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Biodiversity among Mediterranean durum wheat landraces for the improvement of quality and adaptation[1]

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SUMMARY – Mediterranean durum wheat landraces are expected to hold the largest genetic variability in the world for this species. Sixty three landraces from 12 Mediterranean countries were used in a study of the genetic diversity existing between genotypes of different geographical origin within the region. The allelic composition for high and low molecular weight glutenin subunits revealed a relatively high genetic diversity, with 42 haplotypes, 20 allele combinations at the *HMW-GS* loci, and 18 at the *LMW-GS*. Quality profiles grouped the landraces in two pools, being the South-West Asian landraces different from the ones of other Mediterranean areas. Genetic variability in the population was assessed by means of 8 AFLPs primer combinations and 20 SSR loci. Cluster analysis based on Roger's distance and multi-dimensional scaling suggest landraces from the North and the South of the Mediterranean basin having contrasting genetic structures. Results of three field experiments conducted in Lleida in rainfed environments, where yield ranged from 1.5 to 3.5 t/ha, showed that landraces from the North and the South of the Mediterranean basin had different biomass production and allocation, as well as contrasting yield formation strategies and water use efficiency. Our results fit in the framework of the climatic conditions prevalent in both regions, and may be useful to design breeding strategies to improve the adaptation of durum wheat.

Introduction

Durum wheat (*Triticum turgidum* L. convar. *durum* (Desf.) Mackey ssp durum (Desf.) Husn) is mostly grown within the Mediterranean region in rainfed areas, under stressful and variable environmental conditions. Wheat cultivation is believed to have started in the Fertile Crescent around 12,000 B.P. The spread of einkorn can be traced along the northwestern route via the Balkan Peninsula and Greece (8,000 B.P.), reaching the Iberian Peninsula and Algeria from Italy (reviewed in MacKey, 2005). Mediterranean durum landraces, which are adapted to the environmental conditions and agronomic practices of their regions of origin, have been found to have desirable traits lacking in improved cultivars. Moreover, they are expected to hold the largest genetic variability in the world for this species. Thus, the characterization of Mediterranean durum wheat germplasm becomes critical to the optimal improvement of quality and productivity. This study was conducted on a set of 63 landraces from the Mediterranean basin, focusing on germplasm from the Iberian Peninsula, with the following objectives: (i) to evaluate the geographical pattern of high and low-molecular weight glutenin subunits; (ii) to evaluate the genetic diversity of the collection; and (iii) to assess the changes occurred on yield formation and biomass partition and allocation as response to human and natural selection.

Material and methods

A collection of 63 durum wheat landraces, 26 from the Iberian Peninsula and 37 from other Mediterranean countries were analyzed for high and low molecular weight glutenin alleles using SDS-PAGE (for germplasm description see Moragues *et al.,* 2006c). The cultivars were grouped *a priori* according to their geographical region of origin in four regions: SW Europe (Iberian Peninsula), S Europe, N Africa and SW Asia. Genetic diversity was evaluated through the D index (Weir, 1996).

Genetic relationships and variability were evaluated using eight primer combinations for AFLPs, and twenty SSR loci. The Jaccards's (Jaccard, 1908) and shared band similarity (Lynch, 1990) coefficients were calculated on AFLP and SSR matrices respectively. Rogers' distance (Rogers,

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1972) were calculated on the allele frequency matrix. Cluster analysis was performed using the UPGMA method (Sneath and Sokal, 1973). The Mantel test (Mantel, 1967) and non-metric multidimensional scaling (MDS, Krustal, 1964) were applied on the similarity matrices. The statistical program NTSys-pc ver. 2.11j (Rohlf, 2003) was used in these calculations.

The 52 landraces that were properly classified by AFLPs and SSR were sown on three field experiments during 2001-2002 crop season in three sites of the province of Lleida (NE Spain) with total rainfall during growth cycle of 186, 281 and 371 mm. Description of the experimental procedures and the methodology used for yield components determination may be found in Moragues et al. (2006a). Crop dry weight (CDW) and leaf area index (LAI) were calculated as described in Moragues et al. (2006b). Combined analyses of variance were performed by using SAS (SAS Institute Inc., 2000) procedures and programs.

Results and discussion

Large variability in glutenin composition was found among the 63 durum wheat Mediterranean landraces analysed by SDS-PAGE. The number of subunits observed ranged from 5 to 11 (Table 1). Fourty-two different haplotypes were detected, 20 of them corresponding to HMW glutenin and 18 to LMW glutenin (Moragues *et al*., 2006c).

Table 1. Number of alleles present at high (HMW) and low molecular weight (LMW) loci in 63 durum wheat landraces from the Mediterranean Basin (from Moragues *et al*., 2006c)

Loci	Number of alleles
HMW glutenin	
Glu-A1	3
Glu-B1	14
Combination	20
LMW glutenin:	
Glu-A3	7
Glu-B3	8
Glu-B2	2
Combination	18
LMW model	5
Combination of HMW and LMW alleles	42

Global genetic diversity index was relatively high (0.67); it ranged from 0.33 to 0.66 (Moragues *et al.,* 2006c). Cluster analysis based on the allele frequency in each region showed that SW Asian landraces grouped far apart from the other regions considered in this study (SW Europe, N Africa and SE Europe) (Moragues *et al*., 2006c). This result matches the accepted theory of wheat cultivation spreading across the Mediterranean basin.

The average polymorphism information content (PIC) values were 0.24 and 0.70 for AFLP and microsatellites respectively (Moragues *et al*., in press). Cluster analysis based on allele/band frequencies for each area of origin carried out for SSR and AFLP combined data showed that landraces from SW Europe were closely related to those from N Africa, whereas landraces from S Europe and SW Asia tended to cluster together (Fig. 1). Non-metric multi-dimensional scaling clustered the accessions according to their geographical origin with the landraces from the South shore of the Mediterranean Sea closely related (Moragues *et al*., in press). The results support two dispersal patterns of durum wheat in the Mediterranean basin, one through its north side and a second one through its south side.

Given that the north and the south of the Mediterranean Basin have different climatic conditions, the next step of the work was to investigate to which extent climatic differences in the regions of dispersal may have influenced biomass distribution along the plant and the strategies of yield formation of the two groups of landraces. The north part of the Mediterranean basin is characterized by temperate and cold climates, while the south of the Mediterranean is characterized by a dry climate. The average temperatures in the north range from –4.5 to 22ºC, and the rainfall ranges from 300 to 1100 mm per year. Contrarily, the climate of the south is characterized by an annual evapotranspiration exceeding the annual precipitation, and the presence of a marked dry season. The average temperature ranges from 10.5 to 30.5ºC, and the rainfall varies from 35 up to 725 mm per year.

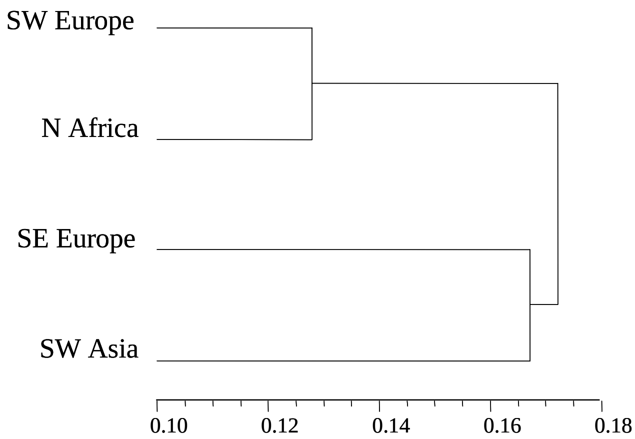

Fig. 1. Cluster analysis based on Rogers' distance for allele frequencies in geographical regions of origin for combined AFLP and SSR data (from Moragues *et al*., in press).

The results of the ANOVA revealed that the region of dispersal significantly affected some yield components and biomass traits (Table 2). However, differences in yield between the two groups of landraces were not statistically significant, probably due to the compensation of yield components. Genotypes from the north showed a higher tillering capacity and more spikelets per spike. These results are in agreement with the climatic conditions prevalent on both regions, since the production of tillers and spikes is favored by low temperatures and high water supply. In spite of being more efficient in the production of tillers, northern landraces were less efficient that southern ones in producing tillers bearing spikes, and their main stems and grains were lighter. This may be consequence of a better adaptation to drought in the southern lines since their lower number of tillers likely reduced the use of water and carbon during the spikelet formation and flowering period.

Our results indicate that northern genotypes, adapted to less restrictive environmental conditions than southern ones, concentrated biomass more in tillers than in the main stem, while southern lines, more adapted to drier environments, relied on the productivity of the main stem. Pre-anthesis assimilates contributed to grain yield by 40 and 90% in northern and southern genotypes, respectively. This suggests a better adaptation of southern landraces to drought environments in which terminal stresses limit transient photosynthesis and grain growth has to be mostly supported by translocation of stored reserves (Moragues *et al*., 2006b).

We concluded that differences in the climatic conditions prevalent in the north and the south of the Mediterranean basin, as well as human selection, may have affected yield formation strategies and biomass allocation of the landraces developed in one or the other geographical region.

Table 2. Mean values of yield and yield components at ripening and biomass traits determined at anthesis of the landraces belonging to the two geographical regions (adapted from Moragues *et al*., 2006a,b)

	Northern dispersal (a)	Southern dispersal (b)	Percentage of difference (a-b)/a x 100
Yield (t/ha)	2.40	2.40	0.0
Number of stems/m^2	313	283	9.3
Number of spikes/m^2	237	224	5.5
Number of spikelets/spike	17.4	17.6	-1.1
Fertile tillering (%)	73.7	78.3	-6.2
Number of grains/spike	28.8	30.2	-4.9
Thousand kernel weight (g)	42.9	43.1	-0.5
Harvest index	0.28	0.30	-7.1*
Plant height (cm)	122	126	-3.3***
LAI, leaf area index	1.40	1.46	-4.3
CDW, crop dry weight (g/m^2)	679	741	-9.1**
Dry weight/plant (g)	6.50	6.71	-3.2
Dry weight of main stem/plant (g)	3.12	3.63	-16.3***
Dry weight of tillers/plant (g)	3.38	3.08	8.9
Number of tillers/plant	2.07	1.63	21.2***

* P<0.05, ** P<0.01, *** P<0.001 according to a Tukey's test.

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