Effect of nitrogen and iron fertilizers on grain concentration of iron in wheat

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Abstract
Greenhouse experiments have been conducted to investigate the effectiveness of various soil- and foliarly-applied iron (Fe) fertilizers in increasing grain Fe concentrations of wheat plants under different nitrogen (N) nutrition regimes. The Fe fertilizers tested were FeSO4, Fe-EDTA, Fe-EDDHA and Fe-citrate and applied either into soil or foliar sprayed at the booting and early milk stages. The rates of soil applied nitrogen ranged between 100 to 600 mg N per kg soil. In an additional experiment, plants were also treated with 0.75 % urea during the booting and early milk stages. At a given N supply, shoot and grain concentrations of Fe were not affected by increasing application of Fe fertilizers. In contrast to soil Fe application, increasing soil application of N significantly enhanced Fe concentrations of shoot and grains. There was a close relationship between tissue concentrations of Fe and N. Foliarly-applied Fe fertilizers were either not effective or tended to improve Fe concentrations. However, at a given foliar application of Fe fertilizers, improving N nutrition of plants stimulated grain Fe accumulation. The results indicate an important role of N nutrition in enrichment of wheat grain with Fe. This N effect should be considered in breeding and fertilization programs focusing on enrichment of staple food crops with Fe.

Key Words
Iron deficiency, biofortification, wheat, iron fertilizers and nitrogen fertilization.

Introduction

Iron deficiency is a growing health concern in the developing world, and responsible for diverse of health complications including anemia and impairments in immune system (Welch and Graham 2004). It is estimated that nearly half of the world population is affected from Fe deficiency problem. Major reason for widespread occurrence of Fe deficiency in human populations is very little dietary diversity and high consumption of cereal-based foods with very low amount and poor availability of Fe (Bouis 2003; Welch and Graham 2004). Increasing concentration and bioavailability of Fe in commonly-eaten food crops is, therefore, a big global challenge and an important public health issue. Various strategies are available to alleviate Fe deficiency problem globally. Among these strategies, agricultural strategies like plant breeding (e.g., genetic biofortification) and agronomic approaches (e.g., fertilization) seem to be highly cost-effective and easily applicable in the developing world (Cakmak 2008). In case of agronomic approaches, there are little published data in literature dealing with the role of Fe fertilization on Fe concentrations in the edible parts of staple food crops. Most of the studies about Fe fertilization focused more on correction of Fe deficiency problem. In addition, in contrast to Zn, Fe fertilization seems to be not effective in increasing Fe concentrations of cereal grains (Rengel *et al*. 1999). Recent evidence in literature indicates that nitrogen nutritional status of plants has a positive influence on grain accumulation of Fe (Kutman *et al*. 2010), possibly by i) contributing to release of Fe-mobilizing compounds from roots (e.g., phytosiderophores, ii) enhancing root uptake and transport of Fe via increasing pool of transporter proteins (e.g., IRT proteins), iii) facilitating translocation and phloem transport of Fe via chelation with nitrogenous compounds (e.g., nicotianamine, peptides) and iv) improving seed deposition of Fe by increasing amount of proteins in seeds (Cakmak *et al*. 2010). In the present study, we investigated role of soil- and/or foliarly-applied various Fe fertilizers on grain accumulation of Fe in wheat under different N nutrition regimes.

Materials and Methods

Greenhouse experiments were conducted by using a calcareous soil containing 5.6 mg DTPA-extractable Fe per kg of soil. Durum wheat (*Triticum durum*, cv: Balcali-2000) plants were grown at different rates of Fe and N fertilizers. Following Fe fertilizers were examined for their effect on shoot and grain concentrations of Fe: $FeSO_4$, Fe-EDTA, Fe-EDDHA and Fe-citrate which were applied either into soil at the rates of 0, 5 and 10 mg Fe per kg soil or sprayed to foliar at the rate of 0.2 % Fe-EDTA at the booting and early milk stages. The same amount of Fe sprayed with 0.2 % Fe-EDTA has been also applied with other Fe fertilizers. The rates of soil applied nitrogen ranged between 100 to 600 mg N per kg soil and applied in form of $Ca(NO_3)_2$. In additional experiments, shoot parts of plants were sprayed with 0.75 % urea at the booting and early milk

stages. At harvest, shoot and grain parts of plants were analyzed for Fe concentrations by using ICP-OES and for determination of dry matter production.

Results

At a given N treatment, soil application of $FeSO_4$, Fe-EDTA, Fe-EDDHA and Fe-citrate did not affect Fe concentrations of shoot and grain, while increases in soil N application significantly elevated shoot and grain concentrations of Fe. Similarly, also foliar spray of urea at the booting and milk stages significantly enhanced grain concentrations of Fe. In the case of foliar application of Fe fertilizers, there were only slight increases in grain Fe. Among the foliarly-applied Fe fertilizers, Fe-EDTA appeared to be the best Fe sources in increasing grain Fe concentrations. There was a significant correlation between shoot or grain concentrations of N and Fe. Similar to Fe, also grain concentration of Zn was increased by improving N nutrition of plants either by soil or foliar application of N fertilizers.

Conclusion

The results indicate a critical role of N nutrition in enrichment of wheat grain with Fe (and Zn). The reason for this positive effect of N on grain Fe is not clear. As discussed recently by Cakmak *et al.* (2010), probably, a high N nutrition contributes to grain Fe concentration by i) affecting the pool of transporter proteins mediating Fe uptake and transport in plants, ii) increasing the amount of Fe-translocating nitrogenous compounds such as nicotianamine and certain peptides) or iii) elevating amount of Fe-binding proteins in grain.

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