Studies on some grain quality traits in durum wheat grown in Mediterranean environments

Nachit M., Baum M., Impiglia A., Ketata H.

in

Di Fonzo N. (ed.), Kaan F. (ed.), Nachit M. (ed.).
Durum wheat quality in the Mediterranean region

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 22

1995
pages 181-187

Studies on some grain quality traits in durum wheat grown in Mediterranean environments

M.M. NACHIT
M. BAUM
A. IMPIGLIA
H. KETATA
CEREAL PROGRAM
CIMMYT/ICARDA
ALEPPO
SYRIA

SUMMARY - The joint durum wheat (*Triticum turgidum* L var. *durum*) breeding program of the International Maize and Wheat Improvement Center (CIMMYT) and the International Center for Agricultural Research in the Dry Areas (ICARDA) employs extensive multilocation trials in the Mediterranean dryland region for grain quality testing. The multilocation trials showed significant genotype-environment (GE) interactions for grain quality parameters. High values of the sedimentation test were associated with the presence of γ-45 gliadin, while low values with the presence of γ-42 gliadin. Further, 68.9% of the Mediterranean durum landraces possessed γ-45 gliadin, 11.1% possessed γ-42 gliadin, and 20% of the landraces showed the presence of both gliadins. The F_2 segregation for Jennah Khetifa/Cham1 cross was different from expected codominance ratio 1:2:1 showing a slight dominance of γ-45. In contrast, the Hedba3/Cham1 cross fitted the expected segregation ratio 1:2:1. Under irrigated conditions high values for broad sense heritability were recorded for kernel weight, test weight, carotene content, sedimentation test, and sedimentation index; medium values for protein content, and vitreousness; and lowest values for farinograph stability and farinograph mixing tolerance. On the other hand, under dryland conditions heritability values were high for most grain quality traits. Under both irrigated and dry conditions carotene content, SDS test, SDS index, kernel weight, and test weight were influenced more by genotypes than by environments. In contrast, protein content, vitreousness, farinogragh stability, and mixing tolerance were influenced more by environment or GE interactions.

Key words: Multilocation trials, genotype-environment interactions, sedimentation test, γ-45 gliadin, γ-42 gliadin, dominance, codominance, heritability, farinograph, carotenoid content.

RESUME - *"Etudes sur certains caractères de qualité du grain chez le blé dur planté en milieu méditerranéen". Le programme conjoint de sélection du blé dur (Triticum turgidum L. var. durum) du Centre International d'Amélioration du Maïs et du Blé (CIMMYT) et du Centre International de la Recherche Agricole dans les Zones Sèches (ICARDA) met en place des essais extensifs multilocaux dans les régions sèches méditerranéennes pour tester la qualité du grain. Les essais multilocaux ont montré des interactions génotype-environnement (GE) significatives pour les paramètres de la qualité du grain. Les hautes valeurs du test de sédimentation ont été associées à la présence de gliadine λ-45, tandis que les faibles valeurs le furent à la présence de gliadine λ-42. En outre, 68,9% des espèces autochtones méditerranéennes de blé dur possédaient la gliadine λ-45, 11,1% possédaient la gliadine λ-42, et 20% des espèces autochtones montraient la présence des deux gliadines. La ségrégation F_2 pour le croisement Jennah Khetifa/Cham1 a été différente concernant le ratio de co-dominance espéré 1:2:1, montrant une légère dominance de λ-45. Par contre, le croisement Hedba3/Cham1 a répondu au ratio de ségrégation espéré 1:2:1. En conditions irriguées, de hautes valeurs pour l'héritabilité au sens large ont été enregistrées pour le poids du grain, le poids moyen des grains, la teneur en carotène, le test de sédimentation, et l'index de sédimentation; des valeurs moyennes ont été montrées en ce qui concerne la teneur en protéine, et la vitrosité; et des valeurs très faibles ont été trouvées pour la stabilité et la tolérance au mélange mesurées au farinographe. D'autre part, en conditions arides, les valeurs de l'héritabilité furent hautes pour la plupart des caractères de qualité du grain. En conditions aussi bien irriguées que sèches, la teneur en carotène, le test SDS, l'index SDS, le poids du grain, et le poids moyen des grains ont été influencés plus par les génotypes que par les milieux. Par contre, la teneur en protéine, la vitrosité, la stabilité au farinographe, et la tolérance au mélange ont été plus influencées par le milieu ou les interactions génotype-milieu.*

Mots-clés : *Essais multilocaux, interactions génotype-milieu, test de sédimentation, gliadine λ-45, gliadine λ-42, dominance, codominance, héritabilité, farinographe, teneur en caroténoïdes.*

Introduction

Development of high yielding and stable durum germplasm with abiotic and biotic stress resistance, and good industrial and nutritional quality, is the main objective of the CIMMYT/ICARDA joint Durum Wheat Breeding Program in the Mediterranean dryland. Evaluation, identification, and development of appropriate germplasm are conducted within dryland durum wheat research programs in Western Asia, Northern Africa and Southern Europe (Nachit *et al.*, 1988).

Durum wheat (*Triticum turgidum* L. var. *durum*) is grown throughout the Mediterranean region. In 1991, durum production in this region was about 20 million metric tons (International Wheat Council, 1992). The majority of the Mediterranean durum wheat is grown in Turkey, Syria, Tunisia, Algeria, Morocco, Spain, France, Italy, and Greece. Durum is used for food in various ways throughout the world, but its primary use in the Mediterranean is for pasta, burghul, couscous, and bread.

Durum wheat normally has an amber vitreous kernel that produces a yellow milling product. Commercial durum milling differs considerably from flour milling, because the desired end-product is semolina, not flour. Colour is of prime importance in semolina, since the consumer generally expects yellow pasta products. The source of colour in durum semolina is the xanthophylls, especially lutein.

Selection for stronger gluten in durums is related to sufficient firmness of good cooked semolina product (pasta, couscous, and burghul). Thus good quality pasta should have the correct firmness after cooking, and it should maintain it after some overcooking. Significant associations were obtained between sedimentation values and mixogram scores. The combined wheat protein and micro-sedimentation score were related to cooked pasta firmness. The presence of gliadin band 45 and the absence of band 42 is associated with strong gluten (Damidaux *et al.*, 1978). An interesting relationship exists between γ-42 and 45 gliadins, mixogram and sedimentation tests, and glume colour. Buff-coloured glumes were found to be associated with weak gluten and γ-42 gliadin, while white ones with strong gluten and γ-45 gliadin (Leisle *et al.*, 1981). The use of these relationships in selection in the early generations has improved the grain quality of durums in our breeding program. In semolina products made from durum wheat include the following traits: (i) yellow colour; (ii) protein quality and quantity to provide strength, proper firmness, and stability to the cooked product; (iii) low speck count.

Protein content in durum wheat is controlled by fertilizer, environment, and heredity. Semolina protein content generally is about one percent less than whole wheat protein. Cooking quality of semolina products is related to both quantity and quality of the proteins present in the endosperm. A moderately high protein (12% or more) is required to produce an acceptable product. Protein content is a heritable trait, however it varies with the environments. Gliadin composition, as determined by electrophoresis and chromatography, is a stable genotypic characteristic that is independent of environmental factors (Lee and Ronalds, 1967; Wrigley, 1970). This finding has been confirmed by others who have used gliadin electrophoresis for cultivar identification (Ellis, 1971; Wrigley and Shephard, 1974; Autran and Bourdet, 1975).

The objectives of this study were to:

(i) Analyze the frequency of the γ-gliadins 45 and 42 in Mediterranean durum landraces and their inheritance in segregating generations.

(ii) Estimate the heritability of traits used in predicting grain quality.

(iii) Determine the effect of genotype x environment (GE) interactions on grain quality traits in different environments.

Materials and methods

One hundred-seventy-one Mediterranean durum landraces were studied for grain quality traits and the presence (or absence) of specific electrophoretic bands of γ-gliadins. The quality traits were protein content (%), thousand kernels weight (g), vitreousness (%), carotene content (ppm), test weight (kg/hl), sedimentation test (SDS, ml), and SDS index (SDS test/ protein content), farinograph stability (minutes), and farinograph mixing tolerance (Brabender unit).

Two crosses were made to study the segregation of γ-45 and γ-42 gliadins in the F2 generation. The first cross involved the Tunisian durum landrace Jennah Khetifa (high gluten strength, γ-45-gliadin) and Cham1 (weak gluten, γ-42-gliadin). The parents of the second cross were an Algerian landrace Hedba3 (high gluten strength, γ-45-gliadin) and Cham1.

In another study, eleven durum wheat genotypes were grown in two contrasting agro-ecological environments in Syria (Table 1). The first environment consisted of 5 sites in the irrigated area; and the second one of 8 sites. A randomized complete block design with two replications was used in each site. Plots consisted of six rows 10 m long sown 0.25 m apart with a sowing rate of 120 kg ha^{-1}. The central four rows of each plot were harvested. The seed of each replication was analyzed for grain quality traits. Analyses of variance were performed to study the effects of genotypes, environments, and GE interaction.

Table 1. Durum wheat genotypes and sites used (Syria, 1992)

Genotypes	Sites	
	Irrigated	Dryland
Haurani	Latmne	Izraa station
D-6102	Deirzor	Izraa farm
D-H312	Jumaa	Tel Hadya
Belikh2	Tebe	Tel Dora
Daraa	Raqqa	Souran
Daki		Sarakeb
D-H300		Abtein
Omrabi17		Hasese
D-6056		
Korifla		
Haucan		

Results

Association of γ-gliadins with grain quality traits in Mediterranean durum landraces

Mediterranean durum germplasm was analyzed for the presence or absence of γ-45-gliadin and γ-42-gliadin and the relationship of these gliadins with grain quality traits. The results in Table 2 show that 68.9% of the landraces displayed γ-45 gliadin, 11.1% γ-42, and 20% both gliadin bands. Further, Table 3 shows that high values of sedimentation (SDS) test and SDS index were associated with the presence of γ-45 gliadin, while low values related to the presence of γ-42. For all other quality traits no significant differences were revealed between the γ-45 and γ-42 gliadin populations.

Table 2. Frequency of γ-45 and γ-42 gliadins in Mediterranean durum landraces (n=171)

Gliadins	Frequency (%)
γ-45 gliadin only (n=117)	68.9
γ-42 gliadin only (n=19)	11.1
γ-45 and 42 gliadins (n=35)	20.0

Table 3. Relationship of γ-gliadins with some grain quality traits in Mediterranean durum germplasm (n=136)

Traits	γ-45 gliadin (n=117)	γ-42 gliadin (n=19)	Difference
Protein (%)	12.5	12.1	0.4
Vitreousness (%)	94.4	95.3	-1.1
Carotene score (ppm)	5.5	5.2	0.3
1000 kernel weight (g)	47.0	47.0	0.0
SDS test (ml)	25.7	18.5	7.2***
SDS index (ml/protein %)	2.4	1.8	0.6*

*Significant at the probability 0.05
***Significant at the probability 0.001

γ-45 and γ-42 gliadins F_2-segregation ratio

The two γ-gliadin bands (γ-42, γ-45) segregated in the F_2 generation for each of the two crosses as shown in Table 4. The observed data were tested for their fit to the expected ratio 1:2:1 by means of a χ^2-test. For the Jennah Khetifa/Cham1 cross, the F_2 segregation was different from the expected segregation ratio of codominance 1:2:1 with a slight dominance of γ-45 gliadin. In contrast, for the F_2 generation of Hedba3/Cham1 cross segregated following a ratio 1:2:1.

Table 4. F2-segregation of γ-45 and γ-42 gliadins

Cross	F_2 offspring			χ^2 values
	iP_1	H	iP_2	1:2:1
Jennah Khetifa/Cham1 cross (n=100)				
γ-45/γ-42	23	64	13	9.84*
Hedba3/Cham1 cross (n=80)				
γ-45/γ-42	19	38	23	0.60 ns

iP_1: Identical with P_1 (γ-45-gliadin band)
H: F_2 plants (possessing both bands)
iP_2: Identical with P_2 (γ-42-gliadin band)

Means, range, and heritability of grain quality traits in dry and irrigated conditions

Table 5 shows the means and ranges for the different grain quality traits under both irrigated and dry conditions. Vitreousness was the most affected trait under irrigated while kernel weight under dry conditions.

Under irrigated conditions, values for broad sense heritability (Table 6) were high for kernel weight, test weight, carotene content, sedimentation test, and sedimentation index; medium for protein content and vitreousness; and low for farinograph stability and farinograph mixing tolerance. Under dryland conditions high heritability values were recorded for most of the traits.

Table 5. Quality traits of durum wheat grown in irrigated and dry areas in Syria, 1992

Genotype	Growing conditions			
	Irrigated		Dryland	
Protein content (%)	10.9	(10.3- 11.6)	12.4	(11.9- 13.4)
Vitreousness (%)	72.7	(61.5- 86.7)	89.9	(77.4- 99.0)
Carotene content (ppm)	4.8	(3.9- 5.9)	5.2	(3.9- 6.3)
1000 kernel weight (g)	44.5	(38.2- 50.1)	38.3	(34.9- 44.8)
Test weight (kg/hl)	79.4	(74.4- 82.5)	78.9	(75.1- 81.1)
SDS test (ml)	26.6	(18.0- 29.2)	25.5	(17.4- 32.7)
SDS index (ml/protein %)	2.0	(1.4- 2.2)	2.2	(1.7- 2.8)
Farinograph stability (min)	1.9	(1.7- 2.1)	1.8	(1.2- 3.5)
Farinograph mixing tolerance (Brabender unit)	138.7	(126.5-147.0)	132.2	(94.7-165.0)

Table 6. Broad sense heritability values for durum grain quality traits

Trait	Growing conditions	
	Irrigated	Dryland
Protein content (%)	.49	.72
1000 kernel weight (g)	.97	.94
Test weight (kg/hl)	.97	.94
Vitreousness (%)	.59	.79
Carotene content (ppm)	.97	.90
SDS test (ml)	.93	.94
SDS index (ml/protein %)	.93	.96
Farinograph stability (min)	.00	.90
Farinograph mixing tolerance (Brabender unit)	.20	.93

Effects of GE interactions on grain quality

The grain quality traits were analyzed for their GE interactions in irrigated and dry conditions (Tables 7 and 8). The results showed that in both environments protein content and vitreousness were more influenced by environments than by genotypes or GE interactions, whereas carotene content, kernel weight, test weight, SDS, and SDS index were more influenced by genotypes than by environments or GE interactions. In contrast, farinogragh stability and farinograph mixing tolerance showed larger effects of environment and GE interactions than the effects of genotype; however, in the dry environment the effects of genotypes were larger (Table 8).

Discussion

The results of gliadins frequency study showed the preponderance of the γ-45 gliadin in the Mediterranean durum landraces and confirm the good quality of this germplasm and the usefulness of the γ-45 gliadin band to characterize quality in durum wheat. As for the presence of both γ-gliadins in some populations, this may be explained by the fact that the landrace populations are heterogenous and contain a mixture of genotypes that can carry different gliadins.

Table 7. Effects of genotype (G), environment (E), and GE interaction on durum grain quality traits under Mediterranean irrigated conditions (data represent percent sum of squares from respective ANOVA tables)

Trait	G	E	GE
Protein content (%)	5.8	76.1	11.7
Vitreousness (%)	14.1	58.1	23.0
Carotene content (ppm)	75.7	5.0	10.4
SDS test (ml)	48.1	27.5	12.7
SDS index (ml/protein %)	72.5	2.6	20.5
Kernel weight (g)	78.3	13.0	8.1
Test weight (kg/hl)	80.3	5.7	11.0
Farinograph stability (min)	8.0	35.7	47.6
Farinograph mixing tolerance (Brabender unit)	12.4	42.9	39.9

Table 8. Effects of genotype (G), environment (E), and GE interaction on durum grain quality under dryland conditions (data represent percent sum of squares from respective ANOVA tables)

Trait	G	E	GE
Protein content (%)	5.1	84.1	10.0
Vitreousness (%)	11.4	70.0	16.9
Carotene content (ppm)	41.0	26.8	27.9
SDS test (ml)	58.6	27.1	11.9
SDS index (ml/protein %)	51.3	28.3	13.2
Kernel weight (g)	49.6	27.8	20.4
Test weight (kg/hl)	52.8	14.0	23.5
Farinograph stability (min)	32.9	23.2	42.6
Farinograph mixing tolerance (Brabender unit)	24.6	12.9	59.9

The strong association of γ-45 gliadin with sedimentation test and sedimentation index corroborate earlier work of Damidaux and Feillet (1978) and Payne *et al.* (1984). The γ-45 gliadin was also found to be highly associated with white glumes in durum wheat. Studies of Joppa *et al.* (1983) have shown that the γ-45 and 42 gliadins are located on the short arm of chromosome 1B and are 7.83-10.32 crossover units from the gene for glume colour (Leisle *et al.*, 1985). In field selection, white glume trait is used as a marker for strong gluten.

Recent studies have shown that the γ-45 gliadin is just a biochemical marker, the functional gluten strength genes are glutenins of low molecular weight (LMW); LMW exists in two forms LMW2 and LMW1. The LMW2 produces strong gluten and LMW1 produces weak gluten. Two recombinants were found to possess either γ-42 gliadin and LMW2 with strong gluten (Margiotta *et al.*, 1987) or γ-45 gliadin with LMW1 with weak gluten (Nachit, 1992).

Further, the results of the crosses in this study showed slightly different segregation ratios, one that fit the segregation ratio 1:2:1 and the other deviating slightly from it, with a slight dominance for γ-45 gliadin. The later result conflicts with findings by Du Cros and Hare (1983) where γ-42 gliadin was found to have a greater degree of dominance than γ-45 gliadin. This may reflect the genetic differences of the parents used in the crosses. The two gliadins are the product of two co-dominant alleles of the same gene (Damidaux *et al.*, 1980; Du Cros *et al.*, 1982).

The results of heritability suggest that grain quality traits were slightly better expressed under dry than under irrigated conditions. The large difference between irrigated and dry conditions for values of farinograph stability and farinograph mixing tolerance demonstrate the negative effect of increased moisture on grain quality in durum wheat.

Similarly, most of the traits used as simple screening tools in the breeding program showed strong genotypic effects with the exception of protein content and vitreousness. The later ones are more influenced by environmental effects. The results of heritability and of GE interactions were compatible. Consequently, selection for improved grain quality in durums in early generations should be feasible if proper selection criteria are used.

The Mediterranean durum landraces possess predominantly the γ-45 gliadin. In durum wheat, good grain quality is associated with the presence of this gliadin. Negative effects of irrigation were also shown on some grain quality traits. More studies are required to analyze further traits for better assessment of grain quality of durums grown under different growing conditions.

References

Autran, J.C. and Bourdet, A. (1975). *Ann. Amelior. Plantes*, 25: 277-301.

Damidaux, R. and Feillet, P. (1978). *Ann. Technol. Agric.*, 28: 799-808.

Damidaux, R., Autran, J.C., Grignac, P. and Feillet, P. (1978). *Compte Rendu Acad. Sci. Paris*, Sér. D, 287: 701-704.

Damidaux, R., Autran, J.C., Grignac, P. and Feillet, P. (1980). *Compte Rendu Acad. Sci. Paris*, Sér. D, 291: 585-588.

Du Cros, D.L. and Hare, R.A. (1983). In: *Proc. 6th Int. Wheat Genet. Symp.*, Kyoto, Japan, pp. 857-861.

Du Cros, D., Wrigley, C.W. and Hare, H.A. (1982). *J. Agric. Res.*, 33: 429-442.

Ellis, R.P. (1971). *J. Nat. Inst. Agric. Bot.*, 12: 223-235.

International Wheat Council (1992).

Joppa, L.R., Khan, K. and Williams, N.D. (1983). *Theor. Appl. Genet.*, 64: 289-293.

Lee, J.W. and Ronalds, J.A. (1967). *Nature*, 213: 844.

Leisle, D., Kosmolak, F.G. and Kovacs, M. (1981). *Can. J. Plant Sci.*, 61: 149-151.

Leisle, D., Kovacs, M. and Howes, N. (1985). *Can. J. Genet. Cytol.*, 27: 674-677.

Margiotta, B., Colaprico, G. and Lafiandra, D. (1987). In: *Proc. 3rd Int. Workshop on Gluten Proteins.* Budapest, Hungary, pp. 314-330.

Nachit, M.M. (1992). ICARDA-040/1300/May 1993. Aleppo, Syria, pp. 74-94.

Nachit, M.M., Ketata, H. and Yau, S.K. (1988). In: *Proc. 3th Int. Symp. on Durum Wheat.* Foggia, Italy, pp. 297-304.

Payne, I.P., Jackson, E.A. and Holt, L.M. (1984). *J. Cereal Sci.*, 2: 73-81.

Wrigley, C.W. (1970). *Biochem. Gen.*, 4: 509-516.

Wrigley, C.W. and Shephard, K.W. (1974). *Ann. N.Y. Acad. Sci.*, 209: 154-162.