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Quality in durum wheat: comparison between landraces and high yielding varieties

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Abstract. Eight durum wheat genotypes: four landraces and four high-yielding varieties were studied in two regions (sub-humid and semi-arid) of Tunisia, using four fertilizer treatments and during two cropping seasons. Three quality parameters were evaluated: thousand-kernel weight (TKW), yellow berry (YB) and protein content (P). Significant Genotype x Environment x Fertilizers interaction ($p< 0.05$) was noted for the quality related traits P and YB. TKW was dependent on Environment x Fertilizers and Environment x Genotype interactions ($p<0.05$). Landraces showed higher values of P (18.32 %) and TKW (44.49 g) than high yielding varieties (15.81%, 40.23 g) respectively. Conversely, landraces showed lower YB rates (4.14%) than high-yielding varieties (7.79%). A pronounced expression of these traits was noted in semi-arid region. N-fertilizer appeared to increase the protein content and reduce TKW. Landraces were associated with reduced YB levels in semi-arid and sub-humid areas, for potassium and nitrogen fertilizers. Nitrogen fertilizer reduced YB in semi-arid region from 11.48 % to 3.5 % in high yielding varieties. In sub-humid region YB rates were similar for nitrogen and potassium combination ($p>0.05$%) ranging from 6.77% to 8.92%. These results support that landraces are adapted to semi-arid area with low fertilizer input while high yielding varieties appeared to improve fertilizer use efficiency for quality traits.

Keywords. Durum wheat quality – Landraces - High-yielding varieties – Environmental interactions.

Qualité chez le blé dur : comparaison entre variétés locales et variétés à haut rendement

Résumé. *Huit génotypes de blé dur, quatre variétés locales et quatre variétés à haut rendement, ont été étudiés dans deux régions (sub-humide et semi-aride) de la Tunisie, en utilisant quatre traitements de fertilisation et pendant deux saisons de culture. Trois paramètres de qualité ont été évalués : le poids de mille grains (PMG), l'indice de jaune (YB) et la teneur en protéines (P). Une interaction significative du Génotype x Environnement x Engrais (p <0,05) a été notée pour les caractères liés à la qualité P et YB. PMG était dépendant des interactions Environnement x Engrais et Environnement x Génotype (p <0,05). Les variétés locales ont montré des valeurs plus élevées de P (18,32%) et PMG (44,49 g) que les variétés à haut rendement (15,81%, 40.23 g), respectivement. En revanche, les variétés locales ont montré des taux plus faibles de YB (4,14%) que les variétés à haut rendement (7,79%). Une expression prononcée de ces caractères a été observée dans la région semi-aride. L'engrais azoté augmentait la teneur en protéines et réduisait le PMG. Les variétés locales ont été associées à des niveaux réduits de YB dans les zones semi-aride et sub-humide, pour les engrais potassiques et azotés. Dans la région semi-aride, les engrais azotés réduisaient le YB de 11,48% à 3,5% chez les variétés à haut rendement. Dans la région sub-humide, les taux de YB étaient similaires pour la combinaison azote et potassium (p> 0,05%), allant de 6,77% à 8,92%. Ces résultats confirment que les variétés locales sont adaptées à la zone semi-aride avec un faible apport d'engrais alors que les variétés à haut rendement améliorent l'efficacité d'utilisation des engrais pour les caractères de qualité.*

Mots-clés. *Qualité du blé dur – Variétés locales – Variétés à haut rendement – L'interaction avec l'environnement.*

I – Introduction

Durum wheat quality is considered as a multidisciplinary concept. Quality aspects are defined according to the user's category. Protein content, test weight and grain moisture are important for commercial transactions; however, grain yield and stability are interesting aspects for the farmers.

For milling and pasta industries, semolina yielding ability, gluten and protein content are the most important traits considered for durum wheat quality (Troccoli *et al*., 2000). In addition, many researchers consider that storage proteins are responsible for the variation in physicochemical and technological durum wheat properties (Martinez *et al*., 2005; Simeone *et al*., 2001; Lerner *et al*., 2004). Strong relationships were detected between the high molecular weight glutenin subunits allelic composition and bread making quality (Ammar *et al*., 2000), spaghettis cooking quality (Aalami *et al*., 2007) and gluten strength (Sisson *et al*., 2005 and Saperstein *et al*., 2007). According to previous researches the durum wheat grain quality parameters are influenced by the environmental, genotypic factors and the potential interactions among them (Rharrabti *et al*., 2003b; Lerner *et al*., 2004; Edwards *et al*., 2007). Protein content is mainly controlled by fertilizer and environments (Mariani *et al*., 1995). Kernel weight and the kernel virtreousness parameters are strongly dependent on the water availability conditions during the grain filling period (Li *et al*., 2013; Jia *et al*., 1996).

The objectives of this study were to:

(i) compare the potential responses of protein content, yellow berry and thousand kernel weight of selected high yielding durum wheat cultivars and local landraces in different growing conditions,

(ii) characterize their high molecular weight-glutenin subunits,

(iii) evaluate the class of genotype, environments and fertilizer treatments effects on the assessed quality traits.

II – Material and methods

Two field trials were grown in sub-humid (BouSalem) and semi-arid (Kef) regions in Tunisia. Each trial included four durum wheat landraces (Chili, Biskri, Mahmoudi and Inrat 69) and four high yielding durum wheat cultivars (Karim, Razzak, Om Rabiaa and Khiar), which were grown using four fertilizer treatments N0K0 (no applied N or K fertilizer), N1K0 (applied N only), N0K1 (applied K only) and N1K1 (applied both N and K fertilizers). Trials were conducted during two successive growing seasons, viz., 2007 and 2008.

The quality parameters measured were: protein content, thousand kernel weight and yellow berry. Grain protein content (P) was determined using NIRS system (near infrared spectroscopy using a Perten-Inframatic-8600) (Sgruletta and Destefanis, 1997). Thousand kernel weight (TKW) was determined using the Numigral Chopin apparatus. Yellow berry (YB) rate was determined by inspecting 50 kernels sliced using thel farinotom apparatus by Pohl.

Glutenins extraction was made as described by Rhazi *et al*. (2009) on the eight durum cultivars. Glutenins were examined by microchip capillary electrophoresis-sodium dodecyl sulfate (microchip CE) platform, LabChip 90. The identification of HMW-GS at the Glu-B1 locus was carried out according to Rhazi *et al*. (2009).

Analysis of variance was carried out using proc anova of SAS with the option LSD to compare means.

III Results and discussion

1. Quality parameters variability with environments, genotypes and fertilizer treatments

The analysis of the variance showed that all three main effects environment (E), genotypic pools (G) and fertilizer treatment (F) were significant for the quality parameters protein content, thousand kernel weight and yellow berry (Table 1). Environmental effect was very large in magnitude and appeared to be the principal effect for thousand kernel weight. Yellow berry appeared to be controlled mainly by genotype. Second order interaction (E x F x G) was significant only for yellow berry and protein content. E x G and E x F interactions were significant for the three measured parameters, whereas they were smaller in magnitude as compared to individual main effects (Table 1). This is in accordance with previous studies which showed that individual environmental and genotypic effects were more important than their interaction on the quantitative quality parameters (Li *et al*., 2013; Mariani *et al*., 1995).

2. Comparison between landraces and high yielding varieties

Landraces showed superiority over the high yielding varieties for the assessed quality traits for all regions-fertilizers' combinations. Overall cultivars means of protein content, thousand kernel weight and yellow berry comparison (Table 3) showed that protein content ranged from 17.76% to 18.70% for landraces (a mean 18.32 %), while it varied within the range of 15.29% to 16.20% for high yielding varieties (a mean 15.81%). Greater values of thousand kernel weight were observed for landraces, ranging from 43.29g to 45.48g (a mean 44.49g) than for high yielding varieties, ranging from 37.30g to 42.01g (a mean 40.23g). Yellow berry rates were lower for landraces, a mean 4.13% was scored ranging from 3.48% to 5.30% ($p>0.05$); whereas it varied significantly ($p<0.05$) from 6.45% to 9.22% for high yielding varieties (with a mean 7.79%). These results confirmed the genotypic effect observed on all three quality traits (Table 1) and suggest that landraces are characterized by a greater semolina yielding ability (Rharrabti *et al*., 2003a).

Table 1. Mean squares of thousand kernel weight (TKW), yellow berry (YB) and protein content (P) assessed on the two classes of genotypes (G) during two growing seasons using four fertilizer treatments (F) in both environments (E) sub-humid and semi-arid regions.

Source of variation	D.f.	TKW (g)	YB (%)	P (%)
E	1	8288.28**	3204.66**	1814.15**
r(E)	4	125.89	254.37	10.49
G	1	5224.12**	3854.78 **	1812.14**
F	3	1889.19**	1633.08 **	489.13**
E x G	1	150.07 *	504.42**	37.41**
G x F	3	43.74 ns	62.56ns	2.41ns
E x F	3	159.62**	280.44**	10.87**
E x F x G	3	79.25 ns	500.53**	26.46*
Error	1132	31.79	58.81	2.48

,, Significant at 5% and 1% , respectively.*

Comparison of cultivars responses to the assessed quality traits according to Environment x Fertilizers interaction (Table 2) showed that protein content was higher in the semi-arid area than in the sub-humi. This may be due to the water shortage that affected dry matter accumulation during grain filling period (Debaeke *et al*., 1996). In addition, protein content increased significantly with the application of nitrogen-fertilizers in both regions and for all genotypes confirming prior results (Lerner *et al*., 2006; Malik *et al*., 2012; Abad *et al*., 2005). In contrast, thousand kernel weight showed lower values in semi-arid area and decreased significantly with nitrogen-fertilizers application. These results would support the dilution effect of protein content which occurs mainly in favorable growing conditions (Jia *et al*., 1996). Yellow berry, the lowest value was observed in semi-arid area. Yellow berry showed similar means ($p>0.05$) for the two groups of genotype (11.53%) using N0K0 fertilizers treatments. Although comparable means for yellow berry was obtained for high yielding cultivars grown either in the sub-humid or semi-arid areas, a significant decrease of this trait was noted for landraces grown in semi-arid area (3.37%). The use of potassium and nitrogen fertilizers alone or combined showed similar (p>0.05) yellow berry in the SH for each group of cultivars. Greater reduction of yellow berry was observed for landraces (4.64%) than for high yielding cultivars (8.01%) when no fertilizer application was used. These results suggested that landraces grown under optimal nitrogen application are characterized by a greater semolina yielding ability (Rharrabati *et al*., 2003a). However, in the SA region, yellow berry decreased from 11.48 to 8.88% within high yielding cultivars gene pool. This was attributed to a greater use efficiency of nitrogen than potassium fertilizers. Whereas, lower yellow berry rates (3.37%) were noted for landraces grown in the same areas and under similar fertilizers applications.

Table 2. Means variation of Thousand kernel weight (TKW), yellow berry (YB) and protein content (P), with second order interaction Environment (sub-humid (SH) and semi-arid (SA))x Genotype (Landraces and high yielding cultivars (High.y.cvs)) x Fertilizers (N0K0, N0K1, N1K0 and N1K1).

		TKW (g)		YB (%)		P (%)	
		SH	SA	SH	SA	SH	SA
Landraces							
	N0K0	50.40 a	43.48 cd	11.91 a	3.37 ef	14.79 h	18.80 b
	N0K1	48.98 a	43.97 bc	4.36 de	1.35 f	16.44 e	18.61 bc
	N1K0	45.78 b	40.62 e	4.10 e	1.42 f	18.16 cd	20.70 a
	N1K1	44.97 bc	37.72 f	5.48 de	1.08 f	18.16 cd	20.92 a
High.y.cvs							
	N0K0	43.72 cd	40.96 e	11.16 ab	11.48 a	13.78 i	15.32 g
	N0K1	43.95 bc	40.95 e	6.77 cd	8.88 bc	13.96 i	15.97 ef
	N1K0	40.64 e	35.53 g	8.36 c	3.29 ef	15.87 f	17.88 d
	N1K1	41.90 de	34.19 g	8.92 bc	3.51 ef	15.35 g	18.39 bcd

Means with the same letters do not differ significantly (P ≤0.05%) (LSD-test).

3. Quality evaluation in relation to high molecular weight glutenin subunits (HMW-GS) compositions

The results of HMW-GS at the Glu-B1 identification showed that three different compositions were found: 20x-20y, 6-8 and 7-8 (Table 3). The 6-8 subunits composition was detected in the cultivar Biskri and was associated with greater values of TKW (44.07g) and protein content (18.38%) and the lowest rate of yellow berry (3.78%).The subunits 20x-20y were observed in landraces Chili, Mahmoudi and Inrat 69 and the high yielding cultivar Om rabiaa. This composition was associated with intermediate values of TKW (with a mean of 43.96g); and protein content (17.77%) and yellow berry (5.04%). The 7-8 subunits composition was found in the high yielding cultivars Karim, Razzak and Khiar. It showed the lowest quality profile with scored means of TKW (39.64 g), P (15.68%) and the highest yellow berry rate (7.91%). ANOVA results in Table 4 showed that two different groups of varieties. The first group composed by varieties carrying the 20x-20y and varieties carrying the 6-8 subunits, and were associated with similar values of P, TKW and YB (p>0.05); the second group was composed by varieties carrying the 7-8 subunits only.

This classification could explain partly the consumers' preference for using derived end products from landraces instead of Tunisian high yielding cultivated varieties (Zaibet *et al*., 2007), especially since Aalami *et al*. (2007) found that varieties with 7-8 subunits showed a poor cooking quality for spaghetti. Therefore the relationships between HMW-GS and quality parameters could depend also from the LMW-GS compositions (Raciti *et al*. 2003). Previous studies showed that differences between 6-8 and 7-8 may be due to the composition of LMW-GS at Glu-A3 and Glu-B3 (Lerner *et al*., 2004; Vazquez *et al*., 1996).

Table 3. Overall means of thousand kernel weight (TKW), yellow berry (YB) and protein content (P) and High molecular weight glutenin subunits identification of the eight durum wheat genotypes (assessed in both sub-humid and semi-arid regions).

		HMW-GS	TKW (g)	YB (%)	P (%)
Landraces					
	Chili	20x-20y	45.48 a	3.98 de	18.45 a
	Biskri	6-8	44.07 ab	3.78 e	18.38 a
	Mahmoudi	20x-20y	45.08 a	3.48 e	18.70 a
	Inrat69	20x-20y	43.29 bc	5.30 cde	17.76 b
High yielding varieties					
	Karim	7-8	40.19 e	6.45 bcd	16.03 cd
	Omrabiaa	20x-20y	42.01 cd	7.43 abc	16.20 c
	Razzak	7-8	41.43 de	9.22 a	15.73 de
	Khiar	7-8	37.30 f	8.08 ab	15.29 e

Means with the same letters do not differ significantly (P ≤0,05%) (LSD-test).

Table 4. Means of thousand kernel weight (TKW), yellow berry (YB) and protein content (P) by HMW-GS composition.

HMW-GS	TKW (g)	YB (%)	P (%)
20x-20y	43.96 a	5.04 b	17.77 a
6-8	44.07 a	3.78 b	18.38 a
7-8	39.64 b	7.91 a	15.68 b

Means with the same letters do not differ significantly (P ≤0,05%) (LSD-test).

IV – Conclusions

The effect of fertilizers use on the protein content appeared to be conditioned by the combined effect of environments (semi-arid or sub-humid region) and by the genotypes. These results would assume that landraces outperform high yielding cultivars in protein content when grown under semi-arid and sub-humid conditions using combined potassium and nitrogen fertilizations.

Even though, the semi-arid region valorized better the expression of all quality parameters for both classes of genotypes than the sub-humid region.

Good management of nitrogen and potassium fertilizers use could improve the quality of high yielding cultivars in the sub-humid region.

In spite of their different HMW-GS composition (20x-20y) and (6-8), landraces showed similar values of the assessed quality traits and superiority over high yielding cultivars which carried the 7-8 HMW-GS subunits.

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