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Effects of different water availability at post-anthesis stage on grain nutrition and quality in strong-gluten winter wheat

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Abstract

Wheat (*Triticum aestivum* L.) is one of the most important agricultural crops worldwide. However, water is the most important limiting factor for wheat production. This study was initiated to test water stress environmental effects on grain quality and nutritional value of wheat by using single different water conditions at post-anthesis stage. Further analyses were conducted to examine variations in concentrations and compositions of the bioactive compounds and nutritions in strong-gluten winter wheat subjected to different levels of water deficit during grain filling. For the experiment on the response to different soil water conditions during post-anthesis stage, effects of soil water environment on protein content and composition in the grains were significant. Soil water conditions in this study greatly affected mineral contents in the grains of winter wheat, particularly with regard to the major minerals (P, K, Ca and Mg). Water deficit during grain filling can result in a decrease in lipid contents in wheat grains, which agrees well with experimental findings elsewhere. Concomitantly, a mild water deficit during grain filling would be beneficial to the grain filling and starch compositions, significantly improved bread-making quality. Therefore, it was concluded that good management of wheat field water at post-anthesis stage was helpful to improving grain quality and nutritions relevant to processing and human nutrition. ***To cite this article: C.-X. Zhao et al., C. R. Biologies 332 (2009).***

Keywords: Winter wheat; Grain quality; Water stress; Post-anthesis stage; Nutritional value

1. Introduction

Wheat is one of the most important food crops. Wheat is grown under irrigated as well as rain-fed conditions worldwide. Under rain-fed conditions the developing grains of wheat are frequently exposed to mild to severe stress at grain development stage [1]. Grain of certain cultivars can often attract a price premium if it has a combination of good characters that make it suitable for bread making, rather than biscuit-making or livestock feed [2,3]. As we know, both protein content and protein quality have marked effects on bread-making quality [4]. In addition, wheat grain is rich in bioactive compounds which provide nutritional benefits to humans. Hence, changes in the elemental composi-

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tion of wheat grain will affect the quality of human nutrition, especially for protein and microelement content, such as Fe and Zn, which are vital for human health [5]. Nutritional problems related to diets of cereal as wheat-based were observed throughout the country, and the consequences of malnutrition create immense economic and social costs [6,7].

Environmental factors, such as temperature, water and nitrogen nutrition also influence the ratio between soluble and insoluble proteins, affect bread-making quality, which is a function of the protein composition that is genetically controlled [8,9]. In addition, in studies focused on the environment or on the cultivar–environment interactions, a randomly chosen set of samples obtained in multisite experiments were often used, without a good knowledge of the potentially interactive factors causing these variations [10].

Wheat grain quality is crucial; in environments limiting the attainment of high quality, durum wheat is replaced by bread wheat of which the grain yield is higher than that of durum wheat [3,11]. Variations in flour quality in a hard-grained winter cultivar were related to changes in protein composition from drought stress during grain filling [12]. Certainly, timing is very important in modifying the effect of stress on yield formation [13]. Although the effect of drought stress on grain development and its yield in wheat is well documented [14,15], the studies on changes in nutritional value of the mature grains in strong-gluten wheat, in response to water stress at post-anthesis are, however, scanty. It is, therefore, imperative that a comprehensive analysis of the drought stress-induced changes in the nutritional value of wheat grains be carried out in cultivars categorized as strong gluten. This paper seeks to further clarify water stress environmental effects on grain quality and nutritional value (such as protein, mineral composition, lipid and starch content, *etc.*) of wheat using single different water conditions at post-anthesis stage.

2. Materials and methods

2.1. Plant materials and growth conditions

From 2007 to 2008, the experiment was conducted at Laiyang experimental station, Qingdao Agricultural University, China. Wheat seeds of strong-gluten variety (*Triticum aestivum* L., cv. Jimai 20) were collected from Crop Research Institute, SAAS (Shandong Academy of Agricultural Sciences). Plants were raised in 30 pots (36 cm diameter and 52 cm height, 18 seeds per pot) filled with local field topsoil in the rain-proof greenhouse. Organic compost (0.60 kg/pot), urea (62.46 g/pot) and $(NH_4)_2HPO_4$ (90 g/pot) were applied prior to planting. Before sowing the soil was irrigated to 80% soil water capacity (SWC). The sowing was done on 8th October and the grains were harvested on 13th June. 20 days after sowing, nine plants left by thinning were maintained in each pot. The plants were irrigated daily and the quantity of water applied was always in excess, up to full drainage before flowering. For imposition of water deficit at post-anthesis stages, three soil water levels, 45% (W1), 65% (W2), and 85% (W3) SWC, were applied to each pot (10 pots per treatment) separately from flowering, and kept constant throughout the entire period of experiment by simply weighing each pot every 2 days, and adding the water lost accordingly. At the late growth phase, when total biomass of wheat accounted for more than 0.5% of the total pot weight (plastic pot + soil + soil water + biomass), that fraction of biomass was taken into account. At last, the grain samples were harvested at maturity in three replicates, which were stored in paper bags and kept in a freezer at −20 °C after being received in the laboratory until the related tests begun.

2.2. Protein isolation and quantification

Protein is analyzed as nitrogen on a Leco TruSpec carbon–nitrogen analyzer according to the method of Forage Analyses Procedures [16]. Protein content was calculated from nitrogen content multiplying by a constant of 5.7. The protein fractions from the grains were extracted using the protocol as described [17,18].

2.3. Mineral content

The ash content of the wheat grain was determined according to the AOAC method 923.03 [19]. Ground wheat samples were brought to room temperature prior to use. Crucibles were pre-dried in a furnace for 5 h at 525 °C. The crucible were cooled to room temperature in a desiccator. Approximately 2 g ground wheat grain samples were weighed into the dried crucibles and samples were ashed in a furnace for 5 h at 525 °C. Minerals were extracted from ash in hot 3 N HCl before analysis using Inductively Coupled Plasma Mass Spectrometer (ICP-MS).

2.4. Lipid content

Oil content was determined according to the AOAC method 960.39 [19]. Approximately 2 g ground wheat grain samples were weighed into a cellulose thimble. The thimbles were then placed in the Soxtec extraction