Assessment Of Adaptability And Stability Of Six Tunisian Cereal Genotypes Under Rainfed Conditions And At Two Semi Arid Environments

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doi: 10.19044/esj.2016.v12n6p122 URL:http://dx.doi.org/10.19044/esj.2016.v12n6p122

Abstract

Three durum wheat (Nasr, Maâli and Salim), two bread wheat (Tahent and Utique) and two barley varieties (Manel and Kounouz) were assessed in two different semi arid locations under rainfed conditions in 2012-2013 growing season for yield related traits performances, stability and adaptability parameters. For determining adaptability and stability of genotypes, regression coefficient (bi) and variance of deviation from regression (S^2di) are used. The evaluation was based on five agro-morphological traits: tiller number/plant, spike number/m^2, plant number/m^2, 1000 kernel weight and grain number/ spike. Variance analysis indicated a highly significant ($p<0.05$) effect of locations and genotypes for all studied traits. Also, the interaction between the genotypes and environments found to be highly significant ($p<0.001$) for all studied traits except the tiller number/plant. Analysis of stability showed that there were differences in stability performances among the genotypes for the traits tested. The unstability for spike number/m^2, plant number/m^2, 1000 kernel weight and grain number/spike among the genotypes was originated from the high mean squares of deviation from regression. Analysis of AMMI model showed that Principal Components (PC) Analysis indicated that the two PCs explained 78.17% (PC1 = 41.51% and PC2 = 36.66%) of the total variation. Results showed that the group of genotypes Nasr, Tahent, Kounouz and Manel having wide adaptability and could be recommended for cultivation across diverse environments.

Keywords: Agro-morphological traits, barley, bread wheat, durum wheat, stability

Introduction

Wheat is the most widely cultivated crops in the world, which is grown both in arid and semi arid regions of the world (FAO, 2013, Li et al., 2011). Also, barley (*Hordeum vulgar* L.) is a principal food or feed crop in the semi-arid regions in Asia, South America and North Africa (Khalili et al., 2013). However, drought had often serious problem in the production areas of wheat and barley (Kiliç and Yagbasanlar, 2010; Farooq et al., 2009, Talebi et al., 2009). Plant drought tolerance varies not only among species but also among various varieties in the same species (Khalili et al., 2013). Morphological and agronomic characters have an important role on increasing yield, since the use of these traits in breeding programs could serve to screen genotypes under unsuitable environmental conditions (Ahmadizadeh, 2013; Jatoi et al., 2011). The performance of a genotype is identified by three components: genotypic effect (G), environmental effect (E) and (G x E) interaction (Yan et al., 2007). Genotypes x environment (G x E) interactions estimation are extremely important for testing the degree of stability and adaptability of genotype under various environments (Hamam et al., 2009). In cereal crops, this adaptability has proved to be crucial, because soil variation between localities and the climatic variation are very high. Thus, identifying stable genotypes is generally difficult because of the presence of genotype x environment interaction. Selecting stable genotypes adapted across a wide range of environments becomes important for cereals breeders. Stability analysis is a method with high potential for determination of the performance of genotypes under different environmental conditions. Several statistical methods of genotype × environment interaction and its relationship with stability were studied. These methods can be univariate (based on regression or variance analysis) or multivariate. The most commonly used methods are based on regression analysis using regression coefficient (bi) and variance of deviation from regression (S^2di) when describing the performance of one genotype across environments (Eberhart and Russell, 1966). In this approach, regression graphs are used to predict adaptability of genotypes. According to this model, a stable genotype, less responsive to environmental changes and more adaptive, have the same behavior and high mean performance across the range of environments and having unit regression coefficient (bi = 1) and deviation from regression as small as possible ($S^2d = 0$). As multivariate, the additive main effects and multiplicative interaction (AMMI) model have been extensively used in the statistical analysis of multi environment assessment (Akcura et al., 2009; Ilker et al., 2011; Altay, 2012). According to Ayalneh et al. (2013), presence of G x E interaction reduces the correlation between phenotype and genotype and reduces the efficiency of potential genetic assessment in various environments. Cereals species responses in different locations were studied by several workers in order to determine yield adaptability and stability. In fact, five wheat genotypes were tested for grain yield stability at three different locations under rained conditions in Pakistan (Khan et al., 2014). Aycicek and Yildirim (2006) also studied 20 bread wheat genotypes for yield performances stability. In barley, Gebremedhin et al. (2014) estimated the magnitude of genotype x environment interaction and stability for grain yield and yield related traits on Ethiopian eight released varieties. The aim of this study is to follow the stability and adaptability of seven genotypes conducted in two semi arid locations on the basis of some yield related traits and adaptability/stability parameters.

Material and methods

Experimental sites and plant materials

Three durum wheat (Nasr, Maâli, and Salim), two bread wheat (Tahent and Utique) and two barley (Manel and Kounouz) varieties derived from the Tunisian National program were chosen to study their stability and adaptability in two semi arid environments based on five agro-morphological traits under rainfed conditions. Field experiments were conducted at Siliana (El Gantra): 36°00’19.28”N 9°25’41.20”E and Kef (Touiref): 36°20’20.21”N 8°34’57.27”E located in the North West of Tunisia during 2012-2013 cropping season.

Cultural practices

The experiment field received 100 kg/ha of Di-Ammonium Phosphate at sowing. Ammonium nitrate was applied at early tillering and stem elongation stages at a rate of 100 kg/ha. In this study, seeding rates were 160 kg/ha for durum wheat, 140 kg/ha for bread wheat and 120 kg/ha for barley. The seeds were sown using an experimental drill in (10 m × 3 m) plots consisting of 12 rows with a 20 cm row space. Plots of 30 m^2 were sown on 24 December with 3 replications. An herbicide was applied as treatment for weed control. Climate temperature and rainfall from sowing to harvest are presented in Figure 1.

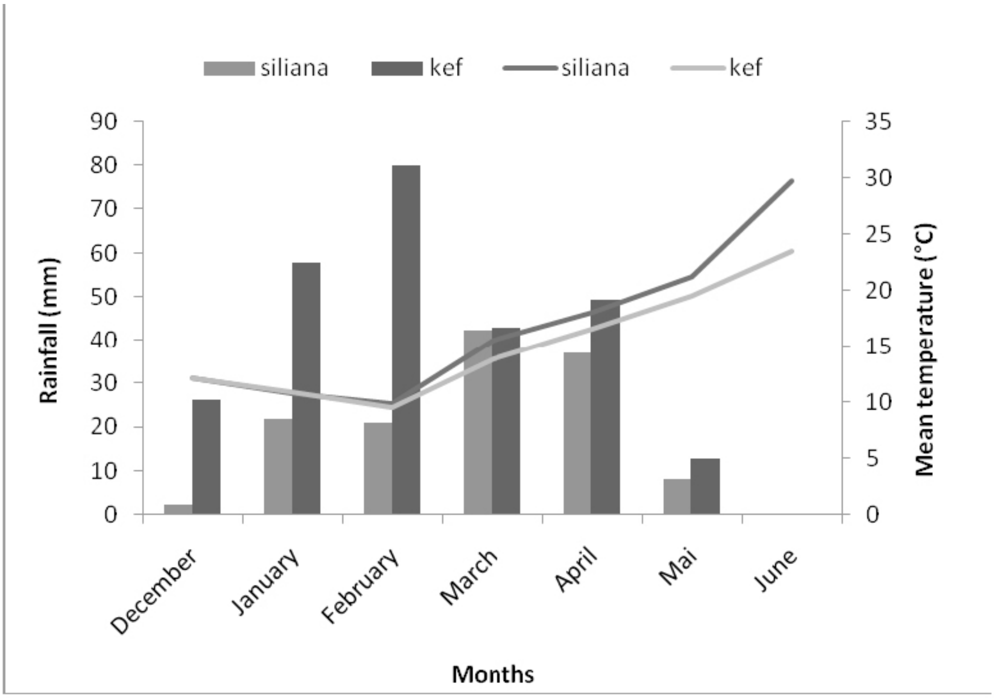

Figure 1: Mean temperature (°C) and rainfall (mm) of Siliana (El Gantra) and kef (Touiref) site from sowing to harvest (2012 to 2013)

Measured traits

At maturity, five morpho-agronomic traits were measured for the seven genotypes tested for their stability and adaptability: tiller number/plant, spike number/m^2, plant number/m^2, 1000 kernel weight (g) and grain number/ spike.

Statistical data analysis

The significance of genotypes x environment interaction was studied for traits measured in the analysis of variance. Variance analysis was carried out using SPSS software (IBM SPSS Statistics, SPSS for Windows, version 16.0. Chicago, SPSS Inc., 2007). Duncan's test was used for means comparisons at $p<0.05$, $p<0.01$ and $p<0.001$ levels. The two stability parameters calculated were the regression coefficient (bi) and deviation from regression (Si^2d). A variety having a (bi) value close to 1 and a small deviation from regression is considered stable. Those genotypes with regression coefficient >1 would be adapted to suitable environment, those with regression coefficient <1 would adapted to unsuitable environment. For additional information, Principal Components Analysis (PCA) was conducted.

Results and discussion

This study was conducted to identify stable and adaptable durum wheat, bread wheat and barley genotypes under two climatic and growing conditions in North West of Tunisia. The two sites differ in latitude and in temperature and water availability (Figure 1). In fact, the mean rainfall recorded at Touiref during the whole study-period (270.0 mm) was higher than that registered at El Gantra (132.8 mm) especially for January and February.

The results of variance analysis showed significant differences ($p<0.05$, $p<0.01$ and $p<0.001$) among the environments and genotypes for all studied traits. Also, the interaction between the genotypes and environments found to be highly significant ($p<0.001$) for all studied traits except the tiller number/plant (Table 1). Significance of G x E indicated inconsistent genotypes in response to environment changes. Similar results were reported by Mohammed (2009) and Jalata (2007) on bread wheat and Barley. Ayalneh (2013) evaluated also an interaction between genotypes and environment on eighteen bread wheat genotypes by testing across nine environments.

Genotype adaptability and stability are useful parameters for recommending varieties for predict suitable environment. In this study, varieties are classified according to the value of their regression coefficients into those having bi less than, equal to, or greater than unity, as well as according to the value of the variance of regression deviations (equal to or different from zero). Basic statistical parameters: mean values, Si^2d values and coefficient of regression, for the seven genotypes under investigation of all studied traits are presented in Table 2.

Table 1: Variance analysis (F value) of the five measured traits for three durum wheat, two bread wheat and two barley varieties under rainfed conditions.

Sources variation	df	Tiller number/plant	Spike number/m²	Plant number/m²	1000 kernel weight (g)	Grain number/spike
Site	1	35.63***	6.46***	7.10***	25.97***	6.26*
Genotype	6	4.18**	54.45***	53.18***	45.59***	62.56***
Site*Genotype	6	0.63 ns	75.60***	72.92***	6.74***	18.30***

df: degree freedom; ns; non significant ; * : significant at the 0.05 level ; ** : significant at the 0.01 level ; *** significant at the 0.001 level

Table 2: Mean values, Si²d values correlation and coefficient of regression, for the seven genotypes tested of all studied traits

Species	**Genotypes**	**Tiller number/plant**				**Spike number/m²**				**Plant number/m²**				**1000 kernel weight (g)**				**Grain number/spike**			
		X	**S_{di}^2**	**r_i^2**	**bi**	**X**	**S_{di}^2**	**r_i^2**	**bi**	**X**	**S_{di}^2**	**r_i^2**	**bi**	**X**	**S_{di}^2**	**r_i^2**	**bi**	**X**	**S_{di}^2**	**r_i^2**	**bi**
Durum wheat	Nasr	3.33	0.665	0.200	0.3	183.00	10645.287	0.996	-0.005	192.67	10722.602	0.996	-0.005	30.76	6.553	0.529	-0.156	35.63	1.968	0.001	-0.010
	Maâli	1.50	0.700	0.429	0.429	177.00	5268.872	0.992	-0.008	186.00	4938.856	0.995	-0.008	49.89	32.307	0.890	-0.091	28.00	3.474	0.345	0.173
	Salim	2.83	0.966	0.862	0.517	164.50	9000.696	0.998	-0.006	177.50	7582.752	0.997	-0.006	40.61b	7.529	0.416	-0.129	26.81	24.334	0.863	0.103
Bread wheat	Tahent	2.67	0.665	0.800	0.6	179.00	11813.516	0.996	-0.005	185.00	11555.175	0.997	-0.005	37.46	4.774	0.382	0.155	40.00	7.182	0.668	-0.167
	Utique	2.00	1.600	0.750	0.375	198.00	12748.442	0.999	-0.005	206.17	12457.015	0.999	-0.005	39.95	3.794	0.02	0.04	29.00	32.832	0.914	0.091
Barley	Manel	2.50	1.100	0.273	0.273	153.00	2153.238	0.983	-0.012	189.50	3991.459	0.994	-0.009	41.43	25.775	0.795	-0.096	40.30	3.396	0.173	0.124
	Kounouz	2.83	1.366	0.610	0.366	141.50	4704.725	0.996	-0.008	147.50	3107.505	0.985	0.01	43.06	2.102	0.254	-0.19	38.00	22.099	0.869	-0.109

Tiller number/plant

Insignificance of genotype x locations interaction revealed that all the genotypes were stable for tiller number/plant. Depending on the regression coefficient values and mean values for tiller number/plant of genotypes, Nasr, Salim, Tahent and Kounouz had a good adaptation to poor conditions (b_i<1 and X_i > X). The varieties Maâli, Utique and Manel showed poor adaptation to the two environments (b_i <1 and X_i < X) (Table 2). In previous research, variable stability for productive tillers/m² has been reported by Al-Awami et al. (2007). According to Faris et al. (1981), cultivars having small bi values for productive tillers/m² are less sensitive to favorable environments. Durum wheat variety Nasr had the highest tiller number/plant, which did not significantly differ to Salim variety. According to Ahmadizadeh et al. (2011), the number of tiller could have an effect on wheat drought tolerance and grain yield. Varieties known for their low tillering capacity were most recommended in semi environment (Elhani et al., 2007).

Spike number/m²

Spike number/m² is an important quantitative trait depending directly on different environment factors. For this trait, the non stability of all genotypes was originated from their high deviation value from regression. The genotypes Nasr, Maâli, Utique and Manel were well adapted to the tested environments. However the other having b_i < 1 and X_i <X showed badly adaptation to the two environments. Similar results were found by Koutis et al. (2012) which reported that spike number/m² is not stable across environment for six wheat landraces tested under three locations.

Plant number/m²

The regression coefficient is <1 for all genotypes tested. The varieties Nasr, Utique and Manel had a plant number/m^2 higher than mean value, thus, this group is well adapted to all conditions. However, the genotypes Maâli, Salim, Kounouz and Tahent had plant number/ m^2 lower than mean value, which indicated a poor adaptation to all conditions.

1000 kernel weight (g)

Based on bi and Si²d values, the genotypes Maâli, Utique and Kounouz were well adapted well to the tested environments. The stability parameters indicated regression coefficient (bi) value ranging from - 0.19 in Kounouz to 0.15 in Nasr. Kounouz, having the smaller Si²d, could be considered as stable and widely adopted for this trait. The instability of 1000 kernel weight was also reported by El-Sheribreny et al. (2006) and Mohamed et al. (2013) on maize and durum wheat crops. Rane et al., (2007) have also observed similar trend of performance among wheat genotypes and variable stability for 1000 grain weight.

Grain number/spike

Variance analysis showed that genotypes were instables for this trait. Nasr, Tahent and Manel varieties revealed well adaptation ($b_i < 1$ and $X_i > X$) to the two environments.

Similarly, Khan et al. (2004) and Mohamed et al. (2013) tried to investigate the effect of environmental conditions on several wheat genotypes adaptation and found that the number of grains per spike is variable according to the environment. .

Stability analysis:

PCA analysis groupes genotypes according to their similarities, estimated on the basis of the AMMI model equation, based on traits tested, indicate the adaptability of each genotype. The similarity was based on the means and responses of genotypes across the two environments. (PC) analysis indicated that the first two PCs explained 78.17% (PCA1 = 41.51% and PCA2 = 36.66%) of the total variation (Figure 2). Sadeghi (2007) and Letta (2009) also found that a high percentage of interaction effects were explained by the first two PCs. According to AMMI model, the interactions lead to different rankings of the genotypes across the environments. In fact, Nasr, Tahent, Kounouz and Manel are relatively the most stable genotypes while Maâli, Salim and Utique were relatively considered to be unstable genotypes.

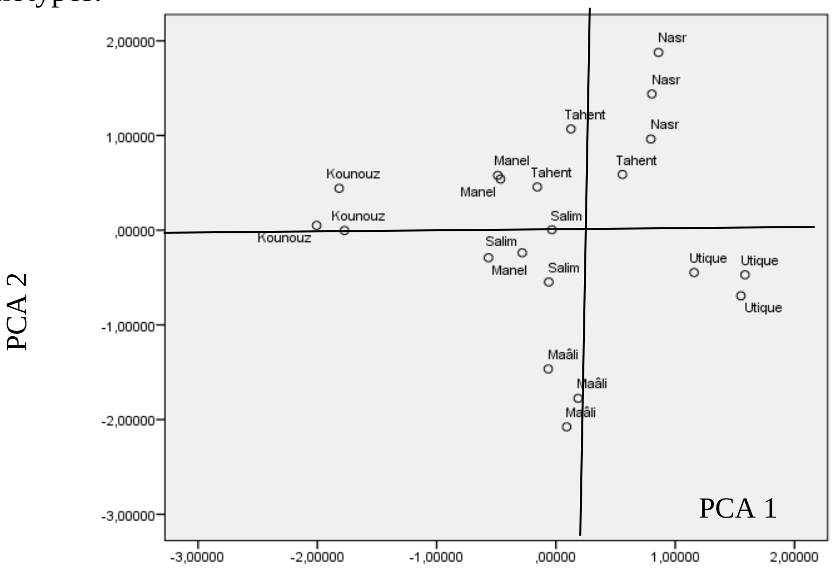

Figure 2: Principal Component Analysis (PCA 1 and PCA 2) of seven genotypes for yield related traits under two locations.

In comparison to El Gantra site, different species and varieties seems to be more powerful in Touiref site. It can be due to the differences of rainfall quantities during emergence to floral initiation stage, 35 days after sowing. Rainfall registered in El Gantra site exceeds those in Touiref for December and January months. The level of sensitivity to water stress appears at all stages of crop growth especially in early stage (Vaezi et al., 2010; Khayatnezhad et al., 2010).

Conclusion

In this study, results showed that genotypes differ in their response to the two localities for the majority of evaluated traits. This could be explained by the difference of climatic conditions (rainfall amount and distribution during growing season) observed in various environments. Varieties of durum wheat (Nasr), bead wheat (Tahent) and barley (Kounouz and Manel) showed relative stability and adaptation to environmental changes.

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