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Influence of Agronomic Fortification through Enriched Organics on Nutrient Uptake and Soil Chemical Properties in Foxtail Millet (*Setaria italica* L.) Cultivation under Organic Production System

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Abstract

Foxtail millet is a short-term catch crop which is drought tolerant. The potential yields are yet to be achieved due to its cultivation on marginal soils with less inputs use. The crop grown under organic system by enriching soil with organic manures seems to be economically viable. Considering these points the experiment was conducted at Main Agricultural Research Station, Raichur, during *kharif* 2018 to study the effect of agronomic fortification through Zn and Fe enriched organics and foliar nutrition in foxtail millet (*Setaria italica* L.) cultivation. The design followed was randomized complete block design with three replications. Application of Zn and Fe enriched compost + foliar spray of panchagavya recorded significantly higher nitrogen, phosphorous, potassium, zinc and iron uptake (50.99, 10.94, 28.68, 0.18 and 2.95 kg ha^{-1}, respectively). Similar results were found with soil available nutrients N, P, K and Fe (148.2, 80.3, 797.9 and 14.21 kg ha^{-1}, respectively) and electrical conductivity. Organic carbon and soil available Zn did not differ significantly but recorded highest values 0.21 d Sm^{-1}, 0.64 per cent and 0.64 ppm, respectively.

Keywords: Nutrient uptake, Soil available nutrients, Nitrogen, Phosphorous, Potassium, Zinc, Iron

Organic farming system is based on the management of soil organic matter, which in turn maintains the physical, chemical and biological properties of soil. It is now a well-established fact that organically managed soil exhibits greater soil organic carbon and total nitrogen, lower nitrate leaching and higher biological soil quality, hence better soil health is inevitable for better growth and development of crop leading to higher production (Drinkwater *et al.,* 1998 and Glover *et al.,* 2000). Application of enriched organic manures lowers the soil pH through liberation of CO_2 and organic acid during decomposition and its decomposition products might give rise to natural complexing agents that solubilized the nutrients already present in soil and rendered the availability of nutrients to the plant and improved nutritional environment in the rhizosphere as well as in the plant system due to decomposition of manures leading to enhanced translocation of N, P and K in plant parts. Uptake of nutrients is a function of their content in plant parts and yield, the higher content of Zn, Fe, Mn and Cu along with higher grain and stover yield results in higher uptake of these nutrients (Shankar *et al*., 2016).

Foxtail millet (*Setaria italica* L.) is fairly a drought tolerant crop. Due to its quick growth, it can be grown as a short-term catch crop either as sole crop or intercrop. It is a very rich source of various micro and macro nutrients, vitamins as well as minerals. The yield level of this crop is not stable under rainfed conditions due to its cultivation on marginal soils with less inputs use and potential yields are yet to be achieved. (Hariprasanna, 2016). The crop responds very well to organics due to its low nutrient requirement and the yield decline is mainly due to low soil fertility status and can be maintained on sustainable manner under organic system. Resorting to organic manure enrichment, which serves as natural chelates, seems economically feasible. The enrichment of organic manures with micronutrients particularly Zn and Fe not only enhances the rate of decomposition but also improves the nutrient status (Prasenjit *et al*., 2016).

MATERIAL AND METHODS

A field experiment was conducted during the *kharif* 2018 at organic block of Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, which is situated between 16° 12' North latitude and 77° 20' East longitude with an altitude of 389 meters above the mean sea level and it falls within the North Eastern Dry Zone (Zone 2) of Karnataka.

A variety, SiA-2644 which is high in Fe and medium in Zn content was selected for study. The experiment was laid out in randomized complete block design with 10 treatments replicated thrice. The treatment consisted of application of Compost equivalent to 100 per cent RDN (T_1), Enriched compost with $ZnSO_4$ @ 15 kg ha^{-1}and $FeSO_4$ @ 10 kg ha^{-1} equivalent to 100 per cent RDN (T_2), Enriched vermicompost with $ZnSO_4$ @ 15 kg ha^{-1}and $FeSO_4$ @ 10 kg ha^{-1}, equivalent to 100 per cent RDN (T_3), Compost equivalent to 100 per cent RDN + Soil application of $ZnSO_4$ @ 15 kg ha^{-1}and $FeSO_4$ @ 10 kg ha^{-1} (T_4), Enriched compost with Zn and Fe, equivalent to100 per cent RDN (T_2) + Foliar spray of 3 per cent Panchagavya at 30 and 45 days after sowing (T_5), Enriched vermicompost with Zn and Fe, equivalent to 100 per cent RDN (T_3) + Foliar spray of 3 per cent Panchagavya at 30 and 45 days after sowing (T_6), Compost equivalent to 100 per cent RDN + soil application of $ZnSO_4$ @ 15 kg ha^{-1}and $FeSO_4$ @ 10 kg ha^{-1} (T_4) + Foliar spray of 3 per cent Panchagavya at 30 and 45 days after sowing (T_7), Enriched compost with Zn and Fe, equivalent to100 per cent RDN (T_2) + Foliar spray of 0.5 per cent $ZnSO_4$ and $FeSO_4$ each at 30 days after sowing (T_8), Enriched vermicompost with Zn and Fe, equivalent to100 per cent RDN (T_3) + Foliar spray of 0.5 per cent $ZnSO_4$ and $FeSO_4$ each at 30 days after sowing (T_9) and Compost equivalent to 100 per cent RDN + soil application of $ZnSO_4$ @ 15 kg ha^{-1}and $FeSO_4$ @ 10 kg ha^{-1}(T_4) + Foliar spray of 0.5 per cent $ZnSO_4$ and $FeSO_4$ each at 30 days after sowing (T_{10}). RDN: (Recommended dose of Nitrogen 30 kg ha^{-1}) was calculated according to the nutrient content (N%) of manures which were analysed before sowing and applied to the field in required quantity according to the plot size. Application of jeevamrutha was done at the time of sowing @ 500 litres ha^{-1}).

The soil of the experimental site was deep black, slightly alkaline with a pH of 7.71, EC 0.22 dSm^{-1} and

TABLE 1
Physical and chemical properties of soil of the experimental site

Particulars	Value obtained	Method adopted
Physical properties		
Fine sand (%)	48.00	International pipette method (Piper, 1966)
Silt (%)	22.00	
Clay (%)	25.00	
Soil type	Silt loam	
Chemical properties		
Soil pH (1:2.5) (w/v)	7.71	pH meter (Piper, 1966)
Electrical Conductivity (d Sm^{-1})	0.22	Conductivity bridge (Jackson, 1973)
Organic Carbon (%)	0.6	Wet oxidation method(Jackson, 1967)
Available Nitrogen (kg ha^{-1})	137.2	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available Phosphorus (kg ha^{-1})	74.70	Olsen's method (Jackson, 1967)
Available Potassium (kg ha^{-1})	752.5	Flame photometry method (Jackson, 1967)
DTPA extractable zinc (ppm)	0.58	DTPA method (Lindsay and Norwell, 1978)
DTPA extractable iron (ppm)	13.91	

TABLE 2

Nutrient composition of enriched manures

Organic manures	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Zinc (ppm)	Iron (ppm)
Compost	0.77	0.68	1.01	75.4	1465
Enriched compost	1.12	0.72	1.05	77.6	1500
Vermicompost	1.57	0.79	1.22	84.0	1247
Enriched vermicompost	1.68	0.82	1.25	90.0	1290
Panchagavya	804 ppm	171 ppm	195ppm	1.27	29.71
Jeevamrutha	470 ppm	159 ppm	140 ppm	4.97	273.6

medium in organic carbon (0.6%) and had low nitrogen (137.2 kg ha^{-1}) and high phosphorus and potassium (74.70 and 752.5 kg ha^{-1}), low Zinc (0.58 ppm) and high iron (13.91) availability in soil (Table 1). Sowing was done by dibbling at 30 cm apart in the shallow furrows on 4th August 2018.

Organic manures (compost and vermicompost) at required quantity based of nutrient content (N %) were enriched with micronutrients like $ZnSO_4$ and $FeSO_4$ at the recommended dose of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1} and the manures were allowed to ferment for a month by frequently sprinkling of water and mixing the contents 2 to 3 times a day. The enriched manures were analysed, calculated the required quantity (enriched compost with 1.12 per cent of N *i.e.,* 2.6 t ha^{-1} and enriched vermicompost with 1.68 per cent of N *i.e.,* 1.7 t ha^{-1}) and applied at the time of sowing as per the treatments (Anilkumar & Kubsad, 2017; Patil *et al*., 2017 and Nikhil & Salakinkop, 2017) (Table 2).

RESULTS AND DISCUSSION

Uptake of nutrients is associated with the metabolic activities of plants and with the concentration and distribution of ions in the external medium. Generally, higher uptake of nitrogen, phosphorus and potassium mainly depends on both economical and biological yield of crops.

Uptake of nutrients by foxtail millet at harvest significantly varied with the different agronomic fortification practices through enriched organics and foliar sprays. Application of Zn and Fe enriched compost + foliar spray of panchagavya recorded significantly higher nitrogen, phosphorous, potassium, zinc and iron uptake (50.99, 10.94, 28.68, 0.18 and 2.95 kg ha^{-1}, respectively) and it was on par with the application of Zn and Fe enriched vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ (49.78, 10.31, 28.34, 0.15 and 2.69 kg ha^{-1}, respectively), Zn and Fe enriched vermicompost+foliar spray of 3 per cent panchagavya at 30 and 45 DAS (46.93, 9.65, 27.24, 0.13 and 2.52 kg ha^{-1}, respectively). The other organic manurial treatments except compost application alone were on par with each other. Significantly lesser nutrient uptake was recorded with compost application alone (26.84, 6.15, 19.32, 0.06 and 1.16 kg ha^{-1}, respectively) and in turn on par with compost + soil application of $ZnSO_4$ and $FeSO_4$ + foliar spray of panchagavya.

Nutrient uptake by crop is the product of total dry matter production and nutrient concentration in plant tissue. The higher concentration of nutrient in plant tissue could be due to increased availability of nutrients in soil solution. Treatments received zinc and iron through fortified compost or vermicompost + foliar spray of 3.0 per cent panchagavya at 30 and 45 DAS and Zn and Fe fortified vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ each at 30 DAS resulted in significantly higher N, P, K, Zn and Fe uptake compared to compost or enriched compost / vermicompost application alone or with soil application of $ZnSO_4$ and $FeSO_4$ due to increased availability of NPK and Zn and Fe nutrients in the soil solution. This shows that

TABLE 3

Nutrient uptake (kg ha^{-1}) and grain yield by foxtail millet after harvest as influenced by agronomic fortification through organic nutrient management practices

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K(kg ha^{-1})	Zn(kg ha^{-1})	Fe (kg ha^{-1})	Grain yield (kg/ha)
T_1: Compost*	26.84	6.15	19.32	0.06	1.16	695
T_2: Enriched compost** with Zn and Fe	34.50	7.61	23.51	0.07	1.76	837
T_3: Enriched vermicompost*** with Zn and Fe	40.87	8.57	25.21	0.09	2.07	917
T_4: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$	36.37	7.95	24.30	0.08	1.92	869
T_5: Enriched compost** with Zn and Fe + Foliar spray of Panchagavya	50.99	10.94	28.68	0.18	2.95	1262
T_6: Enriched vermicompost*** with Zn and Fe + Foliar spray of Panchagavya	46.93	9.65	27.24	0.13	2.52	1137
T_7: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$ + Foliar spray of Panchagavya	31.47	7.10	22.24	0.07	1.33	795
T_8: Enriched compost** + Foliar spray of $ZnSO_4$ and $FeSO_4$	42.54	9.06	25.39	0.10	2.30	951
T_9: Enriched vermicompost*** + Foliar spray of $ZnSO_4$ and $FeSO_4$	49.78	10.31	28.34	0.15	2.69	1232
T_{10}: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$ + Foliar spray of $ZnSO_4$ and $FeSO_4$	38.10	8.35	24.91	0.08	1.98	889
S. Em±	1.99	0.50	1.63	0.01	0.19	83
C. D. at 5%	5.93	1.49	4.85	0.04	0.57	246

*Compost equivalent to 100% RDN in T_1, T_4, T_7 and T_{10}

**Enriched compost equivalent to 100% RDN in T_2, T_5 and T_8

***Enriched vermicompost equivalent to 100% RDN in T_3, T_6 and T_9

Soil application : $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}

Foliar spray : 0.5 % $ZnSO_4$ and 0.5 % $FeSO_4$ @ 30 DAS and 3.0 % of Panchagavya at 30 and 45 DAS

DAS : Days after sowing

Zn and Fe application through organic manures (compost and vermicompost) in the form of fortified compost and vermicompost might be more effective in soils having low organic matter content or Zn deficit soils. This might also be attributed to the potential effect of enriched organics with foliar sprays of liquid organics or micronutrients in improving microbial, physico-chemical properties and nutrients availability in the soil which in turn facilitated and accelerated the uptake of N, P, K, Zn and Fe nutrients. The results are in line with the findings of Chand *et al*. (2007); Sridevi *et al*. (2010); Choudhary *et al.* (2016); Meena *et al*. (2017); Nikhil & Salakinkop (2017) and Patil *et al*. (2017).

Chemical Properties

Treatments which received application of enriched compost with Zn and Fe + foliar spray of panchagavya recorded significantly higher available soil nitrogen, phosphorus, potassium and iron (148.2, 80.3, 797.9 kg ha^{-1} and 14.21 ppm, respectively) compared to the other treatment except application of Zn and Fe enriched vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ (147.1, 79.5, 780.3 kg ha^{-1} and 14.15 ppm, respectively) and Zn and Fe enriched vermicompost + foliar spray of panchagavya (145.4, 79.1, 768.5 kg ha^{-1} and 14.11 ppm, respectively). Significantly lower available soil phosphorus was recorded with compost application treatment alone (137.7, 74.5, 750.9 kg ha^{-1} and 13.92 ppm, respectively)

Among various treatments, compost application alone recorded significantly higher soil pH (7.69) over Zn and Fe enriched compost + foliar spray of panchagavya (7.64), Zn and Fe enriched vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ (7.65) and Zn and Fe enriched vermicompost + foliar spray of panchagavya (7.65) which in turn on par with each other. The lower soil pH was recorded Zn and Fe enriched compost + foliar spray of panchagavya (7.64).

This is due to the fact that application of organic manures and their decomposition might have resulted in higher production of carbon dioxide and release of organic acids which might reflected in reduced the soil pH (Meena and Rathod, 2006). Electrical conductivity, Organic carbon and available zinc content in soil did not differ significantly among the treatments after harvest of foxtail millet.

Higher available N, P, K, Zn and Fe content in soil after harvest of the crop was recorded with the application of zinc and iron enriched compost or vermicompost, equivalent to 100 per cent RDN + foliar spray of 3.0 per cent panchagavya at 30 and 45 DAS and Zn and Fe enriched vermicompost, equivalent to 100 per cent RDN + foliar spray of 0.5 per cent $ZnSO_4$ and $FeSO_4$ each at 30 DAS compared to other treatments. It may be attributed due to the application of enriched organics which resulted in the faster multiplication of soil microbes which could convert organically bound N to inorganic form of nitrogen, reduction of ferric phosphate present in the soil, release of occluded phosphate and phosphate adsorbed on amorphous iron and manganese oxides following soil aluminium oxides. The increase in phosphorus status of soil in enriched plots probably due to the formation of organic-Zn complexes preventing Zn from reacting with soil available P. Increase in the available potassium status of soil was due to application of enriched organic materials which might have ascribed to greater capacity of organic colloids to hold the nutrients at the exchange site and also reduction of potassium fixation and release of potassium to the available pool of soil. The zinc enriched organic manurial treatments were found to be better than the soil application of organic manures alone treatments in increasing the Zn content of soil. This was due to enrichment of organic manure with different levels of fertilizers zinc which might have supplied additional Zn to crop growth. The DTPA extractable iron status of soil increased significantly due to application of iron enriched compost and vermicompost. This may be due to the stable water soluble complexes formed by the organic manures prevent the reaction of Fe and Mn with soil constitution. Foliar spray of organic liquid manures, panchagavya and soil application jeevamrutha which stimulated the plant root activity, finally led to increase in microbial population in soil and which might in turn aided in decomposition and release of nutrients in the soil.

TABLE 4

pH, EC, OC, available soil nitrogen, phosphorous, potassium (kg ha-[1]), zinc and iron (ppm) after harvest of foxtail millet as influenced by agronomic fortification through organic nutrient management practices

Treatments	pH (1:2.5)	Electrical conductivity (d Sm^{-1})	Organic carbon (%)	N	P_2O_5	K_2O	Zn (ppm)	Fe (ppm)
Initial values	7.71	0.22	0.60	137.2	74.7	752.5	0.58	13.91
T_1: Compost*	7.69	0.24	0.60	137.7	74.5	750.9	0.57	13.92
T_2: Enriched compost** with Zn and Fe	7.69	0.23	0.61	139.4	75.9	756.8	0.58	14.00
T_3: Enriched vermicompost*** with Zn and Fe	7.67	0.23	0.61	141.6	77.1	768.5	0.58	14.05
T_4: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$	7.68	0.23	0.61	138.8	75.1	762.6	0.58	14.01
T_5: Enriched compost** with Zn and Fe + Foliar spray of Panchagavya	7.64	0.21	0.64	148.2	80.3	797.9	0.64	14.21
T_6: Enriched vermicompost*** with Zn and Fe + Foliar spray of Panchagavya	7.65	0.22	0.62	145.4	79.1	768.5	0.61	14.11
T_7: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$ + Foliar spray of Panchagavya	7.69	0.24	0.61	139.9	74.9	755.6	0.57	13.94
T_8: Enriched compost** + Foliar spray of $ZnSO_4$ and $FeSO_4$	7.66	0.22	0.62	142.7	77.9	762.6	0.59	14.07
T_9: Enriched vermicompost*** + Foliar spray of $ZnSO_4$ and $FeSO_4$	7.65	0.21	0.63	147.1	79.5	780.3	0.61	14.15
T_{10}: Compost* + Soil application of $ZnSO_4$ and $FeSO_4$ + Foliar spray of $ZnSO_4$ and $FeSO_4$	7.68	0.23	0.61	138.8	75.5	764.4	0.58	14.01
S.Em±	0.01	0.01	0.01	0.48	0.65	1.04	0.02	0.03
C. D. at 5%	0.03	NS	NS	1.43	1.94	3.10	NS	0.08

* Compost equivalent to 100 % RDN in T_1, T_4, T_7 and T_{10}
** Enriched compost equivalent to 100 % RDN in T_2, T_5 and T_8
*** Enriched vermicompost equivalent to 100 % RDN in T_3, T_6 and T_9
Soil application: $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
Foliar spray: 0.5 % $ZnSO_4$ and 0.5 % $FeSO_4$ @ 30 DAS and 3.0 % of Panchagavya at 30 and 45 DAS

DAS: Days after sowing
NS: Non-significant

Similar findings were also reported by Senthil *et al.* (2004; Meena *et al*. (2008); Shilpa (2011); Veeranagappa *et al*. (2011) and Meena *et al*. (2017).

Yield : Application of Zn and Fe enriched compost equivalent to 100 per cent RDN + foliar spray of panchagavya (3 %) at 30 and 45 DAS recorded significantly higher grain yield (1262 kg ha^{-1}) and it was found on par with the treatment receiving Zn and Fe enriched vermicompost equivalent to 100 RDN + foliar spray of $ZnSO_4$ and $FeSO_4$ (0.5% each) (1232 kg ha^{-1}) and Zn and Fe enriched vermicompost equivalent to 100 per cent RDN + foliar spray of panchagavya (3%) at 30 and 45 DAS (1137 kg ha^{-1}). These treatments showed their significant superiority over compost equivalent to 100 per cent RDN which recorded lower grain yield (695 kg ha^{-1}). Higher grain yield might be due to the direct role played by Zn and Fe in the presence of organic manures for the better growth owing to enhanced availability of not only Zn and Fe but also major N, P, K nutrients which was reflected on the total uptake of nutrients. In addition to this, it is evident from the soil fertility data that the application of enriched organics to the soil improved the soil fertility status (Available N, P, K nutrients) (Anilkumar & Kubsad, 2017; Nikhil & Salakinkop, 2017 and Nagaraj *et al.,* 2016).

Soil physico-chemical properties *viz*., electrical conductivity, organic carbon and soil available Zn did not differ significantly, whereas, available nitrogen, phosphorous and iron in soil after harvest of foxtail millet was significantly higher with application of Zn and Fe enriched compost + foliar spray of panchagavya and found on par with the application of Zn and Fe enriched vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ and Zn and Fe enriched vermicompost + foliar spray of panchagavya. Significantly lower available soil nitrogen, phosphorus and iron were recorded with compost application alone. Available potassium in soil was significantly higher with the application of Zn and Fe enriched compost + foliar spray of panchagavya. Significantly lower available soil potassium was recorded with compost application alone. Whereas, nutrient uptake (N, P, K, Zn and Fe) by foxtail millet after harvest was significantly higher with application of enriched compost with Zn and Fe + foliar spray of panchagavya followed by application of Zn and Fe enriched vermicompost + foliar spray of $ZnSO_4$ and $FeSO_4$ and Zn and Fe enriched vermicompost + foliar spray of panchagavya.

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