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Genotypic variation for agro-physiological traits and their utilization as screening indices for drought tolerance in wheat

K. D. Sharma and Ashok Kumar

Crop Physiology Lab., Department of Agronomy, CCS Haryana Agricultural University, Hisar 125 004

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Abstract

Plants of 56 genotypes of bread wheat (*Triticum aestivum* L.) were grown under irrigated and droughted conditions under field conditions at CCS Haryana Agricultural University, Hisar, India. Leaf water status, canopy temperature depression and gas exchange were measured in the flag leaf at anthesis and yield-attributes and yield were recorded at harvest. The results revealed that there was a significant genotypic variation for all traits. Seed yield was positively correlated with yield attributes but a stronger relationship was observed with biomass. Drought susceptibility index (DSI) of genotypes matched for biomass and seed yield. Significant correlations were found among agro-physiological traits. Genotypes with higher soil moisture use from deeper layers (90-180 mm) maintained higher leaf relative water content (RWC), transpiration rate (E), photosynthetic rate (P_N) and cooler canopy (higher canopy temperature depression, CTD). Agro-physiological traits such as soil moisture use (90-180 mm), RWC, P_N and CTD were strongly correlated with seed yield. Since CTD is easier to measure than other characters, therefore, CTD measured at midday at the anthesis stage could be used as selection indices to screen large number of germplasm lines of wheat for drought tolerance under field conditions.

Key words: Canopy temperature depression, drought susceptibility index, drought tolerance, relative water content, wheat

Introduction

Drought constrains productivity more than any other factors, and climate change models predict that conditions will worsen in the future [1]. Inadequate water supplies similarly, cause yield losses in crops worldwide [2]. In India, the north western and central plain zone produces most of the wheat. In north western plain zone, the trend is towards greater restrictions on agricultural water use because of rapidly expanding urbanization and industrialization, while wheat is grown as rainfed or on limited irrigation in central plain zone. Therefore, the development of drought tolerant cultivars is an economic and environmentally sustainable way of increasing wheat yields. To produce these new cultivars, plant breeders must be able to identify germplasm with increased drought tolerance, and must be able to select for traits on a large scale, cheaply and efficiently in a short interval of time.

As water deficits develop, stomata closes progressively, transpiration decreases and canopy temperature rises. Several studies reported close associations of complex physiological traits and seed yield in many crop species [3, 4]. Morgan *et al* [5] used osmotic adjustment as a selection criterion for drought tolerance in wheat. Studies in cowpea and *Brassica* genotypes revealed that osmotic adjustment and canopy temperature are associated with each other [6, 7]. The wheat crop forms a closed canopy after heading, making possible the accurate measurement of canopy temperature. This study explores the possibility of using physiological traits including canopy temperature depression measured during midday at anthesis stage in the screening of wheat germplasm for drought tolerance under field conditions.

Materials and methods

The field experiment was conducted during the winter seasons of 2005-06 and 2006-07 at CCS Haryana Agricultural University, Hisar (situated at 29°10' N latitude, 75°48' E longitude, 215 m altitude), India. The soil of the experimental plot was sandy loam in texture, medium in fertility, slightly alkaline (pH 8.3) and it retained 190 mm of water in the 1 m profile at seeding time. The crop was planted on 17th November in 2005-06 and 16th November in 2006-07. Essential plant nutrients such as 60 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, 60 kg ha^{-1} K_2O and 25 kg ha^{-1} $ZnSO_4$ were supplied as basal dose before seeding under droughted treatment. The crop in irrigated treatment was given 60 kg ha^{-1} N before 1st irrigation in addition to basal dose before seeding. During 2005-06, the experiment was designed in split plot with 2 irrigation treatments, irrigated (4 irrigations applied at 25, 45, 90 and 105 days after seeding) and droughted (no post sowing irrigation) in the main plots and 56 genotypes in the split plots with three replications. Genotypes were grown without post sowing irrigation (droughted) in a randomized block design with three replications in 2006-07. The variation in soil moisture content (measured by Neutron Moisture Meter, Troxler Electronic Laboratories, Inc, NC, USA) was determined in 17 contrasting genotypes during 2006-07.

Measurements of leaf water status, gas exchange and canopy temperature depression (CTD) were made in 17 contrasting genotypes at anthesis stage. RWC was measured by cutting the leaf blade and rapidly transferring the leaf to a humid box placed nearby. Ten 15 mm diameter leaf disks were taken with a cork borer and placed in a humidified petri plate which was weighed to obtain fresh weight (FW), then floated on distilled water for 5 hours at 4° C in the dark. After 5 hours, the disks were carefully blotted dry and weighed to obtain saturated weight (SW). Disks dry weights (DW) were determined after 24 hours in an oven at 70° C. Leaf RWC was calculated according to Kumar and Elston [8]:

$$RWC = [(FW-DW) / (SW-DW)] \times 100$$

LWP was measured by pressure chamber apparatus (PMS Instrument Co., Oregon, USA). An infrared thermometer (Model AG-42 Telatemp Corp. CA, USA) was used to record CTD. Before the measurements of leaf water status, the rates of photosynthesis (P_N) and transpiration (E) were measured with a portable photosynthesis system (Infrared Gas Analyzer, CIRAS-1, PP Systems, UK) using a flag leaf which was later sampled for leaf water status. Average of 4 leaves sampled represent one replication or plot.

The number of spikes/m^2, number of seeds/spike, 1000-seed weight, total biomass and grain yield were recorded after the final harvest at physiological maturity. Data were subjected to analysis of variance using online Statistical Analysis Package (OPSTAT, Computer Section, CCS Haryana Agricultural University, Hisar, India) and mean separated by Duncan's Multiple Range Test at P<0.01. Correlation and regression were also calculated.

Results and discussion

There was large genotypic variation for physiological traits, yield-attributes and yield during the two growing seasons (Table 1), which implies that there is a great scope to exploit these traits for crop improvement. First, however, it must be established that a given trait is related to a major trait of interest, i.e., yield. Plant agro-physiological traits could aid in identifying superior genotypes and our data demonstrate that several of the

Table 1. Agro-physiological traits, yield attributes and yields (mean ± standard deviation) in wheat during the two seasons in irrigated and droughted environments

Characters	2005-06		2006-07
	Irrigated	Droughted	Droughted
Number of spikes/m^2	226 (10.7)	161 (11.1)	95 (22)
Number of grains/spike	54.8 (4.3)	48.0 (3.8)	33.0 (2.2)
1000-seed weight (g)	40.9 (5.1)	42.4 (4.7)	43.0 (1.0)
Harvest index (%)	43.2 (5.9)	43.2 (6.2)	39.5 (5.7)
Biomass (g/m^2)	521 (38.0)	340 (21.7)	293.2 (63.7)
Grain yield (g/m^2)	224 (16.4)	145 (9.8)	116 (31.8)
Leaf water potential (MPa)*			-1.99 (0.18)
Relative water content (%)*			82.0 (6.6)
Canopy temperature depression (°C)*			1.01 (0.51)
Transpiration rate (m mol m^{-2} s^{-1})*			2.36 (0.53)
Photosynthetic rate (µ mol m^{-2} s^{-1})*			12.01 (2.1)
Soil moisture use (mm, 90-180 mm)*			115.0 (15.7)

Figures in parenthesis represent ± standard deviation of mean; *Measured in 17 contrasting genotypes traits we examined show good promise as potential selection criteria for improving drought tolerance in wheat.

The seed yield in cereals is a function of the number of spikes/unit area, number of grains per spike and grain size. Our results have shown that the number of spikes/m^2 and grains/spike were positively correlated with biomass across the irrigation environments and crop seasons (Table 2). The seed yield was positively correlated with the number of spikes/m^2, grains/spike and the harvest index. The seed yield was also strongly correlated with the biomass across the seasons and environments (Table 2, 3). Plants producing higher biomass displayed higher number of spikes/m^2, grains/spike and higher seed yield. The canopy temperature depression (CTD) was negatively but significantly correlated with the yield-attributes and yield. However, CTD showed stronger correlation with seed yield as compared to other characters.

In 2006-07, the correlations were determined among various agro-physiological traits, yield-attributes and yield in 17 contrasting genotypes (Table 3). The leaf water potential (LWP) and leaf relative water content (RWC) related to each other. Genotypes which maintained higher RWC had cooler canopy (higher CTD), higher rates of transpiration (E) and photosynthesis (P_N) and vice-versa. Soil water use from deeper soil layer (90-180 mm) was negatively correlated with LWP and positively with RWC, E, P_N and seed yield. Singh *et al.* [9] reveled that osmotic adjustment was correlated with water use from deeper soil profiles in *Brassica* species. Osmotic adjustment enables the plants to maintain cell turgor and RWC as LWP decreases in response to changes in soil moisture content. This is evident by the strong and positive correlation between E and P_N indicating that genotypes showing high RWC displayed higher rates of E as well as higher rates of P_N. However, LWP showed no

Table 2. Correlation matrix of traits measured in 2005-06 (irrigated and droughted environment) and 2006-07 (droughted) on 56 genotypes

Traits	Spikes/ m^2	Grains/ spike	Seed size	Harvest index	Biomass	Seed yield
Grains/spike	0.07					
Seed size	0.09	-0.05				
Harvest index	0.02	0.64**	0.14			
Biomass	0.63**	0.45**	0.29*	0.15		
Seed yield	0.48**	0.60**	0.30*	0.63**	0.85**	
Canopy temperature depression	-0.51**	-0.60**	-0.28*	-0.54**	-0.82**	-0.93**

*P<0.05, **P<0.01

Table 3. Correlation matrix of traits measured in 2006-07 on 17 genotypes in droughted environment

Traits	LWP	RWC	E	P_N	CTD	Water use	Spikes/ m^2	Grains/ spike	Seed size	HI	Biomass
RWC	-0.89**										
E	-0.31	0.60*									
P_N	-0.31	0.45	0.78**								
CTD	0.47	-0.76**	-0.85**	-0.65**							
Water use	-0.60*	0.62*	0.50*	0.45	0.58*						
Spikes/ m^2	-0.33	0.59*	0.65**	0.39	-0.79**	0.25					
Grains/ spike	-0.37	0.66**	0.57*	0.55*	-0.60*	0.57	0.39				
Seed size	-0.50*	0.36	-0.13	0.02	0.02	0.28	0.11	0.12			
Harvest index	-0.13	0.40	0.33	0.12	-0.46	0.41	0.29	0.49*	-0.13		
Biomass	-0.46	0.66**	0.83**	0.71**	-0.81**	0.50	0.73**	0.49*	0.10	-0.02	
Seed yield	-0.45	0.78**	0.89**	0.67**	-0.95**	0.58*	0.80**	0.69**	0.02	0.52*	0.84**

LWP: leaf water potential, RWC: leaf relative water content, E: transpiration rate, P_N: photosynthesis, CTD: canopy temperature depression, HI: harvest index, *P<0.05, **P<0.01

significant correlation with traits of economic interest whereas RWC was positively related to number of grains/spike, biomass and seed yield. Genotypes displaying higher RWC produced more number of grains/spike, higher biomass and seed yield.

The drought susceptibility index (DSI) calculated for various parameters in 17 genotypes are presented in Table 4. DSI indicated that seed yield was determined by the biomass produced by an individual genotype. It was observed that genotypes RWP 05-09, WH 1012, VL 899, VL 902, KYPO 425, WH 736, AKAW 3997 and C 306 showed tolerance in biomass and also seed yield. In genotypes VL 899, 12 HT 11, VL 902, WH 736 and AKAW 3997 the tolerance also observed in spikes/m^2. The tolerance to number of grains/spike was observed in genotypes HI 8676, UAS 280, WH 1012, 12 HT 11, KYPO 425, WH 736 and C 306. The tolerance to all traits was observed in genotype WH 736. However, the DSI in biomass and seed yield was matched in maximum number of genotypes. Such findings were also reported by Praksh [10]. Therefore, selection for high biomass should bring about positive improvement in grain yield, effective tillers and number of grains/spike.

The selection based on measurements of yield attributes and biomass has been successful. However, there has been considerable discussion about the role of physiological approaches in assisting plant breeding. The utility of the screening traits is whether crop genotypes containing drought tolerance traits give better yields in drought prone environment. Also the major problem with many physiological traits is that they are too detailed and couldn't be used in crop improvement programme. A suitable screening method should assess the plant performance at the critical development stage in a short time by using relatively small quantities of plant material. In this study, we examined the role of simple physiological traits for screening the germplasm for drought tolerance. CTD measured during 20005-06 in irrigated and droughted and during 2006-07 in droughted environment during midday hours showed strong correlation with seed yield (Table 2). CTD also showed strong correlation with P_N rates, biomass and seed yield in the contrasting 17 genotypes. The measurements of CTD by portable infrared thermometer, is non-destructive, and faster than other physiological traits such plant water status, photosynthesis, etc. It can be performed successfully at the anthesis stage in wheat during midday hours in irrigated as well as droughted conditions. About 60 genotypes can be screened in one hour by infrared thermometry. Thus, the midday CTD could effectively

Table 4. Drought susceptibility index of different characters in 17 genotypes (2005-06)

Genotypes	Drought susceptibility index, DSI					
	Spikes/ m^2	Grains/ spike	Seed size	Harvest index	Biomass	Seed yield
12 HT 47	0.90	1.06	0.00	-1.31	1.15	1.17
HI 8676	1.38	0.61	-1.26	-0.81	1.92	1.94
UAS 280	1.13	0.00	-1.16	55.43	1.27	0.96
KO 585	2.35	1.32	-0.25	-17.41	1.10	1.22
RWP 05-09	1.29	1.59	-3.83	6.91	0.58	0.52
WH 1012	1.20	0.50	3.79	34.88	0.49	0.18
VL 899	0.52	1.50	1.21	2.18	0.74	0.73
KYPO 426	0.90	2.27	1.52	56.97	1.49	1.22
12 HT 11	0.40	0.57	3.06	-4.98	0.99	1.03
VL 902	0.37	1.00	2.11	31.69	0.36	0.07
HI 8674	1.22	1.98	1.02	-23.45	1.46	1.59
12 HT 25	1.24	2.27	0.58	-0.23	1.52	1.53
RS 945	1.82	2.27	0.24	-48.38	1.65	1.87
KYPO 425	2.39	0.53	19.13	-10.68	0.07	0.18
WH 736	0.14	0.61	-0.47	-11.94	0.39	0.50
AKAW 3997	0.50	2.27	0.00	-2.11	0.80	0.83
C 306	1.15	0.00	-0.13	-26.37	0.49	0.73

be used as a selection criterion for screening genotypes of wheat for their suitability in situations of limited water availability.

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