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\(_S\) S F\(_S\) ) 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\(_S\) S F\(_F\) ) 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, 30.08% silt, 59.12% clay), pH 7.3, E.C 0.34, low in organic carbon (4.8 g kg\(^{-1}\)), available nitrogen (218.4 kg 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\(_2\)O\(_5\): K\(_2\)O 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 (T1) and seed treatment with Zn and Fe each @ 1% (T2) soil application of Zn and Fe i.e. no soil application (S1), soil application of recommended ZnSO4 and FeSO4 each @ 25 kg ha\(^{-1}\) (S2), FYM enriched ZnSO4 and FeSO4 application each @ 15 kg ha\(^{-1}\) (S3) and FYM enriched ZnSO4 and FeSO4 application each @ 25 kg ha\(^{-1}\) (S4) and foliar application of Zn and Fe i.e. no foliar (F1) and foliar spray of ZnSO4 and FeSO4 each @ 0.5% (F2) at 45 DAS (Table 1).

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

| Factor I : Seed treatment | Zinc (g kg\(^{-1}\)) | Iron (g kg\(^{-1}\)) | Grain yield (q ha\(^{-1}\)) |
|---------------------------|---------------------|---------------------|-----------------------------|
| T1: No seed treatment with Zn and Fe | 42.64a | 68.56a | 69.70a |
| T2: Seed treatment with Zn and Fe | 44.32a | 68.87a | 71.17a |
| SEm ± | 0.77 | 0.29 | 1.55 |

| Factor II : Soil application | Zinc (g kg\(^{-1}\)) | Iron (g kg\(^{-1}\)) | Grain yield (q ha\(^{-1}\)) |
|-----------------------------|---------------------|---------------------|-----------------------------|
| S1: Control (No application of Zn and Fe) | 38.33a | 57.34a | 61.11a |
| S2: Soil application of recommended ZnSO4 and FeSO4 each @ 25 kg ha\(^{-1}\) | 42.31ab | 68.11b | 69.42ab |
| S3: FYM enriched ZnSO4 and FeSO4 application each @ 15 kg ha\(^{-1}\) | 46.29ab | 74.27b | 75.02ab |
| S4: FYM enriched ZnSO4 and FeSO4 application each @ 25 kg ha\(^{-1}\) | 47.00ab | 75.15b | 76.18b |
| SEm ± | 1.09 | 0.41 | 2.19 |

| Factor III : Foliar spray | Zinc (g kg\(^{-1}\)) | Iron (g kg\(^{-1}\)) | Grain yield (q ha\(^{-1}\)) |
|---------------------------|---------------------|---------------------|-----------------------------|
| F1: No foliar application of Zn and Fe | 42.14a | 66.51a | 68.03a |
| F2: Foliar application of ZnSO4 and FeSO4 each @ 0.5% | 44.82a | 70.93a | 72.83a |
| SEm ± | 0.77 | 0.29 | 1.55 |

Interaction

| T1S2F1 | 36.59a | 55.18a | 59.72a |
| T1S2F2 | 37.97a | 59.02a | 61.11a |
| T1S3F1 | 40.27a | 63.16a | 66.25a |
| T1S3F2 | 43.17ab | 72.74b | 69.39ab |
| T2S3F1 | 41.63ab | 72.47b | 71.53ab |
| T2S3F2 | 48.57a | 75.54a | 77.64a |
| T1S4F1 | 45.47a | 74.57a | 73.61a |
| T1S4F2 | 47.43a | 75.81a | 78.36a |
| T2S4F1 | 38.23a | 54.76a | 60.62a |
| T2S4F2 | 40.53b | 60.40a | 62.97cd |
| T1S5F1 | 41.83ab | 63.91a | 66.36a |
| T1S5F2 | 43.97bc | 72.61a | 75.69bc |
| T2S5F1 | 46.47ab | 73.32a | 72.44ab |
| T2S5F2 | 48.48a | 75.75a | 78.47a |
| T1S6F1 | 46.67ab | 74.69a | 73.73ab |
| T1S6F2 | 48.42a | 75.53a | 79.03a |
| SEm ± | 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 ZnSO4 and FeSO4 each @ 25 kg ha\(^{-1}\) (47 g kg\(^{-1}\)), FYM enriched ZnSO4 and FeSO4 each @ 15 kg ha\(^{-1}\) (46.29 g kg\(^{-1}\)) and application recommended ZnSO4 and FeSO4 each @ 25 kg ha\(^{-1}\) (42.31 g 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 ZnSO4 and FeSO4 each @ 25 kg

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The results were in accordance with the finding [8]. The reason over control (57.34 g kg⁻¹) of iron content in grain by 23.6, 22.7 and 15.8 per cent respectively over no foliar application of Zn and Fe each @ 15 kg ha⁻¹. Similarly application of FYM enriched ZnSO₄ and FeSO₄ each @25 kg ha⁻¹ (75.15 g kg⁻¹) and straight application of recommended ZnSO₄ and FeSO₄ 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 FeSO₄ 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 ZnSO₄ and FeSO₄ each @0.5 per cent accounted significantly higher zinc and iron content in grain (44.82 and 70.93 mg kg⁻¹ respectively) over no foliar application of Zn and Fe (42.14 and 66.51 mg kg⁻¹ respectively). Foliar application of ZnSO₄ and FeSO₄ 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.

| Factor | N (kg ha⁻¹) | P (kg ha⁻¹) | K (kg ha⁻¹) | Zn (g ha⁻¹) | Fe (g ha⁻¹) |
|--------|-------------|-------------|-------------|--------------|-------------|
| I: Seed treatment | | | | | |
| T₁, No seed treatment with Zn and Fe | 168.09² | 35.09 | 152.62 | 795.21 | 889.56 |
| T₂: Seed treatment with Zn and Fe | 172.56 | 35.12 | 153.47 | 818.69 | 920.00 |
| S. Em ± | 2.37 | 0.46 | 1.12 | 11.97 | 12.27 |
| II: Soil application | | | | | |
| S₁: Control (No application of Zn and Fe) | 138.52 | 34.36 | 139.08 | 655.35 | 578.29 |
| S₂: Soil application of recommended ZnSO₄ and FeSO₄ each @ 25 kg ha⁻¹ | 163.28 | 35.75 | 148.98 | 786.46 | 898.70 |
| S₃: FYM enriched ZnSO₄ and FeSO₄ application each @ 15 kg ha⁻¹ | 187.87 | 35.52 | 161.39 | 891.35 | 1043.27 |
| S₄: FYM enriched ZnSO₄ and FeSO₄ application each @ 25 kg ha⁻¹ | 191.61 | 34.79 | 162.74 | 894.64 | 1098.86 |
| S. Em ± | 3.36 | 0.66 | 1.58 | 16.93 | 17.36 |
| III: Foliar spray | | | | | |
| F₁: No foliar application of Zn and Fe | 164.89 | 35.07 | 151.57 | 773.60 | 862.21 |
| F₂: Foliar application of ZnSO₄ and FeSO₄ each @ 0.5 % | 175.75 | 35.14 | 154.53 | 840.25 | 947.36 |
| S. Em ± | 2.37 | 0.46 | 1.12 | 11.97 | 12.27 |

Interaction

| | N (kg ha⁻¹) | P (kg ha⁻¹) | K (kg ha⁻¹) | Zn (g ha⁻¹) | Fe (g ha⁻¹) |
|-----------------|-------------|-------------|-------------|--------------|-------------|
| T₁S₂F₁ | 136.07 | 34.46 | 137.62 | 607.05 | 548.39 |
| T₁S₂F₂ | 140.63 | 34.60 | 139.32 | 697.85 | 593.19 |
| T₁S₂F₃ | 146.23 | 35.55 | 147.10 | 724.02 | 811.45 |
| T₁S₂F₄ | 175.53 | 35.73 | 151.82 | 823.74 | 941.25 |
| T₁S₂F₅ | 174.08 | 36.05 | 158.91 | 829.83 | 999.27 |
| T₁S₂F₆ | 192.33 | 35.37 | 160.78 | 916.76 | 1072.17 |
| T₁S₂F₇ | 188.98 | 34.65 | 162.28 | 882.08 | 1073.88 |
| T₁S₂F₈ | 190.83 | 34.32 | 163.17 | 911.75 | 1119.88 |
| T₁S₂F₉ | 138.71 | 33.46 | 139.93 | 615.22 | 549.26 |
| T₁S₂F₁₀ | 138.67 | 34.93 | 140.44 | 701.28 | 622.33 |
| T₁S₂F₁₁ | 153.04 | 35.75 | 142.18 | 720.70 | 854.39 |
| T₁S₂F₁₂ | 178.31 | 35.99 | 154.81 | 877.37 | 1007.70 |
| T₁S₂F₁₃ | 188.44 | 35.81 | 162.93 | 911.87 | 1025.17 |
| T₁S₂F₁₄ | 196.65 | 34.86 | 162.94 | 924.73 | 1116.94 |
Zn and Fe were directly absorbed by leaves and finally accumulated into grain [11]. Foliar application of ZnSO₄ and FeSO₄ 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 soil, seed 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 ZnSO₄ and FeSO₄ each @15 kg ha⁻¹ and foliar application but without seed treatment (T1 S2 F) increased the Zn concentration in grain (48.57 g kg⁻¹) by 24.3 per cent over devoid of seed, 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 ZnSO₄ and FeSO₄ each @25 kg ha⁻¹ and foliar application but without seed treatment (T S2 F₂) 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 ZnSO₄ and FeSO₄ each @15 kg ha⁻¹ and foliar application (T S F) recorded higher uptake 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 ZnSO₄ and FeSO₄ 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 ZnSO₄ and FeSO₄ 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 (164.8 and 151.5 kg ha⁻¹ respectively). Among the interactions treatment combination involving seed treatment, soil application of FYM enriched ZnSO₄ and FeSO₄ each @15 kg ha⁻¹ and foliar application (T S F₂) recorded higher uptake of nitrogen (196.6 kg ha⁻¹) and potassium (162.9 kg ha⁻¹). This could be due to synergistic effect between Zn and Fe with other nutrients. The similar observation was earlier recorded [1,13].

The soil application of FYM enriched ZnSO₄ and FeSO₄ each @25 kg ha⁻¹ recorded significantly lower available N and K in soil after harvest (202.9 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 ZnSO₄ and FeSO₄ 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 S F₂): 202.9 kg ha⁻¹) and potassium (T S F₂: 289.6 kg ha⁻¹) compared to devoid of seed, soil and foliar application (212.7 kg ha⁻¹ and 314.8 kg ha⁻¹ respectively). Availability of Zn and Fe in soil after harvest was the highest in combination involving seed treatment and application of recommended ZnSO₄ and FeSO₄ each @25 kg ha⁻¹ without foliar application (T S F₂): 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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