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**RESEARCH PAPER**

# Effect of zinc and iron enriched organics on yield and economics of *kharif* sorghum

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**Abstract:** Influence of zinc and iron enriched organics in *kharif* sorghum was evaluated during *kharif* season of 2017 at All India Coordinated Sorghum Improvement Project (AICSIP), Main Agricultural Research Station, Dharwad (Karnataka). Results of the experiment indicated that application of $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with FYM recorded significantly higher grain yield (4,132 kg ha$^{-1}$), fodder yield (9.95 t ha$^{-1}$), gross returns (₹ 63,657 ha$^{-1}$), net returns (₹ 20,890 ha$^{-1}$) and BC ratio (1.49). Similarly, the same treatment recorded significantly higher zinc (23.43 and 20.64 mg kg$^{-1}$) and iron (33.89 and 30.67 mg kg$^{-1}$) content in grain and fodder respectively as compared to control, recommended dose of fertilizer and recommended package of practices. Growth and yield indices like plant height (232.7 cm), total dry matter production (218.7 g plant$^{-1}$), grain weight (63.5 g plant$^{-1}$) and test weight (3.02 g) were also higher with the same treatment.

**Key words**: Enrichment, Iron, Micronutrients, Organics, Zinc

## Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the world's fourth most important cereal crops after rice, wheat and maize. It is an important nutritional staple food for more than 300 million people and feed for cattle living in Asia and Africa. It is considered as king of millets, extensively grown as a dual-purpose crop serving both grain and fodder requirement of the farming community. The per capita consumption of the sorghum grain is 75 kg year$^{-1}$ in major sorghum growing areas in India (Kumar *et al.,* 2013). Majority of the population in central India depends on sorghum for their dietary energy and micronutrient requirement (Rao *et al.,* 2006). Further, studies indicated that concentration and bioavailability of micronutrients (Zn and Fe) are limited in cooked sorghum grain (Kayode *et al.,* 2006).

Soil micronutrient deficiencies limit crop productivity and nutritional quality of foods which together affect nutrition and human health. Deficiency of zinc (48 %) and iron (12 %) has been noticed in Indian soils and zinc deficiency is further expected to increase by 49 to 63 per cent by the year 2025 (Singh *et al.,* 2009). In India, zinc is considered as the fourth most important nutrient after nitrogen, phosphorous and potassium. Micronutrient malnutrition, also called "hidden hunger", caused by the deficiency of micronutrients in the diet, afflicts more than two billion people worldwide, especially women and preschool age children in the developing countries who are largely dependent on staple food crops (Welch and Graham, 2004). Generally, farmers do not apply the recommended dose of fertilizer to *kharif* sorghum. They apply either urea or DAP or complex fertilizer which contain only major nutrients ignoring the micronutrients (zinc and iron). Thus, it leads to removal of active micronutrients from soil resulting in nutrient deficiency over years resulting into lower zinc and iron content in grain and fodder of *kharif* sorghum. Nutrient enrichment of staple food crops with micronutrients through the use of agricultural tools is a cost effective and sustainable approach to alleviate malnutrition. Hence, application of zinc and iron enriched organics act as a remedy to tackle the health problems of low-income rural household people with added benefit of increased yield.

## Material and methods

A field experiment was conducted during *kharif* season of 2017 under rainfed condition at All India Coordinated Sorghum Improvement Project, Main Agricultural Research Station, Dharwad (Karnataka). The experiment was laid out in Randomized Complete Block Design with eleven treatments and replicated thrice. The soil of experimental site was clay loam with pH 7.6, medium in organic carbon (0.52 %), low in available nitrogen (276 kg ha$^{-1}$), medium in available phosphorus (17.7 kg ha$^{-1}$), high in available potassium (368 kg ha$^{-1}$) and available sulphur (20.38 kg ha$^{-1}$), deficient in zinc (0.44 mg ha$^{-1}$) and iron (3.6 mg ha$^{-1}$). Eleven treatment combinations were employed as : $T_1$- Control (No nutrients), $T_2$- Recommended dose of fertilizer (RDF), $T_3$- Recommended package of practice (RPP), $T_4$- $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with FYM, $T_5$- $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with FYM, $T_6$- $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with FYM, $T_7$- $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with FYM, $T_8$- $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with vermicompost, $T_9$- $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with vermicompost, $T_{10}$- $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with vermicompost and $T_{11}$- $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with vermicompost. Sorghum variety of DSV-6 was sown at 45×15 cm spacing using a seed rate of 7.5 kg ha$^{-1}$. Nitrogen, phosphorous and potassium were applied at the rate of 100:75:25 kg per hectare in the form of urea, diammonium phosphate and murate of potash, respectively. 50 per cent of the urea was applied at the time of sowing and remaining quantity was top dressed 30 DAS. Recommended dose of fertilizers were mixed with enriched organics *viz,* FYM or vermicompost as per the treatments at the time of sowing. The other recommended package of practices was followed to raise the crop. The crop was sown on 23-06-2017 and harvested on 29-10-2017. The data collected on different parameters were subjected to statistical analysis for better interpretation of results.

Organics *viz.,* FYM and vermicompost each @ 50 kg $ha^{-1}$ were mixed with $ZnSO_4$ and $FeSO_4$ as per the treatments (3.75, 7.5, 11.25 and 15 kg $ha^{-1}$). The mixture was kept in polythene bags for incubation under anaerobic condition for 15 days. The moisture content in the mixture was checked weekly twice. Little quantity of water was added to the mixture to maintain moisture at field capacity. Enriched FYM or vermicompost was mixed with RDF and applied at the time of sowing.

**Results and discussion**

Crop performance in terms of growth, yield and yield attributes, economics and zinc and iron content in grain and fodder were significantly varied due to application of zinc and iron enriched organics (Table 1, 2 and 3). Application of $ZnSO_4$ + $FeSO_4$ @ 15.00 kg $ha^{-1}$ each enriched with FYM recoded significantly higher plant height (232.7 cm) and number of leaves per plant (7.7) as compared to control with recommended dose of fertilizer and recommended package of practices. Total dry matter production was significantly higher with application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ each enriched with FYM (218.74 g $plant^{-1}$) compared to other treatments. However, control (157.23 g $plant^{-1}$) recorded lower total dry matter production as compared to other treatments. The higher dry matter production was due to the continuous supply of zinc and iron to plants which have direct role in the photosynthesis (photosystem I and photosystem II) and translocation of photosynthates from source to sink. These results were in agreement with findings of Bandiwaddar (2015) in wheat crop. Test weight is the most stable character which directly related to yield of *kharif* sorghum. Application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ each enriched with FYM recorded significantly higher test weight (3.02 g) as compared to control (2.67 g), recommended dose of fertilizer (2.77 g) and recommended package of practice (2.86 g). Ear weight and grain weight of *kharif* sorghum was significantly differed due to application of zinc and iron enriched organics. Higher ear weight (100.4 g $plant^{-1}$) was recorded with application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ as compared to rest of the treatments. Similarly, application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ each enriched with FYM recorded significantly higher grain weight (63.5 g $plant^{-1}$) as compared to control (38.5 g $plant^{-1}$), recommended dose of fertilizer (57.6 g $plant^{-1}$) and recommended package of practice (59 g $plant^{-1}$). Increase in the yield attributes might be due to soil application of enriched micronutrients with organics like FYM and vermicompost which are enzymatically digested organic matter containing essential major and micro nutrients in readily available or mineralizable form. When $ZnSO_4$ and $FeSO_4$ are enriched with FYM, it provides the nutrient requirement from beginning of sorghum growth. These also corroborates the results of Nalina (2013), who observed higher test weight and grain weight in *rabi* sorghum with foliar application of $ZnSO_4$ (0.5 %) over RDF alone.

Soil application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$each enriched with FYM recorded significantly higher grain yield (4,132 kg $ha^{-1}$) over control (2,220 kg $ha^{-1}$), recommended dose of fertilizer (3,356 kg $ha^{-1}$) and recommended package of practice (3,708 kg $ha^{-1}$) and the yield increase was to the tune of 46.3, 18.8 and 10.3 per cent over control, recommended dose of fertilizer and recommended package of practice respectively. The increase in grain yield was due to increase in yield attributes like test weight and grain weight per plant as compared to control, recommended dose of fertilizer and recommended package of practices. Similarly, application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ each enriched with FYM recorded significantly higher fodder yield (9.95 t $ha^{-1}$) as compared to control (5.01 t $ha^{-1}$), recommended dose of fertilizer(8.36 t $ha^{-1}$) and recommended package of practices (8.70 t $ha^{-1}$). There was increase in fodder yield was to the tune of 49.7, 15.9 and 12.6 per cent over control, recommended dose of fertilizer and recommended package of practices respectively. Harvest index was not influenced by application of zinc and iron enriched organics. Similar results were reported by Anilkumar (2017) who reported the higher grain yield (4287 kg $ha^{-1}$) and fodder yield (7.51 t $ha^{-1}$) in *rabi*

Table 1. Growth and yield parameters of *kharif* sorghum as influenced by application of zinc and iron enriched organics

| Treatment | Plant height (cm) | Number of leaves per plant | Total dry matter production (g $plant^{-1}$) | Test weight (g) | Grain weight (g $plant^{-1}$) | Ear weight (g $plant^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1$ : Control (No nutrients) | 207.7 | 5.8 | 157.23 | 2.67 | 38.5 | 66.8 |
| $T_2$ : Recommended dose of fertilizer (RDF) | 225.2 | 6.1 | 195.40 | 2.77 | 57.6 | 88.4 |
| $T_3$ : Recommended package of practices (RPP) | 229.3 | 6.5 | 198.83 | 2.86 | 59.0 | 88.7 |
| $T_4$ : $ZnSO_4$ + $FeSO_4$ @ 3.75 kg $ha^{-1}$ each enriched with FYM | 226.7 | 6.9 | 202.59 | 2.92 | 60.9 | 91.3 |
| $T_5$ : $ZnSO_4$ + $FeSO_4$ @ 7.50 kg $ha^{-1}$ each enriched with FYM | 230.7 | 7.2 | 215.35 | 2.98 | 62.4 | 94.6 |
| $T_6$ : $ZnSO_4$ + $FeSO_4$ @ 11.25 kg $ha^{-1}$ each enriched with FYM | 231.7 | 7.5 | 209.39 | 2.96 | 63.0 | 98.9 |
| $T_7$ : $ZnSO_4$ + $FeSO_4$ @ 15.00 kg $ha^{-1}$ each enriched with FYM | 232.7 | 7.7 | 218.74 | 3.02 | 63.5 | 100.4 |
| $T_8$ : $ZnSO_4$ + $FeSO_4$ @ 3.75 kg $ha^{-1}$ each enriched with vermicompost | 227.9 | 6.7 | 204.36 | 2.92 | 60.6 | 94.7 |
| $T_9$ : $ZnSO_4$ + $FeSO_4$ @ 7.50 kg $ha^{-1}$ each enriched with vermicompost | 229.6 | 7.0 | 207.26 | 2.93 | 62.1 | 96.2 |
| $T_{10}$: $ZnSO_4$ + $FeSO_4$ @ 11.25 kg $ha^{-1}$ each enriched with vermicompost | 230.3 | 7.2 | 215.02 | 3.01 | 62.6 | 97.2 |
| $T_{11}$: $ZnSO_4$ + $FeSO_4$ @ 15.00 kg $ha^{-1}$ each enriched with vermicompost | 232.2 | 7.6 | 209.68 | 2.94 | 62.2 | 97.4 |
| S.Em.± | 2.9 | 0.34 | 2.84 | 0.04 | 1.0 | 1.7 |
| C.D. (P = 0.05) | 8.8 | 1.02 | 8.36 | 0.13 | 3.1 | 5.1 |

Table 2. Yield and economics of *kharif* sorghum as influenced by application of zinc and iron enriched organics

| Treatment | Grain yield (kg ha$^{-1}$) | Fodder yield (t ha$^{-1}$) | Harvest index (%) | Gross returns (₹ ha$^{-1}$) | Net returns (₹ ha$^{-1}$) | BC ratio |
|---|---|---|---|---|---|---|
| $T_1$: Control (No nutrients) | 2,220 | 5.01 | 31.28 | 33,874 | 3,022 | 1.10 |
| $T_2$: Recommended dose of fertilizer (RDF) | 3,356 | 8.36 | 28.85 | 51,989 | 14,252 | 1.38 |
| $T_3$: Recommended package of practices (RPP) | 3,708 | 8.70 | 29.93 | 56,912 | 14,655 | 1.35 |
| $T_4$: $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with FYM | 3,947 | 8.92 | 30.74 | 60,231 | 18,566 | 1.45 |
| $T_5$: $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with FYM | 4,013 | 9.26 | 30.25 | 61,430 | 19,398 | 1.46 |
| $T_6$: $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with FYM | 3,998 | 9.15 | 30.41 | 61,131 | 18,731 | 1.44 |
| $T_7$: $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with FYM | 4,132 | 9.95 | 29.36 | 63,657 | 20,890 | 1.49 |
| $T_8$: $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with vermicompost | 3,941 | 8.96 | 30.56 | 60,198 | 18,393 | 1.44 |
| $T_9$: $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with vermicompost | 3,940 | 9.21 | 30.05 | 60,430 | 18,258 | 1.43 |
| $T_{10}$: $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with vermicompost | 4,050 | 8.91 | 31.25 | 61,563 | 19,023 | 1.45 |
| $T_{11}$: $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with vermicompost | 4,032 | 9.42 | 29.96 | 61,828 | 18,921 | 1.44 |
| S.Em.± | 98.9 | 0.41 | 1.41 | 1,288 | 1,288 | 0.03 |
| C.D. (P = 0.05) | 291.4 | 1.20 | NS | 3,798 | 3,798 | 0.09 |

Table 3. Zinc and iron content in grain and fodder of *kharif* sorghum as influenced by zinc and iron enriched organics

| Treatment | Zinc content (mg kg$^{-1}$) | | Iron content (mg kg$^{-1}$) | |
|---|---|---|---|---|
| | Grain | Fodder | Grain | Fodder |
| $T_1$: Control (No nutrients) | 19.68 | 15.48 | 28.26 | 24.37 |
| $T_2$: Recommended dose of fertilizer (RDF) | 20.56 | 16.51 | 29.08 | 25.85 |
| $T_3$: Recommended package of practices (RPP) | 22.93 | 19.74 | 30.40 | 27.27 |
| $T_4$: $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with FYM | 21.79 | 19.07 | 32.11 | 28.49 |
| $T_5$: $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with FYM | 22.21 | 19.14 | 32.45 | 29.07 |
| $T_6$: $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with FYM | 22.92 | 20.19 | 32.90 | 29.44 |
| $T_7$: $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with FYM | 23.43 | 20.64 | 33.89 | 30.67 |
| $T_8$: $ZnSO_4$ + $FeSO_4$ @ 3.75 kg ha$^{-1}$ each enriched with vermicompost | 21.50 | 19.03 | 32.12 | 28.44 |
| $T_9$: $ZnSO_4$ + $FeSO_4$ @ 7.50 kg ha$^{-1}$ each enriched with vermicompost | 21.85 | 19.62 | 32.14 | 28.83 |
| $T_{10}$: $ZnSO_4$ + $FeSO_4$ @ 11.25 kg ha$^{-1}$ each enriched with vermicompost | 22.91 | 20.06 | 32.63 | 29.98 |
| $T_{11}$: $ZnSO_4$ + $FeSO_4$ @ 15.00 kg ha$^{-1}$ each enriched with vermicompost | 23.35 | 20.48 | 33.22 | 30.10 |
| S.Em.± | 0.37 | 0.57 | 0.93 | 0.84 |
| C.D. (P = 0.05) | 1.10 | 1.68 | 2.73 | 2.46 |

sorghum with application of RDF + 3.75 kg ha$^{-1}$ $ZnSO_4$ and $FeSO_4$ each enriched with 50 kg FYM as compared to other treatments. These results also support the findings of Adsu *et al.* (2014) who observed the significant increase in grain yield (20.56 q/ ha$^{-1}$), fodder yield (28.69 q/ ha$^{-1}$) and biomass (49.27 q/ ha$^{-1}$) in *kharif* sorghum over control. Increase in grain and fodder yield was due to enrichment of zinc and iron with FYM regulates their supply to the crop through mineralization and prevents them from leaching and other losses besides mobilizing and supplying the native zinc and iron (Meena *et al.,* 2008). Soil application of $ZnSO_4$ + $FeSO_4$ @ 15 kg ha$^{-1}$ each enriched with FYM realized significantly higher gross returns (₹ 63,657 ha$^{-1}$), net returns (₹ 20,890 ha$^{-1}$) and BC ratio (1.49) compared to other treatments. Significantly lower gross returns (₹ 33,874 ha$^{-1}$), net returns (₹ 3,022 ha$^{-1}$) and BC ratio (1.10) were obtained in control as compared to other treatments. The variation in the gross returns and net returns was mainly due to significant difference in the grain and fodder yield of *kharif* sorghum. These results were in agreement with the findings of Arabhanvi (2017) in sweet corn who realized higher net returns (₹ 2,48,320) and BC ratio (4.62) with the soil application of $ZnSO_4$ and $FeSO_4$ (10 kg each ha$^{-1}$) fortified with 250 kg vermicompost ha$^{-1}$ as compared to other treatments.

Zinc and iron content in grain and fodder after harvest of the crop increased significantly due to soil application of different levels of organically chelated zinc and iron as compared to control, recommended dose of fertilizer and recommended package of practices. Soil application of $ZnSO_4$ + $FeSO_4$ @ 15 kg ha$^{-1}$ each enriched with FYM recorded significantly higher zinc content in both grain (23.43 mg kg$^{-1}$) and fodder (20.64 mg kg$^{-1}$) which was 16.0 and 22.7 per cent higher over control (19.68 and 15.48 mg kg$^{-1}$ in grain and fodder, respectively), 12.2 and 20.0 per cent higher over recommended dose of fertilizer (20.56 and 16.51 mg kg$^{-1}$ in grain and fodder, respectively) and 2.1 and 4.3 per cent over recommended package of practices (22.93 and 19.74 mg kg$^{-1}$, respectively) (Table 3). Similarly, iron content in grain and fodder was significantly higher with application of $ZnSO_4$ + $FeSO_4$ @ 15 kg ha$^{-1}$ each enriched with FYM (33.89 and 30.67 mg kg$^{-1}$, respectively) which was 14.5 and 20.5 per cent higher over control (28.25 and 24.37 mg kg$^{-1}$ in grain and fodder, respectively), 14.2 and 12.5 per cent higher over recommended dose of fertilizer (29.08 and 26.85 mg $kg^{-1}$ in grain and fodder, respectively) and 10.3 and 11.0 per cent higher over recommended package of practices (30.40 and 27.27 mg $kg^{-1}$ in grain and fodder, respectively). The improved zinc and iron content in grain and fodder could be attributed to the formation of stable organometallic complexes with organic matter, especially during the 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. Similar observations were recorded by Mishra *et al.* (2015) in *rabi* sorghum.

## Conclusion

Based on the result it can be concluded that application of $ZnSO_4$ + $FeSO_4$ @ 15 kg $ha^{-1}$ each enriched with FYM to *kharif* sorghum found optimum for getting higher grain yield, fodder yield, zinc and iron content both in grain and fodder and also higher net returns compared to recommended package of practices.

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