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Full Length Research Paper

Effect of supplementary nutrition with Fe, Zn chelates and urea on wheat quality and quantity

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Intensive and multiple cropping, cultivation of crop varieties with heavy nutrient requirement and unbalanced use of chemical fertilizers, especially nitrogen and phosphorus fertilizers reduced seed quality and caused micronutrient deficiency in crops. Balanced fertilization will increase yield and quality of crops. A field experiment was conducted on clay-loam soil at Parsabad Moghan region, Iran during 2009 to 2010 to investigate the effect of foliar application of zinc, iron and urea on wheat yield and quality at filling 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. In this study, parameters such as wheat grain yield, 1000 kernel weight, ear length, plant height, seed Zn, Fe, Cu and Mn concentrations were evaluated. Results show that foliar application of Zn and Fe increased seed yield and its quality when compared with the control. Foliar feeding with urea increased seed yield and yield component, but Fe, Zn and Cu concentration reduced them, as compared to other foliar feeding methods.

Key words: Wheat, foliar feeding, yield, Zn, Fe, urea.

INTRODUCTION

Wheat (*Triticm aestivum* L.) is considered as one of the most important cereal crops in Iran. Increasing the Zn and Fe concentrations 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 cause 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 the 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 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.

Plants require specific amount of certain nutrients in specific form at appropriate time for their growth and development (Sajid et al., 2008). It is well documented that the deficiency of micronutrients (Zn, Mn, Fe and Cu) in soils of arid and semi arid r egions forms one of the major yield limiting factors and can greatly disturb plant yield and quality (Yassen et al., 2010). 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, 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 and 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 about 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 that show 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; 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. As 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 on 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). Foliar feeding technique, as a particular way to supply these nutrients could avoid these factors and results in rapid absorption. Foliar feeding of micronutrients is generally more effective and less costly (El-Fouly and El- Sayed, 1997). It is well known that soil application of NPK fertilizers may lead to some losses of these fertilizers. However, application of such macronutrients as foliar spray may decrease such losses. During the last decades, foliar feeding of nutrients has become an established procedure to increase yield and improve the quality of crop products (Romemheld and El-Fouly, 1999). This procedure can also improve nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil (Abou El-Nour, 2002). On the other hand, foliar feeding of a nutrient may actually promote root absorption of the same nutrient (Oosterhuis, 1998) or other nutrients through improving root growth and increasing nutrients uptake (El-Fouly and El-Sayed, 1997).

Depending on the application method, Zn fertilizers can increase grain Zn concentration up to three- or four-fold (Yilmaz et al., 1997). The most effective method for increasing Zn in grain is 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 great 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 show that grain yield is dependent on available-Fe and Zn in soil. So, the use of Fe and Zn had no effects on soils which had available-Fe and Zn which is more than 4.7 and 0.8 mg kg^{-1}, respectively. Maximum increase 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 was up to 1200 mg kg^{-1} in soils which contained 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 increase by using Fe and Zn were 317 and 330 mg kg^{-1}, respectively. Yield increased to 868 mg kg^{-1} by applying Fe and Zn. So the critical levels of Fe and Zn in

Figure 1. Parsabad location in Iran.

Table 1. Comparison of mean yield, yield component and grain micronutrient content under different treatments.

Parameter	Yield	1000 kernel weight	Ear Length	Plant height	Fe	Zn	Cu	Mn
Fe	7201^{B}	40.14^{A}	9.59^{A}	69.02^{A}	138.9^{A}	29.57^{B}	1.59^{B}	14.31^{B}
Zn	7550^{A}	39.96^{A}	9.32^{A}	66.07^{B}	97.92^{C}	30.68^{A}	1.98^{A}	18.87^{A}
Fe+Zn	7539^{A}	40.27^{A}	9.08^{A}	67.14^{AB}	119.4^{B}	29.23^{B}	1.62^{B}	17.91^{A}
Urea	7574^{A}	40.36^{A}	9.2^{A}	70.10^{A}	90.96^{D}	21.18^{C}	1.33^{C}	17.83^{A}
Control	6573^{C}	38.46^{B}	8.26^{B}	66.31^{B}	87.45^{D}	14.31^{D}	1.62^{B}	11.99^{C}
LSD (α=%1)	266.8	0.937	0.526	2.245	4.651	0.829	0.092	1.159

Numbers in the columns followed by the same letters are not significantly different at $P < 0.01$.

soils were determined to be 4.7 and 0.8 mg kg^{-1} respectively. By this way, 54 and 46% of soils under wheat cultivation had deficiency of 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 Ardabil, Iran during 2009 to 2010 to investigate the effect of foliar application of zinc, iron and urea on wheat (N-89-90 Line) yield and quality at filling stage. The experimental design was a randomized complete block design with three replicates. Treatments were control (no Zn and Fe application), Zn chelate, Fe chelate, Fe + Zn and urea at 0.003 concentration (60 g urea/20 L water). Parameters such as grain yield (kg/ha), 1000 kernel weight, ear length, plant height, seed Zn, Fe, Cu and Mn concentrations (mg/kg) were evaluated.

Moghan is located in the north-west of Iran (Lat 39°, 39' N; Long 47°, 49' E and elevation 72 m) with mean 30-year averages of 275 mm rainfall per year and 14.6°C temperature (Figure 1).

According to soil analysis carried out prior to sowing, the soil texture was a clay-loam with electrical conductivity (EC) = 2.45 dsm^{-1}, pH = 7.91, organic carbon (O.C) (%) = 0.803, soil P_2O_5 = 4 ppm, K_2O = 328 ppm N = 0.109, and the volume weight of the soil was 1.21 $g.cm^3$.a.

The experimental 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 was applied during disk harrowing and the remaining half was used when the plants were at heading stage.

Plant density was 350 plants per m^2 and plots were hand sown on 5th November 2009 using a template to produce 10 rows of plants 12 cm apart. Seeds were sown 4 cm deep and 3 cm apart within rows. Zn, Fe, Cu and Mn concentrations were determined by atomic absorption set.

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 of variance analysis show that application of Fe, Zn and urea fertilizers as foliar feeding, affected seed yield, 1000 kernel weight, ear length, plant height, Fe, Zn, Cu and Mn content at 1% probability. Grain number/main ear and ear number were not affected by foliar feeding.

Mean of yield, yield component and grain micronutrient content are presented in Table 1. According to Table 1, grain yield increased by foliar feeding when compared with the control. The highest seed yield was obtained by using Zn, Fe + Zn chelate and urea fertilizer. 1000 kernel weight and ear length increased by foliar application of

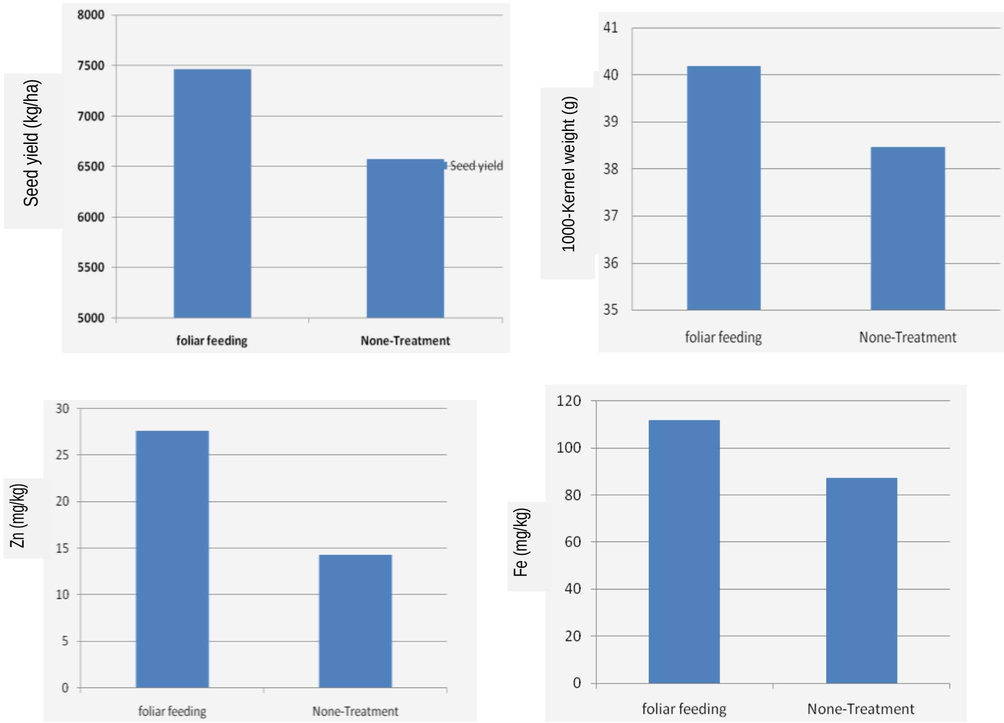

Figure 2. Effect of foliar feeding on wheat yield and its quality.

fertilizer when compared with the control.

According to Table 1, maximum seed yield was obtained by using urea, Zn and Fe + Zn treatments. Although seed yield was affected by using Zn fertilizer (187 $kg.ha^{-1}$), but foliar application of Zn did not increase seed yield significantly when compared with control. Similar results were reported by Maralian (2010), Yilmaz et al. (1997), Seilsepour (2007) and El-Majid et al. (2000). Seilsepour (2007) found that the average grain yield increased by using Fe and Zn (317 and 330 kg/ha, respectively). Foliar feeding increased seed yield from 6573 to 7466 kg/ha (Figure 2). 1000 kernel weight increased by foliar feeding from 38.46 to 40.18 g (Figure 2). Foliar feeding increased ear length in all treatments. Therefore, the increase of 1000 kernel weight and ear length can be the cause of high seed yield as compared to the control (no foliar feeding).

Seed-Zn concentration affected other parameters and increased in all treatments. The highest Zn concentration was obtained by using Zn treatment. Fe application increased grain-Fe approximately up to 58% in comparison with the control (from 87.45 to 138.9 $mg.kg^{-1}$). Yilmaz et al. (1997) reported that fertilizers can increase Fe and Zn concentration up to three- or fourfold. Zn concentration was affected by using Fe treatment when compared with the control (from 14.31 to 29.57 $mg.kg^{-1}$). Generally, foliar feeding (Fe, Zn, Fe + Zn and urea) increased grain-Fe from 87.45 to 111.79 $mg.kg^{-1}$ (Figure 2).

Foliar application of Zn, increased seed yield, 1000 kernel weight, ear length, Zn, Cu and Mn concentration at α = 1% (Table 1). Foliar feeding (Fe, Zn, Fe + Zn and urea) increased grain-Zn from 14.31 to 27.66 $mg.kg^{-1}$ (Figure 2). Fe and Zn concentration increased by using Fe + Zn when compared with the control (Table 1). Foliar feeding by urea increased seed yield and yield component, but Fe, Zn and Cu concentration reduced, as compared to other foliar feeding methods.

Conclusion

To eliminate Fe deficiency, adding chemical compounds such as Premix into wheat flour is common in Iran. Therefore, seed biofortification by foliar feeding is more excellent and has low cost as compared to other chemical methods. Also, application of micronutrients can improve seed yield and its quality. Therefore, application of compound form of Fe + Zn is recommended.

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