Revue Agrobiologia
www.agrobiologia.net
ISSN (Print): 2170-1652
e-ISSN (Online): 2507-7627

MORPHOLOGICAL AND END-USE QUALITY CHARACTERISATION OF TUNISIAN DURUM WHEAT

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Reçu le 16/06/2019, Révisé le 06/09/2019, Accepté le 16/09/2019

Abstract

Description of the subject: The enhancement of wheat species requires the good knowledge of its genetic variability and technological quality.
Objective : The main objective of this work was to study genetic diversity in different genotypes of durum wheat using morphological traits and technological qualities parameters.
Methods: Twenty-eight Tunisian landraces and ameliorated varieties of durum wheat grown in the same environment, and evaluated for their variability in forty traits (linked to technological qualities, phenological periods, morphological traits and protein content). We measured Gluten strength of durum wheat genotypes with SDS-sedimentation (SDSS) volume and mixograph parameters
Results : N accumulation and N use efficiency was positively correlated with vegetative biomass and therefore with protein content. PCA (Principal Component Analysis) and HC (hierarchical clustering) clearly separated the landraces from modern cultivars. Cultivars are higher yielding, quicker growing, have better gluten strength and less protein content than landraces. The two highest yellow index values were observed in the modern varieties “Grécale” and “Om Rabii”.
Conclusion : As a result, together, some local accessions and ameliorate varieties form an interesting resource of favourable glutenin subunits and alleles linked to yellow colour that could be very useful in breeding activities for improving durum wheat quality.
Keywords: Durum wheat, Genetic diversity, Gluten strength, Protein content, yellow index.

CARACTÉRISATION MORPHOLOGIQUE ET DE LA QUALITÉ TECHNOLOGIQUE DU BLÉ DUR TUNISIEN

Résumé

Description du sujet : La valorisation des espèces de blé nécessite une bonne connaissance de sa variabilité génétique et de sa qualité technologique.
Objectifs : L'objectif principal de ce travail est d'étudier la diversité génétique de différents génotypes de blé dur en utilisant des caractères morphologiques et les paramètres de la qualité technologique
Méthodes : Vingt-huit variétés locales et améliorées de blé dur tunisiennes cultivées dans le même environnement et évaluées leurs variabilités par quarante caractères (Tel que la qualité technologique, la période phénologique, traits morphologiques et la teneur en protéines). Nous avons mesuré la force du gluten, le volume de sédimentation SDS (SDSS) et les paramètres du mixographe de différents génotypes de blé dur
Résultats : L'accumulation et l'utilisation efficace de N est positivement corrélées avec la biomasse végétative et par la suite avec la teneur en protéines. La PCA (analyse en composantes principales) et le HC (regroupement hiérarchique) ont clairement séparé les variétés locales des cultivars modernes. Les cultivars ont un rendement plus élevé, une croissance plus rapide, une meilleure résistance au gluten et une faible teneur en protéines par rapport aux variétés locales. Les indices de jaunes les plus élevés ont été observés dans les deux variétés améliorés «Grécale» et «Om Rabii».
Conclusion : En conséquence, certaines génotypes locales et améliorées, ensemble, forment une ressource intéressante de sous-unités de protéines de gluténine et d’allèles, intéressants, liés à la couleur jaune qui pourraient être utiles pour les activités de sélection et d’amélioration de la qualité du blé dur.
Mots clés : Blé dur, Diversité génétique, Force de gluten, Teneur en protéines, Indice de jaune

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INTRODUCTION

Durum wheat (*Triticum turgidum ssp. durum*) is a very important crop for the human diet, particularly in the Mediterranean basin where about 75% of the world's durum grain is produced [1]. Local varieties, which have been developed through a combination of natural and farmer selections [2] for some useful traits, can contribute significantly to the improvement of new cultivars and broaden their genetic base. Therefore, local varieties form a very valuable part of the genetic heritage because they cover most of the intra-specific genetic diversity of the species [3]. The activity of wheat breeders has been focused on selecting varieties with high production. Nevertheless, much remains to be done to improve the technical quality and study its genetic variation to determine the selection markers [4, 5]. Breeding programs depend on knowledge of the main characteristics, the system that controls their genetic heritage and environmental factors influencing their expression. However, the analysis of the variability of phenotypic and phenological characteristics and the study of their correlations with a particular characteristic is essential in order to develop breeding and selection programs for desirable traits [6]. Therefore, it is important to study the relationships between characteristics and understand the genetic association between the different parameters, as this can help improve the efficiency of selection.

A combination of SDS-sedimentation test, mixograph parameters, and protein content have been found to be good predictors of cooked pasta quality [7, 8]. Due to their reliability, these tests of quality are used in durum wheat improvement programs [5].

Little information is available regarding genetic variation in Tunisian durum wheat varieties. The main objective of this work was to study genetic diversity in landraces and cultivars of durum wheat using morphological and phenological traits and quality parameters. This information will be useful for improving techniques for sampling wheat genetic variation, which could increase the efficiency of germplasm conservation. The second objective was to analyze the relationships between traits, especially the technological quality parameters.

MATERIEL AND METHODS

1. Plant material

Twenty-eight varieties of durum wheat cultivated in farmlands in Tunisia were used in this study. The genotypes were sown and grown under rain fed conditions in the experimental station of the Biotechnology Canter of Borj-Cedria (Tunisia). All genotypes were sown in a block, during the seasons (2016-2017 and 2017-2018). Data for forty basic morphological, phenological and quality characteristics were used in this study (Table 1). The basic morphological data has been compiled from standardized codes of the International Union for the Protection of New Varieties of Plants (UPOV).

2. Quality and morphological assessment

2.1. Experiment 1

A sample of grain (50 g) was cleaned and used for the determination of quality. Protein content, on a 14% moisture basis, was estimated by near-infrared reflectance (NIR) analysis using a Technical Infralyzer 300. Gluten strength was estimated by the SDS-sedimentation (SDSS) test according to Dick and Quick [7]. The yellow colour index was examined from grain flour by means of a reflectance colorimeter (CR-300, Konica-MinoltaTM) equipped with a filter tri-stimulate system. The measured parameters of semolina colour index were b*(yellow colour), L*(brightness) and a*(red colour).

2.2. Experiment 2

Fifteen varieties from the two genetic pools of the first collection (Experiment 1) were sown for the second year, in a randomized complete block design with two replicates per genotype, during the season 2017-2018 in order to further study the technological quality and to better understand the relationships between morphological, phenological and quality traits. We used a Mixograph of 10 g whole wheat meal [10] in order to study pasta rheological properties (Table 2): mixing development time (MT), maximum peak height (MH), height at 3 min after peak (H3), and resistance to breakdown (BDR) (percentage difference between MH and H3).

3. Statistical analysis

The morphological variability was analyzed using Principal Component Analysis (PCA) and hierarchical clustering. The Pearson correlation coefficients (α = 0.05, standard PCA without rotation of axes) were calculated by using the software XLSTAT 7.5.2. Differences between mean values were analyzed using the Duncan method for multiple comparisons. Pearson correlation coefficients were calculated to determine the relationships between the mean values of the test results.

Table 1: Pedigrees and origins of varieties [9]

Landraces	Pedigree	Origin / Year
Agili	Landrace	Tunisia, 1925
Aouadhi	Landrace	North Africa
Aouija	Landrace	North Tunisia, 1909
Arbi	Landrace	Tunisia
Baidha	Landrace	Tunisia
Bidi	Landrace	North Africa, 1908
Biskri	Landrace	Algeria, 1909
Chili	Landrace	France, 1932
Derbessi	Landrace	Tunisia, 1909
Frigui	Landrace	Tunisia
Hmira	Landrace	Tunisia, 1893
Jenah-Khotifa	Landrace	Tunisia, 1915
Mahmoudi	Landrace	Tunisia, 1893
Ouard Bled	Landrace	Tunisia
Richi	Landrace	Tunisia, 1908/1909
Sbèi	Landrace	Tunisia, 1908
Souri	Landrace	Tunisia, 1915
Swabaa-Algia	Landrace	Tunisia, 1909
Grécale	S2/WB881//Plinio/F22	Italy, 2004
Inrat69	Mahmoudi/Kyperounda	Tunisia, 1969
Iride	Altar 84/Ionio	Italy, 1996
Karim	Jori“S”/Anhinga“S”//Flamingo“S”	CIMMYT-Mexico, 1980
Khiar	Chen/Altar 84	CIMMYT-Mexico, 1992
Maéstrale	Iride/Svevo	Italy, 2004
Nasr	GoVZ512/Cit//Ruff/Fg/3/Pin/Gre//Trob	ICARDA-Syria, 2002
Om Rabii	Jori C69/ Hau	ICARDA-Syria, 1996
Razzek	Dmx69-331/Karim	INRAT-Tunisia, 1987
Saragolla	Iride/LineaPSB 0114	Italy, 2004
Grécale	S2/WB881//Plinio/F22	Italy, 2004

Table 2: Morphological, phenological and quality characteristics used to describe wheat varieties

Morphologic traits				Phenological and quality traits
Stem and Leaf	spike	Lower glume	Grain	
Growth habit	Glaucosity	Shape (spikelet in mid-third of ear)	Shape	Heading period
Frequency of Plants with Recurved Flag Leaves	Distribution of awns	Shape of shoulder	Length of brush hair in dorsal view	Flowering period
Glaucosity of sheath	Length in relation to ear	Shoulder width	Coloration with phenol (4h)	Heading time

Flag leaf: glaucosity of blade (lower side)	Awn: colour	Length of beak	Coloration with phenol (72h)	Vegetative period
Anthocyanin coloration	Ear: hairiness of margin of first rachis segment	Shape of beak		Grain filling period
Flag leaf area	Ear: colour (at maturity)	Hairiness on external surface		Protein content %
Glaucosity of neck	Ear: shape in profile	Anthocyanin coloration of flowers		SDS-sedimentation (mm)
Straw: pith in cross section	Ear: density			Yellow berry
Twist of neck of the ear	Awns layout			Semolina: yellow index
Height (stem, ear and awns)	Spike length without beard			

RESULTS

1. *Morphological diversity*

The majority of the varieties have white ears (64%), 25% have lightly colored ears and only 11% have a strongly colored ear. Most varieties (89.3%) have a long beard and 50% have a compact ear. Sapegin and Baransky [11] noted that the varieties with compact ear have shown resistance to leaf rust. This characteristic is controlled by two recessive genes, sc1 and sc2 [12].

The dendrogram of similarity by Pearson correlation coefficient clearly separates the modern cultivars from landraces. The hierarchical clustering (HC) of the 28 varieties, as defined by the matrix of the forty characteristics, is presented in Figure 1. Analysis of the similarity dendrogram indicates that the cleavage at 24% similarity defines two main groups, I and II, containing 18 and 9 varieties, respectively. One variety (Jenah-Khotifa) remains outside the groups because it is morphologically very different from all the others (Fig. 1).

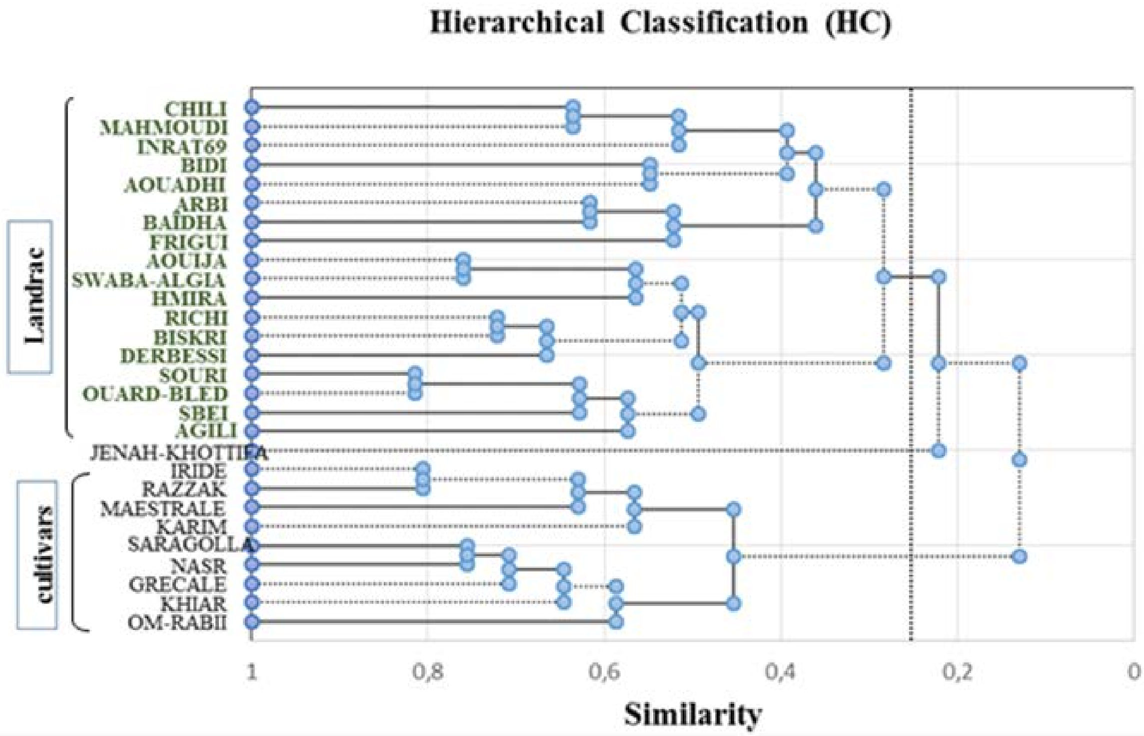


Figure 1 : Hierarchical classification of durum wheat varieties (Similarity Dendrogram)

The first two PCA axes accounted for 34.1% of the total variability expressed by morphological, phenological and quality traits. The first component accounts for 25.4% of the total variation. It is determined mainly by phenological traits, vegetative characteristics (plant length and flag leaf area) and some quality parameters. The second, which accounts for 8.74% of the total variation, is strongly correlated to ear shape and colour. The correlated variability of genotypes shown by axis 1 reveals two groups (Fig. 2). The modern cultivars were separated from the old cultivars, forming two distinct groups. The modern cultivars are more productive, quicker growing and have lower grain protein content than the landraces.

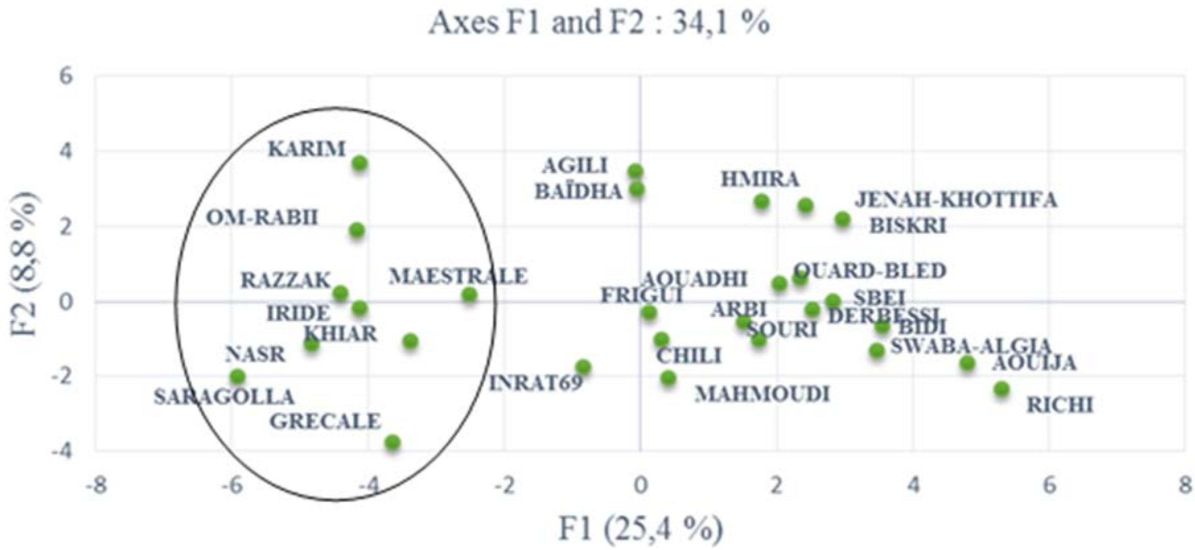
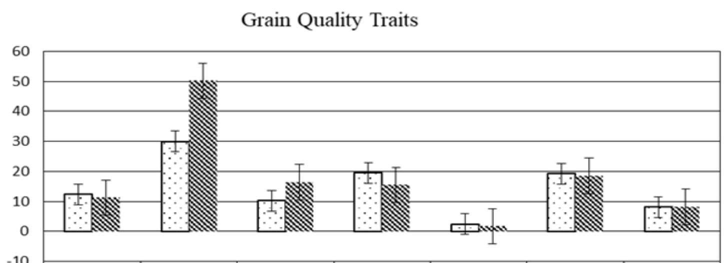


Figure 2 : Principal component analysis (PCA) of morphological, phenological and end-use quality data to classify twenty eight Tunisian landraces and ameliorate cultivars of durum wheat.

2. *Technological Quality*

2.1. Yellow colour

Colorimetric determinations of semolina are often used by breeders as tools to select varieties with a strong yellow colour [13]. The semolina colour parameter b* (indices of yellow colour index) ranged from 13.9 for 'Karim' to 20.9 for 'Grécale', with an average of 18.8. Although the average yellow index (b*) in landraces was slightly larger than that of the improved varieties, we note that the two highest b* values were obtained for the modern varieties Grécale and Om rabii (Fig. 3). No significant correlations were detected between the colour index and others characteristics studied, although the colorimetric values (a, b*, L) had significant correlations between them. The brightness index (L) had negative correlations with (b*) and brown index (a) of -0.75 and -0.66, respectively, and there was a positive correlation between a and b* of 0.33. The yellow pigment content (YPC) in grains and the yellow colour of milling products are considered as complex and heritable traits controlled by several genomic regions [14].



	Protein (%)	SDSS (mm)	MT (x10s)	BDR	a*	b*	L*
	Gluten				Color		
Landraces	12.4	30	10.25	19.5	2.4	19.2	8.1
Cultivars	11.3	50.2	16.37	15.5	1.7	18.5	8.2

Figure 3 : Means values of end-use quality tests of durum wheat landraces and cultivars. SDSS: Sodium Dodecyl Sulphate Sedimentation, MT: Mixing Time, BDR: Breakdown Resistance, b*: yellow colour, L*: brightness, a*: red colour.

2.2. Protein content

Landraces had higher protein contents than the high yielding cultivars, same results were obtained by Rodriguez-Quijano *et al*. [15]. Overall mean protein content for landraces and high yielding cultivars were 12.4% and 11.3%, respectively (Fig. 3). Daaloul *et al*. [16] also obtained the same result with some Tunisian cultivars. However, the range of protein variation is slightly differed, all cultivars were grown under the same conditions. These results confirm the limited genotypic effect on protein content. In fact, the protein content is highly influenced by environmental conditions and fertilizer (N) [17]. Landraces have a higher vegetative biomass than high yielding varieties (semi-dwarf). Therefore, Flag leaf area and plant length were positively correlated with grain protein content (Fig. 4).

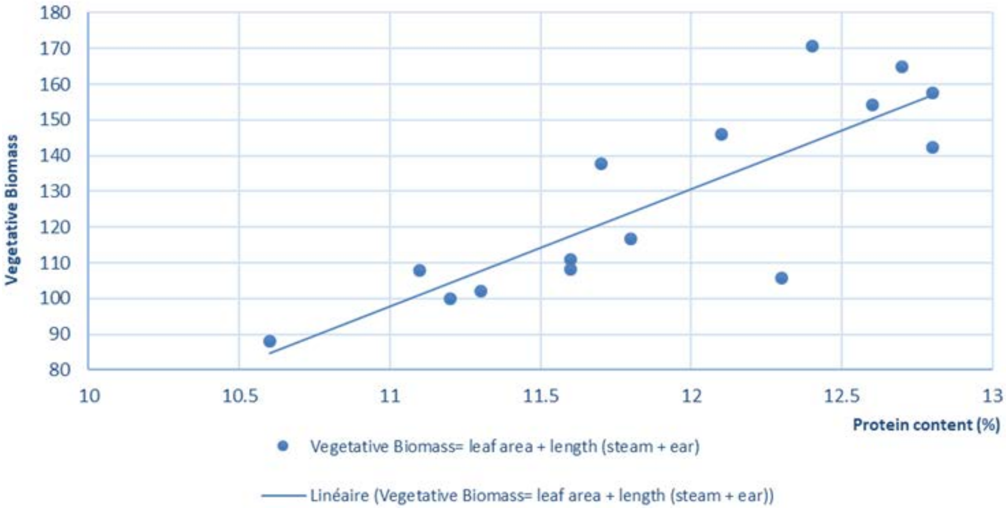


Figure 4 : Correlation between protein content (%) and vegetative biomass (Flag leaf area (cm^2) and plant length (cm))

2.3. Gluten strength

Gluten strength of durum wheat is measured by SDS-sedimentation (SDSS) volume and mixograph parameters (Mixing Time (MT) and Breakdown Resistance (BDR)). A strong positive correlation between MT SDSS and was observed (0.69). Overall means of SDS-sedimentation for landraces and high-yielding cultivars and they were 30.0 mm and 50.2 mm, respectively. For the landraces and high-yielding varieties, respectively, 'Baïdha' and 'Saragolla' had the highest values of SDSS and MT and the lowest values of BDR. Mean values of MT were 102.5 s and 163.7 s for landraces and high-yielding cultivars, respectively. Modern varieties had better mixograph profiles and SDSS volumes than the landraces (Fig. 3). This genotypic variation in gluten strength is probably due to the endosperm storage protein allelic composition [18].

DISCUSSION

The analysis of genetic similarity based on morphological, phenological and quality characteristics, showed that modern cultivars were genetically very similar to each another and very different to the landraces. Some correlations between technological quality parameters and others traits were identified. Despite the fact that most modern cultivars are related by pedigree to the landraces, several agro-morphological parameters are different from those observed in the landraces. Old varieties are taller, have lower yield, are slower growing, have less gluten strength and contain more grain protein than modern cultivars.

Simpson *et al*. [19] reported that, for wheat at mid grain filling, leaves (i.e. leaf laminae and sheaths) contributed 40%, glumes 23%, stems 23% and roots 16% of the daily accumulation of grain N. In wheat, nitrogen (N) salvaged from the leaves accounts for up to 90% of the total grain N content [20]. Nitrogen (N) supply increases flag leaf area by increasing cell number.

The accumulation of grain protein depends on the accumulation and partitioning of reduced N accumulated during the vegetative growth stage and the relative contributions of nitrate assimilation and N redistribution during grain development for both low and high nitrogen supply [21]. However, the nitrogen accumulation ability of landraces is much higher than that of the high-yielding varieties. The high N accumulation of landraces was closely related to their higher biomass. The higher growth potential, and hence, the greater ability for N accumulation in landraces may be a valuable trait in breeding programs aiming to further improve N use efficiency [22].
Landraces retain a wide genetic diversity of morphological and quality characteristics that have been mostly lost in modern varieties. They are a natural reservoir of alleles that are could be used to enhance and diversify gluten characteristics in durum wheat breeding programs. Modern cultivars had greater yields, lower protein contents and higher gluten strength than the landraces. The higher growth potential and hence the greater N accumulation ability of landraces may be a valuable trait in breeding programs aiming to further improve N use efficiency and, therefore, increase the protein content. Furthermore, 'Grécale' and 'Om rabii' can be used by breeders to improve the yellow colour index and "Saragolla" and "Iride" can be used to improve gluten strength.

CONCLUSION

Landraces retain a wide genetic diversity of morphological and quality characteristics that have been mostly lost in modern varieties. They are a natural reservoir of alleles, which could be used to diversify and enhance gluten characteristics in durum wheat breeding programs. Modern cultivars had greater yields, lower protein contents, and higher gluten strength than the landraces. The higher growth potential and hence the greater N accumulation ability of landraces may be a valuable trait in breeding programs aiming to further improve N use efficiency and, therefore, increase the protein content. Furthermore, the varieties 'Grécale','Om rabii',"Saragolla"and "Iride" can be used by breeders to improve the yellow colour index and gluten strength. The national gene bank in Tunisia contains a very large collection of indigenous durum wheat genotypes. A more in-depth qualitative, agro-morphological and proteomic study of this larger collection may reveal interesting results on other genotypes that may contribute in the wheat improvement programs in Tunisia.

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