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Review

Agronomic Biofortification of Maize with Zinc and Iron Micronutrients

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Abstract

A field experiment on agronomic biofortification with zinc and iron micronutrients in maize was carried out during kharif season of 2015 at Agricultural Research Station, Bailhongal. The experiment was laid out in randomized block design with factorial concept with three replications consisted of 16 treatment combinations involving seed treatment (no seed treatment and seed treatment with Zn and Fe each@1%), soil application of Zn and Fe (no soil application, soil application of recommended $ZnSO_4$ and $FeSO_4$ each@25kg ha-1 and FYM enriched $ZnSO_4$ and $FeSO_4$ application each@15kg ha^{-1} and FYM enriched $ZnSO_4$ and $FeSO_4$ application each@25kg ha-1) and foliar application of Zn and Fe at 45 DAS (no foliar and foliar spray of $ZnSO_4$ and $FeSO_4$ each@0.5%).

Soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@25 and 15kg ha-1 recorded higher yield and yield attributes. Similarly foliar spray of $ZnSO_4$ and $FeSO_4$ each@0.5% at 45 DAS found superior over no foliar spray. Among the interactions treatment combination involving seed treatment, soil application of FYM enriched ZnSO4 and $FeSO_4$ each@15 kg ha^{-1} and foliar spray recorded the higher grain yield (78.5q ha^{-1}), Stover yield (106.4q ha^{-1}) and yield parameters viz., cob length (20.7cm), cob weight (286.7g), grain weight per cob (190.0g), number of grains per cob (684.8) and test weight (31.4g) also higher values in growth parameters viz., plant height, leaf area index, SPAD values and dry matter production compared to no seed, soil and foliar application of Zn and Fe. However, it was on par with treatment combination involving seed treatment, soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@25 kg ha^{-1} and foliar spray.

Keywords: Biofortification; FYM enrichment; Micronutrients; Growth; Yield

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop next to wheat and rice in the world as well as in India. It is cultivated in both tropical and temperate regions of the world. Maize is called as "queen of cereals" and "miracle crop" because of its higher productive potential compared to any other cereal crop. Maize is the most important cereal feed for livestock and critical staple food for people living in Asia, Africa and Latin America. In India, out of total production of maize, 45 per cent is consumed as a staple food in various forms [1]. Maize grains utilized in many ways like making roti, rawa, maida, popcorn and some industrial products like protein foods, glucose powder, starch etc. Beside this, stover serves as a good fodder for cattle. Hence, it is proudly known as "queen of cereals and king of fodder crops". Maize is cultivated in all season's viz. kharif, rabi and summer. In India maize is cultivated on 9.4m ha with production of 2.3m tonnes and productivity of 2.55 tonnes ha^{-1}. In Karnataka it is being grown on an area of 1.36m ha with production of 4.4m tonnes and the productivity of 3.5t ha^{-1} [2]. On an average maize grain is composed of 60 per cent carbohydrate, 10 per cent protein, 4.5 per cent oil, 3.5 percent fibre and 2 per cent minerals. It also contains 348mg P, 286mg K, 114mg S, 10mg Ca, 2.3mg Fe and 90 microgram of carotene per 100g grain.

All India Coordinated Research Project on Micronutrients delineated the soils of India regarding the deficiency of micronutrients. At present about 48.1 percent of Indian soils are deficient in diethylene-tri amine pent acetate (DTPA) extractable zinc and 11.2 percent in iron. Zinc (Zn) and iron (Fe) deficiencies are well-documented public health issue and an important soil fertility constraint to crop production. Generally, there is a close geographical overlap between soil deficiency and human deficiency of Zn and Fe indicating a high requirement for increasing concentrations of micronutrients in food crops. Higher rice yield was recorded with combined soil application of $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1} and foliar spray of $ZnSO_4$ and FeSO4 each@0.5% [3]. A rapid and complementary approach is therefore required for biofortification of food crops with Zn and Fe in the short term.

Material and Method

The field experiment was conducted at Agricultural Research Station (ARS), Bailhongal, during kharif season of 2015 which is situated in Northern Transitional Zone of Karnataka and located between 15°.81' North latitude and 74°.86' East longitudes with an altitude of 546m above mean sea level. The soil of the experimental site is medium black in nature and the texture of the soil is clayey, belonging to the order vertisols. Composite soil sample were drawn from 0 to 15cm depth from the experimental site before sowing and was analyzed for physical and chemical properties. Clayey in texture (10.65% sand, 30.0% silt, 59.12% clay), pH 7.3, E.C 0.34, low in organic carbon (4.8g kg^{-1}), available nitrogen (218.4kg ha^{-1}), available phosphorus (36.4kg ha^{-1}) available potassium (347.2kg ha^{-1}) available zinc (0.76ppm) and available iron (4.19ppm).

The experiment was laid out in Randomized Complete Block Design (factorial concept) with 16 treatment combinations. Treatment combinations involving seed treatmenti.eno seed treatment (T_1) and seed treatment with Zn and Fe each@1% (T_2), soil application of Zn and Fe i.e. no soil application (S1), soil application of recommended $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1} (S2), FYM enriched $ZnSO_4$ and $FeSO_4$ application each@15kg ha^{-1} (S3) and FYM enriched $ZnSO_4$ and $FeSO_4$ application each@25kg ha^{-1} (S_4) and foliar application of Zn and Fe i.e. no foliar (F_1) and foliar spray of $ZnSO_4$ and FeSO4 each@0.5 % (F2) at 45 DAS.

Results and Discussion

Crop performance in terms of growth (plant height, leaf area, dry matter production) and yield attributes was significantly increased due application of Zn and Fe. The beneficial effect of application of Zn and Fe enriched FYM was clearly noticed over no application (control). Soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@25kg ha-1 (76.2q ha^{-1}), FYM enriched $ZnSO_4$ and $FeSO_4$ each@15kg ha-1 (75.0q ha^{-1}) and application of recommended ZnSO4 and FeSO4 each@25kg ha^{-1} (69.4q ha^{-1}) increased the grain yield by 19.8, 18.5 and 11.9 per cent respectively over no application of Zn and Fe (61.1q ha^{-1}) (Table 1).

Table 1: Grain yield, stover yield and harvest index of maize as influenced by seed, soil and foliar application of zinc and iron. Means followed by same letters in the column do not differ significantly by DMRT (p=0.05).

	Grain Yield (q ha^{-1})	Stover Yield (q ha^{-1})	Harvest index (%)
Factor I : Seed treatment			
T_1: No seed treatment with Zn and Fe	69.70^a	100.89^a	40.46^a
T_2: Seed treatment with Zn and Fe	71.17^a	102.41^a	40.87^a
S. Em±	1.55	0.68	0.64
Factor II : Soil application			
S_1: Control (No application of Zn and Fe)	61.11^b	95.49^b	38.95^a
S_2:Soil application of recommended $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1}	69.42^{ab}	99.26^{ab}	41.05^a
S_3: FYM enriched $ZnSO_4$ and $FeSO_4$ application each@15kg ha^{-1}	75.02^{ab}	105.87^a	41.10^a
S_4: FYM enriched $ZnSO_4$ and $FeSO_4$ application each@25kg ha^{-1}	76.18^a	105.97^a	41.55^a
S. Em ±	2.19	0.97	0.91
Factor III: Foliar spray			
F_1: No foliar application of Zn and Fe	68.03b	100.40b	40.28^a
F_2: Foliar application of $ZnSO_4$ and $FeSO_4$ each@0.5%	72.83^a	102.90^a	41.05^a
S. Em ±	1.55	0.68	0.64

Similarly stover yield was increased with increased level of application of Zn and Fe. Soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1} (106q ha^{-1}), FYM enriched $ZnSO_4$ and FeSO4 each@15kg ha-1 (105.9q ha^{-1}) and application of recommended $ZnSO_4$ and FeSO4 each@25kg ha^{-1} (99.3q ha^{-1}) increased the stover yield by 9.9, 9.8 and 3 per cent respectively over no application of Zn and Fe (95.5q ha^{-1}). There was significantly higher rice yield and yield attributing characters with combined soil application of $ZnSO_4$ and FeSO4 each@25kg ha^{-1} and foliar spray of $ZnSO_4$ and $FeSO_4$ each@0.5% [3]. The variation in the yield was due to the variation in the yield components viz., cob length, cob weight, grain weight per cob, number of grains per cob and test weight.

The increase in grain yield of maize due to the soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@ 25kg ha^{-1} was mainly due to the increased cob length (19.8cm), cob weight (271.35g), grain weight per cob (189.25g), number of grains per cob (673.5) and test weight (31.61g) compared to control (Table 2). Variation in yield and yield attributes could be traced back to the improved growth parameters like plant height, leaf area index, SPAD reading and dry matter production. Similar observations were recorded by [4] in wheat. Increase in yield was due to improved availability of micronutrients (Zn and Fe) which could be attributed to the formation of stable organometalic complexes of micronutrients with organic matter, especially during the enrichment process to 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. [5].

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Table 2: Cob weight, grains per cob, cob length, grain weight per cob and test weight of maize as influenced by seed, soil and foliar application of zinc and Iron.

	Cob Weight (g)	Grains Per Cob	Cob Length (cm)	Grain Weight Per Cob (g)	Test Weight (g)
Factor I : Seed treatment					
T_1:No seed treatment with Zn and Fe	254.30[a]	657.43[a]	18.89[a]	184.44[a]	30.37[a]
T_2 :Seed treatment with Zn and Fe	263.93[a]	662.13[a]	19.40[a]	184.90[a]	30.74[a]
S. Em ±	3.50	4.01	0.21	0.21	0.14
Factor II : Soil application					
S_1: Control (No application of Zn and Fe)	235.01[b]	620.92[b]	17.75[b]	179.25c	29.26[b]
S_2: Soil application of recommended $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1}	257.04a[b]	659.95a[b]	19.27[a]	183.00[b]	30.27[ab]
S_3: FYM enriched $ZnSO_4$ and $FeSO_4$ application each@15kg ha^{-1}	273.06[a]	678.90[a]	19.77[a]	187.18[a]	31.08[a]
S_4: FYM enriched $ZnSO_4$ and $FeSO_4$ application each@25kg ha^{-1}	271.35[a]	679.35[a]	19.80[a]	189.25[a]	31.61[a]
S. Em ±	4.95	5.67	0.30	0.30	0.20
Factor III: Foliar spray					
F_1: No foliar application of Zn and Fe	253.87[b]	653.43[b]	18.78[b]	183.52[b]	30.30[b]
F_2: Foliar application of $ZnSO_4$ and $FeSO_4$ each@0.5 %	264.35[a]	666.13[a]	19.51[a]	185.83[a]	30.81[a]
S. Em ±	3.50	4.01	0.21	0.21	0.14

Means followed by same letters in the column do not differ significantly by DMRT (p=0.05).

The increase in the yield attributes could be due to continuous supply of organically chelated micronutrients (Zn and Fe) to the crop. Zn and Fe are part of the photosynthesis, assimilation and translocation of photosynthates from source (leaves) to sink (cobs) [6]. Increased grain and stover yield (72.8 and 102.9q ha^{-1} respectively) was also recorded with foliar spray of ZnSO4 and $FeSO_4$ each@0.5 per cent at 45 DAS over no foliar spray (68.03 and 100.4q ha-1 respectively). This could be due to the improved in growth and yield attributes. Foliar spray recorded significantly improved yield components viz., cob length (19.42cm), cob weight (264.3g), grains per cob (666.1), test weight (30.8g) and grain weight per cob (185.8g) over no foliar spray. Similar results were obtained by [7] (Table 3).

Table 3: Plant height (cm), leaf area index, SPAD value and dry matter accumulation (g plant-1) at milking stage of maize as influenced by seed, soil and foliar application of zinc and Iron.

	Plant Height (Cm)	Leaf Area Index	SPAD Values	Dry Matter Accumulation (G $Plant^{-1}$)
Factor I : Seed treatment				
T_1:No seed treatment with Zn and Fe	187.70[a]	5.82[a]	50.66[a]	239.32[a]
T_2 :Seed treatment with Zn and Fe	188.73[a]	5.86[a]	51.22[a]	241.05[a]
S. Em ±	0.93	0.06	0.52	0.74
Factor II : Soil application				
S_1: Control (No application of Zn and Fe)	182.26[b]	5.45[c]	44.96[b]	215.28[c]
S_2: Soil application of recommended $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1}	186.20[ab]	5.78[b]	52.60[a]	242.21[b]
S_3: FYM enriched $ZnSO_4$ and $FeSO_4$ application each@15kg ha^{-1}	191.58[a]	6.03ab	53.14[a]	249.38a[b]
S_4 : FYM enriched $ZnSO_4$ and $FeSO_4$ application each@25kg ha-1	192.84[a]	6.12[a]	53.05[a]	253.88[a]
S. Em ±	1.31	0.09	0.74	1.05
Factor III: Foliar spray				
F_1: No foliar application of Zn and Fe	187.24[a]	5.79[b]	49.88[b]	235.02[b]
$F_{2:}$ Foliar application of $ZnSO_4$ and $FeSO_4$ each@0.5 %	189.20[a]	5.89[a]	51.99[a]	245.35[a]
S.Em ±	0.93	0.06	0.52	0.74

Means followed by same letters in the column do not differ significantly by DMRT (p=0.05).

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Foliar application of $ZnSO_4$ and $FeSO_4$ each@0.5 percent at 45 DAS recorded significant improvement in growth parameters at milking stage viz., plant height (189.2cm), leaf area index (5.89), SPAD values (51.6) and dry matter production(245.4g plant^{-1}). Similar results were noticed by [8]. Foliar spray helped to rapid absorption of Zn and Fe nutrients through leaf and this resulted increase in cell division and elongation, chlorophyll content and photosynthesis. Foliar application of micronutrients might enhance dry matter transformation from store part to sink parts [9].

Interaction effect due to the seed, soil and foliar application of Zn and Fe revealed a significant influence on the yield of maize. There was increase in grain yield from 59.7q ha^{-1} in control to 79.0q ha^{-1} in combined application of Zn and Fe through seed; soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @25kg ha^{-1} and foliar application ($T_2S_4F_2$) which accounts to increased yield by 24.4 percent over no seed, soil and foliar application (T1S1F1). Similarly stover yield increased from 94.4 in control to 106.6q ha^{-1} combined application of Zn and Fe through seed, soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each@25kg ha^{-1} and foliar application ($T_2S_4F_2$) increased the stover yield by 11.4 percent over no seed, soil and foliar application ($T_1S_1F_1$).

Combined application of FYM enriched Zn and Fe each@25kg ha^{-1} was found on par with their each@15kg ha-1. It was due to better growth parameters and yield attributes which could be comparable with best treatment combination ($T_2S_4F_2$). The higher grain yield with Zn and Fe application could be attributed to increased total dry matter production as results of better uptake of Zn and Fe and their translocation to reproductive parts. Improvement in yield attributing characters like cob length, cob weight, grains per cob, test weight and grain weight per cob was the main cause for increased maize yield in combined application of Zn and Fe through seed, soil and foliage.

In present investigation, important yield attributes viz., cob length (20.4cm), cob weight (275.4g), grain weight per cob (189.5g), number of grains per cob (683.5) and test weight (32.1g) were significantly higher under treatment combination involving application of Zn and Fe through seed, soil application of FYM enriched ZnSO4 and $FeSO_4$ each@25kg ha^{-1} and foliar application ($T_2S_4F_2$) compared to no seed soil and foliar application ($T_1S_1F_1$). Difference in yield and yield attributes of maize depends upon the variation in growth parameters like plant height, leaf area index, SPAD reading and dry matter production.

However, it was on par with combined application of FYM enriched Zn and Feeach@15kg ha^{-1} with respect to growth parameters. Improvement in plant growth was due to soil and foliar application of Zn and Fe was due to proper nourishment of crop with nutrient supply. The increase in yield due to zinc and iron application may be attributed to their role in various physiological processes and improvement in growth components better partitioning of carbohydrates from leaf to reproductive parts resulting in increased yield. It could also be ascribed to its improvement in metallo enzymes system regulatory function and growth promoting auxin production [10].

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