68	0.92	-16.84	7.58	-3.20	5.65	-3.33	-8.53	16.58	4.04	-8.59	1.03
6	PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/4/BERKUT//…	16.37	8.12	25.00	-29.41	-15.53	-10.90	2.68	10.21	-17.33	6.06	-23.93	17.97	0.98
7	UP2572	8.64	5.79	4.63	-26.79	-27.35	-35.27	-2.76	6.16	-12.61	-14.55	-41.81	-49.16	1.01
8	VL3001	6.16	17.13	-10.09	10.19	-26.97	-41.82	6.51	1.81	-20.46	-6.88	-38.37	-72.74	0.93
9	NW5054	7.28	4.32	5.41	12.66	-10.62	4.31	0.72	0.36	-9.39	0.30	-2.36	-62.09	1.00
10	PBW644	16.16	14.36	-14.47	29.03	-2.41	2.60	20.43	0.98	-18.82	-28.94	-58.51	21.15	0.96
11	C306	7.80	5.24	9.60	-29.73	26.52	30.12	5.10	5.06	0.76	23.46	15.85	-83.69	0.76
12	WH1080	2.42	3.85	11.11	-59.74	3.31	0.62	18.81	2.96	-25.13	-2.29	-43.55	-25.11	0.86
13	WH1142	3.62	2.07	-19.13	-4.44	1.00	-8.85	6.12	0.00	-3.52	5.98	-15.60	-38.06	0.95
14	HD3086	4.74	16.15	-19.63	-21.05	7.65	6.16	-0.59	1.34	-16.33	-0.44	-39.50	20.52	1.02
15	HD2967	6.00	10.67	36.92	1.68	8.08	7.06	-0.17	1.22	-14.71	-6.58	-40.58	6.73	0.86
16	PBW660	2.56	-10.49	28.68	38.71	-19.14	-32.43	-8.24	-1.31	-13.86	-13.68	-61.23	29.67	0.98

NDVI= Normalised Difference Vegetation Index, CTD= Canopy temperature depression, RWC= Relative water content

While, at 15DAA also seven genotypes *viz*., Gi1, Gi2, Gi4, Gi9, Gi12, Gi13, Gi16 exhibited a marginal decrease (<5%) in NDVI at 15DAA (Table 2), genotypes can be classified as tolerant or moderately tolerant for the trait. NDVI value indicates the vegetative greenness and canopy photosynthetic size, a useful trait for adaptation under water stress conditions (Singh *et al*., 2016). The potential for using NDVI to predict grain yield has also been reported in moisture-stressed conditions (Raun *et al.,* 2001).

The percent decrease in CTD at anthesis varied from (Table 1) -19.63 to 36.92 whereas, at 15DAA ranged from -59.74 to 38.71. Twelve wheat genotypes i.e., Gi2, Gi3, Gi4, Gi5, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13 and Gi14 reflected a marginal decrease in (<25%) CTD at anthesis, can be classified as tolerant or moderately tolerant during anthesis stage. While thirteen wheat genotypes, i.e., Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi11, Gi12, Gi13, Gi14, Gi15 were found tolerant genotypes for the trait CTD, since the percent decrease is <25% at 15DAA (Table 2). CTD is affected by the water status of the soil (Reynolds *et al.,* 2001). Scientist have been estimated a positive correlation between CTD and grain yield (Reynolds *et al.,* 1994). Therefore, CTD has been utilised as a selection criterion for moisture stress tolerance (Sharma *et al.,* 2002; Gutiérrez-Rodríguez *et al*., 2004; Rahman *et al.*, 2016; Din *et al.,* 2020; Ashfaq *et al.,* 2022).

The percent decrease in chlorophyll content varied from (Table 1) -31.18 to 26.52 at the anthesis stage whereas, at 15DAA it ranged from -41.82 to 30.12. Eleven wheat genotypes i.e., Gi1, Gi3, Gi4, Gi6, Gi7, Gi8, Gi9, Gi10, Gi12, Gi13, Gi16 showed marginal decrease (<5%) in chlorophyll at anthesis could be grouped as tolerant genotypes. While, twelve wheat genotypes *viz*., Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi12, Gi13, Gi16 showed a marginal decrease (<5%) in chlorophyll at 15DAA can be classified as tolerant or moderately tolerant for this stage (Table 2). Chlorophyll is one of the most important components of chloroplasts for photosynthesis, and its quantity correlates with photosynthetic rate (Saleem *et al*., 2017). Furthermore, flag leaf chlorophyll content is a measure of photosynthetic activity, and its stability implies assimilating biosynthetic conjugation. Photosynthetic rate is positively related to chlorophyll concentration, which enhances biomass production and grain yield. In the tolerant wheat cultivar, maintaining chlorophyll is critical for photosynthesis under water stress conditions. This feature has been effectively utilised to screen wheat cultivars that are resistant to moisture stress (Almeselmani *et al*., 2011; Saleem *et al*., 2017; Din *et al.,* 2020).

The percent decrease in RWC varied from -8.24 to 22.47 (Table 1). Eight wheat genotypes exhibited <5% reduction for RWC i.e., Gi3, Gi4, Gi6, Gi7, Gi9, Gi14, Gi15, Gi16 (Table 2). RWC represents the plant's water stress by measuring the presence of water in a leaf in relation to full turgor. Leaf RWC is an important indicator of water status in plants under moisture stress condition. It also designates the water status of the cells, which is related with the yield and tolerance to stress condition (Almeselmani *et al.,* 2011; Rahman *et al.,* 2016; Din *et al.,* 2020).

Table 2: Genotypes identified for different morpho-physiological water stress tolerant traits.

Sr. No.	Parameters	Tolerant genotypes
Physiological		
1	NDVI at anthesis (<5%)	Gi1, Gi2, Gi12, Gi13, Gi14 and Gi16
2	NDVI at 15DAA (<5%)	Gi1, Gi2, Gi4, Gi9, Gi12, Gi13 and Gi16
3	CTD at anthesis (<25%)	Gi2, Gi3, Gi4, Gi5, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13 and Gi14
4	CTD at 15DAA (<25%)	Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi11, Gi12, Gi13, Gi14 and Gi15
5	Chlorophyll content at anthesis (<5%)	Gi1, Gi3, Gi4, Gi6, Gi7, Gi8, Gi9, Gi10, Gi12, Gi13 and Gi16
6	Chlorophyll content at 15DAA (<5%)	Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi12, Gi13 and Gi16
7	RWC (<5%)	Gi3, Gi4, Gi6, Gi7, Gi9, Gi14, Gi15, Gi16
8	Quantum yield (<5%)	Gi1, Gi3, Gi4, Gi5, Gi8, Gi9, Gi10, Gi12, Gi13, Gi14, Gi15 and Gi16
Morphological		
1	1000 grain weight (<25%)	Gi1, Gi2, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15 and Gi16
2	Grains/spike (<25%)	Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15 and Gi16
3	Grain weight/spike (<25%)	Gi1, Gi2, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15 and Gi16
4	Grain yield/plant (<50%)	Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15 and Gi16
5	DSI (<1)	Gi1, Gi3, Gi6, Gi8, Gi10, Gi11, Gi12, Gi13, Gi15 and Gi16

NDVI= Normalised Difference Vegetation Index , CTD= Canopy temperature depression , RWC= Relative water

The percent decrease in quantum yield during grain filling (QY 15DAA) ranged from -7.04 to 10.21 (Table 1). The twelve genotypes exhibited <5% reduction for it, i.e., Gi1, Gi3, Gi4, Gi5, Gi8, Gi9, Gi10, Gi12, Gi13, Gi14, Gi15, Gi16(Table 2). QY has been suggested as a useful tool for screening wheat cultivars for moisture stress tolerance. The QY is a measure of the maximal photochemical efficiency of PSII that characterises the maximum yield of the principal photochemical reaction in dark-adapted leaves. Various researchers used this parameter for the evaluation of wheat genotypes for water stress tolerance (Khamssi and Najaphy 2012; Qaseem *et al.,* 2019; Larouk *et al.,* 2021; Ashfaq *et al.,* 2022).

The percent decrease in 1000 grain weight ranged from -28.76 to 0.76 (Table 1). All the sixteen wheat genotypes exhibited <25% reduction for it *viz*., Gi1, Gi2, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15, Gi16 (Table 2). The percent decrease in grains/spike ranged from -28.94 to 25.84 (Table 1). The fifteen wheat genotypes exhibited <25% reduction for it *viz*., Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15, Gi16 (Table 2). The percent decrease in grain weight/spike ranged from -61.23 to 15.98 (Table 1). All the sixteen wheat genotypes exhibited <25% reduction for it *viz*., Gi1, Gi2, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15, Gi16 (Table 2).

The percent decrease in grain yield/plant ranged from -116.29 to 51.60 (Table 1). The fifteen wheat genotypes exhibited <50% reduction for it *viz*., Gi1, Gi3, Gi4, Gi5, Gi6, Gi7, Gi8, Gi9, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15, Gi16 (Table 2). DSI varied from 0.76 to 1.03 (Table 1). Ten genotypes showed less than one (<1) DSI namely, Gi1, Gi3, Gi6, Gi8, Gi10, Gi11, Gi12, Gi13, Gi14, Gi15, Gi16 (Table 2).

Several scientists supported the characterization of material and identified tolerant wheat genotypes using of physiological and morphological traits such as, the NDVI (Singh *et al*., 2016), CTD (Rahman *et al*., 2016), chlorophyll content at anthesis (CC) (Saleem *et al*., 2017; Quaseem *et al.,* 2019), RWC (Rahman *et al.,* 2016) and quantum yield (Pakenjad*et al.,* 2007, Balouchi *et al.,* 2010; Qaseem *et al*., 2019) and in morphological traits 1000 grain weight, grains/spike, grain weight/spike and grain yield/plant (Amiri *et al*., 2013 and Sattar *et al*., 2018 and Ashfaq *et al.,* 2022). Ayed *et al.,* (2021); Soares *et al.,* (2021); Rabieyan *et al.,* (2022) identified drought-tolerant wheat genotypes by evaluation under irrigated and rainfed conditions for different yield components.

CONCLUSION

Wheat is a major cereal crop worldwide. The moisture stress is one of the most important limiting factor for wheat yield. The different morpho-physiological traits are key drought tolerance selection factors. Based on these traits, it may be concluded that various genotypes showed tolerance to moisture stress conditions for different traits. Therefore, identified tolerant genotypes can be used in future breeding programmes to develop water stress-tolerant cultivars.

FUTURE SCOPE

Further detailed investigation is required to confirm the findings of the present investigation and can also study the effect of water stress on quality parameters in the genotypes studied. The water stress tolerant genotypes identified by field screening can be used to development of tolerant cultivars.

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Conflicts of Interest. None.

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