Chapter 5
Macro-Microelements in Wheat Landraces and Their Use in Breeding

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5.1 Macro-Microelements in Wheat Landraces

Cereals provide 60% of the daily calorie requirement, especially for people living in developing countries (Awika 2011). Wheat is an important plant covering the largest cultivation area among cereals in the world. Nutritional quality of wheat (*Triticum* sp.), as one of the first cultivated plants in the world, has a significant impact on human health worldwide. Wheat is an important source of macro-minerals such as K, P, and Mg and micro-minerals such as copper, iron, magnesium, manganese, phosphorus, selenium, zinc etc. However, the mineral content of widely cultivated modern wheat varieties is reported to be significantly reduced (Jaradat 2011).

The concentration of minerals in wheat flour is genetically determined by cultivar and environment-soil, climate, and management practices. Wheat ancient species such as einkorn (*Triticum monococcum* ssp. *monococcum*), emmer (*Triticum dicoccon*) and landraces have been found to have higher nutritional values (Megyeri et al. 2014; Rachon et al. 2015). In previous studies, K, Mg, and P values have been reported to differ according to wheat varieties (Jakobsone et al. 2015; Kan 2015; Lyons et al. 2005).

Zinc, iron, copper, and magnesium concentrations remained stable in wheat cultivars from 1845 to the mid-1960s. Then, they have significantly decreased, which coincided with the introduction of semi-dwarf, high-yielding cultivars (Fan et al. 2008). This causes individuals fed on wheat-based diet to experience health problems called "hidden hunger." Especially in women and children, hidden hunger can cause blindness, premature death, and mental development problems (Ahmed et al. 2012). For example, more than 60% of the world's population has Fe deficiency, more than 30% has Zn deficiency, and approximately 15% has Se deficiency (Mayer

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et al. 2008; Rayman 2008). Mg, Fe, and Zn are mainly found in the aleurone layer of common wheat grains, and these macro- and micro-minerals of whole wheat products are an important source of human daily needs (Piergiovanni et al. 1997). Increasing the nutritional properties of wheat is of great importance for human population worldwide. Increasing the amount of microelements such as zinc, iron, and protein content in planting areas without reducing wheat yield or keeping the yield at a reasonable level will decrease the diseases caused by these deficiencies.

For many years, large-scale commodity production of crops has focused on increasing yield, but increasing interest from health-conscious consumers has stirred interest in grains in order to improve nutrition and health. Depending on growing conditions and wheat variety, important macro-minerals like calcium, magnesium, and potassium and micro-minerals like iron, copper, and selenium are found in wheat kernels. These are distributed throughout the aleurone layer (55%), endosperm (20%), pericarp (10%), scutellum and testa (10%), and embryo (5%).

Summarized below are some of these essential minerals and their important roles in maintaining good health.

- Magnesium: Contributes to efficient metabolism as well as proper muscle and nerve functioning and is shown also to reduce diabetes and metabolic ailments
- Calcium: An essential component for the development of musculoskeletal, cardiovascular, and nervous systems and furthermore promotes overall physiological performance
- Phosphorus: Necessary for proper functioning of kidneys and heart muscle, contributes to bone and dental strength, and regulates protein reactions
- Potassium: Contributes to proper heart muscle contraction, neural impulse transmission, and fluid system balance
- Copper: Facilitates the functions of C-oxidase enzymes and promotes connective tissue development and iron metabolism
- Selenium: Inhibits some types of cancer cell formation and promotes essential antioxidant reactions
- Iron: Needed for hemoglobin synthesis and energy production
- Zinc: Regulates the function of many enzymes, glucose, and insulin and synthesizes proteins

Lyons et al. (2005) investigated whether the genotypic selenium variation in breeding is sufficient. The result indicated that there was no significant genotypic variation among commercial bread and durum wheat cultivars for selenium. Selenium is, on the other hand, an important micronutrient for animals and humans for its antioxidant, anticancer, and antiviral effect. It was found in the study that there was a little difference among commercial varieties for selenium content; moreover, they also discovered that diploid *Aegilops tauschii* wheat had more than 42% selenium than commercial varieties and 35% higher than rye. Ash-rich einkorn wheat was found to be richer in important minerals such as calcium, phosphorus, potassium, magnesium, manganese, and zinc except iron.

Some other studies have shown that genotype and environment interactions are important for Zn and Fe concentrations in wheat (OrtizMonasterio et al. 2007;

Morgounov et al. 2017). As identified in Jaradat (2011) study, Fe content in wheats collected from local wheat plants in Turkey is higher than in other areas, showing strong correlation between Fe content and the cereal. In addition, a high degree of inheritance was observed in both Fe and Zn concentrations (Velu et al. 2017), pointing out a strong genetic share in accumulation of these minerals in grain. It was as well specified that environmental factors were effective as much as genotype in these differences. Besides, multiple regression analysis showed that both increasing yield and harvest index were highly significant factors that explained the downward trend in grain mineral concentration (Fan et al. 2008).

5.2 Wheat Landraces in Breeding Studies

Cereals are grain seeds from plants of Gramineae family such as wheat, corn, rice, barley, oats, and rye, which have been the basis of human nutrition for thousands of years. Mineral deficiencies are common in many people fed by cereals on earth; therefore, improving mineral content in cereals represents an important strategy for increasing human mineral intake and health (Ficco et al. 2009). Widely grown modern wheat varieties have high yield capacity; therefore, they are cheap and important nutrient sources to meet the daily needs of less fortunate people, but these wheat varieties are poor especially in micronutrient sources such as Zn and Fe (Welch and Graham 2004).

In order to overcome this deficiency, local wheats which are mineral- and phytochemical-rich herbal sources (Arzani and Ashraf 2017) may have been utilized as genitors in wheat breeding programs (Hocaoglu and Akcura 2017). As the primary gene source of breeding programs, wheat landraces have been collected intensively since the 1900s, and many of them have been identified and started to be used in breeding programs (Morgounov et al. 2017).

With the increase in yield, mineral content of modern wheat varieties decreased proportionally including copper, iron, magnesium, manganese, phosphorus, selenium, and zinc. High levels of these nutrients can be found in soils and in old low-yield wheat landraces. In many breeding studies, new varieties were firstly selected from wheat landraces by selection and used directly in production or used as genitors in breeding programs. For example, in winter wheat breeding program in Turkey, many varieties of rootstock obtained by hybridization breeding have created wheat landrace varieties (Salantur et al. 2017).

Wheat landraces have also been used as genetic material in breeding programs in different countries. Norin-10 was developed in 1924 by giving Turkey red local variety to the short Daruma x Fultz hybrid made by Japanese breeders in 1917 (Reitz and Salmon 1968). Horarek, which was selected by Zhukovsky from local varieties in 1951, was superior to many varieties in Russia with its earliness, yield, and fusarium resistance (Qualset et al. 1996). Fifty-one lines selected from the Turkish local variety PI 178383 resistant to yellow rust were used as genitors in the development of new varieties in the USA and have made significant contributions to the US economy. Turkey red varieties were taken from Anatolia in 1874 in Kansas City. It has been the most common variety in Kansas for 70 years and formed the basis of the wheat industry. This wheat variety has a unique, rich, and complex flavor and excellent baking qualities (Anonymous 2019).

Utilizing wheat landraces to expand the existing gene pool in bread and durum wheat has been a new approach in recent years. Durum wheat, *Triticum durum* (AABB), is thought to be developed from wild emmer wheat, *Triticum dicoccoides* (*Körn. ex Asch. & Graebner) Schweinf.).* Locally grown emmer wheat (*Triticum dicoccon*) is one of the first examples. It is known that some of the important genetic features found in wild relatives in the process of obtaining cultured plants are lost and cannot be transferred to culture plants anymore (Tanksley and McCouch 1997).

Wheat landraces hulled or hulless are superior to cultivated wheats in many features. For instance, Kamut wheat, which is an old wheat type, contains a significant amount of selenium than cultured wheat (Piergiovanni et al. 2009). Hulled wheats are transitional forms between today's wheat and wild wheat relatives. Einkorn wheat (*Triticum monococcum* ssp. *monococcum*) is the first type of wheat cultivated on the foothills of Karacadağ, Diyarbakır (Heun et al. 1997). It is known to make important contributions to human nutrition and health (Hidalgo and Brandolini 2008; Pirgozliev et al. 2015).

In order to increase the mineral content of durum wheat, *Triticum dicoccoides* and *Triticum dicoccon* were used as female genitors in wheat breeding. Macro- and micro-mineral contents were determined in fixed F7 lines. In this study, it was observed that iron and zinc contents increased significantly than already produced durum wheat varieties. While iron content of durum wheat varieties ranged between 11.80 and 15.61 ppm, iron content ranged between 8.54 and 86.76 ppm. Kamut (Khorasan wheat; Figs. 5.1 and 5.2) or einkorn (Fig. 5.3) wheat also was used in this project as a female for breeding program (Anonymous 2016).

Einkorn wheat proved to have the highest levels of protein, fat, ash, phosphorus, potassium, magnesium, calcium, copper, zinc, iron, and manganese (Rachon et al.

Fig. 5.1 Kamut X bread wheat cross

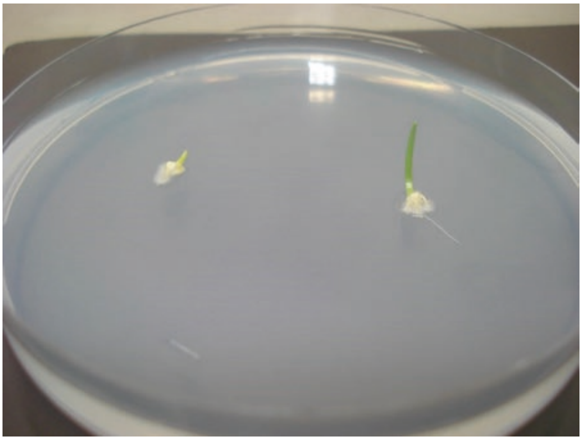

Fig. 5.2 Kamut X bread wheat cross

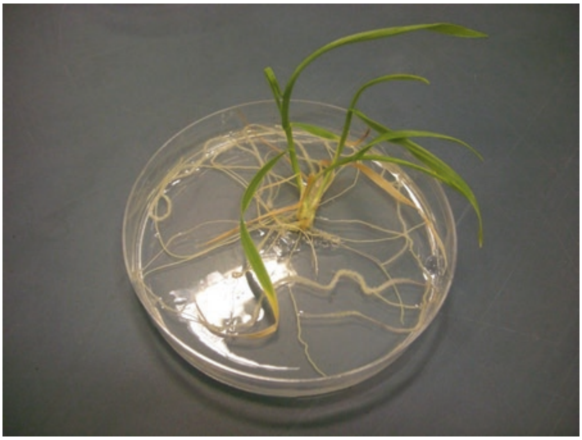

Fig. 5.3 Einkorn X durum wheat cross

2015). It was also found that macro-micronutrient content of spelt (*Triticum spelta*; 2n = 42) was significantly higher than that of cultured wheat (Berecz et al. 2001; Ruibal-Mendieta et al. 2005).

Several studies have shown that some genotypes from landraces are directly related to breeding targets and can be used as a gene source in breeding, i.e., to increase resistance to biotic and abiotic stresses (Jaradat 2011), cold resistance (Küçüközdemir and Tosun 2016), drought resistance, coleoptile length (Öztürk et al. 2014), quality (Akar et al. 2009; Akçura 2011), and mineral content (Fan et al. 2008; Ficco et al. 2009; Hussain et al. 2010).

Wheat landraces of common wheat are important sources for increasing micronutrients in plant breeding programs. In a study, the macro- and micronutrient contents (Fe, Zn, B, K, Mn, Cu, Mg, Ca, Mo) of 37 pure lines and 9 bread wheat varieties obtained from wheat landraces collected from Western Anatolia (Eskişehir and Kütahya) and Thrace (Edirne) were evaluated. Higher correlation existed between iron and zinc contents with boron and molybdenum contents of genotypes. A pure line (L4) was the most prominent genotype for iron and zinc content, while it was superior for both boron and molybdenum contents. Copper content of cereals was negatively correlated with iron and zinc content. While wheat varieties have relatively higher Mo content, they can also be improved for Fe, Zn, B, K, and Ca contents. Fe, Zn, and Mn contents of many pure advanced lines improved based on landraces were usually higher than those of modern cultivars. Moreover, mean grain concentrations of Fe, Zn, and Mn in pure advanced lines improved based on landraces lines from wheat landraces were significantly higher than all cultivars, 9.25, 14.82, and 6.75%, respectively. Therefore, some pure lines could be recommended to be used as genetic material to enhance the genetic basis of bread wheat breeding programs worldwide (Akcura and Kokten 2017).

In another study, it was found that nine wheat landraces have the potential to be incorporated into the wheat gene pool. Of these, two wheat landraces, 782 and 528 ppm, have higher P and Fe composition, respectively, with good grain weight and ideal candidates for crop improvement (Kondou et al. 2016). While comparing the concentrations of 5 macro- and 15 microelements in the whole grain of spring lines of emmer, einkorn, spelt, and two common wheat cultivars, all grown under identical environmental conditions, *Triticum* species differed significantly for P, Mg, Zn, Fe, Mn, Na, Cu, Sr, Rb, and Mo. The grain of all hulled wheats, compared with common wheat, contained significantly more Zn (from 34% to 54%), Fe (from 31% to 33%), and Cu (from 3% to 28%). Significant positive correlations existed between the levels of Fe, Zn, and Mn, in particular in *T. monococcum* ssp. *monococcum* and *T. dicoccon*. A strong correlation between Zn, Fe, and Mn could have important implications for wheat quality breeding (Suchowilska et al. 2012).

Dietary Zn deficiency is widespread, especially in developing countries, and breeding (genetic biofortification) through the HarvestPlus program has recently started to deliver new wheat varieties to help alleviate this problem in South Asia (Khokhar et al. 2018). A study by Lyons et al. (2005) determined no significant genotypic variation in grain Se density among modern commercial bread or durum wheat or triticale or barley varieties. However, the diploid wheat, *Aegilops tauschii*, and rye have 42% and 35% higher, respectively, grain Se concentration than other cereals in separate field trials, and, in a hydroponic trial, rye was 40% higher in foliar Se content than two wheat landraces.

Wheat landraces are indispensable genetic resources for low-input agriculture and organic farming due to uncertainties caused by global warming, demand for good nutrition, and increased demand for organic products. Success in wheat breeding depends on the availability of genetic diversity for target traits in the present gene pool. Wheat landraces are important variation sources (Akçura et al. 2011; Hocaoglu and Akcura 2017). Wheat landraces have become indispensable as they are used directly in improvement as well as genetic material of wheat breeding programs and as such have made significant contributions to the genetic structure of today's wheat and will continue to do so.

In the future studies, wheat breeding will be shaped by attempts to increase the microelement contents such as iron and zinc which are important for human health besides being important quality features of the grain. Local varieties are, above all, part of the world's cultural heritage, an important guarantee of food safety and as such must be cultivated, protected, and inherited for future generations as genetic treasures.

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