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Zinc Partitioning in Maize Grain after Soil Fertilization with Zinc Sulfate

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ABSTRACT

Maize (*Zea mays* L.) is high nutrient demanding crop but sensitive to zinc (Zn) deficiency in soil. Application of Zn fertilizers could be a viable option to fulfill the crop demand for Zn and also to increase its contents in grains. A field experiment was conducted to evaluate the effect of supra-optimal rates of Zn application on maize cultivars. A selected maize hybrid (FHY-421) and a synthetic variety (Golden) were grown at four different rates of Zn application along with recommended doses of nitrogen, phosphorus and potassium. Cobs were harvested; grains were separated and analyzed for their Zn content. Response of genotype varied to different Zn application rates. Maximum grain yield and Zn uptake in maize hybrid (FHY-421) was noted at 18 kg Zn ha^{-1}. However synthetic variety (Golden) exhibited maximum grain yield and Zn uptake when Zn was applied @ 9 kg ha^{-1}. Maize response curve showed that for optimum grain yield, Zn concentration in hybrid was found 28.2 mg kg^{-1}, while for synthetic variety it was 24.1 mg kg^{-1}.

Key Words: Yield; Zn deficiency; Response curve; Fertilization

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop of the world and has great economic value in livestock and poultry production (Harris *et al.*, 2007) and processed for several industrial products for human consumption (Ortiz-Monasterio *et al.*, 2007; Menkir *et al.*, 2008). In Pakistan, national average yield of maize is far below compared to other developed countries, where in the recent era; its use for ethanol production or for biofuels has also been introduced. Among other factors contributing towards its lower yield in our country, imbalanced supply of nutrient is also one of them. Besides nitrogen and phosphorus, most of the agronomic as well as horticultural crops produced on these soils suffer from zinc (Zn) deficiency (Rashid & Ryan, 2004). For example, application of Zn as fertilizer for realizing economic yield of paddy rice (*Oryza sativa* L.) on deficient soils is a common practice but no such practice is exercised by maize farmers (Armani *et al.*, 1999; Obrador *et al.*, 2003), which has led to continuously declining yield of this crop, wherever Zn deficiency occurs. Application of Zn fertilizers to maize crop not only enhances its production, but also increases tissue content and cure Zn deficiency problem in human beings. With intensive agriculture soils have depleted in the essential microelements including Zn and nutrient availability is further aggravated in alkaline and calcareous soils. However in Pakistan, our farmers generally apply nitrogen and phosphorus to the fields but altogether ignore zinc.

Zinc deficiency is an increasingly important risk factor to the global agriculture and human health. This is so because Zn is an essential micronutrient, which is equally important for all forms of life i.e., for plants, animals and human beings (Alloway, 2004). Globally about 2 billion people are considered to be Zn deficient (Müller & Krawinkel, 2005). This situation is more alarming in developing countries where Zn deficiency is the fifth most important factor causing ailments especially in children and women (WHO, 2002). In Pakistan, Zn deficiency has also been reported in children below five years of age and in adult women (Bhutta *et al.*, 2007).

To combat Zn deficiency problem in human beings several strategies are being used worldwide i.e., supplementation, food fortification and food diversification (Maberly *et al.*, 1994) but all these approaches have certain limitations in their use (Frossard *et al.*, 2000). However to alleviate Zn deficiency among the population of the developing nations like Pakistan, there is a dire to fortify the food items with Zn. Recently a more beneficial approach, the biofortication of food that implicates increasing the mineral nutrient contents in staple food crops has been introduced (Nestel *et al.*, 2006; Cakmak, 2008). Biofortication of edible plant parts may be done either through fertilization, plant breeding or genetic engineering (Bouis, 1996).

Breeding cultivars with increased mineral contents is a

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long term strategy (Cakmak, 2008). Crop species/varieties vary in their nutrient requirement and utilization (Maziya-Dixon *et al.*, 2000; Oikeh *et al.*, 2003). Hence the selection of those genotypes having maximum nutrient content in their edible parts is a promising approach. However fertilization of staple food crops to increase the mineral nutrient contents is easier.

Keeping in view the above scenario, a field experiment was conducted with the objective to evaluate the effect of supra-optimal rates of Zn application on Zn partitioning in and grain yield in hybrid and synthetic maize cultivars.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm, University of Agriculture, Faisalabad (located at 31˚, 23´, 46˝ N & 73˚, 6´, 7˝ S) to evaluate the effect of different rates of Zn application on maize (*Zea mays* L.) cultivars [hybrid (FHY-421) and synthetic variety (Golden)]. Seeds of both the maize cultivars selected from a preliminary study were sown in 5 m × 3 m plots in rows on flat beds. Prior to planting, random composite surface soil sample (0-15 cm depth) was collected, air dried and ground to pass through a 2 mm sieve. A portion of the prepared soil sample was used to analyze for its various physico-chemical properties. Soil pH (7.98) was measured in a saturated soil paste by using a Beckman pH meter. Electrical conductivity (1.75 dS m^{-1}) was measured in saturation extract using digital EC meter. Organic matter content in the soil was 0.72% according to Walkley-Black method (Nelson & Sommers, 1982). Free lime was 4.8%, which was estimated by acid dissolution (Allison & Moodie, 1965). Soil textural class as determined by hydrometer method (Gee & Bauder, 1982) was sandy loam. Available Zn in soil, determined with atomic absorption spectrophotometer (Chapman & Pratt, 1961) was 0.72 mg kg^{-1} by extraction with 0.005 M DTPA (Lindsay & Norvell, 1978).

Before sowing, field was irrigated with canal water. At proper moisture conditions, it was ploughed with tractor drawn tillage implements. Ridges were made to draw boundaries between adjacent plots. The experiment was laid out in randomized complete block design with three replications.

Two seeds per hole (made by dibbler) were sown manually. Recommended doses of N, P and K @ 120, 90 and 60 kg ha^{-1}, respectively were applied uniformly as urea, diammonium phosphate and potassium sulfate to all the plots at sowing. Zinc was applied @ 0, 6, 18 and 54 kg ha^{-1} as ZnSO4. The reason for the selection of such high rate (54 kg ha^{-1}) of Zn was to observe the response curve for academic research purposes. Moreover such higher rate for Zn has also been reported in an earlier study conducted by Rashid and Fox (1992). Twenty days after sowing, thinning was performed in order to have uniform number of plants in all the plots and also to maintain row to row and plant to plant distance of 75 cm and 30 cm, respectively. Earthing up of maize plants was performed thirty days after sowing. Canal water was used to irrigate the plots as and when required. Weeds were manually eradicated and Imidacloprid (insecticide) was sprayed to control the attack of maize stem borer. Plants were grown till maturity, after which cobs were separated from the plants and air dried. After oven drying in a forced air oven at 70^{o}C dry weight of cobs was recorded. Grains were separated manually from the cobs and their weight was also recorded. Grains were ground using a Wily mill and digested using a diacid mixture of HNO_3:$HClO_4$ (2:1) and analyzed for Zn using atomic absorption spectrophotometer (Chapman & Pratt, 1961).

Data obtained from the field experiment were analyzed statistically using MS-Excel and Statistix®. Least significant difference test was used to separate various treatment means.

RESULTS AND DISCUSSION

Grain yield: Zinc application to soil had a significant ($p<0.05$) effect on grain yield of both the maize hybrid FHY-421 and synthetic variety Golden (Fig. 1). Rego *et al.* (2007) also noted similar increase in grain yield of maize cultivars by Zn application. Cultivars also differed significantly ($p<0.01$) for the grain yield. Maximum increase (21%) in grain yield of hybrid (FHY-421) was observed when the Zn was applied @ 18 kg ha^{-1}, while synthetic variety (Golden) exhibited maximum increase (13%) in grain yield when Zn was applied @ 6 kg ha^{-1} to the soil. Harris *et al.* (2007) also found an increase in grain yield of maize crop by Zn application. These results implied that maize hybrids required nutrients in greater amounts to attain full yield potential compared to synthetic maize cultivars (Kanwal *et al.*, 2009). In the present study, grain yield of both hybrid and variety was reduced at the highest rate of Zn application (54 kg ha^{-1}). Reduction in grain yield of both hybrid and synthetic variety after Zn application @ 18 kg Zn ha^{-1} and 6 kg Zn ha^{-1}, respectively is assigned to their optimum level of Zn requirement. Moreover at higher rates of Zn application, its toxicity leads to phosphorus deficiency (visual leaf observations). Hence the nutrient imbalance develops, which causes yield decline compared to other treatments.

The genotypic variation in maize cultivars for differential Zn requirement could serve as a base line for plant breeders who aim at increasing the mineral content of staple food crops through breeding techniques. In the past, breeding programs mainly focused on higher yield and resistance to lodging or disease etc., ignoring the improvement of micronutrient concentration in staple food crops (Graham *et al.*, 1999; Ortiz-Monasterio & Graham, 1999).

Grain Zn concentration: A significant ($p<0.01$) effect of different rates of Zn application was observed for grain Zn concentration in maize plants, which ranged from 21.82 to

Fig. 1: Grain yield of maize hybrid (FHY-421) and variety (Golden) at different rates of Zn application

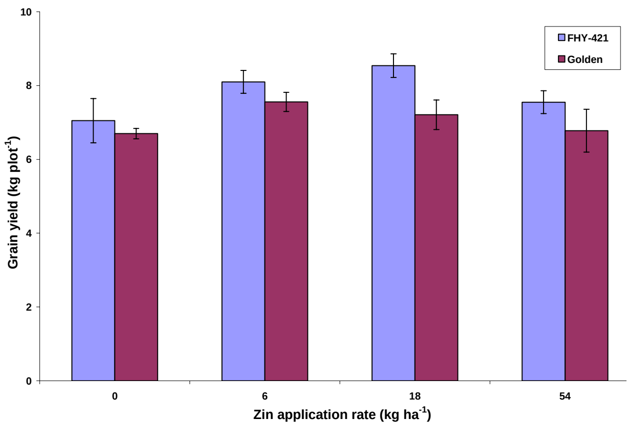


Fig. 2: Grain Zn concentration of maize hybrid (FHY-421) and variety (Golden) at different rates of Zn application

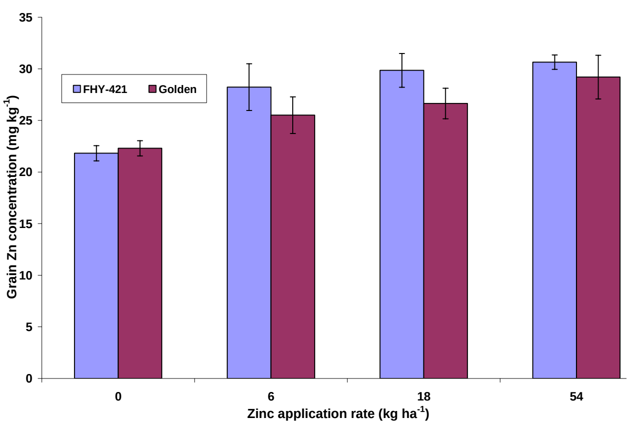
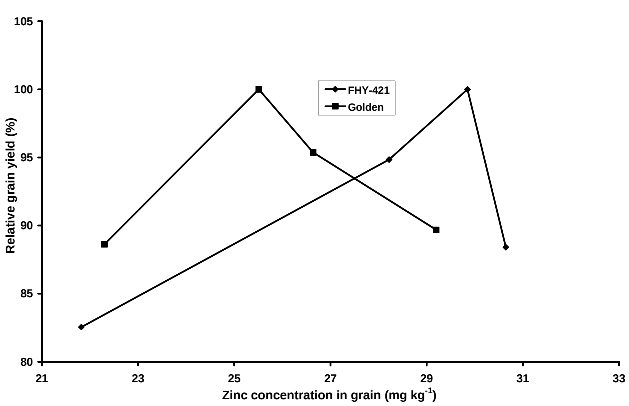


Fig. 3: Critical Zn concentration for optimum yield of maize grain in maize hybrid (FHY-421) and variety (Golden)



30.65 mg kg^{-1}(Fig. 2). Averaged over all the treatments more grain Zn concentration was found in hybrid compared to synthetic variety. However this difference was not statistically significant. Increased Zn application to soil significantly increases its concentration in the edible plant parts of staple food crops (Welch, 2002; Furlani *et al.*, 2005; Khan *et al.*, 2008; Maqsood *et al.*, 2009).

Relatively greater Zn accumulation in maize grains compared to stover is vital for human nutrition i.e., for biofortification of the staple food crops (Prasad, 1984; Graham *et al.*, 1992). However Zn accumulation in grains/seed is a complex and intricate process comprising of a number of steps starting from its translocation by roots to the shoots and finally phloem unloading into developing grains (Welch, 1986). Moreover grains with higher Zn contents when sown in a Zn deficient soil perform better with improved seedling vigor (Graham *et al.*, 1992; Graham & Rengel, 1993).

A significant ($p<0.01$) effect of cultivars and rate of Zn application was found on Zn accumulation in maize grains. Incremental addition of Zn to the soil significantly affected grain Zn accumulation in maize plants. Several earlier scientists also reported increased Zn accumulation in maize grains by the addition of Zn fertilizers (Maftoun & Karimian, 1989; Abunyewa & Mercer-Quarshie, 2004; Rego *et al.*, 2007). However Bickel and Killorn (2007) reported an inconsistent response for Zn accumulation in maize grains by the application of Zn fertilizers and related it to variation in soil and environmental factors. Increase in grain Zn accumulation of maize plants by Zn addition to the root medium might be attributed to enhance Zn concentration in soil solution as well as their higher demand for this element (Rashid & Fox, 1992).

Zn response curve: Differential growth response of maize cultivars was observed at various rates of Zn application. A 95% of relative grain yield in maize hybrid (FHY-421) and synthetic variety (Golden) was obtained when Zn concentration in their grains was 28.2 and 24.1 mg kg^{-1}, respectively (Fig. 3). Hybrid (FHY-421) accumulated 17% more Zn than synthetic one.

CONCLUSION

Zinc fertilization improved grain yield and Zn content of maize hybrids compared to synthetic variety. Hybrid (FHY-421) produced maximum grain yield when Zn was applied @ 18 kg ha^{-1} compared to variety (Golden), which produced maximum when Zn was applied @ 6 kg ha^{-1}. Moreover, internal Zn requirement of maize hybrid was higher than synthetic variety. Further studies may evaluate absorption and utilization of biofortified Zn in human beings.

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