Wild Wheats Represent Valuable Genetic Resource for Improving Grain Zinc and Iron Concentrations

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Abstract

Zinc (Zn) and iron (Fe) deficiencies are prevalent micronutrient deficiencies affecting health of nearly half of the world's population. Cereals play a major role in supplying needed daily micronutrient requirements, especially for resource-poor people. Cultivated modern cereal crops are, however, inherently low in concentrations of Zn and Fe in grain, particularly when grown on micronutrient-deficient soils. Breeding new cereal genotypes with high concentrations of Zn and Fe in grain appear to be most cost-effective approach to the problem. Genetic variation for grain Zn and Fe concentration is very narrow in cultivated cereal crops and not useful in breeding programs. Recent studies indicated that wild and primitive wheat species represent an important source of genetic variation for Zn and Fe. Over 5000 genotypes of wild and primitive wheat species collected from the Fertile Crescent region have been screened for micronutrients in seeds. Results showed existence of a substantial genetic variation for grain Zn and Fe. Among the species tested, *Triticum diccoccoides*, *Triticum urartu* and *Aegilops speltoides* seem to be most promising species in improving grain micronutrient concentrations. Recently, by using RSLs carrying the *Gpc-B1* allele of *Triticum dicoccoides* it was shown that Gpc-B1 locus has an increasing effect on grain Zn and Fe concentrations. The results indicate that wild wheats can be exploited as an important genetic resource for improving cultivated wheat for high grain Zn and Fe.

Media Summary

Iron and zinc deficiencies are important health threat to human beings in the developing world, resulting in severe health complications such as mental retardations, impairments in immune system and anemia. Improving grain iron and zinc concentrations by plant breeding seems to be most sustainable approach to the problem. Wild and primitive wheat species represent promising genetic resources for micronutrients to improve cultivated wheat for micronutrients.

Key Words:

Biofortification, breeding, cereals, iron, nutritional quality, zinc

Introduction

Iron (Fe) and Zn deficiencies are increasing concern in the developing world affecting seriously human nutrition and health. Recent estimates indicate that nearly the half of the world population is affected from micronutrient deficiencies. According to a WHO report, Zn and Fe deficiencies have been ranked as 5th and 6th important risk factors responsible for development of different types of illness and diseases in the developing world (Table 1). The health problems associated with Zn and Fe deficiency include mental retardations in children, impairments in physical development and immune system and increases in anemia and maternal mortality.

Heavy and monotonous consumption of cereal based foods seem to be major reason for widespread occurrence of micronutrient deficiencies in human beings. Cereals are inherently very low in micronutrients when compared to other food crops such as grain legumes (Welch and Graham, 1999). When grown on micronutrient deficient soils having high pH, low organic matter and low soil

moisture, cereal grains are particularly poor in Zn and Fe. Nearly half of the cereal-cultivated soils globally have Zn deficiency problem in soils (Cakmak, 2008). Currently, cereals crops are dominating

Table 1: Ten leading risk factors involved in occurrence of various illnesses and diseases in low-income countries (WHO, 2002).

Risk Factors	Ratio
	(%)
Underweight	14.9
Unsafe sex	10.2
Unsafe water	5.5
Indoor smoke	3.7
Zinc deficiency	**3.2**
Iron deficiency	**3.1**
Vitamin A deficiency	3.0
Blood pressure	2.5
Tobacco	2.0
Cholesterol	1.9

food crops in the cropping systems, and the genetic diversity of food crops cultivated declined very significantly following the green revolution (Fig. 1; Welch and Graham, 1999). There is, therefore, a high need for improving Zn and Fe density of cereal grains to minimize micronutrient deficiency-related health problems in human beings. Improving micronutrient concentrations of cereal grains is of high priority research topic.

Wild Wheats: Valuable Genetic Resource for Improving Grain Zinc and Iron Concentrations
Modern cereal cultivars have generally very low concentrations of micronutrients in grain with little genetic variation, and show only a part of the genetic variation found in wild cereals. In contrast to modern cultivars, wild cereals represent an important pool of useful genes. Exploitation of this large natural variation for nutritional substances in seeds of wild cereals is an attractive approach for enhancing nutritional quality of cultivated modern wheat (Nevo, 2001).

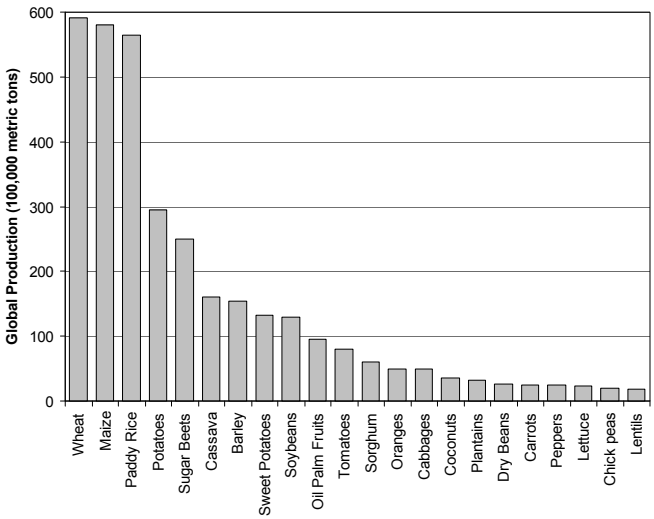

Fig. 1: Global production of various food crops (Mann, 1997)

In a germplasm with more than *Triticum dicoccoides* accessions, the concentrations of Zn and Fe varied from 14 to 190 mg kg^{-1} DW for Zn and from 15 to 109 mg kg^{-1} DW for Fe. Also for total amount of Zn and Fe per seed, *Triticum dicoccoides* accessions contained very high amount of Zn (up to 7 µg per seed) and Fe (up to 3.7 µg per seed). Such high genotypic variation could not be found within cultivated modern wheat. For example, on a Zn-deficient soil under field conditions in Central Anatolia, grain Zn concentration of 28 cultivated wheats varied from 7 to 10 mg Zn kg^{-1} DW (Cakmak et al., 2004). The studies with wheat-*dicoccoides* substitution lines indicated that the genes determining high level of Zn in seeds are located on the *Tr. dicoccoides* chromosomes 6A and 6B (Cakmak et al., 2004). The 6B chromosome is also associated with high protein concentration in the seed (Chee et al., 2001) suggesting that the genes encoding for high Zn-concentration and high protein content are closely linked.

In a set of recombinant substitution lines derived from *Triticum dicoccoide,* a locus *Gpc-B1* has been identified on the short arm of the chromosome 6B affecting both protein and Zn concentrations (Fahima et al., 2006; Distelfeld et al., 2007). These results indicate that breeding for high protein in grain may result in simultaneously high grain Zn. Currently, by using various transgenic approaches a significant progress is being made in developing plant genotypes with increased concentrations of Zn and Fe. However, in these studies published in prominent scientific journals no data is available on grain yield per plant or per spike, and consequently, it is impossible to assess any potential dilution or concentration effects on the reported changes in grain Fe or Zn concentrations.

Conclusions

Wild wheats, especially *Triticum dicoccoides* serve as an important genetic resource for improving modern cereal cultivars with micronutrient concentrations. Recent results indicate that also *Triticum urartu* and *Aegilops speltoides* are rich in micronutrient concentrations and could be exploited in the breeding programs or in understanding of the mechanisms contributing to accumulation of micronutrients in cereal grains. Some selected synthetic wheats derived from A genome contained up to 3- or 4-fold more Zn and Fe than the parental lines. Such promising genotypes are being used in our breeding programs.

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