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Effect of agronomic fortification of zinc and iron on growth parameters and yield of foxtail millet [*Setaria italica* (L.)] genotypes

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Abstract
A field experiment was conducted at ARS, Hagari on medium black soil during *rabi*-2017 to study the effect of agronomic fortification with zinc and iron on growth parameters and yield of foxtail millet [*Setaria italica* (L.)] genotypes. The experiment was laid on split plot design consisting of three genotypes in the main plot and seven different levels of micronutrients application in sub plot. The genotypes recorded non-significant difference with respect to the growth parameters and yield. Among the micronutrients application the treatment M_7: RDF + Soil application of $ZnSO_4$ at 15 kg ha^{-1} and $FeSO_4$ at 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS recorded significantly higher number of tillers $plant^{-1}$ (4.21), leaf area (41.26, 83.47 and 27.82 cm^2 $plant^{-1}$ at 30, 60 and at harvest, respectively), total dry matter accumulation (2.53, 11.01 and 29.69 g $plant^{-1}$ at 30, 60 and at harvest, respectively), grain yield (2272 kg ha^{-1}), stover yield (9298 kg ha^{-1}) and harvest index (19.63 %). In interaction effect G_3: Sia-2644 and M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} & $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS recorded significantly higher number of tillers $plant^{-1}$ (4.32), leaf area (41.75, 85.23 and 30.19 cm^2 $plant^{-1}$ at 30, 60 and at harvest, respectively), total dry matter accumulation (2.48, 11.28 and 30.52 g $plant^{-1}$ at 30, 60 and at harvest, respectively), grain yield (2321 kg ha^{-1}), stover yield (9363 kg ha^{-1}) and harvest index (19.85 %).

Keywords: Foxtail millet, agronomic fortification, zinc, iron, foliar application

Introduction

Foxtail millet (*Setaria italica* L.) is an annual grass grown for human food. It is the second-most widely planted species of millet and the most important in East Asia. This is extensively grown in the arid and semi-arid regions of Asia and Africa and as well as in some other economically developed countries of the world. Foxtail millet is a warm season crop, typically planted in late spring and due to its early maturity and efficient use of available water makes it suitable for raising in dry areas. Foxtail millet is adapted to well-drained soils, but remained as under-utilized food crop. In recent years foxtail millet has a promising role to play in enhancing nutritional and food security. Nutritional composition of foxtail millet is proteins (12.3 g), carbohydrates (60.9 g), fat (4.3 g), crude fibre (8.0 g), calcium (31 mg), minerals (3.3g) and thiamine (0.59 mg) per 100 g edible portion (Gopalan *et al.*, 2007) [5]. Deficiency of zinc and iron are well-documented public health issue and an important soil constraint in production of crops. Moreover, there is a close geographical overlap between soil deficiency and human deficiency of Zn and Fe, indicating high requirements for increasing concentrations of these nutrients in food crops. Usually, millets are cultivated under rainfed condition in India. Generally black soils of North Karnataka are deficient in Zn and Fe due to its low solubility in soils is the major reason for appearance of deficiency in crop plants. Breeding of new genotypes having high Zn and Fe concentration (genetic bio fortification) is the most cost-effective strategy to address the problem; but, this strategy needs long time. A quick and alternative approach is therefore required for fortification of food crops with Zn and Fe in the short term. In this regard, a fertilizer strategy (agronomic fortification) gives an effective way for fortification of food crops including foxtail millet. Biofortification is a process of minerals and vitamins in food staples eaten widely by the poor may be increased either through conventional plant breeding or through use of transgenic techniques (Howarth and Welch, 2010) [6]. Agronomic fortification provides Zn and Fe to plants by seed treatment, soil and application of Zn and Fe to make sure success of breeding efforts for increasing Zn and Fe concentration in seeds. Important complementary approach to the on-going breeding programme is fertilizer strategy and it is a rapid solution to the problem.

Material and methods

The experiment was conducted at Agricultural Research Station, Hagari which is situated between 15° 14' N latitude and 77° 07' E longitude with an altitude of 414 meters above the mean sea level and is located in Zone-3 of Karnataka. The experiment was laid out in split plot design and comprised of two factors for study *viz.,* Main plot treatments: genotypes (G) comprised *viz.,* G_1: HN-7 (low in Fe and Zn), G_2: HN-46 (medium in Fe and high in Zn), G_3: Sia-2644 (high in Fe and medium in Zn). Subplot treatments: micronutrients application (M) comprised *viz.,* M1: Control (RDF), M_2: RDF + Seed treatment with 0.5% $ZnSO_4$ & $FeSO_4$ each, M_3: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}, M_4: RDF + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 DAS, M_5: RDF + Seed treatment with 0.5% $ZnSO_4$ & $FeSO_4$ each + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}, M_6: RDF + Seed treatment with 0.5% $ZnSO_4$ & $FeSO_4$ each + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 DAS, M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 DAS. The gross plot size was 3.0 m × 3.0 m and net plot size was 1.8 m × 2.6 m. The spacing given was 30 cm × 10 cm. The soil of the experimental site belongs to medium deep black soil and clay texture, neutral in soil reaction (7.50) and low in electrical conductivity (0.25 dSm^{-1}). The organic carbon content was 0.72 per cent and low in available N (262.00 kg ha^{-1}), medium in available phosphorus (39.25 kg P_2O_5 ha^{-1}) and medium in available potassium (307.00 kg K_2O ha^{-1}). DTPA extractable zinc (0.67 ppm) and DTPA extractable iron (3.92 ppm). The data was statistically analysed as per the procedure given by Gomez and Gomez (1984) [4].

Results and discussion

1. Effect of agronomic fortification with zinc and iron on grain yield, stover yield and harvest index

In the present investigation all three genotypes were found non-significant with respect to the yield. With respect to the micronutrients application significantly higher grain yield, stover yield and harvest index (2272 kg ha^{-1}, 9298 kg ha^{-1} and 19.63 %, respectively) was recorded with M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} & $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS which was on par with M_6: RDF + Seed treatment with 0.5% $ZnSO_4$ & $FeSO_4$ each + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 DAS (2223 kg ha^{-1}, 9274 kg ha^{-1} and 19.32 %, respectively). In interaction G_3: Sia-2644 and M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} & $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS recorded significantly higher grain yield, stover yield and harvest index (4.32, 25.73 cm, 11.49 g, 2321 kg ha^{-1}, 9363 kg ha^{-1} and 19.85 %, respectively) (Table 1.). The increase in the yield could be due to continuous supply of micronutrients (Zn and Fe) to the crop at different intervals through the soil application, seed treatment, foliar application and their combinations. Zn and Fe are part of the photosynthesis, assimilation and translocation of photosynthates from source (leaves) to sink (ear head) (Singh *et al.,* 1995) [10]. The results are in conformity with the findings of Adsul *et al.* (2011) [1], Dhaliwal *et al.* (2012) [3], Debroy *et al.* (2013) [2], Olusengun *et al.* (2014) [8] and Mosanna and Ebrahim (2015) [7].

Table 1: Grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of foxtail millet as influenced by genotypes and agronomic fortification

	Grain yield (kg ha^{-1})				Stover yield (kg ha^{-1})				Harvest index (%)			
	G1	G2	G3	Mean	G1	G2	G3	Mean	G1	G2	G3	Mean
M1	1732	1724	1846	1767	8464	8549	8699	8571	16.97	16.79	17.49	17.08
M2	1835	1872	1896	1868	8867	8916	8886	8890	17.13	17.35	17.57	17.35
M3	1874	1935	2148	1986	8883	8837	9083	8934	17.41	17.96	19.12	18.16
M4	1953	1944	2150	2015	8980	8934	9109	9008	17.86	17.87	19.09	18.27
M5	2117	2134	2035	2095	9165	9196	9057	9139	18.76	18.83	18.34	18.64
M6	2285	2309	2076	2223	9313	9358	9149	9274	19.69	19.78	18.49	19.32
M7	2256	2239	2321	2272	9274	9255	9363	9298	19.56	19.47	19.85	19.63
Mean	2007	2022	2067	2032	8993	9006	9049	9016	18.20	18.29	18.56	18.35
	S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)	
Main plot	18		NS		28		NS		0.12		NS	
Sub plot	38		108		26		76		0.29		0.84	
Interaction	65		182		46		128		0.50		NS	

Main plot: Genotypes (G)
G_1: HN-7 (low in Fe and Zn)
G_2: HN-46 (medium in Fe and high in Zn)
G_3: Sia-2644 (high in Fe and medium in Zn)
Sub plot: Micro nutrients application (M)
M_1: RDF (control)
M_2: RDF + Seed treatment with 0.5 % $ZnSO_4$ & $FeSO_4$ each
M_3: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
M_4: RDF + Foliar application of 0.5 % $ZnSO_4$ and $FeSO_4$ each at 30 DAS
M_5: RDF + Seed treatment + Soil application ($M_2 + M_3$)
M_6: RDF + Seed treatment + Foliar application ($M_2 + M_4$)
M_7: RDF + Soil application + Foliar application ($M_3 + M_4$)
RDF: (30:15:15 kg N, P_2O_5 and K_2O ha^{-1} + FYM @ 2.5 t ha^{-1}

2. Effect of agronomic fortification with zinc and iron on growth parameters

The genotypes recorded non-significant difference with respect to the growth parameters. Among the micronutrients application the treatment M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} & $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS recorded significantly higher number of tillers $plant^{-1}$ (4.21), leaf area (41.26, 83.47 and 27.82 cm^2 $plant^{-1}$ at 30, 60 and at harvest, respectively) and total dry matter accumulation (2.53, 11.01 and 29.69 g $plant^{-1}$ at 30, 60 and at harvest, respectively) which was at par with M_6: RDF + Seed treatment with 0.5%

$ZnSO_4$ & $FeSO_4$ each + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 DAS with respect to number of tillers plant^{-1} (4.06), leaf area (40.37, 82.22 and 26.51 cm^2 plant^{-1} at 30, 60 and at harvest, respectively) and total dry matter accumulation (2.30, 10.77 and 28.69 g plant^{-1} at 30, 60 and at harvest, respectively). In interaction G_3: Sia-2644 and M_7: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} & $FeSO_4$ @ 10 kg ha^{-1} + Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each 30 DAS recorded significantly higher number of tillers plant^{-1} (4.32), leaf area (41.26, 83.47 and 27.82 cm^2 plant^{-1} at 30, 60 and at harvest, respectively) and total dry matter accumulation (2.48, 11.28 and 30.52 g plant^{-1} at 30, 60 and at harvest, respectively) (Table 2 & 3.). The results are akin to Sharanappa (2017) [9]. Further foliar spray helps to rapid absorption of Zn and Fe nutrients through leaf this results increase in cell division and elongation, chlorophyll content, and photosynthesis. Foliar application of micronutrients might enhance translocation of photosynthates from store part to sink parts.

Table 2: Number of tillers plant^{-1} at harvest and leaf area (cm^2 plant^{-1}) of foxtail millet at different growth stages as influenced by genotypes and agronomic fortification

Number of tillers plant^{-1}					30 DAS				60 DAS				At harvest			
	G1	**G2**	**G3**	**Mean**	**G1**	**G2**	**G3**	**Mean**	**G1**	**G2**	**G3**	**Mean**	**G1**	**G2**	**G3**	**Mean**
M1	2.47	2.37	2.45	2.43	34.84	35.86	35.92	35.54	63.95	64.85	66.85	65.22	16.11	16.53	18.07	16.90
M2	2.70	2.68	2.83	2.74	38.00	37.90	37.99	37.96	69.94	69.15	70.10	69.73	19.05	18.15	19.52	18.91
M3	3.13	3.03	3.40	3.19	40.04	41.37	41.48	40.96	73.51	71.12	75.70	73.44	21.01	19.78	24.39	21.73
M4	3.15	3.12	3.87	3.38	35.89	33.59	39.65	36.38	72.41	74.89	75.85	74.38	21.43	21.05	24.53	22.34
M5	3.81	3.92	3.20	3.64	41.03	42.33	37.71	40.36	80.15	80.59	75.93	78.89	25.23	25.78	21.08	24.03
M6	4.22	4.26	3.71	4.06	41.01	41.16	38.95	40.37	83.25	84.97	78.43	82.22	27.86	28.43	23.25	26.51
M7	4.18	4.15	4.32	4.21	41.07	40.96	41.75	41.26	82.85	82.32	85.23	83.47	26.92	26.34	30.19	27.82
Mean	3.38	3.36	3.40	3.38	38.84	39.02	39.06	38.98	75.15	75.41	75.44	75.34	22.52	22.29	23.00	22.61
	S.Em±		C D(P=0.05)		S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)	
Main plot	0.06		NS		0.47		NS		0.52		NS		0.63		NS	
Sub plot	0.07		0.21		0.90		2.58		0.92		2.63		0.88		2.53	
Interaction	0.13		0.35		1.56		NS		1.59		4.44		1.53		4.28	

Main plot: Genotypes (G)
G_1: HN-7 (low in Fe and Zn)
G_2: HN-46 (medium in Fe and high in Zn)
G_3: Sia-2644 (high in Fe and medium in Zn)
Sub plot: Micro nutrients application (M)
M_1: RDF (control)
M_2: RDF + Seed treatment with 0.5 % $ZnSO_4$ & $FeSO_4$ each
M_3: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
M_4: RDF + Foliar application of 0.5 % $ZnSO_4$ and $FeSO_4$ each at 30 DAS
M_5: RDF + Seed treatment + Soil application ($M_2 + M_3$)
M_6: RDF + Seed treatment + Foliar application ($M_2 + M_4$)
M_7: RDF + Soil application + Foliar application ($M_3 + M_4$)
RDF: (30:15:15 kg N, P_2O_5 and K_2O ha^{-1} + FYM @ 2.5 t ha^{-1}

Table 3: Total dry matter accumulation (g plant^{-1}) in foxtail millet at different growth stages as influenced by genotypes and agronomic fortification

30 DAS					60 DAS				At harvest			
	G1	**G2**	**G3**	**Mean**	**G1**	**G2**	**G3**	**Mean**	**G1**	**G2**	**G3**	**Mean**
M1	1.75	1.82	1.78	1.78	6.12	6.20	6.89	6.40	17.62	18.62	20.38	18.88
M2	2.09	2.00	2.27	2.12	7.13	7.32	7.53	7.32	20.73	20.38	21.01	20.70
M3	2.36	2.37	2.65	2.46	8.44	8.28	9.15	8.62	22.17	22.39	25.30	23.29
M4	1.88	1.87	1.99	1.92	8.69	8.71	9.47	8.96	24.57	24.45	25.76	24.93
M5	2.58	2.60	2.41	2.48	10.14	10.39	9.13	9.89	26.84	27.17	25.14	26.38
M6	2.23	2.29	2.39	2.30	11.03	11.19	10.10	10.77	29.70	30.09	26.27	28.69
M7	2.48	2.47	2.48	2.53	10.88	10.87	11.28	11.01	29.36	29.18	30.52	29.69
Mean	2.20	2.20	2.28	2.23	8.92	8.99	9.08	9.00	24.43	24.61	24.91	24.65
	S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)		S.Em±		C D (P=0.05)	
Main plot	0.02		NS		0.06		NS		0.11		NS	
Sub plot	0.05		0.13		0.08		0.24		0.35		0.99	
Interaction	0.08		NS		0.14		0.41		0.60		1.68	

Main plot: Genotypes (G)
G_1: HN-7 (low in Fe and Zn)
G_2: HN-46 (medium in Fe and high in Zn)
G_3: Sia-2644 (high in Fe and medium in Zn)
Sub plot: Micro nutrients application (M)
M_1: RDF (control)
M_2: RDF + Seed treatment with 0.5 % $ZnSO_4$ & $FeSO_4$ each
M_3: RDF + Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
M_4: RDF + Foliar application of 0.5 % $ZnSO_4$ and $FeSO_4$ each at 30 DAS
M_5: RDF + Seed treatment + Soil application ($M_2 + M_3$)
M_6: RDF + Seed treatment + Foliar application ($M_2 + M_4$)
M_7: RDF + Soil application + Foliar application ($M_3 + M_4$)
RDF: (30:15:15 kg N, P_2O_5 and K_2O ha^{-1} + FYM @ 2.5 t ha^{-1}

Conclusion
The investigation revealed that interaction of Genotype Sia-2644 significantly respond for the application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1} in soil at the time of sowing and Foliar application of 0.5% $ZnSO_4$ and $FeSO_4$ each at 30 days after sowing significantly increases yield and growth parameters. Combined application of zinc sulphate and iron sulphate applied in both soil and foliar spray significantly influenced the growth parameters and yield in foxtail millet.

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