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Environmental determination of amino acid composition in the grain of durum wheat under Mediterranean conditions[1]

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SUMMARY – Grain protein content and amino acid composition of wheat vary greatly depending on the genotype and environment. The objectives of this work were to determine the variation in the amino acid composition of the grain of 10 durum wheat genotypes grown under different water and temperature regimes under Mediterranean conditions. Analyses of variance for amino acid composition, grain yield and protein content showed that water availability during crop growth had a greater effect than genotype or genotype×environment interactions. The relative contents of glutamine and proline were higher in the rain-fed environments, probably due to a decrease in the duration of grain filling and faster leaf senescence, conditions that promote an earlier synthesis of gliadin + glutenin during grain development, proteins especially abundant in glutamine and proline. In contrast, the relative amounts of the other amino acids tended to decrease with the reduction in the duration of grain filling, particularly for tyrosine, lysine, phenylalanine and methionine. These amino acids are particularly abundant in albumins and globulins, proteins mainly synthesized during the first phases of grain development and whose synthesis would finish early under conditions that shorten the duration of grain filling.

Introduction

Amino acid composition is an important feature in determining the nutritional value of wheat grain for human and animal diets. Environmental conditions are known to influence protein quantity as well as grain production and, in turn, amino acid composition. Wheat proteins are known to be low in some amino acids that are considered essential for the human diet, especially lysine (the most deficient amino acid) and threonine (the second limiting amino acid), but they are rich in glutamine and proline which are present in the gluten proteins (Bénétrix and Autran, 2001). The grain protein content and amino acid composition of wheat also vary with genotype and environment, including rate and time of nitrogen fertilization, water availability and temperature during grain filling (Rao *et al*, 1993; López-Bellido *et al*., 1998; Rharrabti et at., 2001). Although the amino acid composition of the grain of wheat has been described in classical work, there are few modern studies of the influence of water availability and temperature during crop growth on amino acid composition, especially for durum wheat grown under Mediterranean conditions.

Materials and methods

During the 1998 growing-season, three field trials were conducted in southern Spain, a Mediterranean-type environment, including irrigation (CIFA) and rain-fed conditions with two different temperature regimes during grain filling (Ochichar and Jerez). Ten durum wheat genotypes were studied, including four Spanish commercial varieties and six advanced lines from the durum wheat selection program of CIMMYT - ICARDA. Genotypes were sown at an adjusted rate of 350 germinable seeds m^{-2} in plots 10 m long by 1.2 m wide, with six rows 20 cm apart. The experimental design at each site was a randomised complete block with three replications. Grain protein content was determined by multiplying Kjeldhal nitrogen by 5.7. Amino acids were quantitatively analysed by high performance liquid chromatography (HPLC) using the Waters Pico-Tag Method. Protein was hydrolysed in 6 N hydrochloric acid + 1% phenol in sealed evacuated tubes at 110ºC for 24 h. Sulfur-containing amino acids were converted into cysteic acid and methionine sulfone by preoxidation with performic acid prior to hydrolysis and derivatization. Tryptophan was not determined. Glutamine and

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asparagine were determined after hydrolysis as glutamic acid and aspartic acid, respectively, with combined values for the acids and amides being presented. α-aminoadipic acid was used as an internal standard.

Results and discussion

Analyses of variance for amino acid composition, grain yield and protein content showed a greater effect of environment in comparison with the effects of genotype and genotype x environment interaction, differences between environments explaining more than 46% of the total variation for all amino acids. Changes in grain protein content and amino acid composition were mainly caused by environmental conditions, particularly water availability and temperature during the growing season. With respect to amino acid composition, results showed (Fig. 1a) that the relative contents of glutamic acid/glutamine and proline increased in the rain-fed environments, probably due to a decrease in grain filling duration and faster leaf senescence caused by higher temperatures and reduction in water availability during grain growth. In contrast, the accumulation of the basic amino acids histidine, lysine and arginine increased when grain growth duration increased (Fig. 1b).

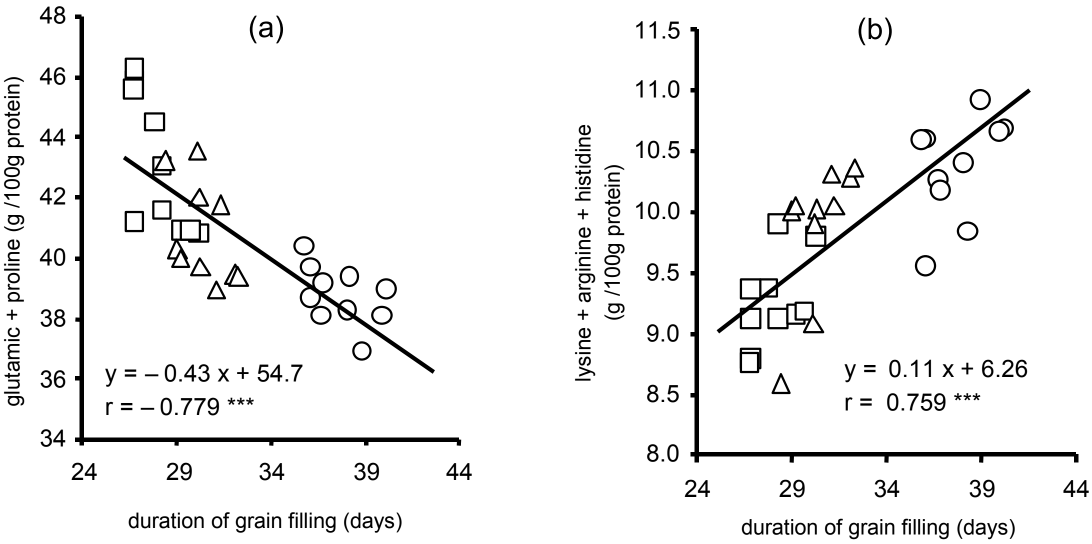

Fig. 1. Influence of grain filling period on some amino acids accumulation in the three studied environments (○, CIFA; □, Ochichar; △, Jerez)

This pattern of accumulation relates to differential effects on the synthesis of the major protein fractions in the wheat grain during kernel development. In effect, in the early stages of grain growth the proteins mainly synthesized are albumins and globulins, whereas 12 or 15 days after anthesis the synthesis of storage proteins (gliadins and glutenins) predominates (Martín del Molino *et al*., 1988). Albumins and globulins have higher contents of basic amino acids (lysine, arginine and histidine), whereas the glutenins and gliadins have higher contents of proline and glutamine (determined as glutamic acid in the present study) (Shewry *et al*., 1995; Bénétrix and Autran, 2001). For this reason, environments where water drought and high temperatures limit grain filling duration (Ochichar and Jerez) seems to favour a faster accumulation of storage proteins than albumins or globulins, thus giving higher quantities of glutamine and proline in the grain. However, the higher grain filling duration obtained under irrigated conditions (CIFA) seems to allow a more gradual accumulation of the different protein fractions in the grain, leading to a more pronounced dilution of gliadins and glutenins as compared with albumins and globulins and causing decreases in the proportions of proline and glutamine.

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