Original Research Article

Maize Yield Response to Zinc Fertilization in Farmer's Field under Rainfed Condition in Hill Region of Assam, Eastern Himalayan Region

ABSTACT

Zinc (Zn) is the micronutrient that most commonly limits maize yields but it receives much less attention than other inputs. The present field experiment was conducted to study the effect of zinc fertilizers on growth and yield of maize in farmer's field under rainfed condition in hill region of Assam, Eastern Himalayan Region for authenticating Zn fertilizer application in increasing the yield of summer maize in actual farmer's field condition. The experiment was carried out in 6 locations (as replication) of three villages with four treatments which consist of recommended dose of fertilizer , recommended dose of fertilizer with $ZnSO_4$ @15 kg ha^{-1}, Farmers' practice with $ZnSO_4$ @ 15 kg ha^{-1} and Farmers' practice as control. Maize responded positively to Zn fertilization where the yields increased from 4.62t ha^{-1} without Zn to 4.91 t ha^{-1} with Zn under recommended dose of fertilizers. The yield response of maize to application of Zn only recorded 9.15 % increase in yield in case of farmers practice without any fertilizers. Zn application increased maize yield due to increased cob length, cob diameter, kernel numbers and kernel weight in Zn-deficient soils. The increase in grain yield in case of combined use of fertilizer and $ZnSO_4$ was mainly due to significantly more number of kernels per cob (392) as well as kernel weight (120.3 g) over application of fertilizers only i.e. 368 and 108.4 g respectively. The result of the present study reveals that, application of Zn as $ZnSO_4$ @ 15 kg ha^{-1} in maize crop along with recommended fertilizers is highly recommended for the soils of North Eastern Hill region of India.

Keywords: Zinc, micronutrient, maize, North Eastern Hill region

INTRODUCTION:

Maize (*Zea mays* L.) is the world's most widely grown cereal and primary staple food crop in many parts of the developing countries. Zinc (Zn) is the micronutrient that most commonly limits maize yields worldwide [1], in the USA, for example, maize receives the largest tonnages of Zn fertilizers of any crop [2]. Zinc removal with the maize kernel and harvest index is the largest among all micronutrients [3]. Although Zn is an essential micronutrient for plant growth, Zn input has received much less attention than nitrogen (N), phosphorus (P), or irrigation [4], [5]. Lack of zinc is a common micronutrient deficiency in arid and semiarid areas of the World. It is stated that approximately 50 % of the land used for the production of cereals in the world are deficient in Zn [6]. Therefore the application of Zn fertilizers is necessary in such soils to ensure cereal yield and grain Zn concentration [7]. Many studies have demonstrated that the maize grain yield increases significantly with the application of Zn fertilizer to Zn-deficient soils [8], [9],[10].

Maize is one of the crops most sensitive to Zn deficiency [11] Zn deficiency hinders maize growth, resulting in decreased kernel yield and quality [12]. Zinc is important in photosynthesis and respiration, and Zn deficiency decreases the photosynthetic rate, chlorophyll content, activity of carbonic anhydrase, and protein biosynthesis [13], [14]. Therefore, application of Zn fertilizer may be an important measure for improving the yield and quality of maize.

In Karbi Anglong district of Assam which falls in the Eastern Himalayan region of India, maize is the second most important cereal crop next to rice where it is grown predominantly during summer as a *kharif* crop. It is cultivated in 10784 hectares of land and producing 24384 tons of maize kernel with the productivity of 2.26 t ha^{-1}. At present, the maize production only met the requirement for human consumption and the booming poultry farming has intensified the demand for maize as poultry feed. The soils of Karbi Anglong district of Assam is deficient in Zinc as observed from the soil health card scheme implemented by Krishi Vigyan Kendra which indicated the potentiality of enhancing the yield of maize crop through Zn fertilization.

The main objective of this study was to study the effect of zinc fertilizers on growth and yield of maize in farmer's field under rainfed condition in hill region of Assam. The results of this study are important for authenticating Zn fertilizer application in increasing the yield of summer maize in actual farmer's field condition.

MATERIALS AND METHODS

Experimental site

Field experiments was conducted under on-farm testing programme of Krishi Vigyan Kendra at Karbi Aanglong district which falls in the hill region of Assam, India and lies between $25^0$32'N to $26^0$36'N latitudes and $92^0$10'E to $93^0$50'E longitude. The experimental sites were characterized by undulating topography with gentle slope (12-20%).

The soils of the experimental sites are with the following characteristics: pH, 5.6-6.4 (1:2.5 w/v in water); organic carbon concentration, 0.64-0.87%; available nitrogen 382.4 – 408.5 $kgha^{-1}$; available phosphorus 12.4 – 21.3 $kgha^{-1}$, available potassium 132.6 -167.2 kg ha^{-1}. The initial soil DTPA-extractable Zn concentration was 0.30 mg/kg, which indicated Zn deficiency (low, 0-0.5 mg/kg; medium, 0.51-0.8 mg/kg; high, > 0.8 mg/kg). The soil texture is sandy clay loam soil with 46.2 to 52.0 % of sand, 21.5 to 23.4 % of silt and 25.5 to 27.25% of clay (Table 1).

Table 1. Initial soil properties of the experimental site

Soil properties	Min	Max	Mean
pH (1:2.5)	5.6	6.4	5.97
Soil organic carbon (%)	0.64	0.87	0.76
Available N (kg ha^{-1})	382.4	408.5	407.5
Available P_2O_5 (kg ha^{-1})	12.4	21.3	6.52
Available K_2O (kg ha^{-1})	132.6	167.2	87.30
Zn (mg kg^{-1})	0.24	0.44	0.30

Experimental details

The experiment was carried out during the 2016 and 2017 growing seasons in Randomized Completely Block Design (RCBD) in 6 locations (as replication) of three villages selected based on the report of the Soil Health Card Scheme of Govt. of India, where soils are predominantly deficient in zinc. There were four treatments which consist of recommended dose of fertilizer (T_1), recommended dose of fertilizer with $ZnSO_4$ @15 kg ha^{-1} (T_2), Farmers' practice with $ZnSO_4$ @ 15 kg ha^{-1} (T_3) and Farmers' practice as control (T_4). Soil samples were taken randomly from four different spots of a plot at a depth of 0-30 cm using tube auger to record physico-chemical properties of soil.

Yield and yield attributes

Cob length and cob diameter

The diameter of these same randomly selected cobs was measured by using verneer caliper. The diameter was taken from middle of the cobs.

Number of kernels per cob

The number of kernels per cob was calculated as given below.

Number of kernels per cob = Number of kernel rows per cob × number of kernels per row.

Thousand kernel weight

Thousand kernel weight was taken from composite sample of the sampling cobs of each plot and then average was taken, weight to record as thousand kernel weight and expressed in gram (g).

Grain yield per hectare

From each experimental plots grain yield was recorded. The data was converted and reported as grain yield kg ha^{-1}. The moisture content of grains of each plot was measured by automated moisture meter and final grain yield was adjusted at 13% moisture level by using the formula as given below:

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{(100 - MC) \times plot\ yield\ (kg)\ \times 1000\ (m^2)}{(100 - 13) \times net\ plot\ area\ (m^2)}$$

Where, MC is the moisture content percentage of grain.

Stover yield

All maize plants were harvested at base from the net cultivated area and maize stem was weighted immediately after harvesting. Husk was also included while taking Stover yield. Stover yield was calculated on hectare basis in kg ha^{-1}.

Agronomic efficiency (AE)

To compare Zn-use efficiency among the treatments, the agronomic efficiency (AE) of Zn was calculated by the following formula [15], [16].

$$AE=(Y_{Zn}-Y_c)/Zn_a$$

where , Y_{Zn} is grain yield in Zn applied plot , Y_c is grain yield in the control pot, and Zn_a is the amount of Zn applied.

Statistical analysis

Analysis of Variance (ANOVA) for all parameters was analyzed by using Gen Stat statistical analysis system. All the analyzed data were subjected to Duncan's Multiple Range Test (DMRT) for mean comparison. Correlation and regression analysis were carried out for important parameters.

RESULTS AND DISCUSSION

Cob length and cob diameter

The data on cob length of maize as influenced by fertilizer and Zn is presented in Table 1. The length of cob (17.0 cm) was found greater in T_2 (RDF + $ZnSO_4$ @ 15 $kgha^{-1}$) which was at par with T_1 (RDF). The farmers practice (T_4) showed the lowest cob length (11.4 cm) followed by application of $ZnSO_4$ only (T_3).

Similarly, significantly higher cob diameter (4.36 cm) was recorded from T_2 which was statistically at par with T_1. The treatment T_3 and T_4 showed similar cob diameter and least cob diameter (3.75 cm) was found in control (T_4). The cob length and cob diameter increased when fertilizer was applied in integration with Zn which might be the result of continuous filling of kernels with sufficient photosynthates as compared to sole fertilizer application [17].

Kernel number cob^{-1}

The significantly higher number of kernels per cob (392.0) was found in the plots where $ZnSO_4$ was applied with recommended dose of fertilizers (T_2). The control plot produced statistically lower kernels (283.0) per cob. Desai and Vinodakumar [18] reported that, availability of nutrients especially nitrogen was an important factor to decide the number of kernels per cob. The increase in number of kernels per cob might be attributed to the availability nutrients. Number of kernel lines per cob is an important yield determining factor in maize. It affects the number of kernels per cob and cob weight.

Thousand kernel weight (TKW)

The data showed that, thousand kernel weights were affected significantly by different levels of fertilizers and Zn. Significantly higher thousand kernel weights i.e. 265 g were recorded from fertilized plots in combination with $ZnSO_4$ and lower TKW (214.5 g) was recorded from the farmers practice (Table 2). The increase in thousand kernel weights could be due to balanced supply of nutrients and Zn throughout the kernel filling and development period of plant [19].

Table. 2. Yield parameters of maize as influenced by Zn application

Treatments	Cob length (cm)	Cob diameter (cm)	Kernel/cob (no.)	Cob weight (g)	Thousand Kernel weight (g)
T1	16.2^{a}	4.18^{a}	368^{a}	108.4^{a}	251.4^{a}
T2	17.0^{a}	4.36^{a}	392^{b}	120.3^{a}	265.2^{a}
T3	14.3^{b}	3.84^{b}	322^{d}	97.2^{c}	226.3^{c}
T4	11.4^{c}	3.75^{b}	283^{c}	72.1^{b}	214.5^{b}

Note: Means followed by common letter (s) within each column are not significantly different at 5% level of significance based on DMRT.

Grain yield ($t\ ha^{-1}$)

Significantly highest grain yield of 4.91 $t\ ha^{-1}$ was recorded from plots where recommended fertilizers were applied with $ZnSO_4$, followed by application of recommended fertilizers only. The lowest grain yield of 3.16 $t\ ha^{-1}$ was recorded from farmer's practice where there was no use of organic and inorganic fertilizers. The lower nutrient level in the soil results in lower yield [20]. Grain yield is a function of interaction among various yield components that are affected differentially by the growing conditions and crop management practices. The increase in grain yield in case of combined use of fertilizer and $ZnSO_4$ was mainly due to more number of kernels per cob as well as better kernel development.

Due to the physiological role of Zn in maize, an insufficient supply of Zn reduces maize yield by about 10% [21]. In the present study under farmers' field condition, soil Zn fertilization increased maize grain yield, which is in agreement with the results reported by Abunyewa and Mercie-Quarshie [22] and Potarzycki [23]. The explanations provided by these researchers for the increase in maize yield with Zn addition was mainly due to improvements in kernel number and thousand kernel weight.

Zinc application likely promoted pollen viability in the current study, because Zn is essential for pollen grain development, and pollen viability is influenced by many factors, such as relative humidity, temperature, oxygen pressure, etc. [24]. Previous studies have shown that developing anthers and pollen grains have higher Zn requirements than do other plant parts [25], and Zn deficiency may limit these developmental processes. An adequate Zn supply is essential for synthesizing cytoplasmic ribosomes in pollen granulocytes [26].

Furthermore, drought in maize are becoming more common in the hill region of Assam. Zinc plays an important role in alleviating reactive oxygen, drought, and heat stress [27], [28] Thus, adequate Zn in shoots could meet the requirements of pollen development, increase resistance to abiotic stress, and maintain high pollen viability during the anthesis stage.

Stover yield (t ha^{-1})

The highest stover yield of (9.80 t ha^{-1}) was produced by T_2 which was significantly higher than all other treatments. The lowest stover yield (6.57 t ha^{-1}) was recorded in T_4 (Control). Stover yield was significantly influenced by application of fertilizers as well as Zn, as application of $ZnSO_4$ alone showed significantly higher stover yield over farmers practice.

Similar findings were reported by Ali., *et al*., [29] who indicated that, higher biomass production produced by maize crop was due to greater LAI, plant height, major and micronutrients availability due to supply of nutrients through both the organic and inorganic fertilizers in suitable proportions.

Table. 3. Garin yield, stover yield, and agronomic efficiency of Zn **in maize as influenced by Zn application**

Treatment	Grain yield	Stover yield	Agronomic efficiency of Zn
T1	4.62^{a}	9.38^{a}	-
T2	4.91^{b}	9.80^{b}	0.34
T3	3.34^{c}	6.89^{d}	0.04
T4	3.06^{c}	6.57^{c}	-

Note: Means followed by common letter (s) within each column are not significantly different at 5% level of significance based on DMRT.

CONCLUSION

Maize responded positively to Zn fertilization where the yields increased from 4.62t ha^{-1} without Zn to 4.91 t ha^{-1} with Zn under recommended dose of fertilizers. The yield response of maize to application of Zn only recorded 9.15 % increase in yield in case of farmers practice without any fertilizers. Zn application increased maize yield due to increased cob length, cob diameter, kernel numbers and kernel weight in Zn-deficient soils. The result reveals that, application of Zn as $ZnSO_4$ @ 15 kg ha^{-1} in maize crop is highly recommended for the soils of North Eastern Hill region of India.

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