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Comparison of quality parameters of wheat varieties with different breeding origin under organic and low-input conventional conditions

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ABSTRACT

The processing quality of 37 wheat varieties grown in Hungary and Austria (2011–2013) were assessed under organic and conventional low input management. The varieties studied were developed using three breeding strategies (conventional, organic and their combination: BFOA). The aim was to evaluate the effect of the field management and to assess the performance of varieties developed using different breeding methods, based on their quality traits under different managements. Furthermore, properties were identified that could characterize wheat quality and be used effectively for selection under both types of growing conditions.

Strong year and genotype effects were found for all the quality traits (protein, starch, gluten, GI, Zeleny, Farinograph water absorption, development time, stability and quality number, falling number, flour yield, hardness index) of the studied varieties, while the effect of the management was significant for the physical properties (test weight, thousand-kernel weight, hardness) and gluten quality characters (gluten spread, GI, dough stability) of the grain. The standard deviation of the gluten quality traits characterized the differences between the breeding strategies. It proved possible to pre select organic varieties for quality traits with high broad-sense heritability under conventional growing conditions, but direct selection in organic fields is suggested for gluten quality characters.

1. Introduction

The necessity for separate organic breeding programmes is still a hot topic for wheat breeders, so there is a need to study the differences between the conventional and organic management systems (M), the effect of the environment (E), the effect of the genotype (G) and the properties of varieties developed using different breeding methods. Several research programmes have been established to obtain useful statements on the agronomical and technological properties of wheat varieties in this respect, but most of these compare high-input conventional and organic systems. Based on the results, a review by Lammerts van Bueren et al. (2011) suggested that indirect selection would be effective for traits with high heritability (early maturity, plant height, thousand-kernel weight) under high-input conventional conditions, but this was not the case for quantitative traits (yield, end-use quality) influenced by GxE interactions, where direct selection under organic condition was suggested (Baenziger et al., 2011; Löschenberger et al., 2008; Muellner et al., 2014; Murphy et al., 2007; Przystalski et al., 2008). Differences in heritability estimates were identified for six traits (test weight, thousand-kernel weight, protein content, plant height, days to anthesis, spikes m^{-2}) under different management systems (conventional, organic) when Reid et al. (2009) studied 79 F_6-derived recombinant inbred lines. At the same time Annicchiarico et al. (2010) found

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Abbreviations

BFOA	'Breeding For Organic Agriculture': method used for selection, involving conventional selection up to F5 and organic selection from the F6 generation
BLUE	Best Linear Unbiased Estimators
C	Country
CONV	Varieties bred conventionally in conventional fields
CV	Coefficient of Variation
E	Environment
G	Genotype
LI	Conventional low input field
M	Management
O	Organic field
ORG	Varieties bred in organic fields
REML	REstricted Maximum Likelihood algorithm: estimates variance parameters in linear mixed models
TKW	Thousand-Kernel Weight
TW	Test Weight
UPP%	Quantity of Unextractable Polymeric Protein as a %
Y	Year

higher broad-sense heritability for grain yield in high-input conventional systems than in organic.

GxE and GxM studies carried out earlier focused on the effects of the year, the weather conditions, the soil and/or the applied field management practices (fertilizers, manure, cultivation, plant protection, etc.) (Anderson et al., 1991; Baresel et al., 2008; Fliessbach et al., 2007; Foulkes et al., 1998; Gosling et al., 2006; etc.). However, these experiments mainly concentrated on the agronomical properties of the plants, and fewer results have been published from the viewpoint of the processing industry.

Previous studies showed that organic farming systems led to variations in the protein content and dough mixing stability of whole wheat flour (Gelinas et al., 2009). The protein content was found to be lower at the organic site, so varieties with high-quality protein and better nitrogen uptake were recommended for organic farming purposes to compensate for the relatively low protein content of the grain (Osman et al., 2012). Significant GxE and GxM interactions were found for protein content by Kamran et al. (2014) when high-input conventional and organic systems were compared. Based on other studies, the gluten content, dough stability and loaf volume were higher under high-input conventional management (Annett et al., 2007; L-Baeckstrom et al., 2004; Krejcirova et al., 2007). Cultivars and farming systems (organic, high-input conventional) were found to have a significant effect on the yield and quality parameters (falling number, gluten content, gluten index, Zeleny) of organically and conventionally bred cultivars in the DOK long-term system comparison trial set up in Switzerland in 1978 (Hildermann et al., 2009). They found that the preceding crop (potato, maize) and the fertilization level had a significant effect on the protein content of wheat. Overall the conventional mixed farming system using half the standard fertilization rate performed the best, with higher grain yields and protein content (Mayer et al., 2015).

In contrast, Mäder et al. (2007) found no difference either in the protein content or in the amino acid composition, mineral content and baking quality of varieties grown under organic or high-input conventional farming systems. No differences were observed for the flavour, aroma or colour attributes of conventional and organic bread, but organic bread was denser in texture with smaller air cells in the crumb (Annett et al., 2007; Kihlberg et al., 2006). In spite of these inconsistent results, wheat varieties suitable for organic cultivation and breeding have been selected, based on the gluten quality (unextractable polymeric protein content: UPP%) of 51 samples grown for 8 years at organic sites in Sweden (Hussain et al., 2012).

Although some of the inconsistencies observed in the previous results may be due to the poor comparability of the field systems (different site, soil, crop rotation, etc.), they nevertheless underline the importance of further GxExM studies. Moreover, no wide-ranging studies have yet been performed on wheat varieties developed with different breeding methods and grown at low input and organic sites in different countries. Hence, in the framework of the EU-FP7 SOLIBAM project, the physical, compositional and end-use quality of 37 bread wheat varieties grown under different agro-climatic conditions in Hungary and Austria for three years were assessed using two different management systems (organic, conventional low input). The varieties were developed with three different breeding strategies: conventional, organic and a combination of these strategies, BFOA (breeding for organic agriculture). This experiment has already been evaluated from the agronomical point of view by Mikó et al. (2014), who found a significant MxG interaction for 15 traits and suggested that early selection should be made for heading date, sensitivity, leaf rust and powdery mildew under the conventional system, while grain yield, test weight, leaf-inclination and vigorous growth during booting should be used for selection in the target organic field.

The first aim in the present work was to evaluate the effect of the field management practices and to assess the effect of the breeding strategies on quality characteristics, followed by the identification of traits that could characterize wheat quality and be used effectively for selection under organic and low input conditions.

2. Materials and methods

2.1. Plant material

Thirty-seven winter wheat varieties and breeding lines were sown at organic and conventional low input sites (henceforth 'low input') in two countries (Austria, Hungary) in 2011, 2012 and 2013. The varieties originated from 5 different countries (Austria, France, Germany, Hungary and Switzerland) and were bred in three different ways (Lammerts van Bueren et al., 2011). Nine varieties (Donnato, Aszita, Wiwa, Scaro, Butaro, Jularo, Sandomir, Gulliver, Karachow) were bred in certified organic fields, twenty (Mv Emese, Mv Béres, Mv Kolo, Mv Kolompos, Mv Tallér, Lukullus, Arnold, Capo, Midas, Claro, Lorenzo, Suretta, Titlis, Montdor, CH111-14426, CH111-14663, CH111-14631, Folklor, Renan, Flamenco) in conventional fields, and eight (Blasius, Peppino, Pireneo, Stefanus, Bitop, Tobias, Hendrix, Skerzzo) using a combined method (breeding for organic agriculture-BFOA), involving selection under conventional conditions in the early generations (usually up to F5) followed by selection in late generations on certified organic farms (Löschenberger et al., 2008). Detailed information on the origin and agronomical properties of the varieties were published by Mikó et al. (2014).

2.2. Plant growing conditions

The growing and management parameters of the trial locations and details of the environmental conditions were reported by Mikó et al. (2014). Between 2011 and 2013, 37 bread wheat varieties were sown in Austria (A) and Hungary (H) using a similar randomised