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Growth and yield of maize as influenced by zinc enrichment through agronomic options

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Abstract

A field experiment on Agronomic options for zinc enrichment in maize was conducted at College farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *kharif* 2019-2020. The experiment was laid out in randomized block design with 10 treatments and replicated thrice. The soil of experimental site was sandy loam type, slightly acidic in pH (6.30), non-saline in EC (0.21 dSm⁻¹), low in organic carbon (0.42%), low in available N (230.60 kg ha⁻¹), medium in available P (24.30 kg ha⁻¹), high in available K (388.40 kg ha⁻¹) and low in available Zn (0.54 ppm). The results revealed that plant growth parameters (plant height and dry matter production), yield attributes (cob length and cob girth), grain (6053 kg ha⁻¹) and stover yield (9084 kg ha⁻¹) were highest with T₅ {RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹} and it was on par with T₇ {RDF + ZSB (1kg/100 kg FYM) + 0.2% foliar spray of ZnSO₄ at Knee-high and Tasseling stages} while the lowest growth and yield parameters were recorded with T₁ {RDF alone (Control-N: P₂O₅: K₂O @ 200:60:50 kg ha⁻¹)}.

Keywords: Enrichment, FYM, grain and stover yield, Zinc, ZSB, ZnSO₄

Introduction

Maize, also known as corn, is a cereal grain that was first grown in Central America. It is now the third most important cereal crop in the world and is called the 'Queen of Cereals'. Maize or corn (*Zea mays*) is cultivated globally being one of the most important cereal crops worldwide. In India, maize is cultivated in an area of 93.8 lakh hectares with production and productivity of 2.87 million tonnes and 3.06 t ha⁻¹ respectively. India produces about 2% the world's maize produce. (Directorate of Economics and Statistics, GOI, 2017-18). In Telangana, maize is cultivated in an area of 6.3 lakh hectares (*Kharif*- 4.63 lakh hectares and *Rabi*- 1.67 lakh hectares) with production and productivity of 2.55 million tonnes (*Kharif*- 1.59 million tonnes and *Rabi*- 0.95 million tonnes) and 4.05 t ha⁻¹ (*Kharif*- 3.45 t ha⁻¹ and *Rabi*- 5.73 t ha⁻¹), respectively. (Directorate of Economics and Statistics, GOT, 2017-18).

In general attention towards the major nutrients is more than the secondary and micronutrients, but in maize zinc nutrition plays a major role in plant metabolism and yielding potential. However, less awareness about micronutrients application and indiscriminate use of major nutrients led to the imbalance in soil nutrient status and as a result micronutrient deficiency is noticed in many parts in general and among them zinc is particular. According to the recent survey, zinc deficiency in human nutrition is the most wide spread nutritional disorder, next to iron, vitamin 'A' and iodine. Nearly, 49% of the global population does not meet their daily-recommended intake of 15 mg day⁻¹ of zinc for an adult and is one of the leading risk factors associated with diseases such as diarrhoea and retarded growth contributing to the death of 8,00,000 people each year (Muhammad and Abdul, 2018) [1]. Negative correlation between irrigation and phosphorous was observed with Zn uptake which leads to the reduction of Zn content in kernels, a major cause of Zn malnutrition among maize consumers.

Target of maize enrichment for Zn contents could be achieved through different agronomic strategies. These strategies are discussed subsequently for usefulness to overcome the hidden hunger for Zn. Application of enriched compost with ZnSO₄, zinc solubilising bacteria (ZSB), zinc seed pelleting and foliar spray to growing plants react with native reserves of micronutrient elements and renders them available to the plants.

Materials and Methods

The experiment was conducted during *Kharif*, 2019-2020 at College farm, Plot no. B-8, Block-B, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural

University, Hyderabad. The geographical location of the experimental site was 17°19' 19.2" N Latitude, 78°24' 39.2" E Longitude with an altitude of 542.3 m above mean sea level. Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana State. The total rainfall received during the cropping period was only 680.8 mm.

The treatment details include recommended dose of fertilizer (RDF- 200: 60: 50-N: P₂O₅: K₂O kg ha⁻¹) N was applied in three equal splits (at sowing, knee-high and tasseling stage), total P was applied as basal and K was applied in two equal splits (at sowing and tasseling stage). FYM was enriched with zinc solubilising bacteria (ZSB) @ 1 kg per 100 kg FYM for about 22 days before sowing i.e., T₂ & T₇. Seed pelleting (1kg seed) was done by adding water with 3.6 g of ZnSO₄, after proper dissolving, polymer was added to above solution and made into slurry by thorough stirring. The slurry was added to 1 kg seed in a polythene cover and thoroughly mixed for 4-5 minutes and shade dried i.e., T₄ & T₉. FYM is enriched with ZnSO₄ @ 50 kg ha⁻¹ with 25 t FYM ha⁻¹ for about 22 days before sowing i.e., T₅ & T₁₀.

Experimental details

The field was ploughed twice with tractor drawn cultivator followed by levelling with rotavator. FYM alone was applied to T₃ and T₈ treatments, FYM enriched with ZSB was applied to T₂ and T₇ treatments and FYM enriched with ZnSO₄ @ 50 kg ha⁻¹ was applied to T₅ and T₁₀ treatments. Crop was sown on ridges. The recommended dose of fertilizers applied (N, P, and K @ 200: 60: 50 kg ha⁻¹). Maize hybrid nk-6240 @ 20 kg ha⁻¹ was sown. In present experiment the spacing was 60 cm × 20 cm. Pre-emergence herbicide like atrazine 50% WP was sprayed @ 2-2.5 kg ha⁻¹. Intercultural operations like gap filling, thinning and weeding was done timely. Crop was entirely grown under rainfall. The crop was harvested at proper stage of maturity as determined by visual observations. Border rows from all sides of each plot were first harvested followed by net plot. Fresh and dry weights of cobs and stover were weighed separately. Shelling of cobs was done by tractor operated maize sheller machine. Biometric observations recorded were plant height, dry matter production, cob length, cob girth, grain and stover yield.

Results and Discussion

Plant height (cm)

Plant height has shown a linear increase at all the stages of crop growth period. Plant height was significantly influenced by integrated approach for zinc enrichment at 30 DAS, knee high stage and at harvest except at 60 DAS (Table 1).

At 30 DAS, highest plant height (70.13 cm) was recorded with T₉ (RDF + Seed pelleting + 0.2% Foliar spray of ZnSO₄ at Knee-high and Tasseling stages) and was on par with all other treatments except T₁, T₂ and T₆. The lowest plant height (56.33 cm) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

At knee high stage, tallest plants (82.53 cm) were recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and was on par with all other treatments except T₁, T₂ and T₆. The lowest plant height (63.53) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹]. Contrary to 30 DAS and knee-high stage plant height at 60 DAS did not vary significantly due to different treatments.

At harvest, highest plant height (184.06) was recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and it was

on par with all other treatments except T₁, T₆ and T₈. The lowest plant height (150.73) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

Significant improvement in the plant height with T₅ and T₇ might be due to rapid cell division and elongation as a result of availability of the needed nutrients to the plant at critical growth stages coupled with application of zinc that resulted in improvement of metallo enzyme system regulatory function and growth promoting auxin production. Similar results were reported earlier by Kumar *et al.* (2017) ^[7], Kumar and Salakinkop (2018) ^[6] and Hekmat *et al.* (2019) ^[5].

Dry matter production (kg ha⁻¹)

The most important index of plant vigour and yield is the accumulation of the photosynthates during the stipulated growth period. Higher dry matter production per unit area is the pre-requisite for higher yield. Data recorded on dry matter production at different intervals during crop growth are presented in Table 2.

An overview of the data indicated that, dry matter accumulation differed significantly by integrated approach for zinc enrichment at 30, knee high stage, 60 DAS and at Harvest.

At 30 DAS, highest dry matter (518 kg ha⁻¹) was recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and was on par with T₁₀ (511 kg ha⁻¹) [RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹ + 0.2% Foliar spray of ZnSO₄ @ Knee-high and Tasseling stages] while, the lowest dry matter (301 kg ha⁻¹) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

At knee high stage also, highest dry matter (995 kg ha⁻¹) was registered with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and it was on par with T₇ (962 kg ha⁻¹) [RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO₄ @ Knee-high and Tasseling stages] while, the lowest dry matter (679 kg ha⁻¹) was obtained with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

Similarly at 60 DAS also, highest dry matter (6301 kg ha⁻¹) accumulation was noticed with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) which was also on par with T₇ (5846 kg ha⁻¹) [RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO₄ @ Knee-high and Tasseling stages] while, the lowest dry matter (3555 kg ha⁻¹) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

At harvest also similar trend was observed wherein highest dry matter (9334 kg ha⁻¹) recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and was on par with other treatments viz., T₄, T₇ and T₁₀. The lowest dry matter (6437 kg ha⁻¹) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹] treatment.

Increased dry matter production in T₅ and T₇ treatments might be due to balanced supply of macro and micro nutrients through soil and foliar fertilization which resulted in better crop growth and photosynthetic activity which led to better supply of photosynthates. Application of enriched FYM with ZSB showed an increasing trend in dry matter production at different crop growth stages due to growth promoting effect of beneficial microbes. Similar findings were earlier reported by Kumar *et al.* (2017) ^[7], Kumar and Salakinkop (2018) ^[6] and Hekmat *et al.* (2019) ^[5].

Yield attributes

Data recorded on yield attributes at different intervals during crop growth period are presented in Table 3.

Cob length (cm)

Cob length was significantly influenced by integrated approach for zinc enrichment. The highest cob length (18.32 cm) was recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and it was on par with T₇ (17.24 cm) [RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO₄ @ Knee-high and Tasseling stages]. The lowest cob length (13.78 cm) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

Cob girth (cm)

Data on cob girth were significantly influenced by integrated approach for zinc enrichment. The highest cob girth (14.5 cm) was observed with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and was on par with other treatments *viz.*, T₇ and T₁₀. The lowest cob girth (10.53) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

The increase in yield attributes in T₅ and T₇ treatments might be due to application of zinc resulted in higher chlorophyll contents, and this had apparently a positive effect on photosynthetic activity, synthesis of metabolites and growth-regulating substances, oxidation and metabolic activities and ultimately better growth and development of crop (Anees *et al.*, 2016) [1].

Yield

Yield is an ultimate end product of many yield contributing components, physiological and morphological processes taking place in plants during growth and development (Chand *et al.* 2017) [2].

Grain yield (kg ha⁻¹)

Perusal of data on grain yield (Table 4) revealed that significantly higher grain yield (6053 kg ha⁻¹) was recorded with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) followed by T₇ (5631 kg ha⁻¹) [RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO₄ @ Knee-high and Tasseling stages] which were on par with each other. The lowest grain yield (3020 kg ha⁻¹) was registered with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹]. The percentage of increase in grain yield in T₅ and T₇ over T₁ treatment was 49.9% and 53.6% respectively.

Increase in grain yield in T₅ and T₇ might be due to improved availability of micronutrients which could be attributed to the

formation of stable organometallic complexes of micronutrients with organic matter, especially during the enrichment process that last for a longer time and release the nutrients slowly in the soil system in such a way that the nutrients are protected from fixation and made available to the plant root system throughout the crop growth period. Zinc fertilization had showed beneficial effect on physiological process, plant metabolism and plant growth, which might had led to higher yield. These findings are in conformity with the findings of Meena *et al.* (2013) [9], Anees *et al.* (2016) [11] and Kumar and Salakinkop (2018) [6].

Stover yield (kg ha⁻¹)

Data on stover yield is presented in Table 4 indicated that significantly higher stover yield (9084 kg ha⁻¹) was registered with T₅ (RDF + FYM enrichment with 50 kg ZnSO₄ ha⁻¹) and was on par with T₂, T₃, T₇, T₈ and T₁₀. The lowest stover yield (6021 kg ha⁻¹) was recorded with T₁ [RDF alone (Control) N: P₂O₅: K₂O - 200:60:50 kg ha⁻¹].

Results revealed that integrated use of chemical fertilizers, FYM and ZSB showed encouraging results in improving stover yield than applied alone. Increase in stover yield might be due to the enhanced translocation of photosynthates with applied zinc, which resulted higher stover yield in T₅ and T₇.

Increase in grain and stover yield might be due to growth and yield attributes of maize and due to integration of Zn and organic manure with inorganic fertilizers. Organics besides release their own nutrient might have increase in the nutrient use efficiency of applied inorganic fertilizers. Patil *et al.* (2017) [12], Kumar *et al.* (2018) [6] and Mishra *et al.* (2019) [10] also reported similar findings.

Conclusion

The growth, yield attributes and yield of maize were significantly high with the integrated application of chemical fertilizers, enriched FYM with ZSB or ZnSO₄ along with foliar spray @ 0.2% ZnSO₄.

Future line of work

- Studies on standard procedures of seed pelleting with zinc may be emphasized along with the dosage.
- Research on cropping system may be focused for arriving at the residual effect of zinc application in the succeeding season with inclusion of zinc responsive crops

Table 1: Plant height (cm) as influenced by integrated approach for zinc enrichment in maize

Treatments		Plant height (cm)			
		30 DAS	Knee-high stage	60 DAS	At harvest
T ₁ -	RDF alone (Control) [N: P ₂ O ₅ : K ₂ O - 200:60:50 kg ha ⁻¹]	56.33 c	63.53 c	101.10	150.73 c
T ₂ -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	59.27 bc	70.00 bc	115.43	179.93 ab
T ₃ -	RDF + FYM (25 t ha ⁻¹)	68.00 a	76.07 ab	114.40	179.47 ab
T ₄ -	RDF + Seed pelleting (3.6 g ZnSO ₄ kg ⁻¹ seed)	63.73 abc	73.33 abc	112.67	178.73 ab
T ₅ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹	67.53 a	82.53 a	120.37	184.07 a
T ₆ -	RDF + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	58.33 bc	64.27 c	104.43	159.80 c
T ₇ -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	65.33 ab	73.80 abc	119.07	183.67 a
T ₈ -	RDF + FYM (25 t ha ⁻¹) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	62.67 abc	72.20 abc	111.47	162.67 bc
T ₉ -	RDF +Seed pelleting + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	70.13 a	79.73 ab	112.80	168.13 abc
T ₁₀ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹ + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	65.33 ab	76.87 ab	116.07	180.20 ab
SEM±		2.61	3.77	4.78	6.08
CD (p=0.05)		7.82	11.29	NS	18.22

Table 2: Dry matter production (kg ha⁻¹) as influenced by integrated approach for zinc enrichment in maize

Treatments		Dry matter production (kg ha ⁻¹)			
		30 DAS	Knee-high stage	60 DAS	At harvest
T ₁ -	RDF alone (Control) [N: P ₂ O ₅ : K ₂ O - 200:60:50 kg ha ⁻¹]	301 e	679 e	3555 g	6437 e
T ₂ -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	419 b	860 c	4791 c	8160 bc
T ₃ -	RDF + FYM (25 t ha ⁻¹)	331 de	846 cd	4312 cde	8251 bc
T ₄ -	RDF + Seed pelleting (3.6 g ZnSO ₄ kg ⁻¹ seed)	413 b	881 c	4593 cd	8450 abc
T ₅ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹	518 a	995 a	6301 a	9334 a
T ₆ -	RDF + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	311 de	783 d	3813 fg	6559 e
T ₇ -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	353 cd	962 ab	5846 ab	8860 ab
T ₈ -	RDF + FYM (25 t ha ⁻¹) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	319 de	849 cd	3890 efg	6927 de
T ₉ -	RDF +Seed pelleting + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	400 bc	857 cd	4202 def	7666 cd
T ₁₀ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹ + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	511 a	916 bc	5460 b	8685 ab
SEm±		17	25	162	307
CD (p=0.05)		52	75	487	919

Table 3: Yield attributes as influenced by integrated approach for zinc enrichment in maize

Treatments		Cob length (cm)	Cob girth (cm)
T ₁ -	RDF alone (Control) [N: P ₂ O ₅ : K ₂ O - 200:60:50 kg ha ⁻¹]	13.78 d	10.53 f
T ₂ -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	15.89 bc	13.00 bc
T ₃ -	RDF + FYM (25 t ha ⁻¹)	15.62 c	12.30 cde
T ₄ -	RDF + Seed pelleting (3.6 g ZnSO ₄ kg ⁻¹ seed)	15.64 c	12.57 bcd
T ₅ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹	18.32 a	14.50 a
T ₆ -	RDF + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	13.90 d	11.30 ef
T ₇ -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	17.25 ab	14.30 a
T ₈ -	RDF + FYM (25 t ha ⁻¹) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	14.34 cd	11.80 de
T ₉ -	RDF +Seed pelleting + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	14.74 cd	12.10 cde
T ₁₀ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹ + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	15.31 cd	13.47 abc
SEm±		0.57	0.37
CD (p=0.05)		1.61	1.12

Table 4: Grain and stover yield (kg ha⁻¹) as influenced by integrated approach for zinc enrichment in maize

Treatments		Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)
T ₁ -	RDF alone (Control) [N: P ₂ O ₅ : K ₂ O - 200:60:50 kg ha ⁻¹]	3020 d	6021 d
T ₂ -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	4686 bc	8570 abc
T ₃ -	RDF + FYM (25 t ha ⁻¹)	4506 c	8218 abc
T ₄ -	RDF + Seed pelleting (3.6 g ZnSO ₄ kg ⁻¹ seed)	3930 cd	7894 bc
T ₅ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹	6053 a	9084 a
T ₆ -	RDF + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	3129 d	6402 d
T ₇ -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	5631 ab	8883 ab
T ₈ -	RDF + FYM (25 t ha ⁻¹) + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	4418 c	7988 abc
T ₉ -	RDF +Seed pelleting + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	3919 cd	7532 c
T ₁₀ -	RDF + FYM enrichment with 50 kg ZnSO ₄ ha ⁻¹ + 0.2% Foliar spray of ZnSO ₄ (Knee-high and Tasseling stages)	4821 bc	8823 ab
SEm±		337	369
CD (p=0.05)		1,010	1,107

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