African Journal of Biotechnology Vol. 8 (24), pp. 6795-6798, 15 December, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Effect of foliar application of Zn and Fe on wheat yield and quality

Maralian Habib

Department of Plant Production, Moghan Junior College of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran.
E-mail: h_maralian@yahoo.com, aghabaraty@yahoo.com. Tel.: 00989141548667. Fax: 00984527463417.

Accepted 15 October, 2009

Intensive and multiple cropping, cultivations of crop varieties with heavy nutrient requirement and unbalanced use of chemical fertilizers especially nitrogen and phosphorus fertilizers reduced quality of grain production and the appearance of micronutrient deficiency in crops. A field experiment was conducted on clay-loam soil in Moghan region during 2007-2008 to investigate the effect of foliar application of zinc and iron on wheat yield and quality at tillering and heading stage. The experimental design was a randomized complete block design with three replicates. The SAS software package was used to analyze all the data and means were separated by the least significant difference (LSD) test at P< 0.01. The treatments were control (no Zn and Fe Application), 150 g Zn.ha^{-1} as $ZnSO_4$, 150 g Fe.ha^{-1} as Fe_2O_3, and a combination of both Zn and Fe. In this study, parameters such as wheat grain yield, seed-Zn and Fe concentration were evaluated. Results showed that foliar application of Zn and Fe increased seed yield and its quality compared with control. Among treatments, application of (Fe + Zn) obtained highest seed yield and quality.

Key words: Wheat, yield, Zn, Fe, fortification.

INTRODUCTION

Increasing the Zn and Fe concentration of food crop plants, resulting in better crop production and improved human health, is an important global challenge. Among micronutrients, Zn deficiency occurs in both crops and humans (White and Zasoski, 1999; Hotz and Brown, 2004; Welch and Graham, 2004). Zinc deficiency is currently listed as a major risk factor for human health and causes of death globally. According to a WHO (2002) report on the risk factors responsible for development of illnesses and diseases, Zn deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries. In a comprehensive study, Hotz and Brown (2004) reported that Zn deficiency affects, on average, one-third of world's population, ranging from 4 to 73% in different countries. The regions with Zn-deficient soils are also the regions where Zn deficiency in human beings is widespread, for example in India, Pakistan, China, Iran and Turkey (Cakmak et al. 1999; Alloway, 2004; Hotz and Brown, 2004). Zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries (Sillanpaa, 1982; Bybordi and Malakouti, 2003; Alloway, 2004; Seilsepour, 2007). Nearly 50% of the cereal-grown areas in the world have soils with low plant availability of Zn (Graham and Welch, 1996; Cakmak, 2002). Cereal crops represent a major source of minerals and protein in developing world. For example, in most of Central and West Asian countries, wheat provides nearly 50% of the daily calorie intake on average, likely increasing to more than 70% in the rural regions (Cakmak et al., 2004).

According to FAO reports, wheat plays a particular role in covering daily caloric requirements of humans in Tajikistan. According to a report published by Hotz and Brown (2004), among all countries in the world, Tajikistan has been listed as the country having the highest percentage of population living under risk of Zn deficiency. Bybordi and Malakouti (2003) reported that wheat is sensitive to zinc deficiency, but less sensitive to Iron and copper deficiencies. Wheat is inherently low in concentrations of Zn in grain, particularly when grown on Zn-deficient soils. Based on a range of reports and survey studies, the average concentration of Zn in whole grain of wheat in various countries is between 20 to 35 mg kg^{-1} (Rengel et al., 1999; Cakmak et al., 2004; Seilsepour, 2007). Most of the seed-Zn is located in the embryo and aleurone layer, whereas the endosperm is very low in Zn concentration (Ozturk et al., 2006). The embryo and aleurone parts are also rich in protein and phytate (Lott and Spitzer, 1980; Mazzolini et al., 1985), indicating that protein and phytate in seeds could be sinks for Zn. According to a Zn-staining study in wheat seed, Zn concentrations were found to be around 150 mg kg^{-1} in the embryo and aleurone layer and only 15 mg kg^{-1} in the endosperm (Ozturk et al., 2006). The Zn-rich parts of wheat seed are removed during milling, thus resulting in a marked reduction in flour Zn concentrations.

Enrichment of cereal grains with Zn is, therefore, a high priority area of research and will contribute to minimizing Zn deficiency-related health problems in humans. Among the interventions currently being used as major solution to Zn deficiency in humans, food fortification and supplementation are being widely applied in some countries. However, these approaches appear to be expensive and not easily accessible by those living in developing countries (Bouis, 2003; Stein et al., 2007). For example, to eliminate micronutrient deficiencies in a nation with 50 million affected people using food fortification program US$ 25 million is needed annually (Bouis et al., 2000). There are several examples demonstrating that applying Zn fertilizers to cereal crops improve not only productivity, but also grain Zn concentration of plants. Depending on the soil conditions and application form, Zn fertilizers can increase grain Zn concentration up to fourfold under field conditions (Bansal et al., 1990; Sharmas and Lal, 1993; Gill et al., 1994; Yilmaz et al., 1997; Seilsepour, 2007).

Cultivated wheat contains very low levels of Zn and shows a narrow genetic variation for Zn. Compared to cultivated wheat, wild and primitive wheat represent a better and more promising genetic resource for high Zn concentrations. Little information is, however, available about the genetic control and molecular physiological mechanisms contributing to high accumulation of Zn and other micronutrients in grain of different genetic materials (White and Broadley, 2005; Ghandilyan et al., 2006; Lucca et al., 2006).

Fertilizer studies focusing specifically on increasing Zn concentration of grain (or other edible parts) are, however, very rare, although a large number of studies are available on the role of soil and foliar applied Zn fertilizers in correction of Zn deficiency and increasing plant growth and yield (Martens and Westermann, 1991; Mortvedt and Gilkes, 1993; Rengel et al., 1999; Bybordi and Malakouti, 2003; Seilsepour, 2007). Depending on the application method, Zn fertilizers can increase grain Zn concentration up to three- or fourfold (Yilmaz et al., 1997). The most effective method for increasing Zn in grain was the soil + foliar application method that resulted in about 3.5-fold increase in the grain Zn concentration. The highest increase in grain yield was obtained with soil, soil + foliar and seed + foliar applications (Yilmaz et al., 1997).

Timing of foliar Zn application is an important factor determining the effectiveness of the foliar applied Zn fertilizers in increasing grain Zn concentration. It is expected that large increases in loading of Zn into grain can be achieved when foliar Zn fertilizers are applied to plants at a late growth stage. Ozturk et al. (2006) studied changes in grain concentration of Zn in wheat during the reproductive stage and found that the highest concentration of Zn in grain occurs during the milk stage of the grain development. Results show a high potential of Zn fertilizer strategy for rapid improvement of grain Zn concentrations, especially in the case of late foliar Zn application. In practical agriculture, it is known that foliar uptake of Zn is stimulated when Zn fertilizer is mixed with urea (Mortvedt and Gilkes, 1993).

Results showed that grain yield is dependent to available-Fe and available-Zn in soil. So use of Fe and Zn had not any effects in soils which had available-Fe and available-Zn more than 4.7 and 0.8 mg kg^{-1}, respectively. Maximum increasing of grain yield by Fe application was 1100 kg.ha-1 in soils which contain 2 mg kg^{-1} available Fe and by Zn application, grain yield increase received to 1200 mg kg^{-1} in soils which contain 0.5 mg kg^{-1} available Zn. There was a positive correlation between grain yield and available soil Fe or available soil Zn. The average grain yield increased by using of Fe and Zn were 317 and 330 mg kg^{-1}, respectively. Yield increased 868 mg kg^{-1} by using of Fe and Zn. So the critical levels of Fe and Zn in soils were determined 4.7 and 0.8 mg kg^{-1}, respectively. In this way, 54 and 46% of soils under wheat cultivation had deficiency in Fe and Zn, respectively. So the use of Zn and Fe fertilizers is highly recommended for yield increase in these soils (El-Majid et al., 2000; Seilsepour, 2007).

MATERIALS AND METHODS

This field experiment was conducted on clay-loam soil in Moghan Agricultural and Natural Resource Research Center during 2007-2008 to investigate the effect of foliar application of zinc and iron on wheat (Darya cultivar) yield and quality at tillering and heading stage. The experimental design was a randomized complete block design with three replicates. Treatments were control (no Zn and Fe application), 150 g $Zn.ha^{-1}$ as $ZnSO_4$, 150 g $Fe.ha^{-1}$ as Fe_2O_3, and a combination of both Zn and Fe. Parameters such as grain yield (kg/ha), seed Zn and Fe concentration (mg/kg) were evaluated.

Moghan is located in the North-west of Iran (lat 39º, 39' N; long 47°, 49' E and elevation 50 m) with mean 30-year averages of 275 mm rainfall per year and 14.6ºC temperatures.

According to soil analysis carried out prior to sowing, the soil texture is a clay-loam with EC=2.03 dsm^{-1}, pH= 8.08, O.C (%) = 0.994, soil P_2O_5 = 4 ppm, K_2O = 379 ppm N= 0.109, field capacity = 21% W/W, wilting point = 10% W/W and the volume weight of the soil was 1.21 $g.cm^3$.

Climate temperature and rainfall from sowing to harvest are presented in Table 1.

The experiment field received 80 $kg.ha^{-1}$ of P_2O_5. Nitrogen at a rate of 150 kg/ha was applied, in the form of urea, the first half of which during disk harrowing and the remaining half used when the plants were at heading stage.

Table 1. Mean temperature (°C), rainfall (mm), relative humidity (%) and number of days below zero of site from sowing to harvest (2007-2008).

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Temp (°C)	17.6	9.1	4.7	-0.8	3.7	13.2	16.8	9.3	23.7
Rainfall (mm)	30	41.2	31.5	19.4	17.4	11.3	6.5	37.1	28.1
Relative humidity (%)	76.3	81.5	82.8	81.2	71	62.5	67.5	67.2	57.7
No. of days below zero	0	4	14	25	17	2	0	0	0

Table 2. Effect of foliar application of Zn and Fe on wheat yield (kg ha-1), seed-Zn and Fe Concentration (mg kg^{-1}).

Treatment\Adjective	Yield ± SE	Zn ± SE	Fe ± SE
Fe	8185 ± 93.853	22.6 ± 1.493	146.7 ± 5.783
Zn	7919 ± 67.3	50.9 ±1.114	123.7 ± 4.667
Fe+Zn	8954 ± 74.638	20.27 ± 1.291	139.6± 2.646
Control	7665 ± 97.994	12.17 ± 1.317	84.93 ± 4.91
LSD (α=0.01)	414.7	3.85	27.41

Plant density was 350 plants per m^2 and plots were hand sown on 10th March, 2008 using a template to produce 10 rows of plants 12 cm apart. Seeds were sown 4 cm deep and 3 cm apart within rows. Two seeds were sown in each position and the plots thinned to the desired plant population when the seedlings reached the first leaf fully emerged stage. Weeds were removed by hand. Zn and Fe concentration was determined by atomic absorption set.

Data given in percentages were subjected to arcsine transformation before statistical analysis. The SAS software package was used to analyze all the data (SAS, 2001) and means were separated by the least significant difference (LSD) test at P< 0.01.

RESULTS AND DISCUSSION

Results showed that foliar application of Zn and Fe (alone or together) has significant effect (at 0.01 probability) on wheat yield, grain-Zn and Fe concentration. Mean wheat yield, Zn and Fe concentration is presented in Table 2. According to Table 2, maximum seed yield was obtained by using (Fe + Zn) and Zn treatments. Although seed yield was affected by using Fe fertilizer (+187 $kg.ha^{-1}$), but foliar application of Fe did not increase seed yield significantly compared to control. Similar results have been reported by Yilmaz et al. (1997), Seilsepour (2007) and El-Majid et al. (2000). Seilsepour (2007) found that the average grain yield increase by using of Fe and Zn were 317 and 330 mg kg^{-1}, respectively. Yield increased 868 mg kg^{-1} by using a combination of Fe + Zn.

Seed-Zn concentration affected more than other adjectives and increased in all treatments. The highest Zn concentration obtained by using Zn treatment. Zn application increased grain-Zn approximately up to threefold comparison with control (from 18.7 to 50.9 $mg.kg^{-1}$). Yilmaz et al. (1997) reported that fertilizers can increase grain Zn concentration up to three- or fourfold. Zn concentration affected by using Fe treatment compared with control, but it was not considerable (from 18.7 to 22.6 $mg.kg^{-1}$).

Foliar application of (Fe+Zn) at tillering and heading stage increased Zn concentration up to 20.27 from 12.17 $mg.kg^{-1}$. Fe concentration increased by using (Fe+Zn) compared with control (from 84.93 to 139.6 $mg.kg^{-1}$).

Conclusion

In order to eliminate Fe deficiency, adding chemical compounds such as premix to wheat flour is common in Iran. However, seed bio-fortification is a more excellent method compared to other chemical fortification. Also, the application of micronutrients can improve seed yield and its quality.

ACKNOWLEDGEMENTS

This study has been supported by University of Mohaghegh Ardabili and Moghan Agricultural and Natural Resource Research Center. I would like to thank Kamal Shahbazi for support and helpful comments.

REFERENCES

Alloway BJ (2004). Zinc in soils and crop nutrition. IZA Publications. International Zinc Association, Brussels. pp. 1-116.

Bansal RL, Singh SP, Nayyar VK (1990). The critical Zinc deficiency level and response to Zinc application of Wheat on typic ustochrepts. Exp. Agric. 26(3): 303-306.

Bouis HE (2003). Micronutrient fortification of plants through plant breeding: can it improve nutrition in man at low cost? Proc. Nutr. Soc. 62: 403-411.

Bouis HE, Graham RD, Welch RM (2000). The Consultative Group on International Agricultural Research (CGIAR) Micronutrients Project: Justifications and objectives. Food Nutr. Bull. 21: 374-381.

Bybordi A, Malakouti MJ (2003). Effects of Iron, Manganese, Zinc and Copper on Wheat Yield and Quality under Saline Condition. Olom-e-Ab Va Khak. 17(2): 48-59.

Cakmak I (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant Soil 247: 3-24.

Cakmak I, Kalayci M, Ekiz H, Braun HJ, Yilmaz A (1999). Zinc deficiency as an actual problem in plant and human nutrition in Turkey: A NATO-Science for Stability Project. Field Crops Res. 60: 175-188.

Cakmak I, Torun A, Millet E, Feldman M, Fahima T, Korol A, Nevo E, Braun HJ, Ozkan H (2004). *Triticum dicoccoides*: an important genetic resource for increasing zinc and iron concentration in modern cultivated wheat. Soil Sci. Plant Nutr. 50: 1047-1054.

El-Majid AA, Knany RE, El-Fotoh HGA (2000). Effect of foliar application of some micronutrients on wheat yield and quality. Ann. Agric. Sci. 1: 301-313.

Ghandilyan A, Vreugdenhil D, Aarts MGM (2006). Progress in the genetic understanding of plant iron and zinc. Physiol. Plant 126: 407-417.

Gill MS, Tarlok S, Rana DS, Bhandari A, Singh T (1994). Response of maize and wheat to different levels of fertilization. Indian J. Agron. 39: 168-170.

Graham RD, Welch RM (1996). Breeding for staple-food crops with high micronutrient density: Working Papers on Agricultural Strategies for Micronutrients, No.3. International Food Policy Institute, Washington DC.

Hotz C, Brown KH (2004). Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr. Bull. 25: 94-204.

Lott JNA, Spitzer E (1980). X-ray analysis studies of elements stored in protein body globoid crystals of *Triticum* grains. Plant Physiol. 66: 494-499.

Lucca P, Poletti S, Sautter C (2006). Genetic engineering approaches to enrich rice with iron and vitamin A. Physiol. Plant 126: 291-303.

Martens DC, Westermann DT (1991). Fertilizer applications for correcting micronutrient deficiencies. In: Mortvedt JJ, Cox FR, Shuman LM, Welch RM (eds) Micronutrients in Agriculture. SSSA Book Series No. 4. Madison, WI. pp. 549-592.

Mazzolini AP, Pallaghy CK, Legge GJF (1985). Quantitative micro-analysis of Mn, Zn, and other elements in mature wheat seed. New Phytol. 100: 483-509.

Mortvedt JJ, Gilkes RJ (1993). Zinc fertilizers. In: Robson AD (ed) Zinc in soils and plants. Kluwer, Dordrecht, The Netherlands pp. 33-44.

Ozturk L, Yazici MA, Yucel C, Torun A, Cekic C, Bagci A, Ozkan H, Braun HJ, Sayers Z, Cakmak I (2006). Concentration and localization of zinc during seed development and germination in wheat. Physiol. Plant 128: 144-152.

Rengel Z, Batten GD, Crowley DE (1999). Agronomic approaches for improving the micronutrient density in edible portions of field crops. Field Crops Res. 60: 27-40.

SAS Institute (2001). The SAS system for windows, release 8.02. The SAS Inst. Cary, NC.

Seilsepour M (2007). The study of fe and zn effects on quantitative and qualitative parameters of winter wheat and determination of critical levels of these elements in Varamin plain soils. Pajouhesh & Sazandegi 76: 123-133.

Sharma S, Lal F (1993). Estimation of critical limit of DTPA-Zinc for wheat in pellusterts of southern Ragastan. J. Indian Soc. Soil Sci. 41(1): 197-198.

Sillanpaa M (1982). Micro nutrients and the nutrient status of soils. A global study. FAO Soils Bull. No. 48, FAO, Rome.

Stein AJ, Nestel P, Meenakshi JV, Qaim M, Sachdev HPS, Bhutta ZA (2007). Plant breeding to control zinc deficiency in India: how cost-effective is biofortification? Pub. Health Nutr. 10: 492-501.

Welch RM, Graham RD (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. J. of Exp. Bot. 55: 353-364.

White PJ, Broadley MR (2005). Biofortifying crops with essential mineral elements. Trends Plant Sci. 10: 586-593.

White JG, Zasoski RJ (1999). Mapping soil micronutrients. Field Crop Res. 60: 11-26.

World Health Organization (WHO) (2002). The World Health Report 2002 Geneva: WHO.

Yilmaz A, Ekiz H, Torun B, Gultekin I, Karanlik S, Bagci SA, Cakmak I (1997). Effect of different zinc application methods on grain yield and zinc concentration in wheat grown on zinc-deficient calcareous soils in Central Anatolia. J. Plant Nutr. 20: 461-471.