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Influence of Agronomic Bio-fortification of Zinc and Iron on Their Density in Maize Grain and Nutrients Uptake

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Abstract

A field experiment on agronomic bio fortification of zinc and iron micronutrients in maize was carried out during *kharif* season of 2015 at Agricultural Research Station, Bail hongal. The experiment 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 @ 25 kg ha^{-1} and FYM enriched $ZnSO_4$ and $FeSO_4$ application each @ 15 kg ha^{-1} and FYM enriched $ZnSO_4$ and $FeSO_4$ application each @ 25 kg 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 %). Significantly higher Zn (47 mg kg^{-1}) and Fe (75.2 mg kg^{-1}) density in maize grain was recorded with soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1} than control. And it was on par with the soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @ 15 kg ha^{-1}.

Similarly higher foliar application of $ZnSO_4$ and $FeSO_4$ each @ 0.5 per cent accounted significantly higher zinc and iron content in grain (44.82 and 70.93 mg kg^{-1} respectively).Combined application of Zn and Fe through soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @ 15 kg ha^{-1} and foliar application without seed treatment ($T_1S_3F_2$) recorded higher Zn concentration in grain (48.57 g kg^{-1}).Whereas, combined application of Zn and Fe through soil application of FYM enriched $ZnSO^4$ and $FeSO^4$ each @ 25 kg ha^{-1} and foliar application without seed treatment ($T_1S_4F_2$) recorded higher Fe concentration in grain (75.81 g kg^{-1}) compared to treatment consisting of no seed, soil and foliar spray.

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. In India maize is cultivated on 9.4 m ha with production of 2.3 m tonnes and productivity of 2.55 tonnes ha^{-1}. In Karnataka it is being grown on an area of 1.36 m ha with production of 4.4 m tonnes and the productivity of 3.5 t ha^{-1} [1]. About half of the world's population suffers from micronutrient malnutrition, including iron, zinc and iodine which are mainly associated with low dietary intake of micronutrients in diets with less diversity of food [2,3]. Recent reports indicate that nearly 500,000 children under 5 years of age die annually because of Zn and Fe deficiencies [4]. Zinc deficiency in humans is widely noticed since zinc is an essential micronutrient for every living organism. In humans, zinc deficiency can lead to stunted growth, poor immune system, and, in children under five, impaired physical and neural development, leading to decreased brain functions that will remain up to adulthood. Iron deficiency is the most common cause of anemia globally. According to a recent report based on the WHO database, anemia affects nearly 1.6 billion people, and pre-school children and pregnant women are under great risk of Fe deficiency anemia [5].

Materials and Methods

The field experiment was conducted at Agricultural Research Station (ARS), Bailhongal, Belagavi District, and Karnataka during *kharif* season of 2015 which is situated in Northern Transitional Zone of Karnataka and located between 150.81' North latitude and 740.86' East longitudes with an altitude of 546 m 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 15 cm depth from the experimental site before sowing and was analysed 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 (4.8 g kg^{-1}), available nitrogen (218.4kg ha^{-1}), available phosphorus (36.4 kg ha^{-1}) available potassium (347.2 kg ha^{-1}) available zinc (0.76 ppm) and available iron (4.19 ppm). Recommended dose of fertilizer (RDF-100:50:25 N: $P_2O_{5:}K_2O$ kg ha^{-1} + 7.5 t ha^{-1} FYM) was applied to soil before sowing. The experiment was laid out in Randomized

Complete Block Design (factorial concept) with 16 treatment combinations. Treatment combinations involving seed treatment, no 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 (S_1), soil application of recommended $ZnSO_4$ and $FeSO^4$ each @ 25 kg ha^{-1}(S_2), FYM enriched $ZnSO_4$ and $FeSO_4$ application each @ 15 kg ha^{-1} (S_3) and FYM enriched $ZnSO_4$ and $FeSO_4$ application each @ 25 kg ha^{-1}(S_4) and foliar application of Zn and Fe i.e. no foliar (F_1) and foliar spray of $ZnSO_4$ and $FeSO_4$ each @ 0.5 % (F^2) at 45 DAS (Table 1).

Table 1: Zinc and iron content (g kg^{-1}) in maize grain after harvest of the crop as influenced by seed, soil and foliar application of zinc and iron.

	Zinc (g kg^{-1})	Iron (g kg^{-1})	Grain yield (q ha^{-1})
Factor I : Seed treatment			
T_1:No seed treatment with Zn and Fe	42.64 ^{a}	68.56 ^{a}	69.70 ^{a}
T_2:Seed treatment with Zn and Fe	44.32 ^{a}	68.87 ^{a}	71.17 ^{a}
S.Em ±	0.77	0.29	1.55
Factor II : Soil application			
S_1:Control (No application of Zn and Fe)	38.33^{b}	57.34^{c}	61.11^{b}
S_2 : Soil application of recommended $ZnSO^4$ and $FeSO_4$ each @ 25 kg ha^{-1}	42.31^{ab}	68.11^{b}	69.42^{ab}
S_3 : FYM enriched $ZnSO^4$ and $FeSO^4$ application each @ 15 kg ha^{-1}	46.29^{ab}	74.27^{a}	75.02^{ab}
S_4 : FYM enriched $ZnSO^4$ and $FeSO^4$ application each @ 25 kg ha^{-1}	47.00^{a}	75.15^{a}	76.18^{a}
S.Em ±	1.09	0.41	2.19
Factor III :Foliar spray			
F_1: No foliar application of Zn and Fe	42.14^{b}	66.51^{b}	68.03^{b}
F_2: Foliar application of ZnSO4 and FeSO4 each @ 0.5 %	44.82^{a}	70.93^{a}	72.83^{a}
S.Em ±	0.77	0.29	1.55
Interaction			
$T_1S_1F_1$	36.59^{d}	55.18^{e}	59.72^{d}
$T_1S_1F_2$	37.97^{cd}	59.02^{d}	61.11^{cd}
$T_1S_2F_1$	40.27^{b-d}	63.16^{c}	66.25^{a-d}
$T_1S_2F_2$	43.17^{a-d}	72.74^{b}	69.39^{a-d}
$T_1S_3F_1$	41.63^{a-d}	72.47^{b}	71.53^{a-d}
T_1S3F_2	48.57^{a}	75.54^{a}	77.64^{ab}
$T_1S_4F_1$	45.47^{ab}	74.57^{a}	73.61^{a-d}
$T_1S_4F_2$	47.43^{ab}	75.81^{ab}	78.36^{a}
$T_2S_1F_1$	38.23^{cd}	54.76^{e}	60.62^{d}
$T_2S_1F_2$	40.53^{b-d}	60.40^{d}	62.97^{b-d}
$T_2S_2F_1$	41.83^{a-d}	63.91^{c}	66.36^{a-d}
$T_2S_2F_2$	43.97^{a-c}	72.61^{b}	75.69^{a-c}
$T_2S_3F_1$	46.47^{ab}	73.32^{ab}	72.44^{a-d}
$T_2S_3F_2$	48.48^{a}	75.75^{a}	78.47^{a}
$T_2S_4F_1$	46.67^{ab}	74.69^{ab}	73.73^{a-d}
$T_2S_4F_2$	48.42^{a}	75.53^{a}	79.03^{a}
S.Em ±	2.18	0.82	4.39

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

Results and Discussion

Zinc and iron content in grain after harvest of crop increased significantly due to soil application of different levels of Zn and Fe. There was increase in grain concentration of Zn and Fe from 38.83 to 47 and 57.59 to 75.23 mg kg^{-1} respectively. Application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1} (47 g kg^{-1}), FYM enriched $ZnSO_4$ and $FeSO_4$each @15 kg ha^{-1} (46.29 g kg^{-1}) and application recommended $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1} (42.31g kg^{-1}) increased the zinc content in grain by 18.4, 17.1 and 9.4 per cent respectively over no application of Zn and Fe (38.33 g kg^{-1}). The higher Zn uptake by maize crop was observed with soil application of FYM enriched $ZnSO_4$ and$FeSO_4$ each @25

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kg ha^{-1} (894.66 g ha^{-1}) over no soil application (655.35 g ha^{-1}). Similar results were reported [6,7]. In none of of treatments density of these two essential heavy metals did exceeded the normal concentration found in plant system. The optimum concentration range of Zn and Fe in plants is 26 -150 ppm and 50- 150 respectively.

Similarly application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1}(75.15 g kg^{-1}), FYM enriched $ZnSO_4$ and $FeSO_4$ each @15 kg ha^{-1} (74.27 g kg^{-1}) and straight application of recommended $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1} (68.11 g kg^{-1}) increased the iron content in grain by 23.6, 22.7 and 15.8 per cent respectively over control (57.34 g kg^{-1}) and they were on par with each other. The results were in accordance with the finding [8]. The reason could be enrichment of FYM with zinc and iron which regulates its supply to the crop by slowly releasing of the nutrients into soil solution would have facilitated the higher nutrient uptake. And further enrichment of nutrients with organics prevents them from leaching and other losses [9]. The higher Fe uptake by maize crop was observed with soil application of FYM enriched ZnSO4 and $FeSO_4$ each @25 kg ha^{-1} (1098 g ha^{-1}) over control (578.29 g ha^{-1}). And it was on par with the application of FYM enriched Zn and Fe each @15 kg ha^{-1}. Foliar application of $ZnSO_4$ and $FeSO_4$ each @0.5 per cent accounted significantly higher zinc and iron content in grain (44.82 and 70.93 mg kg^{-1} respectively) overno foliar application of Zn and Fe (42.14 and 66.51 mg kg^{-1} respectively). Foliar application of $ZnSO_4$ and $FeSO_4$ each @0.5 per cent recorded significantly higher Zn and Fe uptake by maize crop (840.25 and 947.96 g ha^{-1}) over no foliar application (773.66 and 862.21 g ha^{-1}). Similar observations were recorded [10] (Table 2).

Table 2: Nitrogen, phosphorus and potassium uptake by maize at harvest as influenced by seed, soil and foliar application of zinc and iron.

	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (g ha^{-1})	Fe (g ha^{-1})
Factor I : Seed treatment					
T_1:No seed treatment with Zn and Fe	168.09^a	35.09$_a$	152.62$_a$	795.21$_a$	889.56$_a$
T_2 :Seed treatment with Zn and Fe	172.56$_a$	35.12$_a$	153.47$_a$	818.69$_a$	920.00$_a$
S.Em ±	2.37	0.46	1.12	11.97	12.27
Factor II : Soil application					
S_1 :Control (No application of Zn and Fe)	138.52^b	34.36^a	139.08^b	655.35^b	578.29^c
S_2 : Soil application of recommended $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1}	163.28^{ab}	35.75^a	148.98^{ab}	786.46^{ab}	898.70^b
S_3 : FYM enriched $ZnSO_4$ and $FeSO_4$ application each @ 15 kg ha^{-1}	187.87^a	35.52^a	161.39^a	891.35^a	1043.27^{ab}
S_4 : FYM enriched $ZnSO^4$ and $FeSO^4$ application each @ 25 kg ha^{-1}	191.61^a	34.79^a	162.74^a	894.66^a	1098.86^a
S.Em ±	3.36	0.66	1.58	16.93	17.36
Factor III: Foliar spray					
F^1: No foliar application of Zn and Fe	164.89^b	35.07^a	151.57^a	773.66^b	862.21^b
F^2: Foliar application of $ZnSO_4$ and $FeSO_4$ each @ 0.5 %	175.75^a	35.14^a	154.53^a	840.25^a	947.36^a
S.Em ±	2.37	0.46	1.12	11.97	12.27
Interaction					
$T_1S_1F_1$	136.07^b	34.46a	137.62^d	607.05^d	548.39^e
$T_1S_1F_2$	140.63^b	34.60^a	139.32^d	697.85^{b-d}	593.19^e
$T_1S_2F_1$	146.23^b	35.55^a	147.10^{cd}	724.02^b	811.45^d
$T_1S_2F_2$	175.53^a	35.73^a	151.82^{bc}	823.74^a	941.25^{bc}
$T_1S_3F_1$	174.08^a	36.05^a	158.91^{ab}	829.83^a	989.27^{ab}
$T_1S_3F_2$	192.33^a	35.37^a	160.78^{ab}	916.76^a	1072.17^{ab}
$T_1S_4F_1$	188.98^a	34.65^a	162.28^a	882.08^a	1073.88^a
$T_1S_4F_2$	190.83^a	34.32^a	163.17^a	911.75^a	1119.88^a
$T_2S_1F_1$	138.71^b	33.46^a	138.93^d	615.22^{cd}	549.26^e
$T_2S_1F_2$	138.67^b	34.93^a	140.44^d	701.28^{b-d}	622.33^e
$T_2S_2F_1$	153.04^b	35.75^a	142.18^d	720.70^{bc}	834.39^{cd}
$T_2S_2F_2$	178.31^a	35.99^a	154.81^{a-c}	877.37^a	1007.70^{ab}
$T_2S_3F_1$	188.44^a	35.81^a	162.93^a	911.87^a	1025.17^a
$T_2S_3F_2$	196.65^a	34.86^a	162.94^a	924.73^a	1116.94^a

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$T_2S_4F_1$	193.59ª	34.88ª	162.59ª	898.50ª	1065.84ª
$T_2S_4F_2$	193.04ª	35.34ª	162.93ª	899.85ª	1138.37ª
S.Em ±	6.71	1.33	3.17	33.87	34.71

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

Zn and Fe were directly absorbed by leaves and finally accumulated into grain [11]. Foliar application of $ZnSO_4$ and $FeSO_4$ each @0.5 per cent at 45 DAS facilitates much better translocation of applied nutrients into the developing grains [12]. Combined application of Zn and Fe through seed, soil and foliar application recorded significantly higher Zn and Fe density in the maize grain. There was increase in grain concentration of Zn and Fe from 36.59 to 48.57 and 55.18 to 75.81 mg kg^{-1} respectively. Combined application of Zn and Fe through soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @15 kg ha^{-1} and foliar application but without seed treatment (T1S3F2) increased the Zn concentration in grain (48.57 g kg^{-1}) by 24.3 per cent over devoid ofseed, soil and foliar application of Zn and Fe (36.59 g kg^{-1}). Similarly, combined application of Zn and Fe through soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1} and foliar application but without seed treatment ($T_1S_4F_2$) increased the Fe concentration in grain (75.81 g kg^{-1}) by 27.2 per cent over no seed, soil and foliar application of Zn and Fe (55.18 g kg^{-1}). Among the interactions treatment combination involving seed treatment, soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @15 kg ha^{-1} and foliar application ($T_2S_4F_2$) recorded higher up take zinc (924.73 g ha^{-1}) and iron (1116.94 g ha^{-1}) compared to devoid of seed, soil and foliar application.

The application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1} recorded significantly higher uptake of N and K by maize crop at harvest (191.61 and 162.7 kg ha^{-1}) over no application of Zn and Fe (138.5 and 139.0 kg ha^{-1}). Foliar application of $ZnSO_4$ and $FeSO_4$ each @0.5 per cent accounted higher nitrogen and potassium uptake by maize (175.7 and 154.5 kg ha^{-1} respectively) over no foliar application (164.8and 151.5 kg ha^{-1} respectively). Among the interactions treatment combination involving seed treatment, soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @15 kg ha^{-1} and foliar application ($T_2S_4F_2$) recorded higher uptake of nitrogen (196.6 kg ha^{-1}) and potassium (162.9 kg ha^{-1}). This could be due to synergetic effect between Zn and Fe with other nutrients. The similar observation was earlier recorded [1,13].

The soil application of FYM enriched ZnSO4 and $FeSO_4$ each @25 kg ha^{-1} recorded significantly lower available N and K in soil at harvest (204.2 and 291.6 kg ha^{-1}) over no application of Zn and Fe (211.5 and 313.1 kg ha^{-1}). Control recorded significantly higher available nitrogen and potassium in soil after harvest of maize as result of lower uptake of these nutrients in plants. The enrichment of FYM with Zn and Fe caused utilization of nutrients mainly due to its beneficial effect in mobilizing the native nutrients to increase their availability to crop uptake this could be the reason for less available N and K in the soil after harvest. Application of recommended $ZnSO_4$ and $FeSO_4$ each @25 kg ha^{-1} to the soil recorded significantly higher available Zn and Fe (1.12 and 7.75 ppm respectively) over no application of Zn and Fe (0.61 and 4.40 ppm respectively). Similar results were also observed by [3]. Treatment combination involving seed treatment, soil application of FYM enriched Zn and Fe and foliar application recorded significantly lower available nitrogen ($T_2S_4F_2$: 202.9 kg ha^{-1}) and potassium ($T_1S_4F_2$:289.6 kg ha^{-1}) compared to devoid of seed, soil and foliar application (212.7 kg ha^{-1} and 314.8 kg^{-1} respectively). Availability of Zn and Fe in soil after harvest was the highest in combination involving seed treatment and application of recommended $ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1} without foliar application ($T_2S_2F_1$: 1.16 and 7.85 ppm) compared to no seed soil and foliar application (0.6 and 4.41 ppm). Similar results found in maize.

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