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Phenotypic Characterization of Some Durum Wheat (*Triticum durum* Desf.) Genotypes Growing under Semi-Arid Conditions

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Abstract

Breeders are permanently looking for an efficient method of developing genotypes with improved yield. The aim of this study was to evaluate the performance of some durum wheat genotypes, the study of the correlations between traits and the direct effect of each trait on final grain yield. Twenty genotypes of durum wheat (*Triticum durum* Desf.) were planted in the experimental fields of INRAA, Setif, Algeria in (2016 –2017) crop season. The genotypes tested were grown in a randomized block design with three replications. The analyses of variance (ANOVA) demonstrate the existence of genetic diversity between genotypes tested. In addition, significant and positive correlations were registered between grain yield (GY) and days to heading (DH), number of spikes per square meter (NSM) and number of kernels per spike (NKS). The path analysis (PA) demonstrates positive and significant direct effects of the number of spikes per square meter (NSM), thousand kernels weight (TKW) and number of kernels per spike (NKS) on grain yield. Overall, the results proved that the genotypes Rezzak, Ofanto and BIDI 17 have the best ranking with the highest grain yield, and these can be recommended as the best genotypes for some in this area. In addition, the Principal Component Analysis (PCA) proved that the genotypes Rezzak, Bidi17, Ofanto, Kebir and Adnan 2 are very suitable genotypes for growing under semi-arid conditions.

Keywords: Durum wheat, grain yield, path analysis, correlation, semi-arid

1. Introduction

Durum wheat (*Triticum turgidum* subsp. *durum* Desf.) is a minor cereal crop representing 5% of the total wheat crop cultivated worldwide (about 17 mha) (Xynias et al., 2020). Durum wheat (*Triticum durum* Desf.) is one of the main crops consumed by humans and it is cultivated in different environments. Drought is the single largest abiotic stress factor leading to reduced crop yields. So, high-yielding crops, even in environmentally stressful conditions, are essential (Fleury et al., 2010). Total food use of wheat is forecast to approach 518 mt, up 1.1% and rising in close tandem with world population growth. However, large supplies and competitive prices are likely to drive up feed use of wheat by 2.8%, a faster rate than was projected earlier, while industrial use is also anticipated to register strong growth (Anonymous, 2019). Climate changes recorded changes in the composition and geographic redistribution of ecosystems in Algeria. This situation has resulted in a shift towards the north of the arid zones,

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until then confined between the Sahara and the high cereal plains (Haffaf et al., 2003). In Algeria, the actual production of cereals during the period 2010–2017 is estimated at 4.12 mt on average, an increase of 26% compared to the decade 2000–2009 when production is estimated on average at 32.6 million quintals. Production consists mainly of durum wheat and barley, which respectively represents 51% and 29% of all cereal production on average 2010–2017 (Anonymous, 2018). Drought is a meteorological term and is commonly defined as a period without significant rainfall. Generally, drought stress occurs when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation. Drought stress tolerance is seen in almost all plants, but its extent varies from species to species and even within species (Jaleel et al*.,* 2007). Tolerance to abiotic stresses is very complex, due to the intricacy of interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development (Razmjoo et al., 2008). Garcia del Moral et al. (1991) estimate that the grain yield of cereals is not influenced only by the components of the yield but also by the extension of the vegetative period and the filling of the grains. High yield potential under drought stress is the target of crop breeding. In many cases, high yield potential can contribute to yield in moderate stress environment (Blum, 1996). The most promising approach to increase agricultural productivity and satisfy human needs in the future is the genetic improvement of crops which requires a continuous allocation of new sources of genetic variation (Borner et al., 2000). Although breeders are continuing to improve the yield potential of wheat, the progress in increasing wheat yield in drought environments has been difficult to achieve. Grain yield is an environmental and genetic trait, it differs according to variety, soil fertility, soil moisture, temperature, diseases and pests. In defining a strategy for wheat breeding under drought tolerance, Rajaram et al. (1996) suggested that simultaneous evaluation of germplasm should be carried out under both near optimum conditions (to utilize high heritability and identify genotypes with high yield potential) and under stress conditions (to preserve alleles for drought tolerance). The objective of this study is to evaluate the performance of 20 durum wheat cultivars under semi-arid conditions based on different statistical methods.

2. Materials and Methods

2.1. Plant material and growth conditions

Twenty genotypes of durum wheat (*Triticum durum* Desf.) were planted in the experimental fields of INRAA, Setif, Algeria, (5°37'E, 36°15'N) 981 masl in November 19, 2016. The genotypes tested were grown in a randomized block design with three replications, each plot consisted of 6 lines of 10 m long spaced of 0.2 m which made 12 m^2 as plot area. The sowing density adjusted to 300 grains m^{-2}. No specific treatment was administered.

2.2. Agronomical and physiological measurements

At harvest, data was recorded on 1000-kernel weight (TKW) and grain yield (GY). In addition, some parameters such as number of spike m^{-2} (NS/m²) and kernels per spike (NK/S) were determined. The SPAD-502 measured the amount of chlorophyll (Chl) in the leaf, which is related to leaf greenness, by transmitting light from light emitting diodes (LED) through a leaf at wavelengths of 650 and 940 nm. In addition, the plant height and days to heading were determined.

2.3. Statistical analysis

The analysis of variance was performed for agronomical and physiological traits, Fisher's LSD multiple range test was employed for the mean comparisons by using Costat software. Linear correlation analysis was used to determine the relationships between the traits measured and the path analysis, and the Principal Component Analysis (PCA) was done using the Statistica software.

3. Results and Discussion

The results of the analysis of variance demonstrated that the differences among genotypes were highly significant ($p< 0.01$) for all traits (Table 1).

For the chlorophyll content (Chl), the values ranged from 44.53 for the genotype CHEN'S to 54.03 for Ofanto with a general mean of 48.44. In addition, the study of correlations showed no significant correlation between chlorophyll content and all traits. For the agronomic traits, such as Grain yield (GY), the values varied from 29.7 q ha^{-1} for Polonicum to 77.13 q $ha^{-1}$for Ofanto. Significant and positive correlations were registered between GY and number of spikes per m² (NS/m²) and the number of kernels per spike (NK/S) ($r=0.46^*$, $r=0.73^*$, respectively) and a negative correlation was found between GY and days to heading (DH) ($r=-0.66^*$) (Table 2).

Ashraf (1998) reported that the productive spikes per plant contribute to the increasing of the grain yield under water deficit conditions. In addition, these correlations indicated that increase in grains per spike cause simultaneous increase in grain yield. The significant negative correlation between grain yield and number of days from sowing to heading (DH) confirms that the earliness has played a very important role in stability of durum wheat yield in dry areas which are characterized by excessive temperature and hot winds during the period of grain filling (Sharma and Smith, 1986). Some of these correlations among yield traits are in conformity with those of Gupta et al. (2001) who also noted a significant and positive correlation among grains per spike and grain yield and harvest index in their study. Correlation studies are also very useful to plant breeders for improving drought tolerance, in the sense that, any physiological or yield traits having high heritability could be used as indirect selection criteria to improve yield in water-deficit environments. The direct effects of all traits on the grain yield (Table 2) showed significant effect on number of spikes m^{-2} (NS/m²), TKW and number of kernels

Table 1: Mean values of Chlorophyll content (Chl), Days to heading (DH), Plant height (PH), number of spikes per meter square (NSM), Grain yield (GY), 1000-Kernel weight (TKW) and number of kernels per spike (NKS)

Genotype	Chl	DH	PH	NSM	GY	TKW	NKS
Marton Dur	53.16	142.5	70	480	55.1	45.33	25.65
Belikh 2	49.86	142	60.66	470	39.13	36.33	22.77
Rezzak	50.26	142	6066	576.66	78.6	41.33	33.19
Cappiti	46.5	142	65.66	466.66	61.63	46.66	27.07
Guemgoum Rkhem	45.1	146	78.33	443.33	36.5	50	19.3
Adnan 2	52.46	144	56.66	546.66	62.7	41.33	29.44
Polonicum	46.83	146	68.33	490	29.7	47.66	13.01
Djenah Khotifa	46.26	146	89.33	700	62.06	39.33	22.09
Ofanto	54.03	142	63	620	77.13	42.66	28.43
Heider	49.36	142	57.66	473.33	46.93	37.33	25.61
Kebir	44.6	142	76	576.66	60.43	42.33	25.55
Massara	53.16	142	69.66	423.33	40.16	53.33	18.78
Chen's	44.53	141	58	470	56	37.33	31.95
Belioni	48.8	146	68	603.33	32.43	35.66	15.22
Mexicali 75	50.16	142	59.33	523.33	58.56	37.66	29.09
Oum Rabie 17	46.5	142	65.33	443.33	51.06	38.66	30.03
Yavaros 79	45.86	141.5	53.66	393.33	49.3	38.66	32.43
Bidi 17	48.66	146	71.33	550	71.8	46.33	28.88
Hourani	48.96	142	65.66	440	46.13	40	26.64
Oued Zenati	43.26	146	69.66	563.33	47.6	47	18.03
Min	43.26	141	53.66	393.33	29.7	35.66	13.01
Max	54.03	146	6066	700	78.6	53.33	33.19
Mean	48.44	143.25	66.35	512.66	53.15	42.25	25.16
LSD (p=0.05)	4.78	0.786	16.62	168.24	23.48	7.47	9.62

Table 2: Direct effect and correlation test between different traits studied

Traits	Direct effect On the Grain yield	Correlations						
		Chl	DH	PH	NSM	GY	TKW	NKS
Chl	0.042	1.00						
DH	-0.09	-0.27	1.00					
PH	0.002	0.14	-0.15	1.00				
NSM	0.679***	0.05	0.44	0.20	1.00			
GY	/////	0.24	-0.27	0.43	0.46*	1.00		
TKW	0.417***	0.05	0.31	-0.04	-0.18	-0.08	1.00	
NKS	0.905***	0.13	-0.66*	0.32	-0.12	0.73*	-0.39	1.00

Chl: Chlorophyll content; DH: Days to heading; PH: Plant height; NSM: Number of spikes m^{-2}; GY: Grain yield; TKW: 1000-Kernel weight; NKS: Number of kernels $spike^{-1}$

per spike (NK/S) ($P_{NSM/GY}$= 0.67***, $P_{TKW/GY}$= 0.41***, $P_{NKS/GY}$= 0.90***, respectively). Azimzadeh et al. (2000) showed that number of kernels and one-thousand weights were major components of yield, and with regard to direct effects and their meaningful and positive correlation with grain yield, based on these results, we can consider these two traits as selection criteria. Our results agree with those reported by Khaliq et al. (2004) and Guendouz et al. (2013), who found that kernels number per spike exerted a direct positive effect on grain yield. Based on the ranking test (Table 3) for all traits, the genotypes BIDI 17, Rezzak, Ofanto, Djenah Khotifa and MARTON DUR are the best genotypes under these conditions. In addition, the ranking based on the traits which have significant direct effect on grain yield (NSM, TKW and NKS) showed that the genotypes Rezzak, Ofanto, BIDI 17, Adnan 2 and Kebir are the best genotypes. Combination ranking between NSM, TKW, NKS and GY showed that the genotypes Rezzak, Ofanto and BIDI 17 have the best ranking (TOP) with highest grain yield under semi-arid conditions. Data presented in Table 4 and graphically shown in Figure 1 proved that an increase in the number of PCs was associated with a decrease in Eigenvalues. Accordingly, it is reasonable to assume that the PCs analysis had grouped the studied durum-wheat traits into three main components that altogether accounted for 75% of the total observed variation. Principal component analysis (PCA) showed that NKS and GY were well correlated with the first component PC1 which represented 36.49% of the information.

In addition, mean-while, the second PC correlated with NSM and DH traits and accounted for 22.97 % of the detected

Table 3: Ranking of tested genotypes based on the traits studied

Genotype	Ranking							Mean	Combination
	Chl	DH	PH	NSM	GY	TKW	NKS	Ranking	Ranking*
Marton Dur	3	8	5	11	10	7	11	5	8
Belikh 2	7	9	15	13	17	19	14	17	14
Rezzak	5	11	14	4	1	11	1	2	1
Cappiti	13	13	11	15	6	5	9	9	6
Guemgoum Rkhem	17	5	2	17	18	2	16	11	13
Adnan 2	4	7	19	8	4	10	5	6	4
Polonicum	12	6	8	10	20	3	20	13	13
Djenah Khotifa	15	4	1	1	5	13	15	4	5
Ofanto	1	18	13	2	2	8	8	3	2
Heider	8	17	18	12	14	17	12	18	13
Kebir	18	16	3	5	7	9	13	8	5
Massara	2	15	7	19	16	1	17	12	13
Chen's	19	20	17	14	9	18	3	19	10
Belioni	10	3	9	3	19	20	19	14	15
Mexicali 75	6	12	16	9	8	16	6	10	7
Oum Rabie 17	14	14	12	16	11	14	4	16	11
Yavaros 79	16	19	20	20	12	15	2	20	12
Bidi 17	11	2	4	7	3	6	7	1	3
Hourani	9	10	10	18	15	12	10	15	13
Oued Zenati	20	1	6	6	13	4	18	7	9

Chl: Chlorophyll content; DH: Days to heading; PH: Plant height; NSM: Number of spikes m^{-2}; GY: Grain yield; TKW: 1000-Kernel weight; NKS: Number of kernels per $spike^{-1}$; *Combination ranking based on the ranking of GY, TKW, NSM and NKS

Table 4: Coordinates of the eigenvectors of principal components analysis for measured traits of durum wheat genotypes tested

Variable	PCA 1	PCA 2	PCA 3
Chl	0.360	0.028	0.648
DH	-0.691	0.630	-0.051
PH	0.534	0.354	0.206
NSM	0.104	0.919	-0.214
GY	0.804	0.441	0.094
TKW	-0.422	0.096	0.759
NKS	0.910	-0.192	-0.123
Eigenvalue	2.555	1.608	1.111
% Proportion variance	36.497	22.975	15.870
% Cumulative variance	36.497	59.472	75.342

total variation, while the third PC correlated with TKW and Chl traits and accounted for 15.87 % of the total survived variation (Table 4).

Relatively similar results were reported by Frih et al. (2021) and Moragues et al. (2006) who stated that the first two PCs were related to the GY components. As shown in the Figure 1, the distribution of the genotypes tested via the first and the second PC classified the genotypes into three groups, and the first group which includes five genotypes (Rezzek, Bidi17, Ofanto, Kebir and Adnan 2) is characterised by high productivity; the second group, which includes the local landrace, Oued Zenati, Belioni, Polonicum, Djenah Khotifa and Guemgoum Rkhem, has high TKW and long days to heading (Tardive genotypes). Increasing GY potential could enable plant breeders to realise the desired increment in drought-stressed tolerance of durum wheat genotypes. The results illustrated in Figure 1 proved that the genotypes Rezzek, Bidi17, Ofanto, Kebir and Adnan 2 are very suitable as parents in the future programmes of durum wheat ameliorations under semi-arid conditions.

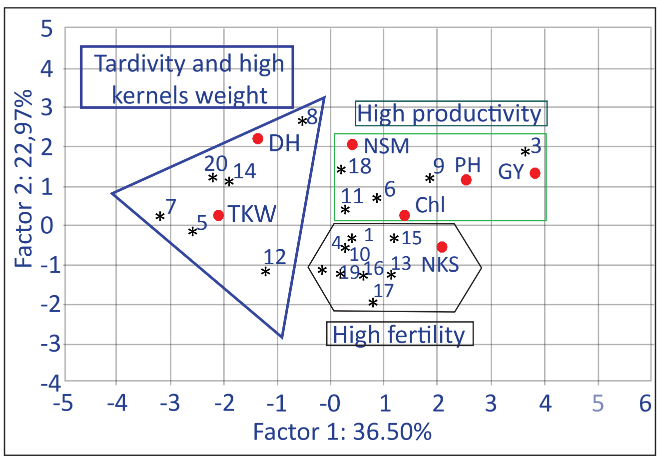

Figure 1: Dispersion and the regrouping of the genotypes in the plan generated by axes 1 and 2 based on the grain yield traits

4. Conclusion

Path analysis revealed that NSM, TKW and NKS had a positive direct effect on GY. Our results demonstrate that the genotypes Rezzak, Ofanto and BIDI 17 have the highest grain yield and can be recommended for cultivation under semi-arid conditions. Based on the Principal Components Analysis, the five genotypes Rezzek, Bidi17, Ofanto, Kebir and Adnan 2 are the preferable genotypes for growing under the semi-arid conditions.

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