African Crop Science Journal, Vol. 18, No. 1, pp. 35 - 42
Printed in Uganda.

ISSN 1021-9730/2010 $4.00

PHENOTYPIC DIVERSITY OF TUNISIAN DURUM WHEAT LANDRACES

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(Received 23 November, 2009; accepted 27 February, 2010)

ABSTRACT

Tunisia is considered as a diversification centre of durum wheat (*Triticum durum* Desf.) and barely (*Hordeum vulgare*). It is characterised by large genetic diversity; however, several genotypes are in the process of disappearance. The safeguard and rehabilitatation of this genetic inheritance requires genetic characterisation, evaluation and *in-situ* and *ex-situ* conservation. In this context, a local collection of thirty durum wheat accessions was evaluated using agronomical traits. Three other phenological traits: days to maturity, days to heading and filling period were evaluated. The phenotypic diversity was determined by the Shannon-Weaver diversity Index (H') revealing that number of kernel/spike (H'=0.91), yield (H'=0.89), plant height (H'=0.87) and thousand kernel weight (H'=0.86) had the highest diversity index. Flag leaf area (H'=0.32) showed the weakest index. This germplasm presented average diversity (0.77) showing a large genetic variability. Correlations between traits showed a significant positive relation between yield and spikeless tillers/plant (0.90), thousand kernel weight (0.39), plant height (0.35) and flag leaf area (0.36), suggesting the usefulness of these parameter for selecting for improving grain yield. The components analysis explained 59.61% of total variability and led to identification of a group of accessions Jeneh kotifa 1, Jeneh kotifa 2, Jeneh kotifa 3, Sbei glabre, Hamira 1, Hamira 2, Biskri glabre, Mahmoudi, Biskri glabre AP2, Swabaa Elgia, Sbei, and Mahmoudi glabre showing the best agronomical characteristics. These genotypes can, therefore, be used as parents for the improvement of durum wheat.

Key Words: Phenological traits, *Triticum durum*, Tunisia

RÉSUMÉ

La Tunisie est un centre de diversité génétique du blé dur (*Triticum durum* Desf.) et de l'orge (*Hordeum vulgare*). En dépit de la large diversité génétique au niveau du germoplasme local, plusieurs génotypes sont en voie de disparition. La sauvegarde et la réhabilitation de ce patrimoine génétique nécessitent sa caractérisation, son évaluation ainsi que sa conservation *in situ* et *ex situ*. Dans ce contexte une collection locale de trente genotypes de blé dur a été évaluée utilisant des paramètres agronomiques. Trois autres paramètres phénologiques à savoir jours de maturation, jours de rétablissement et période de remplissage étaient aussi évaluées. La diversité phénotypique determinée par l'index de diversité de Shannon-Weaver (H') a révélé que le nombre de grains par épi (H'=0.91), rendement (H'=0.89), hauteur des plants (H'=0.87) et le poids de 1000 grains (H'=0.86) avaient un index de diversité le plus élevé. La surface foliare (H'=0.32) a montré un index le plus faible. Ce germplasm presentait un index de diversité moyen de 0.77 montrant ainsi une large variabilité génétique. Les corrélations entre les paramètres a montré une relation positive significative entre le rendement et le nombre de talles d'épillets par plant (0.39), le poids de 1000 grains (0.35) et la surface foliaire (0.36), suggérant ainsi l'utilité de ces paramètres de sélection pour l'amélioration du rendement en grains. L'analyse des composants a expliqué 59.61% de la variabilité totale et a conduit à identifier un groupe de genotypes entre autre kotifa 2, Jeneh kotifa 3, Sbei glabre, Hamira 1, Hamira 2, Biskri glabre, Mahmoudi, Biskri glabre AP2, Swabaa Elgia, Sbei, Mahmoudi glabre montrant les meilleures caractéristiques agronomiques. Ces génotypes peuvent donc être utilisés comme parents pour l'amélioration de blé dur.

Mots Clés: Paramètre phénologiques, *Triticum durum*, Tunisie

INTRODUCTION

The domestication of durum wheat (*Triticum durum* Desf.) dates back to 8,000 - 12,000 years ago in the south west Asia (Henry and De Buyser, 2000). This domestication required multiple polyploïdisations between various species of *Triticum* and types of *Aegilops* (Fukuda and Sakamoto, 1992; Holubec *et al.*, 1992; Belay *et al.*, 1994). Currently, durum wheat is one of the most important crops in the world, widely grown in the arid and semiarid parts of west Asia and north Africa (Jaradat *et al.*, 1992).

The improvement of durum wheat is based on the use of the genetic variability of the local collections (Blixt, 1988; Damania, 1992). These genetic resources contain several important agronomic and resistance genes (Grausgruber *et al.*, 2005; Yahyaoui *et al.*, 2006; Hysing *et al.*, 2007). The availability of such germplasm depends on the identification of the sources of diversification (Devra, 1999), especially within the primary and secondary diversity centres which are characterised by large diversity. The local germplasm is adapted to a wide range of environments and carry a large reservoir of useful genes (Asfaw, 1989; Cherdouh *et al.*, 2005).

North Africa is considered one of the principal secondary centres of origin of durum wheat. Indeed, Tunisia has a wide number of local cultivars (Deghaïs *et al.*, 2007). Population increase and food consumption in Tunisia and elsewhere led to changes in the breeding strategy in order to develop more productive and suitable varieties to intensive agriculture. However, in spite of their high genetic potential, these varieties are sensitive to various diseases and drought (Daaloul *et al.*, 1998).

In Tunisia, many landraces have already completely disappeared and have been replaced by new durum wheat varieties. A country-wide survey and collection of durum wheat landraces in the last few years has led to the need to characterise the collected landraces. This paper reports on the phenotypic diversity for 11 quantitative traits in thirty Tunisian landraces of durum wheat.

MATERIALS AND METHODS

Thirty collected Tunisian durum wheat landraces were used in this study: Adjini (3 accessions), Agili (2 accessions), Hamira (3 accessions), Biskri (2 accessions), Mahmoudi (2 accessions), Media (3 accessions), Sbei (2 accessions), Derbassi (2 accessions), Jeneh Khotifa (3 accessions), Aoudj (1 accession), Bianculida (1 accession), Bidi (1 accession), Mekki (1 accession), Real Sorte (1 accession), Souri (1 accession), Swabaa Elgia (1 accession) and Taganrog (1 accession).

All accessions were sown in fields in the National Agronomic Institute of Tunisia with a density of 120 kg ha^{-1}. These accessions were sown each on 3 lines of 2 m and a spacing of 18 cm. A mineral fertilisation was applied, in pre-sowing for phosphorus (60 kg of P_2O_5 per hectare) and post-sowing for nitrogen (100 kg of ammonitre at 33.5%) with two fractions (lifting and tillering).

The germoplasm was evaluated through eight agronomical traits; namely, thousand kernel weight, number of kernel /spike, spikeless tillers/ plant, spike length, spike fertility, grain yield, flag leaf area (at maturity) and plant height. Also, days to maturity, days to heading and filling period were measured from sowing. Five plants were used to score for the quantitative traits.

Mean and standard deviation were calculated for each quantitative trait and were used to classify genotypes into three groups (i.e., 1] $\leq$x - s.d.; 2] >x-s.d. to <x+s.d. and 3]>x+s.d.)

The proportion of the different classes for each character was calculated. The Shannon-Weaver diversity index H', as described by Hutcheson (1970), was used to determine phenotypic diversity in this collection. The

Shannon-Weaver diversity index (H') has been widely used in studies of germplasm collections (Jaradat, 1992; Bechere, 1996; Ayana and Bekele, 1998). This index is defined as:

$$H' = - \Sigma p_i . \ln p_i$$

Where n is the number of phenotypic classes for a character and p_i is the proportion of the total number of entries in the i^{th} class. H' was estimated for each character.

Analysis of variance (ANOVA) was used to calculate variation among landraces. Finally, in order to better classify the thirty accessions, a principal components analysis was carried out on the correlation matrix. It was calculated on the mean data of the five replications using the SATISTICA 6.0 computer software.

RESULTS

Mean values for quantitative characters measured on 30 landrace genotypes are presented in Table 1. A large genetic variability within the landraces was noted for the plant height (69.6%), days to heading (39%), the filling period (33%) and number of kernels /spike (23.6%)

Results of variance analysis and estimates of phenotypic diversity (H') for each trait are presented in Table 2. Variance analysis showed that there is an important variability among the 30 accessions for all traits. Index diversity showed a large variability for most agronomic traits among these landraces. The diversity indices ranged from 0.91 (highly polymorphic) for thousand kernels weight to 0.32 for flag leaf area with an average of 0.77.

Correlation coefficients computed among the quantitative traits are presented in Table 3. Correlations showed significant positive relations between yield and tillers per plant (0.90), thousand kernels weight (0.39), plant height (0.35) and flag leaf area (0.36). On the other hand, number of kernels/spike (-0.37) and filling period (-0.21) showed negative correlations with grain yield.

The principal components analysis (PCA) was performed with the standardised mean values for each of the eleven quantitative traits and subpopulation. Results of PCA were used to study the interrelationships and adjustments in eleven quantitative traits, and to detect subpopulation groupings based on similarities in trait interrelationships and adjustmcropping season with the objective of estimating the associations between yield and yield-related traits and to identify direct and indirect effects of characters for durum wheat grain yield improvement. Mean sum of squares for all the characters considered showed highly significant differences (P<0.01) indicating the presence of adequate variability. Grain yield had strong positive correlations (P<0.01) with plant height, number of kernels spike^{-1}, grain yield plant^{-1}, biological yield and thousand-kernel weight.

On the contrary, grain yield had a strong negative correlation (P< 0.01) with days to heading suggesting the usefulness of selecting early heading genotypes with long grain filling period in improving grain yield. Results of

TABLE 1. Means and standard deviation for 30 landrace genotypes for different characters

Character	Minimum	Maximum	Mean	Standard deviation
Thousand kernels weight	30.06	57.34	44.18	10.90
Kernels spike^{-1}	31.20	54.8	43.15	10.38
Spikeless tillers plant^{-1}	4.40	9.4	7.3	1.97
Grain yield plant^{-1}	2.57	15.66	8.88	4.82
Plant height (cm)	88.20	157.8	133.73	21.72
Length of spikes (mm)	4.40	9.7	7.09	1.56
Flag leaf area (cm^2)	22.61	44.28	34.08	5.96
Days to maturity	1820	200	192.75	4.43
Days to heading	136	175	163.31	8.80
Filling period (days)	22	55	29.44	6.87
Fertility of spikes	1.24	2.53	1.91	0.45

TABLE 2. Variance analysis for eleven traits for 30 durum wheat landraces

Source of variation	ddl	Thousand kernels weight	Kernels spike^{-1}	Spikeless tillers plant^{-1}	Length of spikes	Fertility of spikes	Grain yield plant^{-1}	Flag leaf	Plant height	Days to maturity	Days to heading	Filling period
Landraces	29	666.72**	673.11**	12.93**	47.09**	25.43**	13.05**	4.49**	449.73**	27.36**	54.06**	22.77**
Error	120	0.91	0.82	1.17	0.25	0.04	6.95	21.15	5.34	3.20	6.83	9.02
Total	150	310540	295370	8570	7910	578.20	15.30	179570	2752970	5575610	4011880	137040
CV (%)		24 .67	24.05	26 .98	22.0	23.56	54 .05	17.48	16.24	2.29	5.38	23.33
Phetotypic diversity (H')		0.86	0.91	0.84	0.85	0.85	0.89	0.32	0.87	0.67	0.69	0.75

**: Significant at the 0.01 probability level

TABLE 3. Correlation coefficients between yield and other traits in durum wheat

Trait	Thousand kernels weight	Kernels spike^{-1}	Spikeless tillers plant^{-1}	Yield	Plant height	Length spikes	Flag leaf area	Days to maturity	Days to heading	Filling period	Fertility of spikes
ThousandKernels weight	1	-0.98**	0.06	0.39**	0.9**	0.18*	0.24**	0.07	0.25**	-0.28**	0.60**
Number of kernels /spike		1	-0.09	-0.37**	-0.89**	-0.17*	-0.29**	-0.04	-0.20*	0.24**	-0.64**
Tillers/plant			1	0.90**	0.10	-0.01	0.33**	-0.13	0.05	-0.14	-0.04
Yield				1	0.35**	0.04	0.36**	-0.08	0.12	-0.21**	0.17*
Plant height					1	0.27**	0.23**	0.06	0.20*	-0.22**	0.49**
Length spikes						1	-0.06	0.01	0.13	-0.16*	-0.06
Flag leaf area							1	-0.31**	-0.14	-0.00	0.21**
Days to maturity								1	0.63**	-0.17	0.01
Days to heading									1	-0.86**	-0.01
Filling period										1	0.03
Spikes fertility											1

*P < 0.05. ** P < 0.01

genotypic correlation indicate that a maximum positive direct effect on grain yield was exerted by biological yield (1.08) followed by days to maturity (0.91) and harvest index (0.69). While, maximum negative direct effects were exerted by days to heading (-0.72) and grain filling period (-0.52). Therefore, days to heading, biological yield and harvest index could be used as an indirect selection criterion for better grain yield. Thus, selecting early heading genotypes having high biological yield and harvest index could improve grain yield.

In order to classify the accessions, the PCA was used and the eigenvector are presented in the Table 4. The PCA explained 59.61% of total variation in the Tunisian germoplasm (Fig. 1). The first axis explained 37.53% of total variability and the most associated traits were thousand kernel weight, number of kernels per spike, plant height, grain yield plant^{-1}, fertility of spikes and flag leaf area. The second PCA axis explained 22.08% and was mostly related to days to heading, days to maturity and filling period (Table 4).

The PCA classified the thirty durum wheat landraces in 4 important groups (Fig.1). The group formed by accessions Media 1. Media 2, Media 3, Real Sorte, Souri, Taganrog. Mekki, Bidi AP1, Derbassi RC1, Agili 1 and Agili Blanc was characterised by an important number of kernels spike^{-1}. The group constituted by accessions Jeneh kotifa 1, Jeneh kotifa 2, Jeneh kotifa 3, Sbei glabre, Hamira 1, Hamira 2, Biskri glabre, Mahmoudi. Biskri glabre AP2, Swabaa Elgia. Sbei and Mahmoudi glabre presented high yield thousand kernel weight and plant height.

DISCUSSION

Variation among thirty local durum wheat accessions was significant (P<0.01) for the eleven characters as shown by variance analysis. Such a high variability in Tunisian durum wheat was also noted by Gashaw *et al.* (2007) and Fakhfak *et al.* (1998). All the characters considered showed significant differences (P<0.05) among the evaluated genotypes indicating the presence of adequate variability (Table 1). Tesfaye *et al.* (1991) evaluated 1223 entries of durum wheat accessions in Ethiopia for agro-morphological

TABLE 4. Projection of the agronomic and phenologic traits on axes 1 and 2 of the principal components analysis

Factor	Thousand kernels weight	Kernels spike^{-1}	Plant height	Length spikes	Fertility of spikes	Spikeless tillers plant^{-1}	Yield	Flag leaf area	Days to maturity	Days to heading	Filling period
1	-0.92	0.93	-0.88	-0.21	-0.63	-0.38	-0.67	-0.52	-0.07	-0.34	0.41
2	0.05	0.01	0.04	0.23	-0.19	-0.34	-0.29	-0.60	0.77	0.86	-0.64

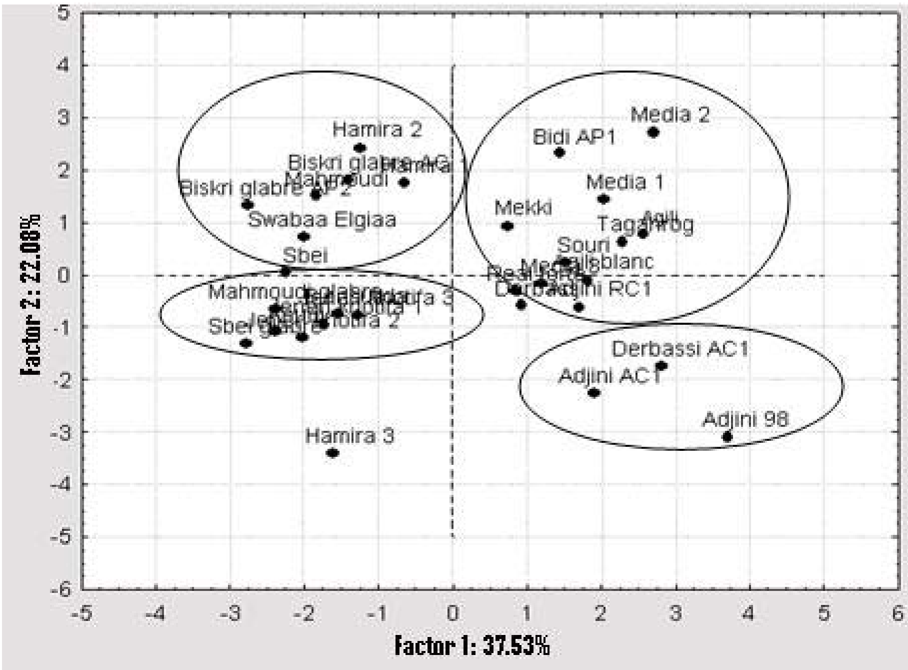

Figure 1. Distribution of the 30 durum wheat accessions for the agronomical and phenological traits in the plan of axes 1 and 2.

characters and reported a high degree of variation in their accessions.

Overall means, minimum and maximum values for the quantitative characters measured on 30 landraces showed that the thousand kernel weight ranged from 30.06 to 57.34 g. The average thousand kernel weight was 44.18 g in landrace genotypes, whereas some of the lines had as high as 50 g. These lines can be used as donor parents to improve seed weight which ultimately increase grain yield.

Plant height ranged between 88.2 and 157 cm, with a mean value of 133.74 cm. This indicated that landraces were relatively taller than the improved cultivars. This is a typical feature of landraces, which excel in capacity to support panicle growth by large stem reserve mobilisation. Few short statured lines were identified which can be further utilised to develop fertiliser responsive and lodging resistant wheat cultivars (Oury *et al*., 1995; Masood *et al.*, 2005).

Flag leaf area is another important trait to be considered because of its contribution to photosynthetic activities. It ranged from 22.61 to 44.28, with a mean value of 34.08 cm^2. Days to 50% flowering ranged from 136 to 175, with a mean value of 163.30 days. Some of the accessions (Hamira 3, Derbasi AC1 and Adjini AC1) in this category can be used in breeding programmes to develop early maturing varieties. The range for physiological maturity was 182 to 200, with a mean value of 192.74 days. This trait is generally difficult to measure precisely because it is highly influenced by the environment such as temperature, soil and rainfall (Masood *et al.*, 2005).

Grain filling period is an important trait in wheat that ultimately affects the overall grain yield. It ranged from 22 to 45 days with a mean value of 29.44. A shorter grain filling period is one of the important criteria for selection in our breeding programmes.

Phenotypic diversity (H') indicated a wide variability for most agronomic traits among these landraces. The diversity indices ranged from 0.91 (highly polymorphic) for thousand kernels weight to 0.32 for flag leaf area with an average of 0.77. Therefore, this germoplasm has a phenotypic diversity. This estimate was slightly higher than the one reported for accessions of Ethiopian wheat landraces of H'= 0.70 (Bechere *et al*., 1996) or the one reported for Jordan's (0.67), which was based on 21 agro-morphological traits (Jaradat, 1992).

There was a positive and significant correlation between thousand kernel weight and grain yield per plant (0.39) confirming the findings of Koksal (2009), that thousand kernel weight increased the yield with the direct effect value of 0.28. Plant height, was significantly and positively correlated with grain yield per plant (0.35**). Gashaw *et al.* (2007) showed also that plant height and thousand kernels weight had significant positive correlation with grain yield and suggested that these traits could be used as a direct criterion for improving yield of durum wheat. In fact, plant height confers to the plant a better capacity to tolerate the dryness (Ben Abdallah and Ben Salem, 1993). This capacity would be explained by higher glucose storage ability in the stems during the period for preceding anthesis (Oury *et al.*, 1995).

Number of kernel was negatively correlated with grain yield per plant. Koksal (2009) reported a similar finding. Positive correlation was found between flag leaf area (0.36) and grain yield per plant. Saleem *et al.* (2006) also revealed that grain yield per plant was positively and significantly correlated with flag leaf area (0.47).

The present results suggested that high yielding genotypes may be selected by concentrating upon number of spikeless tillers per plant (0.90), thousand kernels weight (0.39), flag leaf area (0.36) and plant height (0.35).

The PCA showed that the group constituted by accessions Jeneh kotifa 1, Jeneh kotifa 2, Jeneh kotifa 3, Sbei glabre, Hamira 1, Hamira 2, Biskri glabre, Mahmoudi, Biskri glabre AP2, Swabaa Elgia, Sbei and Mahmoudi glabre presented the best agronomic characteristics with high grain yield, thousand kernels weight and plant height. Genotypes of this group might be good parents to be used in improvement programmes of durum wheat.

The Media 1, Media 2, Media 3, Real Sorte, Souri, Taganrog, Mekki, Bidi AP1, Derbassi RC1, Agili 1, and Agili Blanc accessions are not of Tunisian origin. In fact, Media is from Algeria. Mekki and Agili are from Marrocco and Souri also had a foreign origin. Bidi AP1, Real Sorte, Taganrog had unknown origin (Maamouri *et al.*, 1988; Deghaïs *et al.*, 2007).

CONCLUSION

Correlations between spikeless tillers per plant, thousand kernels weight, flag leaf area, plant height are positive and significant with yield. This study suggests that these traits could be used as a direct criterion for improving yield of durum wheat. Tunisian germplasm present an important diversity index showing large genetic variability. The genotypes Jeneh kotifa 1, Jeneh kotifa 2, Jeneh kotifa 3, Sbei glabre, Hamira 1, Hamira 2, Biskri glabre, Mahmoudi, Biskri glabre AP2, Swabaa Elgia, Sbei and Mahmoudi glabre have the best agronomical characteristics. These genotypes can, therefore, be used as parents for improvement for durum wheat.

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