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Durum wheat productivity in sustainable Mediterranean agro-ecosystems as related to yield components and morpho-physiological traits

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SUMMARY – Durum wheat (*Triticum turgidum* L. var *durum*) is mainly grown in drought-prone areas within the Mediterranean Basin, where terminal stresses, mostly drought and heat, are the major yield constraints. This study was conducted within the framework of the EU-project IDuWUE (Improving Durum wheat for Water Use Efficiency and yield stability through physiological and molecular approaches), in order to ascertain the contribution of yield components and some morpho-physiological traits to explain yield variations in a range of Mediterranean environments. Eight experiments, including a RIL population of 249 lines or a collection of 192 durum wheat accessions, were conducted in contrasting agro-ecological zones within the Mediterranean Basin. Yield, yield components, test weight, flag leaf posture, time from sowing to heading, peduncle length and plant height were measured on each plot. Principal component analysis revealed a wide range of genetic and environmental variability, with the two sets of germplasm showing contrasting phenotypic structure regarding the measured traits. Stepwise regression analysis across environments revealed that yield components accounted for ca. 87.5% of yield variations (grain weight 63.1%, grains per spike an additional 12.5% and spikes per m^2 an extra 11.9%). The contribution of morpho-physiological traits to explain yield variations was much lower. Our results reveal that variability in durum wheat yield across Mediterranean environments was mostly due to variability in grain weight.

Introduction

Durum wheat is mainly grown in drought-prone areas within the Mediterranean Basin where terminal drought and heat stresses are the most important yield constraints. Understanding genetic and environmental factors limiting yield in these environments is essential to improve yield stability. This study was carried out in the framework of the EU-IDuWUE project, in order to ascertain the contribution of yield components and some morpho-physiological traits to explain yield variations in a range of Mediterranean agro-ecosystems.

Material and methods

A RIL population consisting of 249 lines and a collection of 192 durum wheat accessions were grown, in the 2003-2004 growing season, in several locations representing contrasting agro-ecosystems within the Mediterranean basin (Table 1). A modified augmented design with three checks, two of which were common to all the locations and a third one consisting of a locally well adapted cultivar, was adopted.

Table 1. Location of experimental sites and set of genotypes tested at each one. A = Accessions, R = RILs

Site code	Location	Country	Coordinates	Altitude (masl)	Water input (mm)	Set tested
P1r	Cadriano	Italy	44°33' N 11°24' E	32	657	A
P2r	Cerignola	Italy	41º11'N 15º46'E	213	338	R
P3r	Lleida	Spain	41º38'N 0º23'E	200	256	A
P4r	Granada	Spain	37º15'N 3º46'W	674	403	R
P6i	El Kef	Tunisie	36º14'N 8º27'E	532	450	R
P8i	Tal- Amara	Lebanon	33º 51'N35º 59' E	902	592	A, R
P8r	Tal- Amara	Lebanon	33º 51'N35º 59' E	902	592	A, R

Flag leaf posture, time from sowing to heading (in days and in thermal time), peduncle length and plant height were determined on a plot basis. Yield and yield components were measured at ripening. Test weight was assessed in a sample of the grain mechanically harvested. Data of each experiment were fitted through a post-blocking procedure using the proc MIXED of the SAS statistical package (SAS, 2001) to estimate the BLUPs (Best Linear Unbiased Predictor) of the unreplicated entries. The relationship between traits and environments was assessed by means of principal component analysis (PCA) performed on the correlation matrix of the BLUPs. Linear regression analysis was conducted with the pooled data considering yield as dependent variable and yield components and related traits as independent variables.

Results and discussion

Differences between environments led to a wide range of yield on both sets of germplasm (Fig. 1).

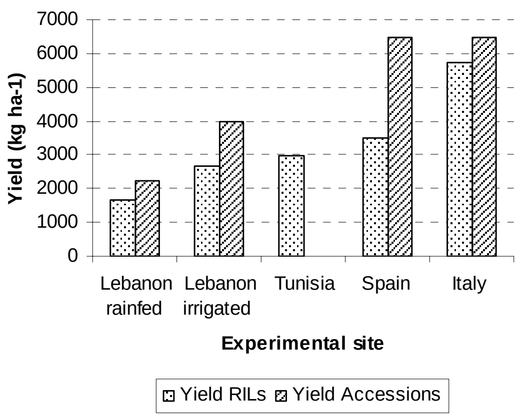

Fig. 1. Mean yield of each experiment.

Principal component analysis was useful to separate sets of genotypes and environments in terms of general productivity. The first two axes of PCA shown in Fig. 2 accounted for *ca*. 66% of total variance (axis 1, 46%; axis 2, 20%). Principal component 1 was related mostly to yield, TKW, spikes per m^2, plant height, peduncle length and cycle duration until heading, while grains per spike and test weight were the main variables influencing PCA2 (Fig. 2a). Experiments with RILs and accessions were plotted separately in the plane determined by the first two axes, the accessions having higher values for axis 1 (Fig. 2b). This indicates that both sets of germplasm expressed a different structure in relation to yield, yield components and morphophysiological traits. In average, the accessions were more productive, had heavier kernels and taller plants and a higher spike density than the RIL population. The phenotypic differences between groups of germplasm were in some cases even higher than the found between agro-ecological zones. The agro-ecosystem in Tunisia produced a low number of grains per spike and light kernels.

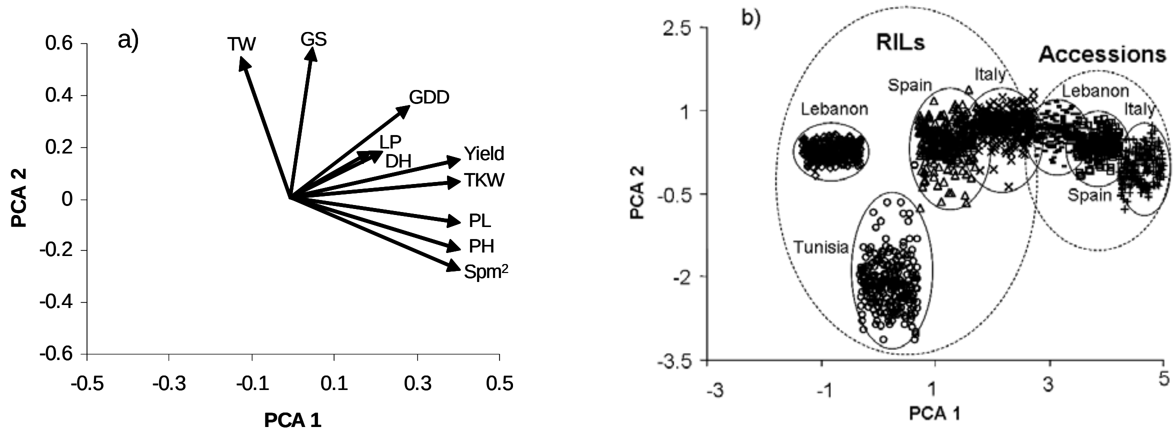

Fig. 2. Principal component analysis two-dimensional graph. a) Eigenvalues symbolyzed as vectors, TW: test weight, GS: grains per spike, GDD: thermal time to heading, LP: leaf posture, DH: days to heading, TKW: thousand kernel weight, PL: peduncle length, PH: plant height, Spm^2: spikes per m^2. b) points for each genotype and experiment plotted on the plane determined by the first to axes.

Multiple regression analysis indicated that thousand kernel weight (TKW) was the trait most related to yield, since it explained 63% of yield variations (Table 2). Kernel weight, which may be reduced by terminal stresses in Mediterranean conditions (Royo *et al.*, 2000), has been reported to be associated to durum wheat yield in different latitudes and water regimes (Royo *et al.*, 2006). Grains per spike and spikes per m^2 entered in the equation in second and third position respectively, accounting jointly with TKW for *ca*. 87.5% of yield variations. All the morpho-physiological traits entered in the equation in subsequent steps, but their contribution to explain yield variations was much lower than that of yield components (Table 2). Our results underline the role of kernel weight in explaining yield variability in durum wheat across Mediterranean agro-ecosystems.

Table 2. Summary of stepwise regression analysis between yield as dependent variable and yield components and related traits as independent variables

Variable entered	Partial R^2	Model R^2	*F* value†
Thousand kernel weight	0.631	0.631	3453
Grains/spike	0.125	0.756	1028
Spikes/m^2	0.119	0.875	1926
Thermal time to heading	0.007	0.882	124
Peduncle length	0.011	0.893	212
Plant height	0.004	0.897	63.5
Test weight	0.001	0.898	28.2
Days to heading	0.001	0.899	29.8

†All *F* values are significant at $P < 0.0001$.

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