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RESEARCH ARTICLE

Evaluation of genetic variation and grain quality of old bread wheat varieties introduced in north-western Italian environments

Angela R. Piergiovanni

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Abstract The increasing consumers' request for new speciality wheat derivatives and the possible widening of marketing opportunities is giving to both landraces and old varieties, new chance of *on farm* survival providing a low cost way to safeguard these important genetic resources. A farmer's consortium acting in north-western Italy, is attempting the introduction of some old bread wheat landraces in marginal environments of Piedmont and Liguria regions. The reason of this attempt is the local market demand of old bread varieties suitable for the preparation of traditional cakes and biscuits. Three Italian bread wheat landraces, a mixture of durum and bread wheat landraces and three modern varieties were evaluated. The entries were cropped in Val Borbera and Val d'Aveto (Piedmont and Liguria region, respectively) in the same growing season (2009–2010). The high variation of gliadin profile detected within the landraces indicates that all have retained the genetic heterogeneity typical of the old wheat landraces. In consequence of the health-promoting effects of whole grain consumption, eleven nutritional and technological traits of whole flours were investigated. The analysis of collected data revealed appreciable differences among the flours obtained from the landraces and the modern varieties. These differences can be mainly attributed to the intensive breeding carried out on bread wheat in the last century. The results of this study suggest that the old bread wheat landraces could have good chance of survive *on farm* when their characteristics fulfil the requirements of local communities.

Keywords Bread wheat · Genetic resources · Gliadins · Grain quality · *Triticum aestivum*

Introduction

In the last two decades, several papers, dealing with Italian landraces and old varieties surviving *on farm,* have been published. This autochthonous material belong to different cultivated plant species such as cereals (D'Antuono 1994; D'Antuono et al. 1997; Pagnotta et al. 2009), pulses (Negri et al. 2001; Laghetti et al. 2008; Piergiovanni and Lioi 2010), vegetable (Mazzucato et al. 2008; Sestili et al. 2011), etc. All are relics of a traditional agriculture that, until the beginning of twentieth century, in Italy as well as in other countries, was entirely based on landraces selected over the time by local farmers. Landraces are well adapted to a specific environment, but are generally unable to satisfy the requirements of intensive agricultural systems as well as the quality traits demanded by food industries.

A. R. Piergiovanni (✉)
Istituto di Genetica Vegetale-CNR, Via Amendola 165/a, 70126 Bari, Italy
e-mail: angelarosa.piergiovanni@igv.cnr.it

Since the beginning of twentieth century, Italian cereals, in particular both bread and durum wheat (*Triticum aestivum* L. and *T. durum* Desf., respectively), were the object of intensive breeding programs aimed to the development of modern cultivars (Maliani 1979). In that period the landraces were extensively used as a source of useful genetic material. After the Second World War the replacement of autochthonous wheat landraces and old varieties with the modern semi-dwarf and high-yielding cultivars was completed (Ciferri and Bonvicini 1959/60; Hammer and Laghetti 2005). In spite of the fast decline of landraces and old varieties, some of them have survived until today on small acreages located in marginal areas (Porfiri and Silveri 2003). The driving force of this process, named *on farm* conservation, has been the appreciation of autochthonous materials by elder farmers or small communities devoted to traditional agriculture.

The increasing consumers' request for new speciality wheat derivatives, organic food and the possible widening of marketing opportunities is giving to both landraces and old varieties, new chance of survival and is providing a way to safeguard these precious genetic resources. In addition to the ancient wheat species, such as emmer (*T. dicoccon* Schrank), spelt (*T. spelta* L.) and oriental wheat or Khorasan (*T. turanicum* Jakubz.) A. Lőve & D. Lőve) (Laghetti et al. 1999; Pasqualone et al. 2011), Italian farmers are rediscovering the old bread wheat varieties (Guarda et al. 2004; Piazza et al. 2008). The old varieties grow under organic conditions, in marginal areas, and can assure higher incomes as compared to modern cultivars because are mainly used to prepare whole-grain foods that are characterised by natural and healthy features (Kantor et al. 2001).

A farmer's consortium acting in north-western Italy, is attempting the introduction of old Italian bread wheat landraces in some marginal environments. The reason of this attempt is the local market demand of old bread varieties suitable for the preparation of traditional cakes and biscuits. Good dough for making these end-products should be characterised by a low gluten amount and weak extensibility. In the last years, the consortium acquired, through exchange with other farmer associations, the following landraces: 'Solina', 'Tosella', 'Rosso d'Alsazia' and a mixture of 'Ruscia and Solina'. 'Solina' is a very old Italian bread wheat landrace. Mentions in historical documents (Torcia 1793) fix the beginning of its cultivation in sixteenth century in Abruzzo region (central Italy) where it is still cultivated on small surfaces located in marginal areas (Porfiri and Silveri 2003). This long tradition is consequent to a high tolerance to cold, a well adaptation to marginal areas and good yields under low input agricultural systems. The plant height ranges from 110 to 135 cm, the spike is awned, white and 8–9 cm long. In the past 'Solina' flour was widely used for preparation of a bread type considered of superior quality as compared to other traditional bread types of Central and Southern Italy. In consequence of this appreciation, 'Solina' has been extensively used in breeding programs carried out in Italy at the beginning of twentieth century. Material introduced in Liguria region and evaluated in this study has been obtained from the consortium grouping farmers that still grown 'Solina' in Abruzzo region (Porfiri and Silveri 2003). 'Tosella' is together with 'Riccella' a synonymous of 'Gentil Rosso', an Italian bread wheat landrace derived from a local population. The spike has a yellow–red colour and is lacking in awns. The beginning of cultivation is dated around 1900, and in the early twentieth century 'Tosella' was extensively cultivated in Italian peninsula (Guarda et al. 2004). In the past the flour, obtained after milling, was highly appreciated for the whitest colour. Unfortunately, in consequence of the great plant height, lodging is a particularly severe trouble for this landrace and one of the reasons of its substitution with the semi-dwarf biotypes. The landrace named 'Rosso d'Alsazia' (Red from Alsace) was obtained from French farmers of Pyrenees region. Oral information provided by donors, describe it as a mixture with the landrace named 'Rosso della Mongolia' (Red from Mongolia), but the origin or pedigree of this last landrace is unknown to French farmers. 'Ruscia' is an old durum wheat variety released in the decade 1930–1940 and derived from 'Messina' landrace (Figliuolo et al. 2007). At the beginning of twentieth century, 'Ruscia' was extensively cultivated in Sicily (Southern Italy), but during the second half of past century, it was introduced in high lands (ca 1,000 m asl) of Italian peninsula. Similarly to others old durum wheat landraces, 'Ruscia' is characterised by a plant height (ca 150 cm) higher to those of modern cultivars. The consortium is testing a mixture of 'Ruscia' and 'Solina' to combine the valuable traits of both these landraces. The farmers of consortium are evaluating the performances of these landraces through field trials in two close valleys named Val Borbera and Val d'Aveto (Piedmont and Liguria region, respectively).

The aim of this study was to investigate: (1) the genetic variation within the described landraces; (2) the proximate composition and technological quality of their whole flours. This information will help the farmers to identify the best landraces for the tested environments.

Materials and methods

The bread wheat (*Triticum aestivum* L.) landraces named: 'Rosso d'Alsazia', 'Solina', 'Tosella' and a mixture of 'Ruscia and Solina' and the commercial varieties 'Autonomia', 'Bolero' and 'Ariosto' were investigated. 'Autonomia' is a typical biscuit variety released in 1930 by the geneticist Strampelli (Guarda et al. 2004). 'Bolero' is a bread wheat cultivar released in Italy in 1990s and widely used in bread preparation. Its most peculiar trait is protein level as high as 13 %. 'Ariosto' is a durum wheat (*T. durum* Desf.) variety and was included in this study to better perceive the performances of the mixture 'Ruscia/Solina'. The entries were grown under low input conditions by farmers of consortium in the growing season 2009–2010 in Val Borbera and Val d'Aveto (Piedmont and Liguria region, respectively). These valleys are characterised by a peculiar microclimate due their proximity at Ligurian Sea, the presence of small rivers (Borbera and Trebbia, respectively), as well as of mountains as high as 1,500 m a.s.l. surrounding them. The valleys are characterised by cold winter (mean minimum temperature from −8 to −10 °C) and rainfall quantity around 1,500–2,000 mm. The altitude of fields was 400 m a.s.l. and 1,000 m a.s.l. in Val Borbera and Val d'Aveto, respectively. 'Tosella' was grown in Val Borbera, while the other landraces and the commercial varieties in Val d'Aveto. The analysed samples, constituted of at least 150 g, were well representative of the harvests from which they had been extracted.

Electrophoresis of seed proteins

Twenty single caryopsides were analysed for each landrace. The caryopsides were finely ground with mortar and pestle before the gliadin extraction. The capillary zone electrophoretic (CZE) analyses were performed as previously described (Piergiovanni and Volpe 2003). Briefly, gliadins were extracted with 70 % (v/v) aqueous ethanol (1:8 w/v) at room temperature. After centrifugation the supernatant was submitted to CZE analysis on the day of extraction. A P/ACE MDQ (Beckman-Coulter, USA) was used to analyse the extracts. Separations were achieved using uncoated fused silica capillaries 30 cm long (22 cm to detector) with 50 μm i.d. The separation was performed in an isoelectric buffer based on aspartic acid. Only for the mixture 'Ruscia/Solina', the albumins were analysed to estimate the percentage of each component. The albumins were extracted from single caryopsides, finely ground with mortar and pestle, with aqueous ethanol. The extracts were analysed by CZE as previously described (Piergiovanni 2007). Beckman Karat 32 software was used for acquiring, storing and comparing the electrophoregrams. The separation buffer was prepared in 18 MΩ cm of distilled and deionised water (Milli-Q water system, Millipore, USA). All chemicals were of analytical reagent grade.

Whole flour quality

About 100 g per sample were ground with a 1.0 mm sieve Cyclotec mill 1093 (Tecator, Sweden). Moisture and ash contents were determined according to standard methods (AOAC 1995). Protein content was measured by the micro-Kjeldhal method (N × 5.7). Total P was determined by the colorimetric method of Fiske and Subbarow (1925). Dry gluten was determined according to the AACC (1995) standard method; bran collected during gluten test was washed until starch was not detected in the washing water, then was dried and weighed. Pigments, expressed as ppm of carotene, were extracted with water saturated 1-butanol and measured spectrophotometrically (AACC 1995). Sodium dodecyl sulfate (SDS) sedimentation assays were performed with a 2 % SDS solution (Dick and Quick 1983). Quality index (QI) was calculated as the ratio between SDS test value and protein content; DG/P was the ratio between dry gluten and protein content. All chemicals were of analytical reagent grade. All the analyses were performed in triplicate.

Statistical analyses

The intra-landrace heterogeneity was assessed by cluster analysis of electrophoretic results. A gliadin profile, selected among those with higher frequencies within each landrace, was assumed as reference. Gliadin profiles of all individuals analysed for each landrace were compared with the reference profile to construct a matrix resuming the detected peaks using a binary code for peak presence/absence. Then the matrices were submitted to cluster analysis. The dendrograms were constructed through the complete linkage joining rule. Data relative to whole flour quality of tested entries were normalised and submitted to the Principal Component Analysis (PCA). All the statistical analyses were computed using the Statistica 6.0 software package (StatSoft 1996).

Results and discussion

Electrophoretic analysis of seed proteins

Despite the increase in the number of DNA markers available for wheat, gliadins, continue to be valuable because they provide easy, repeatable and economical assays for the evaluation of genetic variation at intra-population level (Bean and Lookhart 2000). The capillary electrophoresis (CE) was used to analyse thes gliadin and albumin fractions because this technique has recently established a dominant position with respect to gel electrophoresis (Dolnik 2006). Information available on the landraces involved in this study suggested that all should be genetically heterogeneous. In order to assess the truth of this information, the variation of gliadin profile at intra-variety level was investigated by analysing twenty single individuals. Under the analysis conditions used for CZE analyses, from 30 to 35 peaks and/or shoulders were detected in the electrophoregrams. The comparison of the obtained profiles confirmed that within each landrace there is an appreciable genetic variation not only in terms of presence/absence of peaks but also at quantitative level. The highest variation was observed for 'Solina' where not two identical profiles were found among the 20 analysed individuals. Submitting to the cluster analysis the results of CZE analyses it were obtained the dendrograms shown in Fig. 1. As shown in Fig. 1a, 'Solina' individuals were grouped in two well separated main clusters (A and B). These clusters are constituted by several sub-clusters grouping a different number of individuals and ranking each other at different distances. These results clearly indicate that 'Solina' has a high genetic variation. As expected, the individuals belonging to 'Ruscia/Solina' mixture were grouped in two main clusters (Fig. 1b, C and D clusters). The high linkage distance between these clusters is consistent with the high genetic difference between the components of this mixture. In fact, 'Ruscia' and 'Solina' have a different ploidia level being tetra- and hexaploid, respectively. On the base of albumin profile of single seeds, it was estimated that the ratio of 'Ruscia' and 'Solina' in the mixture was about 1:1. Although, individuals sharing the same gliadin profile were detected in this mixture, some sub-clusters can be identified (Fig. 1b). In agreement with information of French farmers, 'Rosso d'Alsazia' landrace resulted constituted by two distinct groups of individuals. As a matter on fact, two main clusters (E and F) can be detected in the dendrogram generated by the cluster analysis (Fig. 1c). The clusters E and F showed a complex structure suggesting a high genetic variation within both the components of 'Rosso d'Alsazia'. Finally, one seed remained isolate (Fig. 1c), but the rarity of this gliadin profile and the high linkage distance suggest that this seed could be a contaminant more than a third component of 'Rosso d'Alsazia'. Among the studied landraces, 'Tosella' showed the highest number of individuals sharing the same gliadin profile (Fig. 1d). Identical profiles were detected in the clusters G and H. These clusters rank together at high value suggesting that this landrace too is constituted by two main components. In conclusion, the high variation detected within all the landraces indicates that they have retained the heterogeneous nature typical of material not released by breeders. These findings agree with Figliuolo et al. (2007) who, using molecular and biochemical markers, observed a greater genetic diversity in indigenous landraces present in Italy before 1915 than in the material diffused in subsequent historical periods.

Whole flour quality

As shown in Table 1, 1,000-kernel weight discriminates the old landraces from the modern varieties, being higher values invariably associated to the old

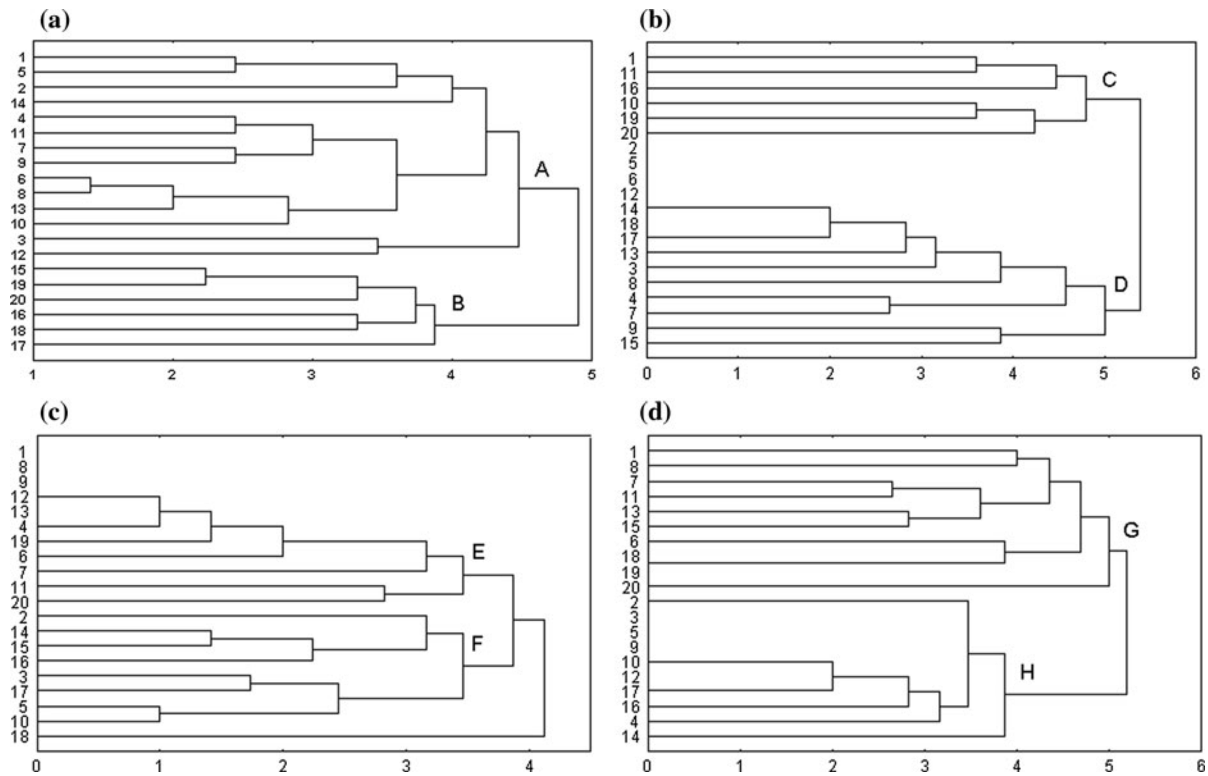

Fig. 1 Dendrograms based on Euclidean distance: (**a**) Solina; (**b**) Ruscia/Solina; (**c**) Rosso d'Alsazia; (**d**) Tosella. For each landrace the analysed caryopsides are numbered from 1 to 20

landraces. The values recorded in this study resulted higher than the average (39 g) reported in a previous study carried out on 16 old and modern Italian bread wheat cultivars evaluated for four growing seasons (Guarda et al. 2004).

The main goal of the present multiple quality trait evaluation was the comparison of whole flour characteristics of material with a different genetic background. Only whole flours were analysed due to the increasing interest toward whole flour derived products that are generally associated with decreased incidence of some diseases (Steffen et al. 2003; Liu et al. 1999). Proteins are important in determining the nutritional value of wheat and are the major determinants of baking quality. One objective of the breeding programmes carried out in the last century was the increase of proteins stored in grains. The tested landraces exhibited a narrow range of variation for proteins contents (107–119 g kg^{-1}). However, it should be noticed that the recorded values were higher than that recorded for the old variety 'Autonomia' and comparable with that of 'Bolero' (Table 1). The disagreement with protein range reported by Guarda et al. (2004), 11.4–16.1 %, can be explained by the different pedoclimatic conditions of growing environments. They were high marginal lands in this study while the fertile Po valley was the growing area selected by Guarda et al. (2004). It is known that gluten is a significant parameter in wheat for bread production. Overall, gluten amounts recorded in this study are low and only the mixture 'Ruscia/Solina' overcomes the 100 g kg^{-1} (Table 1). These results fulfil the demand of farmers consortium which is interested to old landraces characterised by low gluten contents. Moreover, the comparison of the gluten contents recorded for the landraces with the value relative to 'Autonomia', a typical biscuit variety, suggests that 'Tosella' and 'Rosso d'Alsazia' could be those closer to the farmers requests. Overall, DG/P ratio showed a wide variation (from 62.5 to 86.3 %). This could be a direct consequence of breeding, being observed an appreciable difference between the values

Table 1 Composition and technological traits of whole flours. The values are expressed on dry matter bases and presented as the mean ± standard deviation

Landrace or cultivar name	1,000 seed weight (g)	Bran (g kg^{-1})	Dry gluten (g kg^{-1})	SDS test (mm)	DG/P (%)	QI	Moisture (g kg^{-1})	Protein (g kg^{-1})	Ash (g kg^{-1})	Pigments (ppm g^{-1})	P (g kg^{-1})	Ferulic acid (g kg^{-1})
Ariosto	56.6 ± 0.03	88 ± 0.7	100 ± 4.7	33 ± 0.7	72.8	2.40	114 ± 3.2	137 ± 2.3	18.6 ± 0.06	2.45 ± 0.31	3.67 ± 0.15	1.36 ± 0.01
Autonomia	45.5 ± 0.44	120 ± 1.0	75 ± 5.5	36 ± 0.5	76.0	3.65	121 ± 2.4	98 ± 3.2	22.1 ± 0.11	1.65 ± 0.16	4.13 ± 0.13	1.25 ± 0.07
Bolero	39.0 ± 1.32	86 ± 0.4	102 ± 4.1	47 ± 0.8	86.2	3.98	122 ± 2.2	118 ± 1.3	16.7 ± 0.13	1.34 ± 0.17	2.81 ± 0.09	1.21 ± 0.09
Rosso di Alsazia	52.4 ± 0.53	105 ± 1.0	79 ± 7.1	43 ± 1.1	74.3	4.03	123 ± 3.2	107 ± 1.0	19.3 ± 0.09	1.70 ± 0.35	3.68 ± 0.11	0.64 ± 0.09
Ruscia/Solina	56.5 ± 1.11	74 ± 1.3	101 ± 5.8	31 ± 1.2	86.3	2.66	123 ± 2.9	117 ± 0.5	17.8 ± 0.14	2.22 ± 0.23	3.55 ± 0.05	0.84 ± 0.08
Solina	52.6 ± 066	140 ± 1.1	88 ± 8.1	44 ± 1.0	74.8	3.69	128 ± 2.5	119 ± 0.9	20.8 ± 0.10	2.48 ± 0.29	4.14 ± 0.07	0.85 ± 0.04
Tosella	51.4 ± 0.46	83 ± 0.8	71 ± 6.7	45 ± 0.9	62.5	3.94	126 ± 2.5	114 ± 2.2	17.5 ± 0.09	2.57 ± 0.41	3.12 ± 0.10	0.70 ± 0.05

DG/P dry gluten/protein content, *QI* quality index; pigments are expressed as β-carotene (ppm g^{-1})

recorded for 'Autonomia' and 'Bolero' (76.0 and 86.2 %, respectively). In contrast, gluten strength, estimated by the SDS sedimentation test, showed a narrow range of variation (Table 1). The lowest value was recorded for the mixture 'Ruscia/Solina'. This is not surprising due to the high percentage of durum wheat present in the mixture. On the basis of quality index (QI), the tested samples can be divided in two groups not related to their genetic background (landraces or varieties). The first group incorporated 'Bolero', 'Rosso d'Alsazia' and 'Tosella', all having QI close to 4.0; the second one comprised 'Autonomia' and 'Solina' (QI about 3.6). As expected, the value of the mixture 'Ruscia/Solina' was comparable with that of the tetraploid 'Ariosto'.

It is known that high ash content are not desirable by food industry. The low contents of present-day varieties is mainly the consequence of a deliberate selection to increase the quality for milling industry (Troccoli et al. 2000). For this reason, the ash amount can be considered an indicator of the primitiveness of a wheat species and, within each species, of each variety. As a matter of fact, the ash values relative to 'Autonomia', 'Rosso d'Alsazia' and 'Solina' were close or higher than 20 g kg^{-1} and, as predictable for material not obtained by breeding, they were appreciably different from the value of 'Bolero' (16.7 g kg^{-1}), the most recently released variety included in this study.

Nowadays, cereals are recognised sources of health-enhancing bioactive components (i.e.: minerals, fiber, tocopherols, etc.). The development of speciality foods based on wheat landrace flours requires the careful evaluation of these minor components to substantiate differences or similarities between old landraces and modern cultivars. It is well known that diets rich in carotenoids are associated with a reduced incidence of both cancer and of age-related pathologies (Handelman 2001; Hughes 2001). Wheat carotenoids include xanthophylls, mainly lutein, xanthophylls esters and carotenes (Abdel-Aal et al. 2007). In this study, the landraces had pigment amounts higher than that of 'Bolero' variety (Table 1).

The aptitude to store phosphorous in grains has been also estimated because high levels of phytates, which account for the main fraction of P, are detrimental. In fact, phytates form with calcium insoluble complexes that are nutritionally unavailable at the pH of the small intestine (Bohn et al. 2008). This is an important nutritional limit, being wheat seriously deficient in calcium. A wide variation was observed for P amount among the landraces as well as between the hexaploid varieties (Table 1). The highest values were recorded for 'Solina' and 'Autonomia' (4.14 and 4.13 g kg^{-1}, respectively), while the lowest one was that of 'Bolero' (2.81 g kg^{-1}). This suggests that breeding has strongly affected this feature. Scientific investigations have demonstrated that significant levels of antioxidant activity are present in whole wheat and that ferulic acid is the most abundant constituent of this group of compounds (Yu et al. 2004; Menga et al. 2010). Antioxidant compounds are located in the outer layers of cereals grains mainly as phenolic compounds both in free and insoluble form. The nutritional value of these compounds is related to their release from the food matrix (bioaccessibility) during the digestion (Serrano et al. 2007). A recent study (Menga et al. 2010) suggests the possibility of producing whole grain of soft wheat as well as of other cereals rich in natural antioxidant by selecting eligible cultivars and suitable growing locations. Data collected in this study (Table 1) showed that antioxidant activity is a distinctive trait of old and modern wheat samples. As a matter of fact, the values reported in the Table suggest that landraces have a lower aptitude to store these compounds in the tested environments.

Table 2 shows Pearson correlation coefficients among the recorded biochemical traits. Weight of 1,000 seeds was positively and significantly correlated only with the pigment content. Moreover, bran was correlated positively and significantly with both ash and total phosphorus, while ash was correlated only with total phosphorus. These findings are consistent with the distribution of minerals among the different tissues of caryopsis.

To better perceive the differences between landraces and modern varieties, all traits listed in Table 1 were submitted to the principal component analysis (PCA). The obtained three dimensional plot is shown in Fig. 2. The accounted variance was 35.5, 61.3 and 80.2 for PC1, PC2 and PC3 axes, respectively. On the first principal component (PC1) ferulic acid showed the highest absolute value of loading (2.759). The second principal component (PC2) was mainly influenced by bran and QI (absolute values of loading 1.882 and 1.469, respectively); while the third principal component (PC3) was characterised by high absolute loading of pigment and bran contents (1.638 and 1.466, respectively). Although, landraces as well as varieties are well distinguishable from each other in the plot, some aggregations can be identified. The hexaploid samples fell on the left side of the diagram, while the tetraploid ones on the right side. Moreover, 'Solina', 'Rosso d'Alsazia' and 'Tosella' are closer to 'Autonomia' than 'Bolero'. This is consistent with the genetic background of the entries because 'Bolero' is most recently released variety included in this study. As expected, 'Ruscia/Solina', being a mixture of hexaploid and tetraploid landraces, fell in a zone intermediate between those of bread and durum samples. These findings show that, in the tested environments, the quality of whole flour landraces is far from that of modern bread wheat varieties. This is in line with the data recently reported by Dinelli et al. (2007, 2011), who compared the profiles of phenolic

Table 2 Pearson's correlation coefficients among weight of 1,000 seeds and eight biochemical traits recorded on flours

	WS	Bran	Glu	SDS	Prot	Ash	Pigm	P	Fer
WS	1.00	−0.10	0.05	−0.57	0.42	0.06	0.77*	0.40	−0.34
Bran		1.00	−0.37	0.25	−0.33	0.85*	−0.01	0.75*	−0.02
Glu			1.00	−0.32	0.67	−0.46	−0.09	−0.27	0.45
SDS				1.00	−0.21	−0.19	−0.24	−0.41	−0.34
Prot					1.00	−0.47	0.51	−0.22	0.32
Ash						1.00	−0.01	0.92*	0.12
Pigm							1.00	0.23	−0.27
P								1.00	0.04
Fer									1.00

WS weight of 1,000 seeds, *Glu* dry gluten, *Prot* proteins, *Pigm* pigments, *Fer*—ferulic acid

* Significant at $p < 0.05$

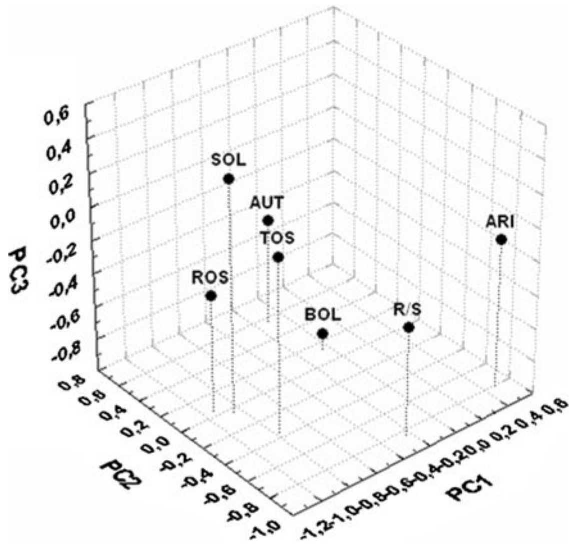

Fig. 2 Three-dimensional scatterplot of the first three principal components. The sample codes are: ARI – Ariosto; AUT – Autonomia; BOL – Bolero; ROS – Rosso d'Alsazia; R/S – Ruscia/Solina; SOL – Solina; TOS – Tosella

compounds in modern and old common wheat varieties, and by Guarda et al. (2004), who investigated the differences in grain yield and nitrogen-use efficiency between modern and old common wheat varieties.

Conclusions

It is widely accepted the important role of landraces for food security not only as source of gene readily available for breeders, but also because they perform well in marginal environments and are less responsive to changes in environmental conditions as compared to the modern cultivars (De Vita et al. 2010; Newton et al. 2010). In consequence of the strategic relevance of the wheat landraces, efforts to expand cultivation areas devoted to them could increase their chance of *on farm* survival. Of course, the promotion of landrace cultivation might take into consideration both nutritional and technological traits of flours. This study show that landraces and modern varieties differ not only for genetic diversity at intra-population level, but also for grain composition. As a matter of fact, the most recently released variety, such as 'Bolero', has a grain composition far from those of both landraces and the old variety 'Autonomia'. The ever-pressing demand for a sustainable agriculture with low environmental impact and the continuing spread of organic farming could allows the reintroduction of old wheat germplasm, at least at local scale and in marginal areas, such as is happening in Liguria region. Bread wheat landraces could have new market opportunities not only in the production of traditional niche food products but also in the preparation of novel products naturally enriched with health-beneficial compounds.

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