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Studies on nutrient uptake by *rabi* sorghum [*Sorghum bicolor* (L.) Moench] as influenced by fortified organics with iron and zinc

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Abstract
A field experiment was conducted during *rabi* 2016 under rainfed condition on clay loam soil at All India Coordinated Sorghum Improvement Project, Main Agricultural Research Station, Dharwad (Karnataka). The experiment was conducted to study the effect of fortification of organics with iron and zinc in *rabi* sorghum under rainfed condition. The experiment was laid out in randomized complete block design with three replications and eleven treatments. Results of the study revealed that soil application of RDF + Enriched FYM 1 recorded significantly higher nitrogen uptake (57.19 and 42.03 kg/ha), phosphorous uptake (23.13 and 24.14 kg/ha), potassium uptake (20.08 and 44.96 kg/ha), sulphur uptake (11.14 and 10.55 kg/ha), iron uptake (161.16 and 305.66 g/ha) and zinc uptake (116.27 and 213.21 g/ha) by grain and fodder respectively over control, recommended dose of fertilizer and recommended package of practice. Whereas, soil application of RDF + Enriched vermicompost 4 recorded significantly higher iron and zinc content both in grain (39.52 and 28.44 mg/kg) and fodder (42.34 and 29.44 mg/kg) respectively.

Keywords: Fortification, iron, *rabi* sorghum, uptake, zinc

Introduction

Plants require 16 nutrients (primary, secondary and micronutrients) for their normal growth and development. Micronutrients play a vital role in the growth and development of both crops and humans. These micronutrients are necessary for the plants to complete their life cycle (Chaney *et al.*, 1992) [5]. Insufficient micronutrient availability in soils not only causes low crop productivity, but also poor nutritional quality of the crops and consequently contributes to malnutrition in the human population (Kumssa *et al.*, 2015) [7].

Zinc and iron deficiencies are a growing public health concern and socioeconomic issue, particularly in the developing countries (Welch and Graham 2004) [18]. Nearly five lakhs children under five years of age die annually due to zinc and iron deficiencies (Black *et al.*, 2008) [2]. In Asia about 35 per cent of children between age group of 0 and 5 years suffer from zinc or iron deficiencies and 58 per cent of pregnant women in developing countries are anemic due to iron deficiency (Cababallero, 2002) [3]. 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) [14]. The intake of iron and zinc in low income rural households in sorghum consuming regions is lower than the recommended dietary allowance. Fortification of sorghum by increasing mineral micronutrients (especially iron and zinc) in the grains provides a sustainable solution to iron and zinc deficiency (Pfeiffer and McClafferty, 2007) [13]. *Rabi* sorghum predominantly grown for food purposes had lower zinc and iron content than that of rainy season sorghums (Kumar *et al.*, 2013) [6]. Most of the sorghum growing soils of arid and semi-arid regions of India are deficient in zinc and iron contents (Singh, 2001) [16].

Hence, fortification in post-rainy sorghum cultivars is one of the cheapest options to address the problem of hidden hunger in predominantly sorghum consuming populations of semi-arid tropics. Addition of zinc enriched fertilizer to the soil results in increased uptake of zinc in wheat crop and increases the bio-available zinc concentration in the edible portion of the plant (Cakmak, 2008) [4]. Generally, farmers do not apply the recommended dose of fertilizer to *rabi* sorghum. They apply either urea or DAP or complex fertilizer which contain major nutrients ignoring the micronutrients (iron and zinc).

Thus it leads to removal of micronutrients from soil resulting in nutrient deficiency over years. Hence the iron and zinc content in grain and fodder of *rabi* sorghum will be low. *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 due to lower uptake. In view of the above, a field experiment was conducted to study the uptake of nutrients by *rabi* sorghum as influenced by fortified organics with iron and zinc under rainfed condition.

Materials and methods

The field experiment was conducted during *rabi* 2016 under rainfed condition at All India Coordinated Sorghum Improvement Project, Main Agricultural Research Station, Dharwad (Karnataka) which is situated at $15^0$29' N latitude, $74^0$59' E longitude at an altitude of 689 m above mean sea level and it comes under Northern transition zone (Zone-8) of Karnataka. The soil was clay loam, medium in organic carbon (0.59%), low in available nitrogen (245 kg/ha), medium in available phosphorous (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) and calcareous in nature (8.05% free $CaCO_3$ content) with pH 7.45. The experiment was laid out in Randomized complete block design with three replications and eleven treatments. The treatments comprised of T_1- Control (no nutrients), T_2- Recommended dose of fertilizer @ 50:25 kg N and P_2O_5/ha (RDF), T_3- Recommended package of practice includes RDF+ 15 kg $ZnSO_4$/ha and seed treatment with *Azospirillum* @ 500 g/ha (RPP), T_4- RDF+ Enriched FYM 1 [(50 kg FYM/ha + 3.75 kg $ZnSO_4$/ha) + (50 kg FYM/ha + 3.75 kg $FeSO_4$/ha)], T_5- RDF+ Enriched FYM 2 **[(**50 kg FYM/ha + 7.5 kg $ZnSO_4$/ha) + (50 kg FYM/ha + 7.5 kg $FeSO_4$/ha)], T_6- RDF+ Enriched FYM 3 [(50 kg FYM/ha + 11.25 kg $ZnSO_4$/ha] + [50 kg FYM/ha + 11.25 kg $FeSO_4$/ha)], T_7- RDF+ Enriched FYM 4 [(50 kg FYM/ha + 15 kg $ZnSO_4$/ha) + (50 kg FYM/ha + 15 kg $FeSO_4$/ha)], T_8- RDF + Enriched vermicompost 1 [(50 kg vermicompost/ha + 3.75 kg $ZnSO_4$/ha) + **(**50 kg vermicompost/ha + 3.75 kg $FeSO_4$/ha)], T_9- RDF + Enriched vermicompost 2 [(50 kg vermicompost/ha + 7.5 kg $ZnSO_4$/ha) + **(**50 kg vermicompost/ha + 7.5 kg $FeSO_4$/ha)], T_{10}- RDF + Enriched vermicompost 3 [(50 kg vermicompost/ha + 11.25 kg $ZnSO_4$/ha) + **(**50 kg vermicompost/ha + 11.25 kg $FeSO_4$/ha)] and T_{11}- RDF + Enriched vermicompost 4 [(50 kg vermicompost/ha + 15 kg $ZnSO_4$/ha) + **(**50 kg vermicompost/ha + 15 kg $FeSO_4$/ha)].

Enrichment method

FYM and vermicompost @ 50 kg/ha each were mixed with different quantities of $ZnSO_4$ as per the treatments (3.75, 7.5, 11.25 and 15 kg/ha) separately. Little quantity of water was added to the mixture at field capacity and the mixture was kept in polythene bags under anaerobic condition for 15 days for incubation. The moisture content in the mixture was checked weekly twice.

Sorghum variety SPV-2217 was sown at 45 × 15 cm spacing using a seed rate of 7.5 kg/ha. Nitrogen and phosphorus @ 50:25 kg N and P_2O_5/ha in the form of urea and diammonium phosphate respectively were mixed with enriched FYM or vermicompost as per the treatments and applied at sowing. The other recommended pacakage of practice were followed to raise the crop. The total rainfall received during cropping period was 124.0 mm distributed in 9 rainy days which was 53.5 per cent deficit as against 66 years average rainfall. The rainfall of 41.6 mm was received on 29^{th} September an sowing was done. The rainfall during October and November month received a deficit rainfall to an extent of 70.8 and 80.9 per cent respectively as compared to average of 66 years. The furadon granules @12 kg/ha were applied to whorls of crop followed by cymbush spraying @ 10 ml per 15 litre of water to control shoot fly and stem borer. The crop was sown on 29/09/2016 and harvested on 10/02/2016. Plant samples of sorghum crop collected at harvest were used for estimation of nutrient content. The dried sample were ground and passed through 40 mesh sieve. The ground material was collected in butter paper bag and used for chemical analysis. Uptake of nitrogen, phosphorous, potassium, sulphur, iron and zinc (Tandon, 1998) [17] were recorded as per the standard procedure. The data collected on different parameters were subjected to statistical analysis as described by Panse and Sukhatme (1967) [11] for better interpretation of results.

Results and discussion

Uptake of major nutrients

Uptake of major nutrients by grain and fodder of *rabi* sorghum differed significantly due to soil application of different levels of fortified organics with iron sulphate and zinc sulphate (Table-1). Application of RDF + Enriched FYM 1 recorded significantly higher nitrogen uptake by both grain (57.19 kg/ha) and fodder (42.03 kg/ha) which was 73.0 and 78.6 per cent higher over control, 26.9 and 52.4 per cent higher over RDF (41.82 and 20.00 kg/ha by grain and fodder respectively) and 18.6 and 42.7 per cent higher over RPP (46.58 and 24.08 kg/ha by grain and fodder respectively) and was at par with rest of the enriched treatments (Table 1). There results corroborate the findings of Rathod *et al.* (2012) [15]. The beneficial effect of iron and zinc enriched organics in improving soil properties and enhancing nitrogen availability and its uptake has been reported by Latha *et al.* (2001) [9]. Phosphorus uptake both by grain and fodder was significantly higher with the soil application of RDF + Enriched FYM 1 (23.13 and 24.14 kg/ha respectively) over control (2.42 and 3.12 kg/ha respectively), RDF (11.17 and 14.19 kg/ha respectively) and RPP (13.37 and 17.14 kg ha^{-1} respectively) and it was at par with rest of the fortified treatments. Similarly, higher potassium uptake was recorded with the soil application of RDF + Enriched FYM 1 by grain (20.08 kg/ha) and fodder (44.96 kg/ha) as compared to control (4.89 and 6.41 kg/ha by grain and fodder respectively), recommended dose of fertilizer (7.55 and 9.21 kg/ha by grain and fodder respectively) and recommended package of practice (11.63 and 23.47 kg/ha by grain and fodder respectively). Soil application of RDF + Enriched FYM 1 enhanced significantly the higher sulphur uptake by grain (11.14 kg/ha) and fodder (10.55 kg/ha) over control (4.50 and 4.28 kg/ha by grain and fodder respectively), recommended dose of fertilizer (5.28 and 4.91 kg/ha by grain and fodder respectively) and recommended package of practice (8.82 and 7.63 kg/ha by grain and fodder respectively) (Table-1). The higher nitrogen uptake, phosphorus uptake, potassium uptake and sulphur uptake by grain and fodder may be attributed to higher grain and fodder yield and higher total dry matter production. These results were in agreement with the findings of Pawar *et al.* (2014) [12] in *kharif* sorghum.

Iron and zinc content and their uptake

Iron and zinc content in the grain and fodder after harvest of the crop increased significantly due to soil application of different levels of enriched organics with iron and zinc as compared to control, recommended dose of fertilizer and recommended package of practice (Table-2). With an increased level of application of $FeSO_4$ from 3.75 to 15 kg/ha enriched with FYM and vermicompost, there was a linear increase in iron concentration in grain and fodder from 37.64 to 39.52 mg/kg and 40.69 to 42.34 mg/kg respectively. Similarly, with increased level of application of $ZnSO_4$ from 3.75 to 15 kg/ha enriched with FYM and vermicompost, the zinc concentration in grain and fodder increased from 27.11 to 28.44 mg/kg and 28.42 to 29.44 mg/ kg respectively. Soil application of RDF + Enriched vermicompost 4 recorded significantly higher iron content both in grain (39.52 mg/kg) and fodder (42.34 mg/kg) which was 13.4 and 15.8 per cent higher over control (34.23 and 35.67 mg/kg in grain and fodder respectively), 12.6 and 13.8 per cent increase over recommended dose of fertilizer (34.56 and 36.49 mg/kg in grain and fodder respectively) and 9.4 and 9.4 per cent increase over recommended package of practice (35.79 and 38.36 mg/kg in grain and fodder respectively). Similarly, zinc content in grain and fodder was significantly higher with the soil application of RDF + Enriched vermicompost 4 (28.44 and 29.44 mg/kg respectively) which was 13.5 and 16.0 per cent increase over control (24.60 and 24.73 mg/kg in grain and fodder respectively), 12.2 and 14.5 per cent increase over recommended dose of fertilizer (24.97 and 25.17 mg/kg in grain and fodder respectively) and 7.4 and 5.6 per cent increase over recommended package of practice (26.33 and 27.78 mg/kg in grain and fodder respectively). These results were supported by the findings of by Mishra *et al.* (2015) [10] in *rabi* sorghum. The higher iron and zinc content both in grain and fodder in RDF + Enriched vermicompost 4 might be due to the fact that enrichment of FYM and vermicompost with iron and zinc regulates supply of iron and zinc to the crop by slow releasing of the nutrients into soil solution. It also enhanced the mineralization process by converting unavailable nutrients in to available nutrients which might have taken up by the crop easily. Significantly higher iron uptake by grain and fodder in *rabi* sorghum was recorded with the soil application of RDF + Enriched FYM 1 (161.16 and 305.66 g/ha respectively) which was 35.8 and 47.9 per cent higher over control, 19.8 and 23.6 per cent higher over recommended dose of fertilizer and 15.4 and 15.1 per cent higher over recommended package of practice, respectively (Table 2). Similarly higher zinc uptake by grain and fodder was noticed with the soil application of RDF + Enriched FYM 1 (116.27 and 213.21 g/ha respectively) which was 36.0 and 48.1 per cent higher over control, 19.7 and 24.4 per cent increase over recommended dose of fertilizer and 13.7 and 11.8 per cent increase over recommended package of practice.

The higher uptake of iron and zinc by grain and fodder was mainly attributed to higher dry matter production, higher grain and fodder yield. The higher uptake of iron and zinc by grain and fodder might be also due to the faster decomposition of organic and inorganic sources of nutrients and further, enrichment of nutrients with organics prevents them from leaching, fixation and other losses. This increases the available cationic micronutrient concentration in soil solution thereby increased the uptake of these micronutrients by grain and fodder. Similar findings were also reported by Adsul *et al.* (2014) [1] in fodder sorghum.

Available soil nutrients after harvest

Soil application of RDF + Enriched FYM 1 recorded significantly lower available nitrogen in soil after harvest (207.16 kg/ha) as compared to recommended package of practice (235.38 kg/ha). While the lower available phosphorus was higher with the same treatment (23.11 kg/ha) compared to RPP (27.87 kg/ha). Recommended package of practice recorded significantly higher available nitrogen and phosphorus in soil after harvest which can be related to lower uptake of these nutrients by sorghum. Significantly lower available potassium and sulphur was recorded in the treatment containing RDF + Enriched FYM 1 (313.31 and 10.19 kg/ha) respectively over control, RDF and RPP (Table-3). Control recorded significantly higher available potassium and sulphur in soil after harvest of the crop due to the lowest uptake of potassium and sulphur by sorghum. The lower available nitrogen, phosphorus, potassium and sulphur in the soil after harvest may be attributed to enrichment of FYM and vermicompost with iron and zinc caused maximum utilization of nutrients and also due to its beneficial effect in mobilizing the native nutrients to increase their availability to crop (Latha *et al.*, 2001) [9].

Soil available iron and zinc after harvest of crop differed significantly due to application of different levels of iron and zinc enriched organics (Table 3). Soil application of RDF + Enriched FYM 4 recorded significantly higher available iron and zinc (4.70 and 0.626 mg/kg respectively) over control (4.06 and 0.520 mg/kg iron and zinc respectively) and RDF (4.04 and 0.517 mg/kg iron and zinc respectively). These results were in accordance with the findings of Kustigar (2016) [8] in maize. This might be due to the fact that enriched organics enhanced the availability of nutrients in to the soil. It was also noticed that DTPA extractable iron and zinc in soil found to increase due to application of iron and zinc enriched organics into the soil.

Table 1: Nitrogen, phosphorous, potassium and sulphur uptake (kg ha^{-1}) by grain and fodder of *rabi* sorghum as influenced by iron and zinc fortified with organics

Treatments		Nitrogen uptake		Phosphorous uptake		Potassium uptake		Sulphur uptake	
		Grain	Fodder	Grain	Fodder	Grain	Fodder	Grain	Fodder
T_1 -	Control (No nutrients)	15.46	8.99	2.42	3.12	4.89	6.41	4.50	4.28
T_2 -	Recommended dose of fertilizer (RDF)	41.82	20.00	11.77	14.19	7.55	9.21	5.28	4.91
T_3 -	Recommended package of practice (RPP)	46.58	24.08	13.37	17.14	11.63	23.47	8.82	7.63
T_4 -	RDF + Enriched FYM 1	57.19	42.03	23.13	24.14	20.08	44.96	11.14	10.55
T_5 -	RDF + Enriched FYM 2	54.55	37.98	21.81	21.90	16.43	39.66	10.69	10.08
T_6 -	RDF + Enriched FYM 3	50.92	31.34	18.63	19.64	13.35	30.31	9.47	8.94
T_7 -	RDF + Enriched FYM 4	51.25	31.01	18.21	18.78	14.58	31.57	9.49	9.57
T_8 -	RDF + Enriched vermicompost 1	55.88	38.67	22.12	22.27	18.47	42.53	10.74	10.25
T_9 -	RDF + Enriched vermicompost 2	51.06	28.62	19.84	20.14	14.11	31.42	9.28	8.81
T_{10} -	RDF + Enriched vermicompost 3	52.94	35.04	21.16	21.51	15.75	38.13	10.31	9.72
T_{11} -	RDF + Enriched vermicompost 4	52.20	32.31	20.09	20.67	15.05	33.64	10.12	9.14
S.Em. +		1.22	1.10	0.44	0.43	0.58	0.71	0.22	0.28
C.D. (P=0.05)		3.59	3.25	1.31	1.26	1.72	2.10	0.64	0.83

Table 2: Iron and zinc content and their uptake by grain and fodder of *rabi* sorghum as influenced by iron and zinc fortified with organics

Treatments		Iron content ($mg\ kg^{-1}$)		Zinc content ($mg\ kg^{-1}$)		Iron uptake ($g\ ha^{-1}$)		Zinc uptake ($g\ ha^{-1}$)	
		Grain	Fodder	Grain	Fodder	Grain	Fodder	Grain	Fodder
T_1 -	Control (No nutrients)	34.23	35.67	24.60	24.73	103.46	159.29	74.46	110.62
T_2 -	Recommended dose of fertilizer (RDF)	34.56	36.49	24.97	25.17	129.21	233.56	93.39	161.19
T_3 -	Recommended package of practice (RPP)	35.79	38.36	26.33	27.78	136.35	259.42	100.29	188.04
T_4 -	RDF + Enriched FYM 1	37.64	40.69	27.11	28.42	161.16	305.66	116.27	213.21
T_5 -	RDF + Enriched FYM 2	38.02	41.03	27.47	28.78	155.56	301.83	112.30	211.34
T_6 -	RDF + Enriched FYM 3	38.71	41.54	27.82	29.06	152.70	289.76	109.63	202.75
T_7 -	RDF + Enriched FYM 4	39.32	42.14	28.21	29.30	155.27	286.54	111.52	199.65
T_8 -	RDF + Enriched vermicompost 1	37.94	40.93	27.54	28.49	155.24	291.41	112.70	202.57
T_9 -	RDF + Enriched vermicompost 2	38.30	41.25	27.92	28.91	151.67	283.62	110.55	198.90
T_{10} -	RDF + Enriched vermicompost 3	38.84	41.68	28.06	29.13	157.30	295.61	113.81	206.40
T_{11} -	RDF + Enriched vermicompost 4	39.52	42.34	28.44	29.44	159.50	303.53	114.92	210.80
S.Em.+		0.73	1.05	0.47	0.35	5.75	13.25	4.13	7.58
C.D. (P=0.05)		2.16	3.11	1.37	1.04	16.96	39.09	12.17	22.36

Table 3: Available nitrogen, phosphorous, potassium, Sulphur, iron and zinc in soil after harvest of *rabi* sorghum as influenced by iron and zinc fortified with organics

Treatments		Nitrogen	Phosphorous	Potassium	Sulphur	Iron	Zinc
		($kg\ ha^{-1}$)				($mg\ kg^{-1}$)	
Initial soil nutrient status		**245**	**22.64**	**357.36**	**19.80**	**4.24**	**0.54**
T_1 -	Control (No nutrients)	217.60	21.06	349.11	15.82	4.06	0.52
T_2 -	Recommended dose of fertilizer (RDF)	228.59	25.07	345.89	15.69	4.04	0.52
T_3 -	Recommended package of practice (RPP)	235.38	27.87	340.57	15.06	4.66	0.62
T_4 -	RDF + Enriched FYM 1	207.16	23.11	313.31	10.19	4.58	0.61
T_5 -	RDF + Enriched FYM 2	214.76	24.88	320.89	11.64	4.61	0.63
T_6 -	RDF + Enriched FYM 3	224.10	26.63	335.18	13.67	4.69	0.63
T_7 -	RDF + Enriched FYM 4	225.07	27.63	332.64	13.94	4.70	0.63
T_8 -	RDF + Enriched vermicompost 1	212.12	25.26	318.53	11.37	4.59	0.61
T_9 -	RDF + Enriched vermicompost 2	229.69	26.12	333.19	13.49	4.67	0.62
T_{10} -	RDF + Enriched vermicompost 3	218.74	26.69	323.90	12.87	4.63	0.62
T_{11} -	RDF + Enriched vermicompost 4	221.73	26.33	329.26	12.23	4.64	0.62
S.Em. +		2.83	0.37	3.01	0.45	0.13	0.02
C.D. (P=0.05)		8.36	1.10	8.87	1.32	0.38	0.06

Conclusion

Based on the results, it may be concluded that application of fortified form of either FYM or vermicompost with iron sulphate and zinc sulphate to *rabi* sorghum enhanced the iron and zinc content in grain and fodder along with nutrient uptake. Thus, soil application of RDF with Enriched FYM 1 (50 kg FYM/ha + 3.75 kg $ZnSO_4$/ha) to *rabi* sorghum found optimum as compared to direct application of iron and zinc without fortification.

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