Micronutrient zinc and iron enriched organic manures impact on *rabi* grain sorghum

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1. Intoduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the second most important millet crop of India after pearl millet both in terms of area and production. On account of severe grain mold menace in rainy i.e. *kharif* season (Das *et al*., 2020), sorghum cultivation has shifted to *rabi* season rain fed crop (also as irrigated crop to some extent in rice fallows or after other arable *kharif* legume crops) and has 64.36% share in 4.77 m t of total production during 2019-20 (DES, 2021). Being grown on residual soil moisture, its stress limits its productivity both directly and also indirectly through reduced nutrient availability. Hence, response to applied fertilizers (currently recommended NP fertilizers) is poor. On the other hand, other nutrients especially micronutrients zinc (Zn) and iron (Fe) are increasingly becoming deficit. An estimated 48 and 12% of Indian soils are reported to be deficit in Zn and Fe i.e. a DTPA extractable Zn and Fe content < 0.60 and 4.50 ppm being critical limit (Singh *et al.,* 2009). These soil nutrient deficiencies are getting manifested in not only a poor crop yields but also on their consumers. An estimated 17.3 (Wessells *et al.,* 2013) and 43% of children under 5 years of age & 38% of pregnant women as reflected in low haemoglobin concentration i.e. anaemia (Stevens *et al.*, 2013) are at risk of Zn and Fe deficiency due to dietary inadequacy. Majority of the people in central India rely on sorghum for dietary energy and micronutrients (Rao *et al.*, 2006) and the constrained bioavailability of Zn and Fe from cooked sorghum grain (Kayode *et al.*, 2006) makes them Zn and Fe inadequate and are prone to various health risks. In this context, bio-fortification (increasing the minerals/vitamins in edible plant parts by genetic means) of staple crops has been explored as a sustainable strategy under HarvestPlus scheme globally. Besides genetic approaches, agronomic efforts also to some extent help in biofrtification of staple crops. In this context, studies were made to assess the impact of use of organic manures (FYM and vermicompost) enriched iron and zinc sulphate fertilization on *rabi* grain sorghum productivity, profitability and biofrtification.

2. Material and Methods

Field experiments were conducted during *rabi* seasons of 2017, 2018 & 2019 at All India Coordinated Sorghum Improvement Project (AICSIP) centre Nandyal, Andhra Pradesh. Eleven treatments formed by combination of two organic manures (FYM and Vermi-Compost, VC) @ 50 kg/ha enriched with four levels of $ZnSO_4$ and $FeSO_4$ (3.75, 7.50, 11.25 and 15.00 kg/ha each) for a period of 15 days prior to soil application along with three checks *i.e.* control (no manure & no fertilizer), recommended dose of fertilizers (RDF, 80-40 kg/ha N-P_2O_5) and RDF + 15 kg $ZnSO_4$/ha soil application + seed treatment with *Azospirillum* (0.5 kg) and *Trichoderma* (0.03 kg) were evaluated in RBD with three replications. Experimental soil was a deep vertisols rated as low for organic carbon (0.42%), DTPA extractable zinc and iron (0.52 and 4.2 ppm) has 201-49-342 kg/ha of available N-P-K. Fertilizer application was applied as basal with enriched manures applied as broadcasting. Rainfed sorghum cultivar 'CSV29R' was sown in 45 cm rows with a plant to plant spacing of 15 cm. A rainfall of 184.7, 82.6 and 99.0 mm was received during 2017, 2018 and 2019 crop life cycle respectively. Sorghum crop was raised following package of practices recommended for the *rabi* season crop. Data on growth, yield attributes, yields were recorded and economics were worked out using MSP of grain and assumed price of stover and market price of inputs and analysed statistically. As data has similar trend, results based on pooled analysis was presented.

3. Results and Discussion

3.1 Growth, Yield attributes and yield

Plant height, a measure of crop growth was significantly improved due to 11.25 kg/ha zinc and iron sulphate each enriched manure (FYM and VC) application along with RDF over RDF. Pooled data reveals a significant improvement in *rabi* sorghum grain and stover yields (19.64 and 3.17%) due to application of RDF + 15 kg $ZnSO_4$ to soil and seed treatment with *Azospirillum* (0.5 kg) and *Trichoderma* (0.03 kg) as compared to unfertilized and un-manured control (2.75 t/ha). Though there is a 13.5 and 1.3% improvement in grain and stover yields of *rabi* sorghum due to RDF use over control, these increases could not qualify for remained statistical significance, however, made it at par with RDF + 15 kg $ZnSO_4$ + seed treatment. Thus to obtain marked response to fertilizer application in the experimental soils, $ZnSO_4$ and bio fertilizers use along with RDF is necessary. A significant improvement in grain yield of *rabi* sorghum (16.7%) was obtained with 15 kg/ha zinc and iron sulphate each enriched FYM fertilization over RDF (3.12 t/ha). Similar but slightly higher (18.9%) improvement on grain yield were obtained with 25% lower level of zinc and iron sulphate (11.25 kg/ha) with use of vermicompost as manure source for micronutrient enrichment. However, both the FYM and VC enriched Zn and Fe treatments remained at par with RDF + 15 kg $ZnSO_4$ + seed treatment for grain yield. The increases in stover yields due Zn and Fe enriched manures application irrespective of their level over RDF remained insignificant. The above increases in grain yield was ascribed to the cumulative effect of enhanced panicle and test weights while stover yield was ascribed to enhanced plant height primarily and to yield attributes to some extent. The experimental soil was medium and near high for available N and P, hence, no significant response to RDF was seen. Poor response to NP fertilization could also be attributed to the cultivation of crop on residual soil moisture and associated moisture stress that could not facilitate their mineralization and uptake as that of an irrigated crop. However, *Azospirillum* seed treatment associated symbiotic atmospheric N fixation has made it available to crop directly. Further, application of 15 kg/ha $ZnSO_4$ along with bio fertilizers on account of its enhanced supplies of Zn and S in soil might has improved their crop uptake from a soil low in DTPA extractable Zn and thus together have boosted he crop performance over RDF alone and thus has markedly better performance than control. In manure enriched Zn and Fe treatment, Fe supplies in soil are improved in addition to Zn & S and thus *rabi* sorghum crop performance is boosted in a DTPA extractable zinc and iron deficit soil. Vermicmpost owing to its narrow C: N ratio as compared to FYM has released these micronutrients quickly and thus has as good crop performance as FYM at 25% lower level of Zn and Fe fertilizers. Superiority of manure enriched zinc and iron fertilizers for *rabi* sorghum crop reported in this study were corroborated by the findings of Durgude *et al*. (2019) from Rahuri who found better *rabi* sorghum yields with use of cow dung slurry (500 L/ha) incubated 20 kg/ha $ZnSO_4$ along with RDF (80:40:40 kg/ha $N:P_2O_5:K_2O$) as compared to RDF. The current superiority reported with use of FYM enriched zinc and iron sulphate @ 15 kg/ha each was however, four times higher than those reported by Kumar and Kubsad (2017) on *rabi* sorghum at Dharwad, Karnataka. Meena *et al*. (2006) have opined that the formation of stable organo-metallic complexes with organic matter, especially during the enrichment process to last for a longer time and release the nutrients slowly in the soil system in such a way that the nutrients are protected from fixation and made available to the plant root system throughout the crop growth as the reason for superiority of enrichment over no enrichment.

3.2 Economics

Economics (Table 1) indicate that FYM enriched $ZnSO_4$ + $FeSO_4$ application @ 11.25 kg each or VC enriched $ZnSO_4$ + $FeSO_4$ application @ 7.5 kg each being at par with each other have recorded significantly higher net income than control (Rs. 39969). VC enriched $ZnSO_4$ + $FeSO_4$ application @ 11.25 kg each has further significantly improved net income over RDF alone. The increases in net income could be ascribed to the cumulative effect of increase in grain and stover yields over control and RDF. Similar impacts of enriched Zn and Fe fertilizers on economics were reported by Kumar and Kubsad (2017).

Zn and Fe Biofortification of sorghum grain

Low iron and zinc status of soil is manifested in their low concentration in grain (Table 2) that was lowest in unfertilized control (26.9 & 13.3 ppm) and RDF (28.1 & 17.5 ppm). FYM enriched $ZnSO_4$ + $FeSO_4$ fertilization up to 11.25 kg/ha has significantly improved the Fe and Zn concentration in grain, however, with VC, no such dose dependent differences in Fe concentration of grain were observed. Irrespective of manure used for enrichment, 15 kg $ZnSO_4$ + $FeSO_4$ dose recorded the highest Fe and Zn concentration in sorghum grain.

4. Conclusion

From the three-year (2017-19) investigation on *rabi* sorghum, it was concluded that soil application of RDF i.e. recommended dose of fertilizers (80-40 kg/ha N-P_2O_5) along with 15 kg/ha $ZnSO_4$ to seed treated with Azospirillum (500 g) + Trichoderma (30 g) is promising over no fertilizers. FYM or VC (both @ 50 kg/ha) enriched with 11.25 or 7.5 kg/ha of $ZnSO_4$ + $FeSO_4$ each was promising for realizing not only higher *rabi* sorghum grain yields but also Zn and Fe bio fortified grains and net profits in Nandyal agro-ecoregion of Andhra Pradesh.

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Table 1. Growth, yield attributes, yield and economics of *rabi* sorghum as influenced by use of iron and zinc enriched organic manures (pooled over 3 years)

TREATMENT	Plant height (cm) at harvest	Panicle weight (g)	Test weight (g)	Grain yield (t/ha)	Straw yield (kg/ha)	Net returns (Rs./ha)
Control (no manure & no fertilizer)	306.0	75.1	32.83	2.75	8.53	39969
RDF (80-40 kg/ha N-P_2O_5)	306.8	89.2	33.93	3.12	8.64	44026
RDF + 15 kg $ZnSO_4$ + seed treatment	308.8	88.6	34.33	3.29	8.80	47408
RDF + 3.75 kg Zn and Fe each enriched FYM	309.5	90.4	34.86	3.28	8.65	46570
RDF + 7.5 kg Zn and Fe each enriched FYM	311.2	93.6	35.50	3.40	8.76	48942
RDF + 11.25 kg Zn and Fe each enriched FYM	313.8	93.6	35.76	3.55	8.76	51337
RDF + 15 kg Zn and Fe each enriched FYM	316.3	95.3	37.04	3.64	8.86	52759
RDF + 3.75 kg Zn and Fe each enriched VC	310.8	90.2	36.53	3.41	8.58	49552
RDF + 7.5 kg Zn and Fe each enriched VC	313.3	93.5	36.73	3.52	8.65	51196
RDF + 11.25 kg Zn and Fe each enriched VC	315.1	95.6	37.16	3.71	8.74	54855
RDF + 15 kg Zn and Fe each enriched VC	316.5	94.2	36.76	3.70	8.85	53521
SEm$\pm$	1.91	1.14	0.14	0.146	0.089	
CD (P=0.05)	5.68	3.41	0.42	0.433	0.264	

Table 2. Zinc and iron densification of *rabi* sorghum grain and their uptake as influenced by iron and zinc enriched organic manures (pooled over 3 years)

TREATMENT	Grain concentration (ppm)		Grain uptake (g/ha)	
	Zn	Fe	Zn	Fe
Control (no manure & no fertilizer)	13.3	26.9	36.58	73.98
RDF (80-40 kg/ha N-P_2O_5)	17.5	28.1	54.60	87.67
RDF + 15 kg $ZnSO_4$ + seed treatment	26.0	28.6	85.54	94.09
RDF + 3.75 kg Zn and Fe each enriched FYM	24.5	29.8	80.36	97.74
RDF + 7.5 kg Zn and Fe each enriched FYM	28.6	30.9	97.24	105.06
RDF + 11.25 kg Zn and Fe each enriched FYM	32.8	32.0	116.44	113.60
RDF + 15 kg Zn and Fe each enriched FYM	33.5	32.6	121.94	118.66
RDF + 3.75 kg Zn and Fe each enriched VC	27.0	31.6	92.07	107.76
RDF + 7.5 kg Zn and Fe each enriched VC	29.0	31.3	102.08	110.18
RDF + 11.25 kg Zn and Fe each enriched VC	33.2	31.8	123.17	117.98
RDF + 15 kg Zn and Fe each enriched VC	35.0	32.6	129.50	120.62