INTERNATIONAL JOURNAL OF ADVANCED BIOLOGICAL RESEARCH

www.scienceandnature.org

SCREENING OF BARLEY (*HORDEUM VULGARE* L.) GENOTYPES FOR PHYSIOLOGICAL TRAITS UNDER DROUGHT STRESS

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ABSTRACT
Barley (*Hordeum vulgare* L.) is one of the earliest coarse cereal crops. Stress due to drought condition is one of the major factors responsible for low crop productivity. In the present investigation, thirty barley genotypes comprised of two and six row type including checks (AZAD, K 560, K 603, LAKHAN, RD 2624 and RD 2660) were studied for physiological traits *viz*., Normalised Difference Vegetative Index (NDVI), canopy temperature and SPAD chlorophyll content, at anthesis and 15 days after anthesis of the growth period, under drought stress conditions. The physiological parameters *viz*., NDVI (0.40-0.76 and 0.49-0.82); SPAD chlorophyll content (17.2-21.4 and 14.5-18.7) and canopy temperature (19.6-43.4 and 17.1-46.8 ºC), at the time of anthesis and 15 days after anthesis, respectively, showed significant variation among the genotypes for all the characters studied. On the basis of physiological parameters, the promising genotypes for drought tolerance can be selected and utilized as elite breeding material to transfer drought tolerance through crossing programs. Hence, these physiological traits could be considered as suitable selection criteria for the development of high yielding barley varieties under drought condition.

KEYWORDS: NDVI, canopy temperature, SPAD chlorophyll content.

INTRODUCTION
Barley (*Hordeum vulgare* L.) is first domesticated and an important coarse cereal crop ranks fourth among cereal crops after rice, maize and wheat. It is widely adapted crop which is grown throughout tropical and temperate regions of the world. Drought stress due to limited water supply is one of the most important environmental factors which affect crop productivity worldwide. Major losses in crop production are due to drought stress conditions. The drought tolerance of a crop is essentially linked to its ability to access soil water and to use it most productively (Richards *et al.*, 2010). Severity of water stress during the grain-filling period decreased the net photosynthetic rate of the flag leaf of barley (Sanchez *et al*., 2002; Farooq *et al*., 2017). Barley is considered to be the most drought tolerant grain crop and a simple genetic model for evaluating mechanisms of drought tolerance and associated agronomic and physiological traits (Forster *et al*., 2004). Chlorophyll content is one of the major factors affecting photosynthetic capacity and indicator of photosynthetic capability of plant tissues (Nageswara *et al*., 2001). Reduction in chlorophyll content of plant under drought stress has been dependence on different genotypes and magnitude of stress and stress duration (Jagtap *et al*., 1998). Chlorophyll content in both resistant as well as sensitive genotypes reduced under drought stress condition. Genotypes showed resistance behavior to drought stress conditions had high in chlorophyll content (Sairam *et al*., 1997). Chlorophyll was one of the major components of chloroplasts, and positively correlated with photosynthesis rate. The reduction of chlorophyll content in drought conditions was considered a typical symptom of oxidative stress that could be the result of pigments photo-bleaching and chlorophyll degradation (Anjum *et al*., 2011).

According to Blum (1996) under water-limited conditions comparison of canopy temperature depression relative to air temperature makes it possible to detect genotypic differences related to the genetic improvement of cereals. Balota *et al*. (2007) have proposed low canopy temperature (CT) is the most important mechanism for drought adaptation. Roohi *et al*. (2015) observed that CT showed negative relationship with grain yield and the triticale, wheat and barley genotypes with low CT, produced more grain yield, suggested that the cooler canopy results in better adaptation to water stress. Chaudhari *et al.* (2017) reported that the wheat lines with low CT in grain filling produced more grain yields. Stay-green in the post anthesis phase is reported to be associated with drought tolerance in several crops (Campos *et al*., 2004).

NDVI is calculated using wavelengths within the NIR (near infrared) and VIS (visible) regions of the electromagnetic spectrum. NDVI relates to leaf chlorophyll content, leaf nitrogen and ultimately the photosynthetic capacity of the plant (Tattaris *et al*., 2016). CT, which is measured from emitted infra- red radiation, can be used as a tool to indirectly evaluate the transpiration rate, water status and stomatal conductance of a plant (Penuelas *et al*., 1997) while NDVI can estimate relative crop biomass at different growth stages (Babar *et al*., 2006) as well as nitrogen deficiency and crop senescence rate (Olivares-villegas *et al*., 2007). CT, chlorophyll content and NDVI (Normalized Difference Vegetative Index) have been effectively combined for rapid screening of drought and heat tolerance in wheat (Reynolds *et al*., 2007); hence these parameters were studied in barley genotypes under drought stress conditions. Therefore, the current study examined the response of yield and physiological traits to drought occurred in barley plants, according to the expected situations of climatic change.

MATERIALS & METHODS

Thirty barley genotypes comprised of two and six row type including six checks viz. AZAD,K 560, K 603, LAKHAN, RD 2624 and RD 2660 were studied for physiological parameters at anthesis and 15 days after anthesis. The experiment was conducted during *rabi* season of 2016-17 in a randomized block design (RBD) with three replications under drought conditions at research crop area of Wheat and Barley section, CCS Haryana Agricultural University, Hisar.

Each plot consisted of four rows of 2.5 m length with 23 cm row to row spacing. These barley genotypes were evaluated for physiological parameters and grain yield per plot given below as:

1. **Normalized difference vegetation index (NDVI)**: NDVI was recorded using optical handheld Instrument Green Seeker^{TM} sensor (Trimble industries, Inc.).
2. **Canopy temperature (CT)**: CT was measured during 12.00 and 14.00 hrs with hand-held infrared thermometer Sixth Sense LT300 IRT and three readings for each plot were averaged to get true representative values.
3. **Chlorophyll content index (SPAD)**: Mean chlorophyll of three tagged plants flag leaves were determined by a SPAD-502 chlorophyll meter (Konica Minolta Sensing, Osaka, Japan).
4. **Grain yield/plot (g)**: Grain yield was recorded after harvesting and thrashing the plot. The thrashed grains were cleaned and yield was recorded in gram.

The data was subsequently analyzed to determine the variability and phenotypic correlation coefficient using the OP STAT software of CCS Haryana Agricultural University, Hisar.

RESULTS

Variability for physiological and grain yield parameters

The data was collected for the physiological parameters at the time of anthesis and 15 days after anthesis of the thirty genotypes including six checks. The data obtained was analyzed for one factor analysis using the online OPSTAT software. Physiological parameters and yield was significantly influenced by drought at anthesis and 15 days after anthesis but the reduction was found more at 15 days after anthesis. The data for NDVI (Normalised Difference Vegetative Index), canopy temperature and SPAD chlorophyll content, at anthesis and 15 days after anthesis of the growth period showed huge variation (Table 1). NDVI ranged from 0.40 ±0.01 (2nd GSBSN 02) to 0.76 ±0.02 (LAKHAN) at anthesis and 0.49 ±0.04 (2nd GSBSN 02) to 0.82 ±0.001 (2nd GSBSN 94) at 15 days after anthesis. Canopy temperature ranged from 14.5±0.19 ºC (2nd GSBSN 66) to 18.7±0.46 ºC (2nd GSBSN 02) at anthesis and 17.2±0.27 to 21.4±0.32 ºC at 15 days after anthesis for LAKHAN and PL 890, respectively, whereas, SPAD chlorophyll content varied between 19.6±0.93 (2nd GSBSN 02) to 43.4±1.03 (2nd GSBSN 66) SPAD unit at anthesis and 17.1±0.49 to 46.8±1.39 SPAD unit at 15 days after anthesis for 2nd GSBSN 02 and RD 2660, respectively.

Drought condition showed a great variation between grain yield per plot; ranged between 401.7±33.71 g (2nd GSBSN 23) to 741.7±46.67 g (NDB 3) at the time of physiological maturity after harvesting and threshing. The genotypes NDB 3(741.7±46.67 g), KB 1326 (720.0±20.82 g), JB 485 (686.7±46.04 g), 2nd GSBSN 28 (676.7±63.86), KB 1317 (656.7±60.58 g) and 2nd GSBSN 93 (648.3±46.76 g) showed maximum grain yield per plot among all genotypes under drought conditions.

Correlation coefficient analysis

Correlation coefficients for all possible pairs of characters were calculated as per the procedure by Fisher and Yates (1963) using OPSTAT software of CCS Haryana Agricultural University, Hisar (Table 2). NDVI at anthesis and 15 days after anthesis showed negative correlation with canopy temperature at anthesis and 15 days after anthesis. The plants with higher biomass i.e. more NDVI have less canopy temperature. Hence it revealed that the plants with cooler canopy were found to be more drought stress tolerant. Canopy temperature at 15 days after anthesis also showed negative correlation with SPAD chlorophyll content at anthesis and 15 days after anthesis, while there is no significant correlation between canopy temperature at anthesis and SPAD chlorophyll content at anthesis and 15 days after anthesis (Table 2). SPAD chlorophyll content was positively correlated with SPAD chlorophyll content at 15 days after anthesis.

TABLE 1: Variation for physiological parameters and grain yield in barley genotypes under drought condition

Genotypes	At anthesis			15 Days after anthesis			Grain yield/plot (g)
	NDVI-I	CT-I (ºC)	SPAD-I	NDVI-II	CT-II (ºC)	SPAD-II	
BL 1122	0.55±0.02	16.0±0.48	35.8±1.92	0.71±0.07	19.3±0.69	29.9±0.84	481.7±37.68
BL 1163	0.64±0.03	15.1±0.47	32.7±1.78	0.77±0.02	18.8±0.58	27.7±0.69	625.0±42.53
JB 481	0.57±0.02	16.2±0.19	35.9±1.26	0.78±0.02	19.1±0.38	34.5±0.89	636.7±40.96
JB 482	0.59±0.03	15.8±0.62	28.1±2.06	0.76±0.03	18.6±0.14	28.9±3.51	493.3±23.15
JB 483	0.51±0.05	17.3±0.64	20.5±1.03	0.69±0.02	19.2±1.11	30.1±1.48	463.3±20.28
JB 484	0.43±0.02	16.8±0.45	27.4±1.71	0.58±0.02	19.7±0.89	26.8±2.71	613.3±28.48
JB 485	0.49±0.02	16.5±0.15	29.4±1.28	0.62±0.03	21.2±0.49	29.6±1.93	686.7±46.04
KB 1055	0.53±0.07	17.9±0.27	27.6±2.76	0.65±0.05	19.8±0.26	26.9±1.72	526.7±40.55
KB 1302	0.67±0.02	16.7±0.48	29.4±1.34	0.80±0.02	18.1±0.26	25.1±1.77	628.3±70.97
KB 1317	0.55±0.03	15.0±0.45	23.0±1.12	0.74±0.03	18.0±0.14	24.5±1.23	656.7±60.58
KB 1326	0.62±0.03	15.6±0.25	38.7±0.94	0.73±0.03	18.7±0.23	39.2±1.11	720.0±20.82
KB 1401	0.58±0.04	16.5±0.33	26.6±0.67	0.80±0.01	18.8±0.21	26.5±2.09	618.3±42.07
NDB 1	0.66±0.03	14.5±0.30	32.7±1.10	0.78±0.01	18.4±0.46	26.7±0.67	583.3±18.56
NDB 2	0.48±0.02	16.0±0.31	31.1±1.14	0.69±0.03	21.2±0.18	29.5±1.56	431.7±13.64
NDB 3	0.51±0.02	15.6±0.46	23.7±1.98	0.62±0.02	19.1±0.34	18.9±1.21	741.7±41.67
PL 751	0.40±0.02	17.4±0.21	24.7±2.24	0.60±0.03	20.4±0.67	25.6±1.82	551.7±34.44
PL 890	0.45±0.01	18.6±0.87	27.7±1.48	0.53±0.02	21.4±0.32	26.8±1.96	481.7±10.93
2^{nd} GSBSN 02 (2015)	0.40±0.01	18.7±0.46	19.6±0.93	0.49±0.04	21.0±0.81	17.1±0.49	521.7±34.92
2^{nd} GSBSN 23 (2015)	0.60±0.04	17.3±0.51	23.2±1.06	0.80±0.02	20.0±0.44	23.6±1.09	401.7±33.71
2^{nd} GSBSN 28 (2015)	0.66±0.02	15.3±0.23	29.5±1.23	0.74±0.02	17.9±0.68	37.0±0.51	676.7±63.86
2^{nd} GSBSN 60 (2015)	0.48±0.04	16.6±0.26	37.9±0.66	0.72±0.05	19.6±0.15	22.2±0.64	510.0±47.26
2^{nd} GSBSN 66 (2015)	0.49±0.02	14.5±0.19	43.4±1.03	0.70±0.05	18.9±0.48	31.4±2.31	575.0±59.23
2^{nd} GSBSN 93 (2015)	0.52±0.02	15.6±0.27	24.0±1.57	0.69±0.08	19.6±0.77	21.1±1.19	648.3±46.76
2^{nd} GSBSN 94 (2015)	0.62±0.03	15.2±0.67	29.6±1.74	0.82±0.00	19.4±0.19	26.7±0.81	520.0±55.08
AZAD	0.48±0.01	15.5±0.37	34.1±2.07	0.61±0.01	19.4±0.09	30.1±2.56	555.0±60.07
K 560	0.54±0.04	15.7±0.15	30.9±1.43	0.69±0.02	19.5±0.24	30.5±0.90	540.0±45.83
K 603	0.65±0.01	16.1±0.46	31.3±1.95	0.77±0.02	17.6±0.19	22.6±1.36	501.7±39.41
LAKHAN	0.76±0.02	15.6±0.27	27.8±0.88	0.79±0.01	17.2±0.27	26.3±1.53	536.7±49.10
RD 2624	0.47±0.05	17.0±0.53	32.5±1.92	0.59±0.02	20.1±0.61	21.6±1.28	550.0±28.87
RD 2660	0.52±0.03	15.2±0.74	35.0±2.00	0.67±0.04	20.3±0.76	46.8±1.39	523.3±40.96
C.D.	0.08	1.02	4.19	0.09	1.13	3.90	120.22
E(m)	0.03	0.36	1.49	0.03	0.40	1.39	42.36
SE(d)	0.04	0.51	2.11	0.04	0.57	1.96	59.90
C.V.	10.77	4.46	10.00	8.66	4.16	9.96	12.95

TABLE 2: Correlation coefficient between grain yield and physiological parameters in barley under drought stress environment

Parameters	NDVI at anthesis	NDVI 15 days after anthesis	CT at anthesis	CT 15 days after anthesis	SPAD at anthesis	SPAD 15 days after anthesis
NDVI at anthesis	1.000					
NDVI 15 days after anthesis	0.838^{**}	1.000				
CT at anthesis	-0.789^{**}	-0.692^{**}	1.000			
CT 15 days after anthesis	-0.490^{**}	-0.553^{**}	0.562^{**}	1.000		
SPAD at anthesis	0.140^{NS}	0.225^{NS}	-0.136^{NS}	-0.486^{**}	1.000	
SPAD 15 days after anthesis	0.178^{NS}	0.187^{NS}	-0.050^{NS}	-0.376^{*}	0.514^{**}	1.000

DISCUSSION

The huge range of variation was found between genotypes for Normalised Difference Vegetative Index (NDVI), canopy temperature and SPAD chlorophyll content, at anthesis and 15 days after anthesis (Table 1). The data showed that the SPAD chlorophyll content declined at 15 days after anthesis when compared to SPAD chlorophyll content at the time of anthesis. Gonzalez *et al*. (2010) also studied that the loss of chlorophyll induced by water deficit reached 11%. One of the reasons for the reduction of the amount of chlorophyll is chlorophylase enzyme activity, which is the expression of this enzyme induced in stress conditions (Ranjan *et al*., 2001). The loss of chlorophyll in the final stages of grain filling was as a result of oxidative stress and remobilization of nitrogen to grains (Oncel *et al*., 2000). Physiological parameters such as and the Normalized Difference Vegetation Index (NDVI) and chlorophyll content (SPAD) are directly related with nitrogen contents in leaves of plant and indicate plant fitness under stress; useful indicators for selection of superior genotypes under stress condition to enhance stress tolerance (Anithakumari *et al*., 2012, Cabello *et al*., 2013).

Bilge *et al*. (2008) reported pattern of changes in CTD values during pre-anthesis, anthesis and grain filling stages. Our results are in agreement with the finding of Talebi (2011), water stress affect positively canopy temperature. Previous studies on wheat presented a positive phenotypic correlation of Normalized Difference Vegetation Index, chlorophyll content and canopy

temperature with biomass production and grain yield (Gutierrez *et al*., 2010; Bowman *et al*., 2015).
It is well established that drought stress impairs numerous metabolic and physiological processes in plants (Levitt, 1980). Drought stress leads to reduction in growth, grain yield per plot, chlorophyll content, NDVI and canopy temperature (Li *et al*., 2006; Yang *et al*., 2006; Balota *et al*., 2007). Grain yield and physiological traits associated with drought tolerance are suitable indicators for selection of drought tolerant genotypes and can minimize the losses in crop productivity due to drought stress. It was concluded that NDVI, canopy temperature and SPAD chlorophyll content could be considered as reliable indicators for screening barley genotypes for drought tolerance.

CONCLUSION

The genotypes NDB 3, KB 1326, JB 485, 2nd GSBSN 28 (2015), KB 1317 and 2nd GSBSN 93 (2015) showed maximum grain yield per plot among all genotypes under drought conditions and performed better than the checks. The parameters such as canopy temperature, chlorophyll content and Normalized Difference Vegetation Index can prove to be beneficial as non-destructive methods of measuring plant drought stress and can screen field grown barley genotypes under stress condition.

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