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Bread wheat genetic variation for grain's protein, iron and zinc concentrations as uptake by their genetic ability

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ABSTRACT

Genetic diversity among 80 irrigated bread wheat genotypes was studied for their grain's protein, iron and zinc concentrations as well as agronomic traits. The trend of these traits over the 70 years of cultivar releasing was demonstrated. The experiment was conducted as a RCBD with three replicates under normal and terminal drought stress conditions in Kermanshah, Iran during 2011–2012 cropping season. The results of combined ANOVA revealed high significant genotypic differences for all traits, except grain iron and zinc yield. Terminal drought stress reduced all studied traits except grain iron concentration which it increased by 14.10%. The maximum effect of drought stress was on grain zinc yield, grain yield and thousand grain weight as much as 26.65, 23.48 and 18% reduction, respectively. In both conditions, there were negative correlations among grain yield and grain iron, zinc and protein concentrations. Moreover, it was found that grain yield was increased with a small improvement during 70 years while protein, iron and zinc concentrations were decreased over the years. A wide range of genetic diversity in micronutrients uptake, particularly iron and zinc within studied wheat genotypes was identified which suggesting that selection for improved micronutrients efficiency is possible. What was concluded from this study is breeders' attention to enhancing grain production caused to neglect the quality of wheat production specially protein, iron and zinc concentrations during the last 70 years.

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1. Introduction

Wheat (*Triticum aestivum* L.) is the most important dietary source of food providing up to 50% of the daily calorie intake of populations in developing countries (Cakmak, 2008). Like many regions of the world, bread and other wheat-grain derivative products are the main daily source of population's food in Iran. About 52% of Iranian populations energy obtained from cereals and wheat, while only about five and 11% of the energy intakes from meat and high protein content resources, respectively (Kalantari et al., 2005).

Nowadays, due to cultivation of high yielding wheat genotypes and using new agricultural systems, modern plant breeding has been extremely oriented toward high agronomic yield rather than nutritional quality (Morris and Sands, 2006). Therefore, deficiencies of various vitamins and minerals particularly micronutrients together is one of the most serious growing concerns to global human health particularly in the developing world (Stein, 2010). Micronutrient deficiencies which lead to compromised health and economic losses affect more than half of the world's population which over two billion of them are in the developing world (Cakmak et al., 2010; Rawat et al., 2013). Iron (Fe) and zinc (Zn) deficiencies constitute the world's most common micronutrient deficiencies and are a growing public health concern (WHO, 2009). It has been estimated that 60–80% of the world's people are iron deficient and over 30% are zinc deficient (Teklić et al., 2013).

As wheat is a dominant dietary source of calories, proteins, and bioavailable micronutrients, the composition and nutritional quality of the wheat grain has a significant impact on human health (Peleg et al., 2008). For example, results of a study indicated that of the total Iranian people's iron intake, only 10.4% obtained from animal products, while the rest is provided from other resources which bread wheat by 45% had the highest share (Kalantari et al.,

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2005). Therefore, improving the nutritional value of such type of food will positively affect the nutritional status and human health.

As the processes of micronutrient uptake, translocation and utilization as well as their accumulation in the grains are under genetic control (Yang et al., 2007), identification genotypes with higher ability in uptaking micronutrient from the soil and high density of micronutrients in their edible parts is increasing (EL-Bendary et al., 2013). Therefore, biofortification by conventional plant breeding in the form of screening germplasm for genotypes with elevated micronutrients as the first stage of breeding programs has become a major task for plant breeders. Success in such cases depends on the existence of genetic variation for the target traits in the available germplasm (Ficco et al., 2009). Several researchers have identified a wide range of genetic diversity in micronutrients uptake, particularly iron and zinc (Welch and Graham, 2004) suggesting that selection for improved micronutrients efficiency is possible. It is well documented that increased grain Fe and Zn concentrations can be combined with improved agronomic traits (Monasterio and Graham, 2000; Welch et al., 2005). On the other hand, the concentration of micronutrients in wheat grain is affected by environmental factors such as soil, climate and management practices (Hussain et al., 2010). For example, in arid and semi-arid regions such as Iran, inadequate rainfall and high temperatures during grain filling period greatly restrict grain production.

Keeping in view of above discussion, the aim of this study was to screen 80 genotypes of bread wheat representing the most commercial wheat cultivars and elite lines cultivated in Iran, under normal and terminal drought stress conditions to identify cultivars that not only tolerate drought stress, but also having high productivity and economically important traits as well as quality attributes such as protein, iron and zinc concentrations.

2. Materials and methods

Eighty irrigated bread wheat genotypes (75 commercial cultivars released from 1942 to 2012 and five elite lines listed in Table 1) were obtained from the Department of Seed and Plant Improvement, Kermanshah Agriculture and Natural Resources Research Centre, Kermanshah, Iran. This investigation was conducted during 2011–2012 cropping season at the Research Farm of Razi University, Kermanshah located on the western part of Iran (latitude 34° 21′ North, longitude 47° 9′ East, altitude 1319 m. above sea level). The rainfall at the cropping season of the experiment was 308 mm. Experimental layout was in RCBD with three replicates under normal and drought stress conditions. Sowing was done by hand at five row plots, 1.2 m length, and 0.20 m row spacing as 400 seeds per square meter density. Terminal (end-season) drought stress was imposed in May 17, 2012 at stressed plots. Meanwhile, non-stressed plots were irrigated three times more. Chemical fertilizer, herbicide and pesticide were not used at both sites. At full physiological maturity, two middle rows of each plot were harvested to determine agronomic traits, grain's protein and iron and zinc concentrations. Grain's protein concentration was measured by near infrared reflectance (NIR) spectrometer (Perten Instruments DA7200) method (Osborne et al., 2007).

Before planting, the soil samples from 0 to 30 cm depth were collected from different part of the field, air dried, crushed to pass a 2 mm sieve, and saved for further analyses (Table 2). Soil's pH and EC were determined using a 1:2 soil to water suspension. Organic matter was estimated using a modified Walkley–Black procedure (Allison, 1965). Hydrometer method and rapid titration method (Page, 1982) were used to determine particle-size and calcium carbonate equivalent of the soil, respectively. Soil Fe and Zn concentrations, were measured by atomic absorption spectrophotometer (Blair et al., 2011).

In order to determine grain Fe and Zn concentration, the grains were rinsed with distilled water and oven dried at 50 °C for 24 h according to Emami (1996). Dried grains were ground by a laboratory non-rust steel miller (IKA® A11 B, Germany). Two grams of each powder sample was incinerated at 550 °C in a muffle furnace. Then, 10 ml hydrochloric acid (2 N) was added to crucible containing the ash, and placed on water bath at 80 °C for an hour. The digested samples were diluted with distilled water to 100 ml before analysis. Finally, grain Fe and Zn concentrations were measured by atomic absorption spectrometer (SpectrAA-220, VARIAN, Australia). Both micronutrients were measured for two replicates of each site.

Data were subjected to combined analysis of variance using SAS software. Means were compared by the least significant differences test. Pearson correlation analysis was carried out using SPSS software ver.16. GGE-biplot software version 6.3 was used to perform principal component analysis.

3. Results

3.1. Combined analysis of variance and mean comparison

The results revealed high significant genotypic differences for all traits, except grain Fe yield and grain Zn yield (Data not shown). Effect of environment was significant for grain Zn yield, grain protein concentration, grain yield, biological yield, straw yield, harvest index, thousand grain weight and hectoliter weight. In this experiment, stress intensity (SI) was 0.23 which is mild. Variations in the reduction percentage of studied traits due to terminal drought stress are presented in Table 3. Drought stress reduced all traits except grain Fe concentration which was increased by 14.1%. The increase of Fe concentration was genotype-dependent so that stress increased Fe in 72 out of 80 studied genotypes and Fe reduced in other genotypes (Data not shown). The maximum effect of drought stress was on grain Zn yield, grain yield and thousand grain weight as much as 26.65, 23.48 and 18% reduction, respectively. All studied traits except grain protein concentration were not significantly affected by genotype × environment interaction.

Mean comparison of studied traits in both conditions is presented in Table 4

. Grain iron concentrations ranged from 63.56 to 102.19 mg/kg, with a mean value of 77.82 mg/kg. Genotypes 74 (Maroon), 79 (Sistan) and 13 (Parsi) by 102.19, 99.34 and 91.05 mg/kg had the highest grain iron concentrations, respectively. For zinc, the range was between 31.65 and 54.06 mg/kg with a mean value of 42.31 mg/kg. The highest grain Zn concentration was obtained from genotypes 13 (Parsi), 63 (Shahpasand), 80 (Norstar), 74 (Maroon), 70 (Sabalan), 42 (Rassoul), 25 (Gaspard), 32 (Oroom) and 15 (M-85-7) by more than 50 mg/kg. Genotypes 74 (Maroon) and 13 (Parsi) were the superior based on both micronutrients, so they could be known as genotypes with high genetic capacity in uptaking and reservation of these micronutrients. According to Table 4, maximum grain protein concentration was obtained from genotypes 63 (Shahpasand), 80 (Norstar), 42 (Rassoul), 67 (Sholleh), 19 (Bezostaya), 50 (Chenab), 47 (Morvarid) and 7 (Niknejad) by more than 13%, while the minimum value was observed for genotype 79 (Sistan) by 12.17%. A wide range of variation was observed for the other studied traits which are presented in Table 4. For example, grain yield ranged from 2311 to 8186 kg/ha which was recorded for genotypes 80 (Norstar) and 5 (Ghods), respectively.

3.2. Correlation analysis

Under non-stress conditions both grain Fe and Zn concentrations were highly significant and positively correlated with grain

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