Journal of Agriculture and Ecology Research International
7(4): 1-6, 2016; Article no.JAERI.24532
ISSN: 2394-1073

SCIENCEDOMAIN *international*
www.sciencedomain.org

Biofortification of Maize Grain with Zinc and Iron by Using Fertilizing Approach

Ifra Saleem[1*], Shahid Javid[1], Fatima Bibi[1], Shabana Ehsan[1], Abid Niaz[1] and Zahid Ashfaq Ahmad[1]

[1]Soil Chemistry Section, Institute of Soil Chemistry and Environmental Sciences (ISCES), Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan.

Authors' contributions

This work was carried out in collaboration between all authors. Author IS conducted the experiment in the field, performed all the analysis and wrote first draft of the article. Author SJ planned the research and review the article. Author FB helped in all field work. Author SE was involved in the laboratory work. Author AN managed the literature searches. Author ZAA supervised the experiment in the field and analysed in the laboratory. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2016/24532
Editor(s):
(1) Mirza Hasanuzzaman,Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Bangladesh.
(2) Daniele De Wrachien, Department of Agricultural and Environmental Sciences of the State University of Milan, Italy.
Reviewers:
(1) Anonymous, ICAR-Indian Agricultural Research Institute, New Delhi, India.
(2) Kathleen Hefferon, Cornell University Researcher, USA.
(3) Ernest U. Eteng, Michael Okpara University of Agriculture, Umudike, Nigeria.
(4) Mónica Guadalupe Lozano Contreras, National Institute of Forest Research Agricultural and livestock (INIFAP) Researcher, Mexico.
Complete Peer review History: http://sciencedomain.org/review-history/14085

Original Research Article

Received 24th January 2016
Accepted 25th March 2016
Published 8th April 2016

ABSTRACT

The study was conducted to evaluate the response of hybrid maize towards zinc (Zn) and iron (Fe) fertilization applied both as soil and foliar application. It is a possible way to increase the zinc and iron concentration in maize grain by the application of Zn and Fe fertilizers. To verify the claim an experiment was conducted. Maize hybrid was selected and three levels of Zn & Fe (viz.10, 20 and 30 kg ha^{-1}) were applied at the sowing time. The foliar appliance of zinc sulphate and iron sulphate at the rate of 0.1% Zn and Fe was applied. Nitrogen, Phosphorus and Potassium were applied at recommended levels. There was a control plot with no use of Zn and Fe. Maize crop was harvested, grains were separated. Maize grain yield was recorded and analyzed for their Zn and Fe

**Corresponding author: E-mail: ifrasaleem17@gmail.com;*

content. The results indicated that maize grain yield and their Zn and Fe content responded positively towards Zn and Fe application applied as soil or foliar application. The 30 kg of Zn and Fe ha^{-1} gave highest grain yield (7.76 t ha^{-1}) which is at par with 7.64 t ha^{-1} grain yield from the plots receiving 20 kg of Zn and Fe/ha. The foliar reliance of Zn and Fe application raised the grain Zn (31.8 mg kg^{-1}) and Fe (153.8 mg kg^{-1}) contents. This increase is 55% and 51.8% in case of Zn & Fe, respectively over control. It is concluded from the study that iron and zinc fertilization is an effective way to increase corn yield, their concentration in maize grain and finally to get better quality corn.

Keywords: Biofortification; fetilizers; iron; nutrient partitioning; response curve; zinc.

1. INTRODUCTION

Maize is the third most important cereal crop of the country. Its yield increased over the last few years but there is still a wide gap between the average maize yield at national level of Pakistan and developed countries [1]. Maize crop has a high monetary value as its use in livestock and poultry industries. It is processed on a bulk scale to manufacture a range of products for human use [2].

The cereals crops are the main source of food to fulfill the nutritional requirement of the masses in the under developed countries [3]. These people not have enough resources to broaden their horizons of diet and are in front of many nutritional disorders [4]. The agriculture has met the challenge of feeding the increasing population but these people are not receiving the essential nutrients for a dietary health [5].

The two most important nutrients for humans that are limiting in the diet of developing world people are Zn and Fe [6]. Globally billions of people are facing Zn and Fe deficiency and there ratio are very frightening in children [7]. [8] reported that the deficiency of Zn causes DNA damage and poorly developed defense system and stunted physical growth which ultimately allow many health complications. Millions of people are anemic due to Fe deficiency in poor countries [9]. The main reason of Zn and Fe deficiency is minimum diversification in food items and less amount of bio-available forms of these essential nutrients.

The challenge to agriculture is not only to feed the masses but also to provide the nutrient rich food to the poor people and for this have to design the agriculture that focused on the health of masses too [10]. The need is to increase the contents of these deficient nutrients in the edible part of the cereal crops. This enrichment of nutrients in the grains is a sustainable and continuing way of supplying the deficient nutrients to masses [11]. This study was designed to increase the Zn and Fe content in the grains to maize crop eventually to minimize the threat of human Zn and Fe deficiencies.

2. MATERIALS AND METHODS

A field trial was conducted at the farm area of Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan. The hybrid maize (hybrid-919) was sown in August 2014 and harvested in December 2014 to estimate the effect of Zn & Fe appliance on grain Zn & Fe contents. Seeds of maize were sown in a plot size of 7.5 m × 4.5 m on ridges. The adjacent plots were separated by making boundaries and experiment was laid out in Randomized complete block design with three replications. Two seeds per hole were added made by the Dibbler on the ridges. The Recommended doses of Nitrogen, Phosphorus and Potassium by Agriculture Department in Government of Punjab, Pakistan for hybrid maize were applied @ 275 kg ha^{-1} N, 125 kg ha^{-1} P_2O_5 and 75 kg ha^{-1} K_2O, respectively as a basal dose. The urea, single super phosphate (SSP), potassium sulphate (SOP), ZnSO4 and FeSO4 were used as fertilizer sources. On the maize crop following Zn and Fe treatments were applied.

i. Control (No zinc & Fe)
ii. Soil Zn & Fe (each @10 kg ha^{-1})
iii. Soil Zn & Fe (each @20 kg ha^{-1})
iv. Soil Zn & Fe (each @30 kg ha^{-1})
v. foliar Zn & Fe spray (each @ 0.1%)

Half of the N, full phosphorus and potassium were applied at the time of sowing and ½ N after 20 days of germination. All the soil applied Zn & Fe treatments were applied at the time of sowing. The foliar treatment of Zn and Fe was done to crop at silking and grain filling stage. After ten days of germination thinning was done to maintain the plant population and plant to plant distance. All the management practices for the

Table 1. Fertility status of field used for study

Soil depth (cm)	pH_s	EC_e (dSm^{-1})	O.M (%)	Available P (mg kg^{-1})	Extractable K (mg kg^{-1})	DTPA Zn (mg kg^{-1})	DTPA Fe (mg kg^{-1})	Textural class
0-15	8.13	1.20	0.89	8.32	220	0.96	3.04	Sandy clay loam
15-30	8.09	1.13	0.76	8.00	200	0.87	3.39	Sandy clay loam

maize crop were performed throughout the growing season. The canal water was used to irrigate the crop when required. At crop maturity harvesting was done as black layer is formed in the tenth leaf [12]. The grains were separated from the cobs by thresher and grain yield was recorded and changed into globally used unit i.e. tons per hectare (t ha^{-1}).

2.1 Soil Sampling and Analysis

Before sowing of the maize crop and prior to fertilizer addition composite soil samples from two depths (0-15 and 15-30 cm) were collected. The samples were air dried and grounded to pass through a 2 mm sieve to be used for analysis. The pH of soil was measured in saturated paste and from soil extract electrical conductivity (EC) was determined using [13] method. Walkley-Black method [14] was used to determine the soil organic matter content of the soil. Olsen's method [15] was used to measure the available phosphorus and for potassium, [16] method was used. The zinc and iron status of soil was determined using DTPA extraction [17] method. The pre-planting soil fertility status is given in above Table 1 above. The soil analysis showed that the soil was sandy clay loam in texture with 8.13 pH. There was no salinity and sodicity problem in the field. The organic matter content was low in soil. The phosphorus content of soil was moderate in range and available potassium was in adequate array. The fertility analysis indicated that Zn content in soil used for experiment was deficient while iron was adequate.

2.2 Plant Sampling and Analysis

After harvesting grains were separated from the cobs and samples of grain were collected for Zn and Fe analysis. The samples were dried in air circulation plant oven at 70℃ till constant weight and ground in a Wiley micro mill. The 0.5 g of dried sample was digested in a tri-acid mixture i.e. sulphuric acid, nitric acid and perchloric acid (5:2:1) [18] and run on Atomic Absorption Spectrophotometer (Shemadzu 7000) for zinc and iron determination.

2.3 Data Analyses

The data obtained in this experiment was analyzed using the computerized system Statistix®. Least Significant Difference (LSD) among the treatment means were compared at 5% probability level [19].

3. RESULTS AND DISCUSSION

3.1 Maize Grain Yield

The corn yield data is presented in Fig. 1. It was indicated from the results that corn yield increased with each addition of Zn and Fe fertilizers in all the treatments over the control (NPK alone). The treatments where 30 kg of Zn and Fe fertilizers ha^{-1} were applied gave highest corn yield i.e. 7.76 kg ha^{-1}, followed by Zn and Fe application at the rate of 20 kg ha^{-1}. The minimum yield (4.96 t ha^{-1}) was found in case of control where there was no Zn and Fe appliance. The yield response to these two essential micronutrients was freeze after 20 kg ha^{-1} application. The yield data showed that 10 kg ha-1 application of these nutrients (Zn and Fe) gave statistically similar response towards grain yield as by two sprays of 0.1 % Zn & Fe. [20] reported that on high pH soil Fe deficiency causes decrease in the maize yield and its application enhanced the yield. Similarly, increase of maize yield was reported by [2] by Zn application. [21] showed significant increase in yield of maize with the application of micronutrients. The decline in yield in the absence of these micronutrients is due to nutrient imbalance as reported by [1].

3.2 Iron and Zinc Concentration in Maize Grain

The data regarding Zn and Fe content of maize grain is presented in Table 2. The results showed that Zn and Fe contents were significantly influenced by the application of these nutrients to the maize crop. It is clearly observed from the data that grain nutrients content increased with the application of each treatment comparing with the treatment where NPK was applied alone. The highest Zn (31.8 mg kg^{-1}) and Fe (153.6 mg kg^{-1}) content were calculated in treatments where foliar application of 0.1% was applied to the maize crop. This increase is 122.4% in case of Zn and 107.3% in case of Fe. The minimum contents were obtained in case of control i.e. 14. 3 and 74.1 mg kg^{-1} of Zn and Fe, respectively. When all the treatments were compared it was further verified that more zinc and iron accumulation in grain occurred where foliar application was done as compared to soil application.

Roemheld and El-Fouly [22] reported that foliar application of nutrients is a quick responsive way to increase the quality in terms of nutrient status of the crop. [23] indicated the fact that low organic matter and clay adsorption decreased the flow of nutrients in soil and preferred the foliar application of nutrients. [24] reported the accumulation of micronutrients in the grain with the addition of their fertilizers. [25] investigate that grain richer in iron was capable to inverse iron deficiency in six months' time in children.

3.3 Zn and Fe Response Curve

Response curves of maize at different levels of Zn and Fe application was observed. The growth response curves are shown in Figs. 2 and 3 at different levels of Zn and Fe, respectively. At maximum grain relative growth yield zinc content of maize was 25.1 mg kg^{-1} (Fig. 3). The Fe content in maize grain was 122.7 mg kg-1 at this same relative grain yield of maize grain.

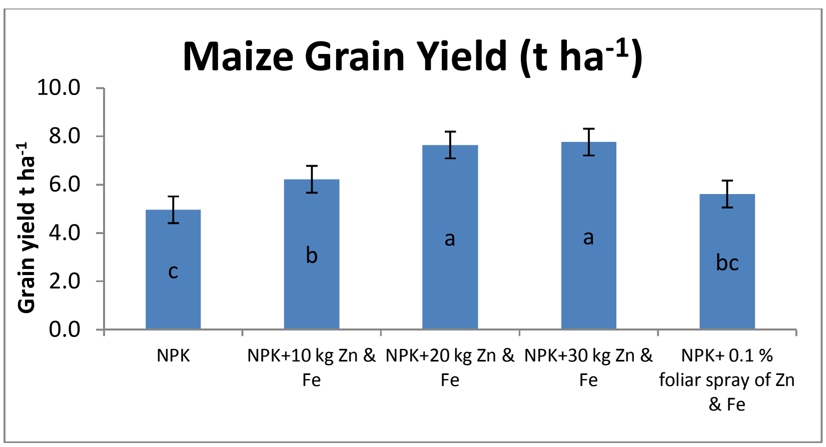

Fig. 1. Effect of Zn & Fe application on the maize yield (t ha-1)

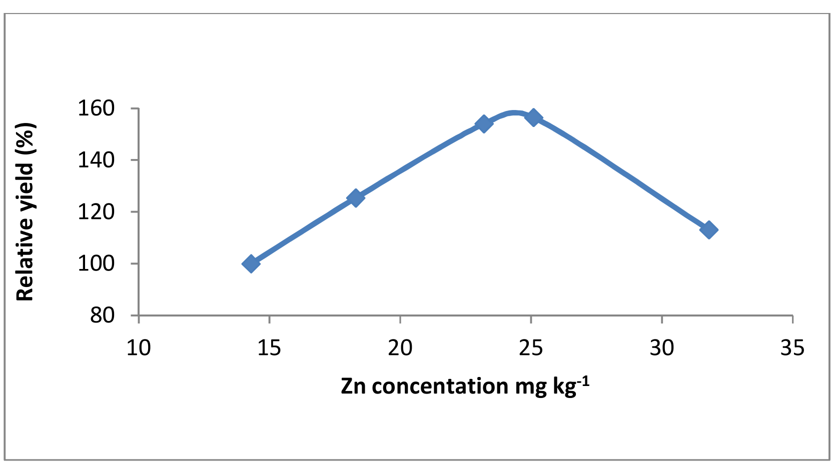

Fig. 2. Critical Zn concentration for optimum yield of maize grain in maize hybrid

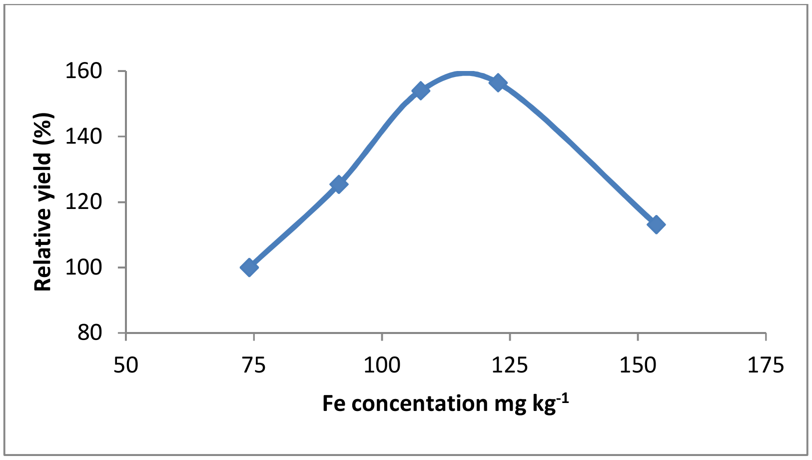

Fig. 3. Critical Fe concentration for optimum yield of maize grain in maize hybrid

Table 2. Effect of Zn & Fe application on the zinc and iron contents of maize grain

Treatments	Fe Content (mg kg^{-1})	% increase	ZnContent (mg kg^{-1})	% increase
NPK	74.1	--	14.3	--
NPK+10 kg Zn & Fe	91.6	23.6	18.3	28.0
NPK+20 kg Zn & Fe	107.6	45.2	23.2	62.2
NPK+30 kg Zn & Fe	122.7	65.6	25.1	75.5
NPK+ 0.1 % foliar spray of Zn & Fe	153.6	107.3	31.8	122.4

4. CONCLUSION

The application of Zn and Fe increased the grain yield and Zn and Fe contents of maize. The foliar application of Zn & Fe proved a better way to increase the nutrients contents in maize grain. The increase in yield was freeze after 20 kg of Zn and Fe ha^{-1}. The maximum accumulation of iron and zinc was in grains when foliar application of Zn & Fe @ 0.1% was applied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kanwal S, Rahmatullah, Ranjha AM, Ahmad R. Zinc partitioning in maize grain after soil fertilization with zinc sulfate. Int. J. Agric. Biol. 2010;12:299–302.
2. Harris A, Rashid G, Miraj M, Arif, Shah H. On-farm seed priming with zinc sulphate solution– A cost-effective way to increase the maize yields of resource-poor farmers. Field Crops Res. 2007;110:119–127.
3. Bouis H. Enrichment of food staples through plant breeding: A new strategy for fighting micronutrient malnutrition. Nutr Rev. 1996;54:131–137.
4. Cakmak I, Pfeiffer WH, McClafferty B. Biofortification of durum wheat with zinc and iron. Cereal Chemistry. 2010;87:10–20.
5. Welch RM, Graham RD. A new paradigm for world agriculture: Meeting human needs productive, sustainable, nutritious. Field Crops. 1999;60:1-10.
6. Welch RM, Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. J. Exp Bot. 2004;55:353–364.
7. Black RE, Lindsay HA, Bhutta ZA, Caulfield LE, De Onnis M, Ezzati M, Mathers C, Rivera J. Maternal and child undernutrition: Global and regional exposures and health consequences. Lancet. 2008;371:243-260.
8. Gibson RS. Zinc: The missing link in combating micronutrient malnutrition in developing countries. Proc. Nutr. Soc. 2006;65:51–60.
9. Lung'aho MG, Mwaniki AM, Szalma SJ, Hart JJ, Rutzke MA, Kochian LV, Glahn

RP, Hoekenga OA. Genetic and physiological analysis of iron biofortification in maize kernels. PLoS One. 2011;6(6).
10. Maberly GF, Trowbridge FL, Yip R, Sullivan KM, West CE. Programs against micronutrient malnutrition; Ending hidden hunger. Annu. Rev. Nutr. 1994;15:277–301.
11. Singh U, Paraharj CS, Singh SS, Singh NP. Biofortification of food crops. Technology & Engineering. Springer. 2016;480.
12. Ritchie SW, Hanway JJ, Benson GO. How a corn plant develops. Spec. Rep. 48 (revised). Iowa State Univ. of Sc. and Technol. Coop. Ext. Serv., Ames. IA; 1993.
13. Mclean EO. Soil pH and lime requirement. In: Methods of Soil Analysis part 2: Chemical and microbiological properties. Page AL, Miller RH, Keeney DR, (2nd eds). American Society of Agronomy. 9. Madison, WI, USA. 1982;199-209.
14. Nelson DW, Sommers LE. Carbon, organic carbon and organic matter. In: Methods of soil analysis Part 2: Chemical and microbiological properties. Page AL, Miller RH, Keeney DR, (eds). American Society of Agronomy. 9 (Madison), WI, USA. 1982;539-580.
15. Rowell DL. Soil science. Methods and application. Longman Scientific & Technical, UK; 1994.
16. Sheldrich BH, Wang C. Particle size distribution. In: Soil sampling and methods of analysis, (ed Carter MR). 1993;499-511. Canada.
17. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J. 1978;42: 421-428.
18. Rashid A. Mapping zinc fertility of soils using indicator plants and soils analysis. PhD Dissertation, University of Hawaii, HI, USA; 1986.
19. Steel RGD, Torrie JH, Dickey DA. Principles and procedures of statistics: A biometrical approach, 3rd Ed. McGraw Hill Co. New York, USA; 1997.
20. Chad BG, John PS, Alan JS, Randal KT, Curtis RT, Ronald JG. Correcting iron deficiency in corn with seed row– Applied Iron Sulfate. Agron. J. 2003;95:160–166.
21. Ya-Ling ZAN, Chao-Hui WANG, Hui MAO. Effect of Se, Zn and Fe application on yield and nutritional quality of maize and soybean. J. Acta Metallurgica Sinica. 2010;16(1):252-256.
22. Roemheld V, El-Fouly MM. Foliar nutrient application challenge and limits in crop production. Proceedings of the 2nd International Workshop on Foliar Fertilization, Bangkok, Thailand, 4-10 April; 1999.
23. Cakmak I. Enrichment of cereal grains with zinc: agronomic or genetic biofortification? Plant Soil. 2008;302:1–17.
24. Rego TJ, Sahrawat KL, Wani SP, Pardhasaradhi G. Widespread deficiencies of sulfur, boron and zinc in Indian semi-arid tropical soils: On-farm crop. J. Plant Nutr. 2007;30:1569–1583.
25. Kkeeton. New results indicate biofortified crop reverses iron deficiency in children. CGIAR, Research program on Agriculture for nutrition and health; 2015.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14085