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Biofortification of maize grain with zinc by using fertilizing approach

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Abstract

Biofortification is a long-term strategy for increasing the availability of zinc (Zn) to people who need it most. Plant breeding efforts at the CGIAR and NARS have made significant progress in the development of Zndense cultivars, and new bio-fortified varieties have been successfully released. When compared to other tactics, genetic modification through gene technology provides a quick and precise way to generate nutrient-dense crops with minimal on-going investment. Using zinc fertilisers to improve zinc concentrations in maize grain is a viable option. A maize hybrid was chosen, and three levels of Zn (10, 20 and 30 kg ha^{-1}) were applied at the time of sowing. The results showed that maize grain production and Zn content increased in response to Zn application in the soil or on the leaves. The plots that received 30 kg of Zn ha^{-1} produced the maximum grain yield (7.76 t ha^{-1}), which is comparable to the 7.64 t ha-1 grain yield from plots that received 20 kg of Zn ha^{-1}. In the case of Zn, the increase over control is 55% and 51.8%, respectively. The findings showed that Zn application applied as a soil or foliar application increased maize grain production and Zn content. The study concluded thatzinc fertilisation is an efficient strategy to boost corn yield, concentration in maize grain, and, ultimately, corn quality.

Keywords: Biofortification, maize, zinc, fertilisation

Introduction

Maize is the country's third most important cereal crop. Its production has increased in recent years, although there is still a significant gap between Pakistan's average maize yield and that of industrialised countries. Because of its application in the cattle and poultry industries, maize has a high monetary value. It is processed in large quantities to create a variety of human-use items. Dietary diversity is the best way to ensure appropriate nutrition, however low-income, impoverished families' diets in developing nations tend to be based on basic plant items, and many of these foods (such as grains) are deficient in nutrients. With the introduction of biofortification, a greater emphasis was placed on Zn homeostasis in order to better our understanding of the physiology of these element as well as the genetics involved in increasing Zn nutrition in crop plant' sedible parts.

To satisfy Zn targets set by the nutrition community, inherent variation in Zn was used within germplasm banks.

Maize is the only cereal crop that can be cultivated in a wide range of seasons, ecosystems, and uses. Regular yellow/white grain maize, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, and so on are some of the other forms of maize. Aside from that, maize is a valuable industrial raw material. Dent, flint, flour, sweet, pop, and pod corn, among others, can be intentionally characterised based on kernel type, with the exception of pod corn, these classifications are based on the quality, quantity, and pattern of endosperm composition in the kernel, rather than natural correlations.

Zn is themost critical nutrients for humans that are deficient in the diets of people in underdeveloped countries. Zn deficiencies affect billions of people around the world, and the ratios in youngsters are alarming. According to reports, a Zn shortage causes DNA damage, a weakened defence system, and inhibited physical growth, all of which lead to a slew of health issues. The main cause of zinc insufficiency is a lack of variety in food and a lack of bio-available forms of these vital elements. The challenge for agriculture is not just to eed the masses, but also to give nutrient-dense food to the impoverished, and to do so, agriculture must be designed with the health of the masses in mind. Increased amount of these lacking elements in the edible section of cereal crops is required.

Nutrients found in grain crops' edible parts. This nutritional enrichment in grains is a long-term and sustainable method of delivering insufficient nutrients to large populations.

The goal of this study was to raise the Zn content of maize grains in order to reduce the risk of human Zn deficiency.

Material and Methodology

Climatic condition of Maize

1. The optimum temperature for maize Growth and development is 18 to 32 °C, with temperatures of 35 °C and above considered inhibitory.
2. The optimum soil temperatures for germination 12 °C or greater, and at tasseling 21 to 30 °C is ideal.
3. Low temperature is rarely a limiting factor for crop production
4. Rainfall: Minimum 50-100cm
   Maximum 250-400cm
5. Harvesting Temperature: 25-30 °C

Field Preparation

- Forming ridges and furrows or beds
- Form ridges and furrows providing sufficient irrigation channels. The ridges should be 6 m long and 60 cm apart.
- If ridges and furrows are not made, form beds of size $10m^2$ or $20m^2$ depending on the availability of water.
- Use a bund former or ridge plough to economise cost of production.

Seed treatment

Seed treatment is required to protect seeds from soil-borne diseases and insect pests. Seed treatment with Metalaxyl or Thiram @ 2 g/kg of seed is used for the control of many diseases.

Intercultural Operations

- Weed Management
- Roguing
- Pest Management
- Disease Management
- Harvesting
- Seed Yield

The Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan, conducted a field trial. To determine the effect of Zn application on grain Zn concentrations, hybrid maize (hybrid-919) was seeded in August 2020and harvested in December 2020. Maize seeds were planted on ridges in a plot measuring 7.5 m x 4.5 m. The experiment was set up in a Randomized full block design with three replications, with the adjacent plots divided by establishing boundaries. The Dibbler added two seeds every hole produced on the ridges.

Table 1: Fertility status of field used for study

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

The Agriculture Department of the Government of Punjab, recommended basal doses of nitrogen, phosphorus, and potassium for hybrid maize of 275 kg ha-1 N, 125 kg ha-1 P2O5, and 75 kg ha-1 K2O, respectively.

Fertilizer supplies included urea, single super phosphate (SSP), potassium sulphate (SOP), zinc sulphate (ZnSO4). The Zn treatments were administered to the maize crop.

a. Management (No zinc)
b. Zn in the soil (@10 kg ha-1)
c. Zn in the soil (@20 kg ha-1)
d. Znin the soil (@30 kg ha-1)
e. Foliar Zn sprays (@ 0.1%)

At the time of seeding, half of the nitrogen, full phosphorus, and potassium were administered, followed by 12 N after 20 days of germination. All Zn treatments were administered to the soil at the time of sowing.

To crop at the silking and grain filling stages, Zn foliar treatments were applied. Thinning was done after ten days of germination to maintain the plant population and plant to plant distance. Allof the company's management practises

Throughout the growing season, maize crops were harvested. When necessary, canal water was utilised to irrigate the crop. Harvesting was done as the tenth leaf produced a black coating at crop maturity. A thresher was used to separate the grains from the cobs, and the grain yield was recorded and converted into a universally accepted unit, tonnes per hectare (t ha-1).

Soil Analysis and Sampling

Composite soil samples were taken from two depths (0-15 and 15-30 cm) before the maize crop was sown and before fertiliser was applied. The samples were air dried and powdered before being filtered through a 2 mm sieve for examination. The electrical conductivity (EC) of soil extract was calculated using the method after the pH of the soil was measured in saturated paste. The soil organic matter content was determined using the Walkley-Black method. The available phosphorus was measured using Olsen's method, while the potassium was measured using the method. The DTPA extraction method was used to determine the zinc status of the soil. The soil fertility status before to planting is listed above.

Table 1 is shown above. The soil investigation revealed that the texture was sandy clay loam with a pH of 8.13. There was no concern with salinity or sodicity in the field. The soil had a low organic matter concentration. The amount of phosphorus in the soil was modest, while the amount of potassium available was adequate.

The fertility investigation revealed that the soil utilised for the experiment had a low Zn concentration, whereas the iron content was appropriate.

Plant Sampling and Analysis

Following harvest, grains were separated from cobs and grain samples were taken for Znanalyses. The samples were dried at 70 °C in an air circulation plant oven until uniform weight was achieved, then ground in a Wiley micro mill. The 0.5 g of dried material was digested in a tri-acid mixture (5:2:1), which included sulphuric acid, nitric acid, and perchloric acid. Zinc determination using a spectrophotometer (Shemadzu 7000).

Data Analyses

The automated system Statistix was used to analyse the data collected in this investigation. At a 5% probability level, the Least Significant Difference (LSD) between the treatment means was compared.

Table 2: Effect of Zn application on the zinc contents of maize grain

Treatments	NPK	NPK+10 kg Zn	NPK+20kg Zn	NPK+30 kg Zn	NPK+0.1% foliar spray of Zn
Zn content (mg kg^{-1})	14.3	18.3	23.2	25.1	31.8
% Increase	--	28.0	62.2	75.5	122.4

Result and Discussion

Grain Yield of Maize

Figure 1 depicts the corn yield data. The results showed that maize production rose with each addition of Zn fertilisers in all treatments when compared to the control (NPK alone). The treatments that applied 30 kg of Zn fertilisers ha-1 yielded the highest corn yield, 7.76 kg ha-1, followed by 20 kilogramme of Znfertiliser ha-1. Greater emphasis was placed on Zn homeostasis in order to improve our understanding of their physiology as well as the genetics involved in increasing Zn nutrition in crop plant edible parts. The lowest yield (4.96 t ha-1) was discovered in the case of no Zn application. After 20 kg ha-1 application, the yield response to these critical micronutrients was frozen.

According to yield statistics, a 10 kg ha^{-1} application of these nutrients (Zn) had a statistically identical response to grain production as 0.1%Zn sprays. reported that Zn application increased maize yield. demonstrated that adding micronutrients to maize increased output significantly. According to the decrease in yield in the absence of certain micronutrients is attributed to nutritional imbalance.

Maize Grain Zinc Concentration

Information on the Znlevels of maize grain. The findings revealed that the Zn contents were substantially higher.

The administration of these nutrients to themaize crop has an impact. When compared to the treatment where NPK was given alone, the data clearly show that grain nutrients content increased with the application of each treatment. The highest Zn content was found in treatments with a 0.1% foliar application of Zn (31.8 mg kg-1).

In the case of control, the minimal levels were 14.3 Zn. When all of the treatments were examined, it was discovered that foliar application resulted in higher zinc accumulation in grain than soil application.

Roemheld and El-Fouly reported that foliar application of nutrients is a quick Roemheld and El-Fouly reported that foliar application of nutrients is a quick responsive way to improve the crop's quality in terms of nutritional status stated that low organic matter and clay adsorption reduced nutrient flow in soil and that foliar application of nutrients was favoured. With the use of their fertilisers, found that micronutrients accumulated in the grain.

Response for Zn

Maize response curves were seen at various amounts of Zn treatment. The growth response curves for varied amounts of Zn, respectively. Zinc content of maize at optimum grain relative growth yield was 25.1 mg kg-1.

Agronomic Biofortification in Maize

Maize is a popular cereal crop because of its many uses as a source of food for both people and animals. It is a demanding crop that necessitates main nutrients as well as micronutrients, particularly zinc, in order to produce higher yields. However, maize grains are naturally low in zinc, especially when grown on zinc-deficient soils. Recent studies have shown that Zn concentrations in maize grain can be increased using various agronomic tactics such as soil application or seed priming, and that the crop reacts effectively to Zn fertilization.

In comparison to a single fertilisation technique, combining soil and foliar Zn fertilisers under field circumstances is a very effective and practical way to increase Zn uptake and accumulation in whole grain and yield. According to the findings of a field investigation, combining soil and foliar applications resulted in significantly higher Zn concentrations in maize grain and stover.

Similarly, foliar Zn spray combined with Zn fertiliser broadcasting or banding considerably increased crop production and Zn concentration in grains. It could be related to increased auxin production, as Zn is necessary for the synthesis of tryptophan, which is a precursor of IAA and plays a key role in internodal elongation. In the same experiment, it was discovered that Zn fertilisation reduced grain phytic acid concentration in maize grain due to the diluting impact of enhanced plant development and yield.

It was also discovered that priming seeds with Zn sulphate solution boosted maize grain yield. In maize hybrids, however, using Zn as seed priming (2% Zn solution) and foliar spray (2% Zn solution) together boosted the Zn grain content.

Zn concentration in cereal grains is determined by Zn deposited in vegetative tissues, primarily leaves, and subsequently re-translocated into grain during the reproductive stage. Foliar application of Zn is thus more successful than soil application in increasing grain Zn accumulation among the various techniques of Zn fertilisation The impact of Zn feeding on plant structure, physiology, and biochemistry is extensively documented. Several studies have been published on the influence of foliar micronutrient administration on chlorophyll concentration in chlorotic leaves of plants (Fernandez *et al*. 2004) Clearly, better plant health leads to increased yield and quality.

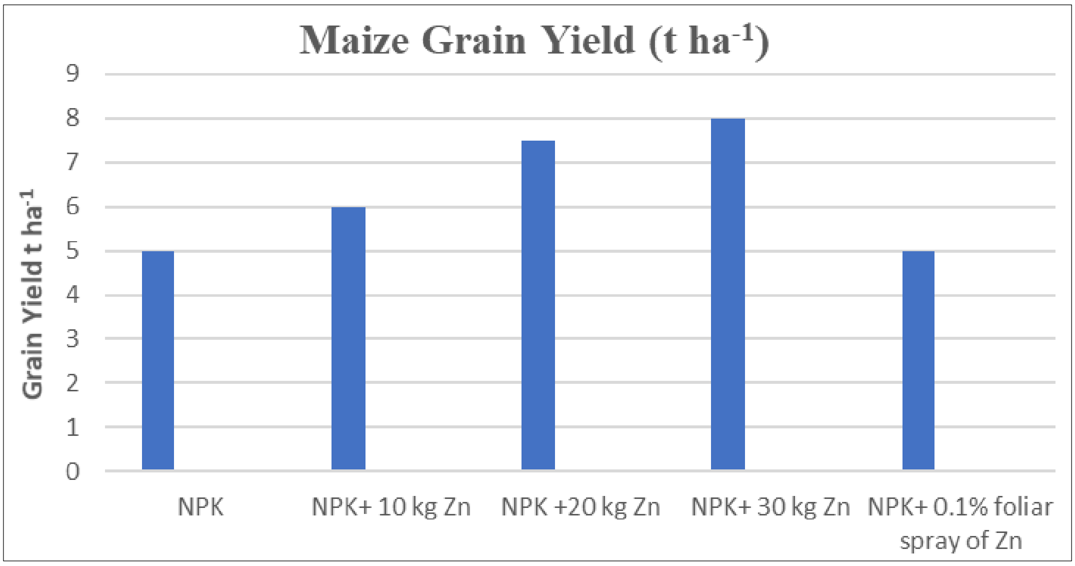

Fig 1: Effect of Zn application on the maize yield (t ha^{-1})

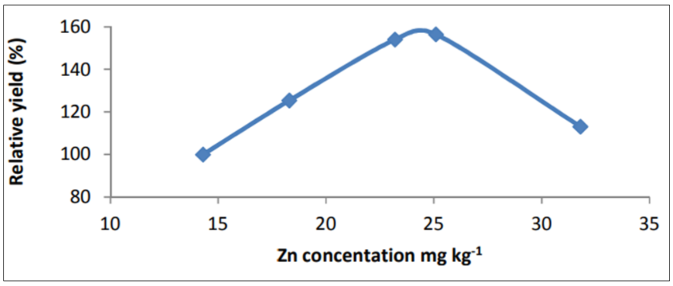

Fig 2: Critical Zn concentration for optimum yield of maize grain in maize hybrid

Conclusion

The addition of Zn to maize enhanced grain yield and Zn content. The foliar spray of zinc and iron showed to be a more effective means of increasing the nutritional content of maize grain. After 20 kg of Zn ha-1, the rise in yield was frozen. When Zn @ 0.1 percent was applied to the leaves, the most zinc was accumulated in the grains.

One of the most significant components in effective crop production is nutrient management; consequently, in this experiment, we attempted to use soil microorganisms instead of chemical approaches to identify a good method for long-term crop nutrient management. In recent years, growing usage of chemical inputs in agricultural fields has resulted in a number of environmental and health hazards, as well as a reduction in product quality. As this experiment demonstrated, integrated nutrient management with less reliance on chemical fertilisers is a promising technique for achieving sustainable and healthy production and food safety.

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