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Agronomic and quality characteristics of old, modern and mixture wheat varieties and landraces for organic bread chain in diverse environments of northern Italy

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ABSTRACT

Wheat landraces and old varieties could have an important role for food security not only as source of gene readily available for breeders, but also because they perform well in marginal environments and are more resilient as compared to the modern cultivars. The Italian cereal sector suffers from lack of seed companies that breed specifically adapted varieties for organic and biodynamic farms. Participatory and evolutionary plant breeding (PPB and EPB) have been used in this research to (i) evaluate the agronomic characteristics of old, modern and mixture of varieties and landrace of bread wheat (*Triticum aestivum* spp.) and their adaptability to organic farming in hilly and mountainous areas; (ii) assess the technological, nutritional and functional properties of grains (rheological characteristic, macro and micro elements contents and antioxidants); (iii) explore the consumers' preferences for breads obtained by old and modern varieties. Between five and seven old (Sieve, Verna, Gentil Rosso, Andriolo, Gambo di ferro, Frassineto and Abbondanza), two mixtures and four modern (Bolero, Blasco, Arabia and Bologna) varieties were tested for two years in between two and three organic farms (FARM1, FARM2 and FARM3) in hilly areas of Piedmont. Agronomic characteristic were strongly affected by locations and years. On average, Bologna, Abbondanza and Arabia, and the two mixtures were the highest yielding varieties. Flour strength (W) varied greatly ranging from 230 in 2011 for Andriolo to 38 in 2012 for Gambo di ferro. Gluten quality, expressed by GI, was found to be almost within the optimal range but was affected by the year. All six bread samples were acceptable to the 233 consumers who scored them, but the bread produced with old wheat varieties, particularly with Andriolo and Gambo di Ferro, was the preferred one. The old varieties and their mixtures yielded less than the modern varieties but with higher stability as shown by the inability of the modern varieties in FARM1 to survive the winter (they were not harvested) while the old varieties reached maturity showing higher robustness, Therefore, the use of old bread wheat varieties and their mixture, assessed with participatory and evolutionary plant breeding, could represent a strategy for local communities to cope with climate change while improving food security and food quality.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is the second most important staple crop in the world (FAOSTAT, 2014). Given its predominant presence in human diet, cultivated wheat has to meet quality criteria. Bread wheat production in Italy is insufficient to satisfy the demand, and 4,7 Mt are imported annually, of which 77% from EU countries (France, Austria, Germany), 12% from OCSE (Canada, Australia and USA) and 11% from other countries (Ukraine, Mexico and Turkey) to fulfil the market needs for flour (Zuppiroli, 2013). The domestic wheat production (2.9 Mt) meets about 38% of the national requirement of the volumes processed by the milling industry (80%) and confectionery (20%). The massive import does not stimulate the selection of grains of quality, in particular for the

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organic sector, which has a limited choice of specifically adapted varieties. A range of diverse varieties, adapted to different environments, is needed to respond to the needs of the organic and biodynamic farms that need locally adapted varieties. During the last centuries, wheat breeding efforts have concentrated on yield increases, and modern varieties are characterized by genetic uniformity and adaptation to conventional agriculture typically using high-energy inputs in terms of fertilizers, herbicides, insecticides and fungicides (Guarda et al., 2004). Modern varieties are often selected in favourable environments that do not represent the diversity of local conditions. Modern agriculture and conventional breeding have resulted in a reduction of genetic diversity and the stagnation of cereal yields in less favourable areas (Newton et al., 2010). A local variety of plant (and animal), or landrace is a domesticated, traditional, regional ecotype, locally adapted that has developed over time becoming adapted to its natural and cultural agricultural environment (and pastoralism) due to isolation from other populations of the same species (Jones et al., 2008; FAO, 2013; Camacho et al., 2005). Local wheat varieties, or landraces, are very tall, less productive than modern varieties, not homogeneous nor regular, with variable grain protein content, and with gluten with less gliadin and less glutenins (Sanchez-Garcia et al., 2015). Their flours are not suitable for the industrial processing and the best results are obtained when milled with natural stone ground (flour type 2), with attractive results from the quality point of view (sensorial and functional); they produce excellent bread with the use of sourdough (Torri et al., 2013). As they are dynamic (evolutionary) populations, they represent a way to protect and enhance biodiversity, to create local supply chains for small producers while representing an historical/cultural/social heritage.

The lack of suitable genotypes as well as the difficulty of using a high-input based agriculture, are the main causes of the constant and progressive abandonment of cereal cultivation in most Italian marginal areas (hilly areas), once extensively cultivated. The area planted with autumn-winter cereals (durum wheat, common wheat, barley, oats and other cereals) in Italy decreased by 10% in 2013 compared to 2012, to 2.1 million hectares (MIPAAF, 2013). This was due to both poor autumn weather, which in many areas delayed planting, and to reduced market prices. Piedmont in 2013 was the third highest producing region in Italy, after Emilia Romagna and Veneto, with 5.1 million tons (MIPAAF, 2013).

The production of certified organic wheat allowed to maintain a premium price compared with the conventional market. Grain quality has been a secondary objective of breeding programme and has been limited to few attributes such as test weight, protein content and gluten quantity and quality (Canerava et al., 1994). In the Italian context, bread wheat flour is commercially classified in different quality categories on the basis of a Synthetic Index of Quality (Indice Sintetico di Qualità, ISQ). ISQ is based on parameters such as hectolitre weight (HeW), falling number (determining the amylase activity of some enzymes in dough, that influence dough viscosity), protein content, alveographic indexes (indicating the degree of resistance opposed by the dough to a deformation stress, in terms of dough 'strength' – alveograph W – and the ratio between dough tenacity and dough extensibility – alveograph P/L ratio), and farinograph stability (expressing the time for which the dough maintains the maximum consistency during the dough mixing process). Ranging from the stronger to the weaker type, the four quality categories are defined as improved wheat (FF), superior bread making wheat (FPS), ordinary bread making wheat (FP) and wheat for biscuits (FB). This classification was proposed in 1997 (Borasio, 1997) and it is suitable for industrial processing, which require grains with a high gluten content and high dough strength, in order to obtain standardized loaves with the use of selected yeasts and short rising times. Another very important parameter for the milling industry is the Hardness Index as it affects the yield of flour.

In the seed market, wheat varieties are classified according to their potential technological features following the ISQ, based on which prices for the various commodity exchanges are determined. Therefore, it becomes essential the varietal selection for yield and milling characteristics, which in turn depends on soil characteristics, climate (rainfall, temperature), as well as biotic (weeds, insects, cryptogams) and abiotic (lodging) stresses.

In Italy, bread production was liberalized as an activity related to agriculture in 2006 (Decreto Legge n.233 del 4 Luglio 2006) and in 2010 (Decreto del Ministero dell'Economia e delle Finanze del 5 Agosto 2010). This authorization leads to some technical considerations about whether the farm is able to produce the right quality for commercial bread, or rather a type of bread that can go beyond that offered by the current market. Making bread in a farm means making technical choices that affect the cultivation, processing and marketing.

The main objective of this study was to recover and evaluate old varieties on-farm and to practice evolutionary plant breeding (Ceccarelli, 2009). *In situ* and *on farm* conservation offer stable solutions to biotic and abiotic problems, provide opportunities for scientific research and for genetic improvement, meet the needs of both farmers and the market for local products, and respect historical and cultural traditions. This also allows the development of a local supply chain for the production of quality bread that involves researchers, producers, processors and consumers, using a participatory plant breeding approach (PPB). PPB is an important tool of agricultural research to find varieties for low-input agriculture acceptable to farmers (Ceccarelli et al., 2000). Cereal improvement programs conducted to date addressed mainly higher yields and improved technological characteristics for industrial transformation, while neglecting nutritional, functional, digestibility and potential allergenicity characteristics (Van den Broeck et al., 2010).

A further development of PPB is evolutionary plant breeding (EPB) which is a simple but very innovative and revolutionary idea initially proposed by Suneson (1956) but never applied. By letting mixtures of varieties, or of breeding lines, or of segregating populations, evolve under the selection pressures of soil type, climate, agronomic practices and pests, every year the genetic composition of the seed, which is harvested, will be different from that of the seed which was planted. The farmers will then harvest a vintage wheat, which is the fruit of a blend of those local varieties cultivated in *that* place, that have been more productive, more competitive, more successful in *that* year. Just like wine, we will have a vintage bread and typical of the area, without having to resort to disciplinary and bureaucratic super-controls. In addition, this population will evolve over time, adapting gradually and continuously to climate change (Ceccarelli, 2014).

The specific objectives of this work were to: (i) evaluate the agronomic characteristics of old, modern and mixture of varieties and landrace of wheat (*Triticum aestivum* L.) and their adaptability to organic farms in hilly and mountainous areas; (ii) assess the technological, nutritional and functional properties of grains (rheological characteristic, macro and micro elements contents and antioxidants); (iii) explore the consumers' preferences for breads obtained by old and modern varieties of wheat.

2. Materials and methods

2.1. Farming techniques

The research was conducted for three years (2010/11, 2011/12 and 2012/13) in three organic farms (FARM1, FARM2 and FARM3). In 2010/2011 and 2011/2012, in the context of a project of varietal comparison of wheat for bread-making quality, five old (Sieve, Verna, Gentil Rosso, Andriolo and Gambo di ferro) and three mod-