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

Nilim Kalita [a*†], P. Boruah [b], S. Bhuyan [c¥], R. K. Saud [d#] and S. Maibangsa [e€]

[a] *Citrus Research Station, Assam Agricultural University, Tinsukia, Assam, India.*
[b] *SMS, KVK, Karbi Anglong, AAU, Diphu, Assam, India.*
[c] *College of Sericulture, AAU, Jorhat, Assam, India.*
[d] *AAU, Jorhat, Assam, India.*
[e] *KVK, Karbi Anglong, AAU, Diphu, Assam, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

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 Zn 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 (90:40:40 kg NPK kgha^{-1}), recommended dose of fertilizer with $ZnSO_4$ @15 kg ha^{-1}, Farmers' practice with $ZnSO_4$ @ 15 kg ha^{-1} and Farmers' practice (No application of fertilizers) as control. Maize responded positively to Zn fertilization where the yields increased from 4.62 t ha^{-1}

[†] *Jr. Scientist;*
[¥] *Assistant Professor;*
[#] *Associate Director of Extension Education;*
[€] *Head;*
**Corresponding author: E-mail: nilim.kalita@aau.ac.in;*

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 $ZnSO_4$ (heptahydrate) 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, basal soil 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.

1. INTRODUCTION

Maize (*Zea mays* L.) is the world's most widely grown cereal and primary staple food crop in many countries. Zinc (Zn) is the micronutrient that most commonly limits maize yields worldwide [1]. Zinc removal is the highest among all micronutrients with the maize kernel and harvest index [2]. Despite the fact that zinc (Zn) is an important element for plant growth, it has gotten far less attention than nitrogen (N), phosphorus (P), or irrigation [3,4]. Zn deficiency appears to be the most common micronutrient deficiency problem in agricultural and pasture plants around the world, resulting in significant production and nutritional quality losses [5]. It is estimated that nearly half of the world's cereal-growing land is deficient in Zn [6]. As a result, Zn fertilisers must be applied to such soils in order to ensure cereal yield and Zn concentration in grains [7]. Many research have shown that applying Zn fertiliser to Zn-deficient soils boosts maize grain production significantly [8,9], and [10]. Maize is one of the most sensitive crops to zinc deficit [11]. Zn deficiency slows maize growth, resulting in lower kernel yield and quality [12]. Zinc is required for photosynthesis and respiration, and a lack of it lowers photosynthetic rate, chlorophyll content, and protein biosynthesis [13,14]. As a result, applying Zn fertiliser to maize could be a key step toward increasing production and quality. 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 of the district but recently it is becoming a popular crop due to its demand as poultry feed. The soils of Karbi Anglong district of Assam is deficient in Zn 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.

2. MATERIALS AND METHODS

2.1 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); soil organic carbon, 0.64-0.87%; available nitrogen 382.4 – 408.5 kg ha^{-1}; available phosphorus 12.4 – 21.3 $kgha^{-1}$ and 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).

2.2 Experimental Details

The experiment was carried out during the 2016 and 2017 growing seasons in Randomized Completely Block Design (RCBD) in 6 locations

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

(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 v 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 i.e. without any fertilizers 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 as per standard procedures [15].

2.3 Yield and Yield Attributes

2.3.1 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.

2.3.2 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.

2.3.3 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).

2.3.4 Grain yield per hectare

From each experimental plots grain yield (kg ha^{-1}) was recorded. 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:

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

Where, MC is the moisture content (%) of grain.

2.3.5 Stover yield

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

2.4 Agronomic Efficiency (AE)

To compare Zn-use efficiency among the treatments, the agronomic efficiency (AE) of Zn was calculated by the following formula [16, 17].

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

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.

2.5 Statistical Analysis

The Gen Stat statistical analysis system was used to conduct an analysis of variance (ANOVA) for all parameters. Duncan's Multiple Range Test (DMRT) was used to compare the means of all the studied data.

3. RESULTS AND DISCUSSION

3.1 Cob Length and Cob Diameter

The data on cob length of maize as influenced by fertilizer and Zn is presented in Table 2. 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 [18].

3.2 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 [19] 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.

3.3 Cob Weight

The cob weight showed significant variations among the treatments. Highest cob weight was recorded in treatments receiving $ZnSO_4$ with RDF (120.3g) which was not significantly different with the treatment receiving only RDF (108.4g). Farmers practice recorded significantly lowest cob weight (72.1 g). The higher cob weight in treatments receiving Zn and RDF may be attributed to more cob length, cob diameter, and more number of kernels per cob as well as higher kernel weight as discussed earlier.

3.4 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 [20].

3.5 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 RDF 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 [21]. 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 may be atributed 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 was reported to reduce maize yield by about 10% [22]. 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 [23] and Potarzycki [24]. 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.

Because zinc is required for pollen grain production, and pollen viability is controlled by a variety of variables, including relative humidity, temperature, and oxygen pressure [25], zinc administration likely improved pollen viability in the current study. Previous research has demonstrated that developing anthers and pollen grains require more Zn than other plant parts [26], and that a lack of Zn could limit these developmental processes. In pollen granulocytes, sufficient Zn is required for the synthesis of cytoplasmic ribosomes [27].

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

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

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 [28,29]. Thus, adequate Zn in shoots in the treatments receiving ZnSO4 might have met the requirements of pollen development, increased resistance to drought and maintained high pollen viability during the anthesis stage resulting higher yield.

3.6 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., [30] 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.

3.7 Agronomic Efficiency of Zn

The agronomic efficiency of Zn was higher (0.34) when it was applied together with RDF than Zn applied without any fertilizers (0.04). The result indicates that application of fertilizers in nutrient deficient soils enhances the absorption of Zn by the crop due to better root growth and results in improved Zn use efficiency [31].

4. 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} with RDF in maize crop is highly recommended for the soils of North Eastern Hill region of India.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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