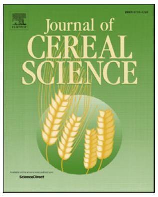
Journal of Cereal Science 61 (2015) 126–132

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs



Influence of the cultivar, environment and management on the grain yield and bread-making quality in winter wheat

Jan Rozbicki [a], Alicja Cegli ńska [b], Dariusz Gozdowski [c, *], Magdalena Jakubczak [a], Grażyna Cacak-Pietrzak [b], Wiesław Mądry [c], Jan Golba [d], Mariusz Piechociński [a], Grzegorz Sobczyński [a], Marcin Studnicki [c], Tadeusz Drzazga [e]

[a] *Department of Agronomy, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776 Warsaw, Poland*
[b] *Division of Cereal Technology, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776 Warsaw, Poland*
[c] *Department of Experimental Design and Bioinformatics, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776 Warsaw, Poland*
[d] *Department of Functional Foods and Commodities, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776 Warsaw, Poland*
[e] *Małopolska Plant Breeding Ltd., Sportowa 21, 55-040 Kobierzyce, Poland*

ARTICLE INFO

Article history:
Received 30 May 2014
Received in revised form
11 September 2014
Accepted 9 November 2014
Available online 19 December 2014

Keywords:
Winter wheat
Genotype-by-environment interaction
Crop management
Bread-making traits

ABSTRACT

The genotype, environment and their interaction play an important role in the grain yielding and grain quality attributes. The main aim of this study was to determine the contributions of the genotype, environment and their interaction to the variation in bread-making traits. The data that were used for the analyses performed in this study were obtained from 3 locations in Poland from post-registration multi-environment trials with winter wheat in 2009 and 2010. The experimental factors were the cultivar (7 cultivars) and the crop management level (low input and high input). In the multi-environment trials, 17 traits were investigated that characterize grain, flour and dough quality. Most of the traits were affected much more strongly by environmental factors (i.e., year and location) than by genotype. The variance components revealed an especially strong effect of the year on the baking score, loaf volume and water absorption, as well a strong effect of the location on dough development and protein content. The obtained results demonstrate that the grain quality as measured by the parameters based on the protein content and quality may be substantially improved by crop management practices, especially by N fertilization level.

1. Introduction

It has long been recognized that wheat productivity and grain quality vary considerably as a result of the genotype (G), environment (E) and their interaction (G × E) (Carson and Edwards, 2009; Cooper et al., 1996; Smith and Gooding, 1999; Taghouti et al., 2010; Williams et al., 2008; Yong et al., 2004), but there is no general consensus about which of these factors is more important for most of the quality traits. In general, the G × E effects are usually smaller than those of G or E (Peterson et al., 1998), and variation of the relative contributions of G, E, and G × E on different quality parameters, most likely due to the different studied genotypes and environment, have been observed (Li et al., 2013). Certain quality traits are highly influenced by the genotype, i.e., hardness, flour yield, and Zeleny sedimentation value (Carson and Edwards, 2009; Yong et al., 2004), while other parameters are mostly influenced by the environment, i.e., protein content, TGW, test weight, and Hagberg falling number (Carson and Edwards, 2009; Kong et al., 2013; Yong et al., 2004).

Denčić et al. (2011) tested a large group of wheat genotypes originating from 28 countries and recorded high cultivar variances in the rheological dough properties, i.e., Farinograph quality number, Farinograph water absorption and baking value. The variation in the baking score was 10 times greater across the cultivars than across the years. In another study, the starch quantity, chemical

---

Abbreviations: BS, baking score; CH, crumb hardness; CV, coefficient of variability; DD, dough development; DS, dough stability; DSF, dough softening; E, environment; FA, flour ash content; FN, Hagberg falling number; FY, flour yield; G, genotype; GI, gluten index; GY, grain yield; HI, high input management; L, location; LI, low input management; LV, loaf volume; M, (crop) management; NUE, nitrogen use efficiency; PC, grain protein content; SV, Zeleny sedimentation value; TGW, thousand-grain weight; TW, test weight; WA, water absorption; WG, wet gluten content; Y, year.

[*] Corresponding author. Tel.: +48 22 59 32 730; fax: +48 22 59 325 06.
E-mail address: dariusz_gozdowski@sggw.pl (D. Gozdowski).

http://dx.doi.org/10.1016/j.jcs.2014.11.001
0733-5210/© 2014 Elsevier Ltd. All rights reserved.

composition and pasting properties were mainly influenced by the cultivar factor rather than by the site factors (Brennan et al., 2012).

An important portion of the observed variability in quality is determined by the environment, and the nitrogen supply is the principal factor affecting the environmental variation in the protein content and composition. The total protein content increased with higher supplies of nitrogen, and as the grain protein increased, the gliadin and glutenin contents and their ratio increased (Triboï et al., 2000). Cormier et al. (2013) reported that genotype (G) × nitrogen (N) interactions, as management variables, were significant for the yield, grain protein content, N concentration in the straw, N utilization, and NUE.

In addition, durum wheat experiments showed that the environment significantly affected the protein content, thousand-grain weight, yellow berry and gluten content. The genotype × environment × fertilizer (G × E × F) interaction was significant only for the protein content, and the E × F interaction was significant for all of the parameters. N-fertilizers seem to enhance the protein content and to reduce the thousand-grain weight (Daaloul Bouacha et al., 2014).

A high environmental variance was recorded, especially for the antioxidant capacity. Both the genotype and genotype-by-environment interaction significantly affected the wet gluten and lipid soluble antioxidants (Šukalović et al., 2013).

Beleggia et al. (2013) found a small impact of the genotype and large effects of both the year and genotype-by-environment interaction on the metabolite composition and quality of the wheat grain. These authors analysed sets of different polar and non-polar compounds, including amino acids, sugars, organic acids, fatty acids (saturated and unsaturated), and sterols.

In general, some environmental factors, including soil physico-chemical properties, geographic latitude, moderately high temperature, proper soil moisture (resulting from rainfall and irrigation), and sufficient solar radiation, may improve the wheat quality (Kong et al., 2013). However, the grain quality may be substantially improved by the crop/farming management practices and by exploiting the synergism between the genotype and the environment. Genotype × environment and genotype × crop management interactions are very often significant, which means that response of various wheat genotypes, e.g. grain protein content, can be very different in similar agronomical and environmental conditions (Kong et al., 2013; Šíp et al., 2013) The impacts of management factors is modified by their interactions with the genotype. Especially strong interaction for grain quality traits of wheat, e.g. grain protein content was observed for nitrogen × genotype interaction (Luo et al., 2000; Saint Pierre et al., 2008). The understanding of these effects is essential to help breeders to set proper objectives and strategies to develop wheat cultivars with specific quality attributes to meet market needs (Williams et al., 2008) and to help farmers to produce wheat grain of a high level of uniformity to meet the demands of the modern baking industry and the automated processing facilities that are used (Finlay et al., 2007). Farmers and wheat buyers should realize that a given wheat genotype could produce different grain qualities in different environments (Vázquez et al., 2012).

In Latin American environments, no relationship was found between the quality and yield, providing that it is possible simultaneously to obtain a high yield and good quality even in poor quality environments, highlighting the importance of selecting the best performing genotypes as an effective measure to improve grain quality, particularly under variable and generally poor-quality environments (Vázquez et al., 2012).

The objectives of this research were three-fold: i) to determine the contributions of the genotype, environment and their interaction to the variation in bread-making traits of 7 genotypes that were tested across 3 locations and 2 years; ii) to analyse the relationships between the grain, flour, dough and baking traits; and iii) to determine the impact of the use of different management factors on the bread-making wheat quality.

2. Materials and methods

The data used for the analyses that were performed in this study were obtained from 3 locations at which post-registration multi-environment trials were conducted by COBORU (Research Centre for Cultivar Testing in Poland) with winter wheat in two seasons 2008/2009 (sowing/harvesting) and 2009/2010. The soil and weather conditions are presented in Table 1. The cumulative post-anthesis precipitation was variable in the seasons and much greater than 50 mm, negatively influencing the protein content and quality (Kong et al., 2013). These three trials were located in the main Polish wheat-producing regions (Mądry et al., 2011). Each field experiment was conducted according to a split-block design with 2 replications. The experimental factors were the cultivar (7 cultivars, Table 2) and the crop management level (two levels: HI and LI, i.e. HI – high input crop management: where foliar fertilizers, fungicides, growth regulators and additional dose of 40 kg/ha N; LI – low input crop management). Combination of year × location was treated as various environments. The choice of winter wheat varieties was based on the acreage that they are cultivated in the main wheat-producing regions in Poland, covering a range of grain end-use quality. The area of an individual plot was 15 m^2. The agronomical traits: grain yield (GY) and yield components, number of spikes (SN), mean number of grain per spike (GpS), and thousand-grain weight (TGW) were measured during the harvest based on a one square meter sample from the middle of the plot. A detailed description of the experiment was presented by Golba et al. (2013).

The end-use quality trait (test weight (TW), grain protein content (PC), wet gluten content (WG), gluten index (GI), Zeleny sedimentation value (SV), Hagberg falling number (FN), flour yield (FY), and flour ash content (FA)), the Farinograph traits (water absorption (WA), dough development (DD), dough stability (DS), and dough softening (DSF)) and the baking properties (loaf volume (LV), baking score (BS) and crumb hardness (CH)) were used to evaluate the effects of the cultivar, environment, management and their interaction on all of the quality traits.

The grain samples were ground in a laboratory Brabender Quadrumat Senior mill. The protein content (N × 5.7) was determined according to the Kjeldahl method (Foss Tecator, Denmark) of the ICC method 105/2 (ICC 1994), while the sedimentation value was obtained by the Zeleny method ICC 116/1. The falling number was determined using a Falling Number Test Apparatus, type 1400 (AACC Method 56-81B). The wet gluten content and gluten index of the samples were determined using a Glutomatic 2200 (AACC Method 38-12). The loaf volume was measured by rapeseed

Table 1
Characteristics of the soil and weather conditions at the experimental sites.

Location	Latitude longitude	Season	Soil type[a]	Soil pH in KCL	Rainfall June–July (mm)
Radostowo	53.99°N, 18.73°E	2008/2009	CL	6.1	158
		2009/2010	CL	6.5	119
Głubczyce	50.20°N, 17.82°E	2008/2009	SC	6.4	291
		2009/2010	SC	6.1	312
Seroczyn	52.01°N, 21.92°E	2008/2009	LS	6.4	203
		2009/2010	LS	7.1	118

[a] CL – clay loam, SC – silty clay, LS – loamy sand.