

Effective Selection Criteria for Screening Drought Tolerant and High Yielding Bread Wheat Genotypes

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Abstract Bread wheat is the major staple food in Morocco. Drought is the most important abiotic stress decreasing yield. Breeding for drought tolerance may be improved by various plant traits. In order to investigate the best selection criteria to develop drought tolerant varieties, 40 bread wheat genotypes were evaluated under two locations representing the stressed and non-stressed environments, using randomized complete block design with three replications during the cropping season 2014. Under stressed conditions, analysis of variance exhibited significant differences among grain yield, thousand kernel weight, number of plants, number of spikes and tillers per plant, plant height, plant vigor, chlorophyll content and canopy temperature; and non-significant differences for biomass, harvest index, number of days to heading and flowering, and chlorophyll fluorescence. According to correlation and principal component analysis, the grain yield was positively related with biomass, thousand grain weight, number of fertile spikes and plant vigor; and indirectly associated positively with harvest index, plant height and negatively with number of days to flowering, canopy temperature and chlorophyll content. Those traits, correlated to grain yield under stress, can be used as indirect selection for drought tolerance to obtain higher yield potential in dryland conditions. Moreover, thousand grain weight in non-stressed conditions was positively correlated to biomass, number of fertile spikes and its homologue in stressed conditions. Also, the biomass in favorable conditions was correlated to thousand grain weight and harvest index in mild stressed conditions. Thus, those two traits may be used to improve performance in drought prone environments.

Keywords Bread Wheat, Drought Tolerance, Selection Criteria, Agro-morphologic, Physiological

1. Introduction

Bread wheat (*Triticum aestivum* L.) is one of the most

important mainstay crops for food security over the world, including Morocco. In order to cope with 8.5 billion expected world population growth by 2030, the average world wheat productivity should reach 4.3 t/ha, representing 1.6 % of yield increase on annual basis [1,2].

Drought is a common feature of Mediterranean climate, causing large inter annual fluctuations in rainfed wheat productions, especially in dry lands areas such as Morocco. The development of new high yielding varieties tolerant to drought stress is one of the most efficient strategies to improve yields in unpredictable drylands environments. However, breeding for drought resistance is complicated by the complexity of the wheat genome and the lack of fast, reproducible drought screening techniques due to the involvement of many physiological and morphological characters [3-5]. Currently, efforts are directed to access new and cheap reliable indices that can help in selection of drought tolerant genotypes.

In general, breeding for drought tolerance involves combining good yield potential in optimum conditions and the selection of high heritable traits related to drought tolerance. Yield is the principal selection index used under drought stress conditions. However, the yield is a complex polygenic trait which QTLs are located differently from those controlling drought [6,7]. Thus, the selection efficiency could be improved if particular physiological and/or morphological attributes related to yield under a stress environment could be identified as selection criteria for complementing conventional breeding [8]. Genetic improvement of crops for drought tolerance requires a search for possible relationship between agronomic, morphologic and physiological traits and grain yield [9,10]. These traits should be highly heritable, greatly correlated with stress tolerance and can be easily assessed [5].

For this purpose, correlations and principal components analysis are used by researchers to distinguish significant relationships between traits. The correlation coefficient measures the mutual association between a pair of variables independent of the other variables. The principal

components analysis is a multivariate analysis method that aims to explain the correlation between a set of variables in terms of small number of underlying independent factors [11,12].

The objective of this study was to determine and identify effective agro-morphological and physiological traits for screening drought tolerance in bread wheat.

2. Materials and Methods

2.1. Genetic Material and Layout of Experiments

Fourteen bread wheat genotypes of diverse characters and origins were chosen based on their reputed differences in yield performance under irrigated and non-irrigated conditions. The trials were conducted during 2014 at two experimental fields of the National Institute of Agricultural Research in Morocco: Taoujtate representing the favorable conditions and Sidi El Aidi for stressed conditions.

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each plot is composed of 6 rows of 5 m; with row to row distance of 0.3 m.

2.2. Characteristics of Experimental Sites and Growing Season Pattern

The experimental site of Taoujdate is located in the Sais region. It represents the favorable or non-stressed conditions in Morocco. The long term average rainfall is about 500 mm with a deep clayey soil (Tirs). During the 2013-2014 growing season, the total amount of precipitations was 277.5 mm/year. Additional irrigation (about 100 mm) was applied during critical growing stages.

The experimental site of Sidi El Aidi belongs to Settat province located in the south of Morocco and represents the semi-arid region of Morocco. The average rainfall is about 300 mm/year with limestone- clay texture soil. The total amount of precipitations during the studied season was 181mm.

The sowing was operated during the second half of November (13th and 27th respectively for stressed and non-stressed environments). The herbicides and fungicides were applied in both environments to limit the foliar diseases and weeds development, thus restraining the confounding effects with drought stress.

The nitrogen and phosphor fertilizers (18-46-00) were applied prior to sowing at a rate of 1.5 quintal/hectare; and additional side dressing of nitrogen (33.5%) was applied at jointing stage.

2.3. Data Collected

Agronomic data, such as biomass (BY) (g), number of plants (NP), number of fertile spikes (NFS) and tillers per plant (NT), plant height (PH), thousand grain weight (TGW)

(g) were evaluated based on 1 meter in each plot.

Plant height (PH) (cm) was measured from soil surface to the awns of the spike at maturity stage.

Harvest index % (HI) was calculated as the ratio of seed yield divided to total dry matter x 100.

Finally, the grain yield (GY) (t/ha) was measured by harvesting each plot at crop maturity.

The plant early vigor (PV) was assessed using visual scale from 1 to 5, where 1 = low growth rate and 5 = very vigorous growth. This parameter was assessed three times during the vegetative stage of plants with approximately 10 days of interval.

The phenological observations number of days to heading (NDH) and flowering (NDF) were calculated based on number of days from sowing to heading and flowering respectively. The dates of heading or flowering for each genotype were recorded when 50% of the ears were at this stage.

The canopy temperature (CT) (°C) was evaluated using the infrared thermometer IR 1000. The reading includes the average of leaf temperature of 1 linear meter in each plot.

The chlorophyll fluorescence (CF) was evaluated using the fluorimeter Handy PEA 2307. The average of two readings was reported in each plot. The parameter calculated (Fv/Fm) is the ratio of variable fluorescence (Fv) over the maximum fluorescence value (Fm).

The chlorophyll content (CC) was assessed using the SPAD 502 chlorophyll meter. The average of three SPAD readings was reported in each plot. This parameter was evaluated only under stressed conditions.

All the physiological traits were scored twice during this cycle. The first reading corresponded to heading stage, whereas, the second reading referred to the late flowering stage based on the intensity of drought.

Data were analyzed using GENSTAT software (3th free edition) for analysis of variance and Pearson correlations. The XLSTAT was used for the Principal Components Analysis. The statistical model used for the analysis of variance was: $Y = \text{Site} + \text{Block} (\text{Site}) + \text{Genotype} + \text{Genotype} \times \text{Site} + \text{Genotype} \times \text{Block} + \text{Error}$.

3. Results

3.1. Grain Yield and Yield Related Traits

The results of analysis of variance for grain yield indicated the presence of a considerable genotypic variation under non-stressed and stressed conditions (Table 1 & 2). The mean yield under favorable conditions is about 3.3 t/ha compared to 1.9 t/ha in stressed conditions. The drought stress significantly reduced the yield by 42% (Table 1).

Under non-stressed conditions, significant differences were observed among genotypes for all yield traits recorded, with the exception of biomass, number of plants and number of fertile spikes and tillers per plant. In the drought stressed site, significant differences were observed ($p \leq 0.05$) for the

biomass, harvest index, number of days to heading and flowering (Table 1).

The drought stress reduced biomass significantly by 23%. The mean biomass under favorable conditions was about 271 g/m compared to 208 g/m in stressed conditions. The TGW was reduced only by 4% approximately. The mean HI under favorable conditions was 36.13% compared to 31.46% under stressed conditions. The reduction caused by drought was about 13%.

Regarding the number of plants, this parameter showed non-significant reduction between the two treatments. However, the number of tillers and fertile spikes per plant were reduced significantly by 34.6 % and 52 % respectively.

3.2. Morphological and Physiological Traits

Under non-stressed conditions, the analysis of variance exhibited significant differences among genotypes for plant height, number of days to heading and flowering and the first reading of the chlorophyll fluorescence. However, in drought stressed environment, significant differences were observed for all the traits except for the phenological data, the first reading of the chlorophyll fluorescence and the second reading of canopy temperature. (Table 1)

Regarding the phenological data, the number of days to heading decreased from 132 days in favorable conditions to 113 days in stressed environment, meaning 9% of reduction.

Similarly, the number of days to flowering was shortened from 135 days in favorable conditions to 123 days in stressed environment, thus reduced by 15 %.

The plant height was reduced by 34%. The mean height in favorable conditions is 110 cm, while it reached only 73 cm in stressed conditions. Contrariwise, the plant vigor was not significantly reduced, even if the genotypes performed differently under stress conditions compared to the non-stressed one.

For the first reading of chlorophyll fluorescence, the Fv/Fm ratio means varied from 0.77 in the non-stressed conditions to 0.72 in stressed conditions, thus 7% only of reduction. However, in the second reading, it dropped to 0.67 in stressed conditions, meaning a reduction of 13%.

For the chlorophyll content, the measurements were only applied at the stressed environment. The CC means were 37.09 and 39.57 for the first and second measurements, respectively.

During the first reading, the canopy temperatures were reduced by 8% with 21.08°C as an average for the non-stressed environment and 19.33°C in stressed conditions. However, in the second reading, the CT increased in stressed conditions (19.23°C) compared to non-stressed environment (15.31°C) by 26 %.

3.3. Combined Analysis of Variance

The combined analysis of variance (Table 2) over both conditions revealed significant differences among genotypes for agronomic parameters: grain yield, grain weight, number of plants, number of fertile spikes per plant, and thousand

grain weights; and for the morpho-physiological traits, plant height, chlorophyll fluorescence and canopy temperatures. The site had significant impact on differences for all traits except number of plants and plant vigor.

The site x genotype interactions was significant only for the number of days to flowering, plant height, plant vigor, chlorophyll fluorescence and canopy temperature.

3.4. Correlation among Yield Related Traits

In favorable conditions, the grain yield had significant positive correlation with the number of plants ($r = 0.36$), the biomass ($r = 0.45$) and the harvest index ($r = 0.516$). The number of fertile spikes per plant was positively significantly correlated with the biomass ($r = 0.53$) and tillers number per plant ($r = 0.634$), while it had negative correlation with the number of plants per linear meter ($r = -0.33$). The thousand grain weight was also positively correlated with the plant number per meter ($r = 0.384$) but negatively correlated with the tillers number per plant ($r = -0.43$).

In drought stress conditions, the grain yield had significant positive correlation with the biomass ($r = 0.55$), thousand grain weight ($r = 0.43$) and number of fertile spikes per plant ($r = 0.5$), and these traits showed positive correlation between them. However, the grain yield didn't displayed significant correlation with the harvest index even if it is positively correlated to the two latter parameters ($r = 0.50$ and 0.54 respectively). The number of fertile spikes is negatively correlated with plants number per meter ($r = -0.48$).

The grain yield and its components under favorable conditions was not correlated with their homologues in stressed conditions, except for TGW ($r = 0.63$). Moreover, the TGW in non-stressed conditions was positively correlated with the biomass ($r = 0.37$), number of fertile spikes ($r = 0.41$) and negatively correlated with the plants number ($r = -0.34$) under stressed conditions. Also, the biomass in favorable conditions had significant positive correlation with TGW ($r = 0.33$) and HI ($r = 0.34$) in stress conditions.

3.5. Correlations among Phenological and Morphological Traits

No correlations were found among morphological traits in favorable conditions. On the other hand, the number of days to flowering is positively correlated to number of days to heading ($r = 0.40$) and negatively correlated to plant height ($r = -0.45$) and plant vigor ($r = -0.45$) in stressed conditions. The latter parameter was positively correlated to the plant height ($r = 0.56$).

Moreover, the number of days to heading and plant height in favorable conditions were positively correlated to their homologues in stressed conditions ($r = 0.34$, $r = 0.48$ respectively), except for plant vigor ($r = -0.36$).

3.6. Correlations among Physiological Traits

No correlations found between physiological traits except

between the two readings of canopy temperatures in stressed conditions ($r = 0.72$).

3.7. Correlations among All Traits

In non-stressed environment, the grain yield and the harvest index were negatively correlated to number of days to heading in favorable ($r = -0.36$ and $r = -0.42$ respectively) and stressed conditions ($r = -0.40$ and $r = -0.39$ respectively). The biomass was positively correlated with the second reading of chlorophyll fluorescence ($r = 0.36$).

In stressed environment, the grain yield was positively correlated with plant vigor ($r = 0.62$) and negatively correlated with the number of days to flowering ($r = -0.33$). The biomass was positively correlated with plant vigor ($r = 0.574$) and plant height in stressed ($r = 0.52$) and non-stressed conditions ($r = 0.47$). The number of fertile spikes per plant was positively correlated with plant vigor and plant height ($r = 0.57$, $r = 0.52$ respectively). The plant height was positively correlated with plant vigor ($r = 0.561$) and TGW ($r = 0.39$). The first reading of chlorophyll content was negatively correlated with tillers number per plant ($r = -0.37$); while the second reading is negatively correlated with TGW ($r = -0.35$), plant vigor ($r = 0.52$) and plant height ($r = -0.42$). The canopy temperature of both readings were negatively correlated with TGW ($r = -0.45$ and $r = -0.39$ respectively) and harvest index ($r = 0.32$ and $r = -0.40$ respectively). The first reading of canopy temperature was also negatively correlated with plant vigor ($r = -0.34$) and positively correlated to the plant number ($r = 0.43$).

The grain yield in stressed conditions is negatively correlated with plant vigor in favorable conditions ($r = -0.35$).

The number of plants was negatively correlated to plant height in non- stressed conditions ($r = -0.34$).

The number of tillers in favorable conditions was negatively correlated with plant vigor in stressed conditions ($r = -0.34$).

The plant height in stressed conditions was positively correlated with TGW and plant height in favorable conditions ($r = 0.32$; $r = 0.48$ respectively). The plant vigor in favorable conditions was negatively correlated with TGW in stressed conditions.

The canopy temperature of both reading in stressed conditions were negatively correlated to TGW in favorable conditions ($r = -0.49$ and $r = -0.37$ respectively).

3.8. Principal Component Analysis

The Principal Components analysis explained 51 % of the total variation considering the first five PCs. The PC1 explained about 17.42% of the total variation showing correlations mainly with traits under stressed conditions.

The PC1 had positive correlation with grain yield, thousand grain weight, number of fertile spikes, biomass, harvest index, plant height, plant vigor; and negative correlation with number of plants, number of days to flowering, canopy temperature, and chlorophyll content under stressed conditions. For non-stressed parameters, the first component had positive correlation with plant height, number of days to flowering, number of plants, thousand grain weight and the second reading of canopy temperature; and negative correlation with plant vigor, tillers number and the first reading of chlorophyll fluorescence.

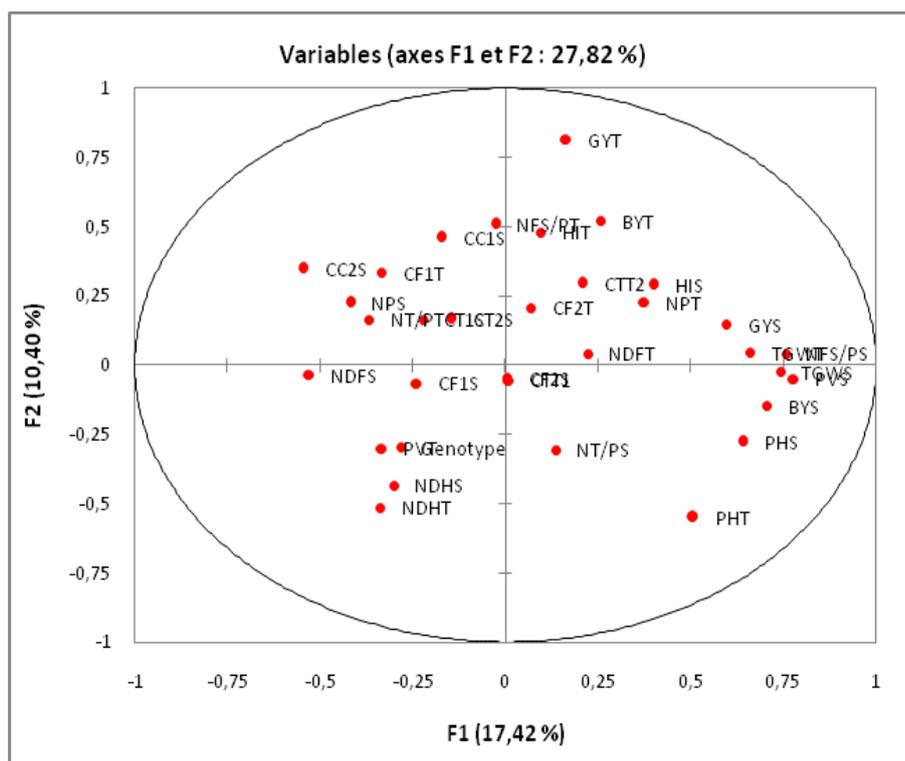
Table 1. Analysis of genotypic variance for all traits per site

Trait	Non – Stressed			Stressed		
	Mean Square	F pr.	Mean	Mean Square	F pr.	Mean
BY	3092	0.543	270.9	3880	0.503	207.8
GY	0.7476	0.003	3.311	0.6102	0.026	1.908
HI	47.48	0.007	36.13	128.8	0.285	31.46
TGW	29.167	<0.001	30.1	1.1263	<0.001	29
NP	41.34	0.517	37.02	113.16	0.015	57.54
NFS/P	0.5244	0.086	3.035	0.2333	0.016	1.459
NT/P	1.15	0.352	4.596	0.2574	<0.001	3.006
NDF	16.55	0.043	135.12	16.03	0.165	122.94
NDH	19.101	<0.001	131.82	34.43	0.816	112.66
PH	137.32	<0.001	110.42	142.79	0.009	72.82
PV	1.706	0.407	5.11	1.1263	0.008	5.333
CF1	0.00108	0.002	0.7751	0.04206	0.147	0.724
CF2	0.0058	0.474	0.7697	0.11791	0.028	0.67
CCS1				14.956	<0.001	37.09
CCS2				16.562	0.004	39.57
CT1	2.555	0.213	21.083	5.87	0.001	19.33
CT2	2.081	0.66	15.31	3.796	0.063	19.23

Table 2. Combined Analysis of Variance for all the traits studied

Trait	Genotype		Site		Interaction	
	MS	F pr.	MS	F pr.	MS	F pr.
Biomass	3532	0.71	241293	<0.001	3645	0.668
Grain Yield	0.8736	<0.001	118.53	<0.001	0.4893	0.159
Harvest Index	90.73	0.181	1327.8	<0.001	87.57	0.246
Thousand Grain Weight	50.66	<0.001	74.39	0.016	11.09	0.658
Number of plants	86.34	<0.001	25429	0.097	71.26	0.304
Number of Fertile Spikes/Plant	0.4182	0.021	148.54	<0.001	0.3405	0.121
Number of Tillers/Plant	0.7294	0.135	151.56	<0.001	0.6775	0.212
Number of Days to Flowering	12.53	0.343	8914.9	<0.001	20.18	0.007
Number of days to Heading	35.46	0.062	22013	<0.001	18.09	0.868
Plant Height	202.32	<0.001	84708	<0.001	78.28	0.048
Plant Vigor	0.881	0.818	2.752	0.121	1.957	0.01
Chlorophyll Fluorescence1	0.022	0.001	0.126	<0.001	0.02106	0.002
Chlorophyll Fluorescence 2	0.0594	<0.001	0.6395	<0.001	0.06433	<0.001
Canopy Temperature1	4.073	0.001	130.5	<0.001	4.809	<0.001
Canopy Temperature 2	3.301	<0.001	1364.8	<0.001	5.463	<0.001

*MS Mean Square

**Figure 1.** The biplot graphical display of the Principal Components Analysis of the traits measured in both conditions

The second component explained about 10.4% of variation. It is more related to the non-stressed conditions representing positive correlation with grain yield, number of fertile spikes, biomass, harvest index, chlorophyll fluorescence and the second lecture of canopy temperature; and negative correlation with plant vigor, plant height and number of days to heading. The other three components accounted for 9, 8 and 6.6% of variation between traits respectively. The PC3 were positively related to the first measurement of chlorophyll fluorescence and content and

negatively correlated to canopy temperature in stressed conditions. The PC4 and PC5 were more related to non-stressed conditions. The PC4 had positive correlation with the first reading of canopy temperature and negative one with the second lecture; while PC5 is positively correlated to tillers and fertile spikes number, and negatively correlated to plant number.

4. Discussion

In order to evaluate the effectiveness and reliability of a set of agro-morphological and physiological traits for screening drought tolerant genotypes, this study was conducted under stressed and non-stressed field conditions during 2014 growing season.

In the stressed conditions, the growing season was characterized by a mid and late drought, affecting differently the heading, flowering and maturity stages of the genotypes. In wheat, yield is greatly reduced mostly when drought stress occurs during the heading or flowering and soft dough stages [13,14].

From the combined analysis, the significant variation due to genotypes for almost all the characters suggested that the variability among genotypes was sufficient to provide some scope for selecting traits of drought tolerance in bread wheat.

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The non-significant interaction between site and genotypes for almost all traits revealed that cultivars presented similar ranking under both moisture conditions and that all were affected by the stress treatment which suggested that drought tolerant cultivars could reliably be selected. However, significant interactions were found for number of days to flowering, plant height, plant vigor, chlorophyll fluorescence and canopy temperature; indicating that cultivars performed differently over the stress conditions for those traits.

The grain yield is the most important component in any breeding program. However, grain yield is a complex trait that reflects the interaction of numerous components and yield related traits. Those parameters occur under different growth and development processes throughout the life cycle [15]. It is determined by several physiological, biochemical and metabolic plant processes and its genetics and associations are greatly ambiguous [16]. The comprehension of the relationships between those parameters may lead to identify the criteria that can influence the final yield under different environments. Thus, the breeders can use them as indirect selection criteria to increase the yielding capacity of bread wheat.

In this study, the grain yield under favorable conditions was about 1.6 times the yield under stress. Thus, the water stress had a great impact on the yield potential of genotypes.

The drought affected the grain yield and its components differentially among the genotypes. The number of fertile spikes was the most affected (52% of reduction) followed by grain yield (42%), number of tillers (34%), biomass (23%), harvest index (13%) and thousand grains weight (4%).

Moreover, the genotypes behaved differently in the presence of stress conditions. The genotypic variation for number of plants, tillers and fertile spikes per plant was observed only under stressed conditions.

According to the results of correlation coefficients, the grain yield had a high correlation with thousand grain weight, biomass and number of fertile spikes under stressed

conditions. The two former parameters had positive correlation with the harvest index. Thus, in order to increase grain yield under dryland condition, the focus should be emphasized on parameters which should be used in selection for drought tolerance breeding programs. Moreover, the trait "thousand grain weight" under favorable conditions was correlated with its homologue in stressed conditions, suggesting that high potential TGW under optimal conditions can improve yield under stress conditions. The TGW in non-stressed conditions was positively correlated with the biomass, number of fertile spikes under stressed conditions; whereas, the biomass in favorable conditions had significant positive correlation with TGW and HI in stress conditions. Thus, indirect selection in a drought prone environment based on the results found in optimum conditions can be efficient.

Those findings are in accordance with some previous studies that indicated the positive correlation between grain yield and yield component traits in wheat such as harvest index [17,18], number of spike per square meter [18-20] and thousand grain weight [18,20-24]. Taheri et al. [25] indicated a positive and significant correlation between stress tolerance index with grain yield, biomass and harvest index under normal conditions. Numerous studies deduced a positive and significant genetic correlation of wheat biomass and yields under the both moisture conditions [26,28]. The increase of biomass under conditions of drought is essential as the translocation of assimilates from vegetative parts into grain significantly contributes to yield [9, 29-31].

Regarding morphologic traits, the genotypes had more homogeneous path regarding number of days to heading and flowering under stress in comparison with non-stressed conditions. This indicated that genotypes have shortened their plant growing cycle (by reducing the number of days to heading and flowering) as a mechanism to escape from drought stress. In stressed conditions, the number of days to flowering was positively correlated to number of days to heading, and negatively correlated to the plant height and vigor. It means that when the genotype shortened its cycle and had early maturity (expressed by the increase in the number of days to flowering), it had positive effect on its growth establishment through avoidance of drought during pollination and grain filling. The correlation analysis confirmed also that the grain yield was negatively correlated to the number of days to flowering under stress conditions; while no correlation was found under favorable environment. Those findings are in agreement with previous studies [26, 32--33].

Plant height was the most influenced by drought stress (34% of reduction) and affected the genotypes differently. Plant height had a significant indirect effect on grain yield via positive correlation with biomass, fertile spikes, plant vigor and thousand grain weights in stressed conditions. Many studies have selected plant height under dryland condition as one of the reliable morphologic trait for selecting drought tolerant genotypes to obtain a high yield potential in dryland conditions [22, 24, 34].

Plant vigor showed genotypic variation only under drought stress, thus illustrating the diversity among genotypes. Under stressed conditions, this parameter is positively correlated to grain yield, number of fertile spikes, biomass, plant height and thousand grain weights. The [31, 33, 35] studies showed that grain yields of wheat were linearly related to early vigor. The early vigor was associated with greater leaf area and ground cover and probably a greater proportion of total evapotranspiration used in crop transpiration rather than soil evaporation. It allows also a better competitiveness of wheat crops against weeds [9,36]. Kandic et al. [33] indicated that early vigor was found to be suitable for wheat breeding under different moisture regimes.

For the physiological traits, the genetic variation was important in stressed conditions, showing difference in genotypes behavior and response to drought. Canopy temperature and chlorophyll fluorescence increased when conditions became more stressed.

The surface temperature of the canopy is related to the amount of transpiration resulting in evaporative cooling. Studies have shown that canopy temperatures is correlated with many physiological factors such as stomatal conductance, transpiration rate, plant water status, water use, leaf area index and crop yield. Genotypes with cooler canopy temperatures can be used to indicate a better hydration status. Thus, this parameter assessed the capacity to extract water from deeper soil profiles and/or agronomic water use efficiency under drought conditions [37-38]. Those statements are in concordance with our finding. Canopy temperature had a significant negative correlation with thousand grain weight and harvest index under stress conditions. Many studies attested the effectiveness of the canopy temperature as selection criteria based on its correlation with grain yield in stressed environments [39-42] and the ability to extract water under drought [43].

The chlorophyll is the green photosynthetic pigment which absorbs sunlight and transfers this energy to the reaction center of the photosystems. Thus, measuring chlorophyll content indicates photosynthetic potential [44]. Many studies concluded that the chlorophyll content could be considered as a reliable indicator for drought tolerance [41-42,45-46]. In the same way, the chlorophyll content had a significant indirect effect on grain yield via thousand grain weight, plant vigor and plant height. However, in this study, this relationship was negative.

The fluorescence is an indicator of the leaf photosynthetic performance. In the literature, there are many fluorescence parameters defined, including (Fv/Fm). It is a sensitive indicator of plant photosynthetic performance, with optimal values of 0.83 independent of the plant species [47-48]. Unlike some studies [49,50], no significant correlation with yield related traits were found for chlorophyll fluorescence in our study. This could be explained by the intensity of drought. Araus et al. [50] stated that the chlorophyll fluorescence changes only under extreme stress conditions and have lower heritability.

The relationships found by correlation analysis were in agreement with the principal component analysis. The first component related grain yield in stressed conditions positively with thousand grain weight, number of fertile spikes, biomass, harvest index, plant height, and plant vigor; and negatively with plant number, number of days to flowering, canopy temperature, and chlorophyll content.

5. Conclusions

In conclusion, the positive correlation of biomass, thousand grain weight and number of fertile spikes with grain yield confirmed that these characters are important for direct selection of high yielding under stress and non-stressed conditions. Also, plant vigor, plant height, chlorophyll content and canopy temperature could be used simultaneously as reliable indirect morphologic and physiologic selection criteria for drought tolerance and obtaining a high yield potential under dryland condition. Moreover, the thousand grain weight, biomass and harvest index may be used to improve drought prone environments based on the favorable conditions results in order to cope with variability of rainfall over years.

However, the selected characters should be assessed under additional cropping seasons in order to confirm their efficiency under different drought stress severities.

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