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Research Paper

Agronomic fortification of iron and zinc with organics in post-rainy season sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiment was conducted during post-rainy (*rabi*) seasons of 2016 and 2017 under rainfed condition at Dharwad, Karnataka, to study the effect of agronomic fortification (enrichment) of iron and zinc with organics on growth, yield, economics and quality of post-rainy (*rabi)* sorghum [*Sorghum bicolor* (L.) Moench] under rainfed condition. The experiment was laid out in a randomized complete block design with 3 replications and 11 treatments. The treatments consisted of control, recommended dose of fertilizer (RDF) @ 50–25 kg N–P/ha, recommended package of practices (RPP, 50–25 kg N–P/ha + 15 kg $ZnSO_4$/ha), Zn + Fe @ 3.75 kg/ha each enriched with FYM, Zn + Fe @ 7.50 kg/ha each enriched with FYM, Zn + Fe @ 11.25 kg/ha each enriched with FYM, Zn + Fe @ 15 kg/ha each enriched with FYM, Zn + Fe @ 3.75 kg/ha each enriched with vermicompost, Zn + Fe @ 7.5 kg/ha each enriched with vermicompost, Zn + Fe @ 11.25 kg/ha each enriched with vermicompost and Zn + Fe @ 15.00 kg/ha each enriched with vermicompost. Soil application of Fe and Zn @ 15 kg/ha each enriched with vermicompost recorded significantly higher plant height (200.2 cm), total dry matter production (191.14 g/plant), leaf area index (5.89/plant), ear weight (94.7 g), ear length (24.8 cm), grain weight (62.0 g/ear), 1,000-grain weight (38.17 g), grain yield (4.35 t/ha), fodder yield (7.85 t/ha), gross returns (₹110.2 × 10^3/ha) and net returns (₹76.2 × 10^3/ha) over the control, recommended dose of fertilizer and recommended package of practices. Maximum zinc (28.44 mg/kg) and iron content (36.52 mg/ kg) in grain as well as maximum uptake of zinc (116.27 g/ha), iron (161.16 g/ha), nitrogen (57.19 kg/ha), phosphorus (23.13 kg/ha) and crude protein (8.55%) were recorded with application of Fe and Zn @ 15 kg/ha each enriched with vermicompost.

Key words: Fortification, Hidden hunger, Iron, Organics, Post-rainy sorghum, Zinc

Sorghum is one of the most important staple food and fodder cereal crops of dry land and rainfed areas in the world. In India, *rabi* sorghum is cultivated over an area of 3.57 million ha with a production of 2.60 million tonnes and productivity of 730 kg/ha. Maharashtra, Karnataka and Andhra Pradesh are the major states in India growing *rabi* sorghum and contributing to the extent of about 85% of the total production. In Karnataka, the *rabi* sorghum is grown over an area of 0.95 million ha with a production and productivity of 0.85 million lakh tonnes and 939 kg/ha, respectively (Indiastat.com, 2016). Zinc and iron deficiencies are a growing public health concern and socio-economic issue particularly in the developing countries (Welch and Graham, 2004). About 0.5 million children under the age of 5 years die annually due to zinc and iron deficiencies (Black *et al.,* 2008). Sorghum is the second cheapest source of energy and micronutrients after pearl millet, and a majority of the population in Central India depends on sorghum for their dietary energy and micronutrients requirement (Rao *et al.,* 2006). The micronutrient enrichment of staple food crops has been considered as a sustainable strategy for immediate solution to tackle the problems of micronutrient deficiencies in human beings.

Rabi sorghum is mainly grown on Vertisols which are said to be calcareous in nature and these calcareous soils are deliberately found deficient in zinc and iron. Hence crop gown on these soils contains very low amount of zinc and iron, and it causes malnutrition problems in both humans and animals. Post-rainy sorghums that are predominantly grown for food purposes have lower zinc and iron contents than that of rainy season sorghums (Kumar *et al.,* 2013). Most of the sorghum-growing soils of arid and semi-arid regions of India are deficient in zinc and iron contents (Singh, 2001). Hidden hunger or micronutrient deficiency in soils not only causes low crop productivity,

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but also poor nutritional quality of the crops and consequently contributes to malnutrition in the human beings (Kumssa *et al.,* 2015). Micronutrient enrichment or fortification is a potential cost-effective and sustainable agronomic way to enrich the micronutrient content of foodgrains. It is an upcoming strategy for dealing the deficiencies of micronutrients in the developing world. Generally, farmers do not apply the recommended dose of fertilizer to *rabi* sorghum. This leads to mining of micronutrients from soil leading to their deficiency over years resulting in lower iron and zinc content in sorghum grains and stover. In view of the above facts, the present investigation was conducted to study the effect of agronomic fortification of iron and zinc with organics in post-rainy sorghum.

MATERIALS AND METHODS

The field experiment was conducted during post-rainy seasons of 2016 and 2017 under rainfed condition at All India Coordinated Sorghum Improvement Project, Main Agricultural Research Station, Dharwad, Karnataka. The soil was clay loam, medium in organic carbon (0.59%), low in available nitrogen (245 kg/ha), medium in available phosphorus (22.64 kg/ha), high in available potassium (357.36 kg/ha), medium in available sulphur (19.80 kg/ha), deficient in iron (4.24 mg/ kg) and zinc (0.54 mg/kg), with *p*H 7.4. The experiment was laid out in randomized complete block design with 3 replications. The farmyard manure (FYM) @ 3 t/ha was applied 15 days prior to sowing to all treatment plots except control and RDF plots. There were 11 treatment combinations, namely control, recommended dose of fertilizer (RDF) @ 50–25 kg N-P/ha, recommended package of practices (RPP, 50–25 kg N-P/ha + 15 kg $ZnSO_4$/ha), Zn + Fe @ 3.75 kg/ha each enriched with FYM, Zn + Fe @ 7.50 kg/ha each enriched with FYM, Zn + Fe @ 11.25 kg/ha each enriched with FYM, Zn + Fe @ 15 kg/ha each enriched with FYM, Zn + Fe @ 3.75 kg/ha each enriched with vermicompost, Zn + Fe @ 7.5 kg/ha each enriched with vermicompost, Zn + Fe @ 11.25 kg/ha each enriched with vermicompost and Zn + Fe @ 15 kg/ha each enriched with vermicompost. The enrichment of Fe and Zn with FYM @ 50 kg/ha was done by mixing 4 levels (3.75, 7.50, 11.25 and 15 kg/ha) of Fe and Zn separately in a polythene bags. A little quantity of water was added to each mixture and kept for incubation for 15 days. The moisture content was checked twice a week to avoid drying of sample. Similar method was followed for vermicompost (VC). The seeds of sorghum variety 'SPV 2217' @ 7.5 kg/ha were sown at 45 cm × 15 cm spacing and all the nutrients (fertilizers with enriched Fe and Zn) were applied at sowing as per the treatments. Urea, DAP, $FeSO_4$ and $ZnSO_4$ were used as sources of fertilizers for N, P, Zn and Fe respectively. The total rainfall received during cropping period was 124.0 mm in 9 rainy days and 286.0 mm in 21 rainy days during 2016 and 2017 respectively. The Furadon granules @ 12 kg/ha were applied to whorls of crop followed by Cymbush (10 EC) spraying @ 10 ml/ 16 litres of water to control shoot fly and stem borer. The crop was sown on 29 September 2016 and 28 September 2017; and harvested on 10 February 2017 and 3 February 2018. The data collected on different parameters were subjected to statistical analysis as described by Gomez and Gomez (1984) for better interpretation of results. Iron and zinc concentration in grain were anlysed using atomic absorption spectrometer (Shimadzu AAF-6701).

RESULTS AND DISCUSSION

Growth and yield attributes

The pooled data of 2 years indicated that the enriched iron and zinc with FYM and vermicompost (VC) significantly improved the growth and yield attributes, iron and zinc content in grain, quality, yield (grain and fodder) and economics of post-rainy sorghum. Among the treatments, application of enriched Fe and Zn @ 15 kg/ha each with VC recorded significantly higher plant height total dry matter production, leaf area index, ear weight, ear length , grain weight and 1,000-grain weight as compared to the control, RDF and RPP (Table 1). However, It was at par with other enriched treatments. Further, the improvement in yield attributes could be owing to continuous supply of organically chelated iron and zinc to the crop which have direct role in photosynthesis, assimilation and translocation of photosynthates from source to sink. Further, better availability of major and micro nutrients in the rhizosphere enhanced the various metabolic activities and stimulated the rapid cell division and elongation (Meena *et al*., 2008). Verma *et al*. (2005) also reported the improvement in yield parameters owing to application of nitrogen and zinc in forage sorghum.

Yield and economics

Application of enriched Fe and Zn @ 15 kg/ha each enriched with VC recorded significantly higher grain and fodder yield of *rabi* sorghum over the control, RDF, RPP and was at par with rest of enriched treatments (Table 2). The grain and fodder yield with enriched $FeSO_4$ and $ZnSO_4$ @ 15 kg/ha each with VC were 29.6 and 17.3, 15.6 and 10.1 and 14.3 and 9.9% higher than control, RDF and RPP respectively. The increase in grain and fodder yield may be attributed to enrichment of iron and zinc with VC which regulates their supply to the crop through mineralization and prevents them from leaching and other losses besides mobilizing and supplying the zinc and iron and also better uptake of nutrients by the crop. This might have helped in increased photosynthetic activity and resulted in better translocation of photosynthates to sink leading to improvement in growth and yield attributes that ultimately enhanced the yield as reported by Choudhary *et al*. (2015) in sorghum. However, the grain and fodder yield with all enriched treatments were at par which clearly indicated that the higher yields can be achieved by applying lower levels of enriched iron and zinc with either FYM or vermicompost. The harvest index did not differ significantly due to different treatments. The gross returns and net returns followed the similar trend as that of grain and fodder yield. Significantly higher gross returns (₹110.2× 10^3/ha) and net returns (₹76.2× 10^3/ha) were realized with enriched Fe and Zn @ 15 kg/ha each with VC as compared to the control, RDF, RPP and it was at par with rest of the treatments (Table 2). The higher monetary returns were mainly owing to higher grain and fodder yields. Similar findings were owing also reported by Mishra *et al.* (2015) in *rabi* sorghum.

Nutrient uptake and quality

The zinc and iron contents in grain were significantly higher with application of Fe and Zn @ 15 kg/ha each enriched with vermicompost compared to the control, RDF and RPP. The zinc and iron contents in grain with enriched

Table 1. Growth and yield parameters of *rabi* sorghum as influenced by agronomic fortification of iron and zinc with organics (pooled data of 2 years)

Treatment	Plant height (cm)	Total dry matter production at harvesting (g/plant)	Leaf area index	Ear weight (g)	Ear length (cm)	Grain weight (g/ear)	1,000-grain weight (g)
Control (No nutrients)	172.5	143.3	4.89	71.7	19.3	40.8	33.9
Recommended dose of fertilizer (RDF)	188.6	168.7	5.51	85.2	20.4	51.7	36.2
Recommended package of practice (RPP)	191.0	175.6	5.63	85.4	22.3	52.9	36.2
Zn + Fe @ 3.75 kg/ha each enriched with FYM	192.6	189.2	5.74	89.6	24.6	59.5	38.1
Zn + Fe @ 7.50 kg/ha each enriched with FYM	191.3	190.3	5.81	90.3	24.6	61.7	37.5
Zn + Fe @ 11.25 kg/ha each enriched with FYM	188.7	189.2	5.79	87.2	24.5	55.9	36.3
Zn + Fe @ 15 kg/ha each enriched with FYM	196.5	191.1	5.82	84.3	24.7	51.1	36.3
Zn + Fe @ 3.75 kg/ha each enriched with VC	190.4	182.5	5.73	91.7	24.4	60.2	37.3
Zn + Fe @ 7.5 kg/ha each enriched with VC	195.6	183.1	5.77	84.8	24.1	56.7	36.0
Zn + Fe @ 11.25 kg/ha each enriched with VC	189.8	186.4	5.84	94.5	24.4	57.0	37.3
Zn + Fe @ 15 kg/ha each enriched with VC	200.2	191.1	5.89	94.7	24.8	62.0	38.2
SEm±	2.6	3.31	0.08	1.9	0.9	1.9	0.47
CD (P=0.05)	7.6	9.89	0.24	5.7	2.6	5.7	1.39

FYM, Farmyard manure; VC, Vermicompost.

Table 2. Yield and economics of *rabi* sorghum as influenced by agronomic fortification of iron and zinc with organics (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Fodder yield (t/ha)	Harvest Index (%)	Cost of cultivation (× 10^3₹/ha)	Gross returns (× 10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: cost ratio
Control (No nutrients)	3.06	6.53	31.5	29.4	81.2	51.8	2.76
Recommended dose of fertilizer (RDF)	3.67	7.10	34.1	31.4	94.8	63.4	3.02
Recommended package of practice (RPP)	3.73	7.12	34.5	32.8	95.7	62.8	2.91
Zn + Fe @ 3.75 kg/ha each enriched with FYM	4.11	7.74	34.7	32.7	105.8	73.1	3.23
Zn + Fe @ 7.50 kg/ha each enriched with FYM	4.04	7.44	35.3	33.1	103.4	70.3	3.12
Zn + Fe @ 11.25 kg/ha each enriched with FYM	3.85	7.34	34.4	33.5	98.4	64.9	2.94
Zn + Fe @ 15 kg/ha each enriched with FYM	3.82	7.49	33.9	33.8	98.1	64.3	2.90
Zn + Fe @ 3.75 kg/ha each enriched with VC	4.23	7.73	35.5	32.9	107.6	74.8	3.27
Zn + Fe @ 7.5 kg/ha each enriched with VC	4.12	7.37	35.9	33.3	104.4	71.1	3.14
Zn + Fe @ 11.25 kg/ha each enriched with VC	4.32	7.85	35.4	33.6	109.6	75.9	3.26
Zn + Fe @ 15 kg/ha each enriched with VC	4.35	7.90	35.6	33.9	110.2	76.2	3.24
SEm±	0.21	0.26	0.8	–	4.9	4.3	0.09
CD (P=0.05)	0.64	0.76	NS	–	14.7	12.9	0.26

FYM, Farmyard manure; VC, Vermicompost.

Table 3. Nutrient uptake and quality in *rabi* sorghum as influenced by agronomic fortification of iron and zinc with organics (pooled data of 2 years)

Treatment	Zinc content in grain (mg/kg)	Iron content in grain (mg/kg)	Nutrient uptake in grain: Zinc (g/ha)	Iron (g/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Crude fiber (%)	Crude protein (%)
Control (No nutrients)	24.6	34.2	74.5	103.5	15.5	2.4	22.1	6.88
Recommended dose of fertilizer (RDF)	25.0	34.6	93.4	129.2	41.8	11.8	23.4	7.24
Recommended package of practice (RPP)	26.3	35.8	100.3	136.4	46.6	13.4	23.9	7.65
Zn + Fe @ 3.75 kg/ha each enriched with FYM	27.1	37.6	114.9	159.5	52.2	20.1	24.7	8.35
Zn + Fe @ 7.50 kg/ha each enriched with FYM	27.5	38.0	112.3	155.6	54.6	21.8	25.3	8.37
Zn + Fe @ 11.25 kg/ha each enriched with FYM	27.8	38.7	109.6	152.7	50.9	18.6	25.8	8.07
Zn + Fe @ 15 kg/ha each enriched with FYM	28.2	39.3	111.5	155.3	51.3	18.2	26.3	8.11
Zn + Fe @ 3.75 kg/ha each enriched with VC	27.5	37.9	112.7	155.2	55.9	22.1	25.1	8.10
Zn + Fe @ 7.5 kg/ha each enriched with VC	27.9	38.3	110.6	151.7	51.1	19.8	25.5	8.06
Zn + Fe @ 11.25 kg/ha each enriched with VC	28.1	38.8	113.8	157.3	52.9	21.2	26.7	8.20
Zn + Fe @ 15 kg/ha each enriched with VC	28.4	39.5	116.3	161.2	57.2	23.1	27.5	8.55
SEm±	0.47	0.73	4.13	5.75	1.22	0.44	1.06	0.21
CD (P=0.05)	1.37	2.16	12.17	16.96	3.59	1.31	NS	0.61

FYM, Farmyard manure; VC, Vermicompost.

Fe and Zn @ 15 kg/ha each with VC were 7.5 and 6.6, 7.3 and 6.2 and 5.3 and 6.1% higher over the control, RDF and RPP respectively (Table 3). The higher iron and zinc contents in grain could be attributed to the formation of stable organometallic complexes with organic matter especially during enrichment process to last for longer time and release the nutrients in such a way that the nutrients protected from fixation and made available to the plant root system throughout the crop growth. It also facilitated much better translocation of iron and zinc into developing grains as revealed by Rathod *et al*. (2005) in sorghum. Further, a linear increase in iron and zinc content from 36.52 and 27.11 mg/kg to 36.64 and 28.44 mg/kg, respectively, was observed with an increase in enriched iron and zinc level from 3.75 to 15 kg/ha each owing to application of higher levels of iron and zinc to crop. The increase in zinc and iron contents could be due to positive interaction and their efficient translocation to grain at later stages of crop phenophase as reported by Singh *et al*. (2014). As the DTPA-extractable iron and zinc levels in the soil were lesser than critical limits, the application of these micronutrients through fertilizers increased their content in grain, as also reported by Prasad *et al*. (2014). The uptake of zinc, iron, nitrogen and phosphorus with enriched $FeSO_4$ and $ZnSO_4$ @ 15 kg/ha each with VC was 35.9, 35.8, 72.9 and 89.5%, respectively higher over the control, 19.7, 19.8, 26.9 and 49.1% respectively higher over RDF and 13.7, 15.4, 18.6 and 42.2% respectively higher over RPP (Table 3). The higher nutrient uptake in grain was mainly attributed to higher dry matter production, grain and fodder yield which can be related to better and continuous availability of nutrients in root zone for longer period of crop growth. These results confirm the findings of Pawar *et al*. (2014) in *kharif* sorghum. The crude protein with Fe and Zn @ 3.75 kg/ha each enriched with vermicompost was 19.5, 15.3 and 10.5% higher over the control, RDF and RPP respectively. While the crude fibre was not significantly influenced by different treatments (Table 3). The higher crude protein content might be owing to higher nitrogen uptake and higher yield. Nitrogen is a key element for protein synthesis in plant and application of zinc and iron through enriched organic manures facilitated the higher nitrogen uptake owing to the synergistic effect of zinc and iron with nitrogen, as also revealed by Rana *et al.* (2013) in sorghum.

Based on these results, it may be concluded that soil application of 50-25 kg N-P + 3 t FYM along with enriched $ZnSO_4$ and $FeSO_4$ @ 3.75 kg/ha each with FYM or vermicompost to *rabi* sorghum is optimum for getting higher yield, net returns, iron and zinc content in grain as compared to recommended package of practice.

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