

Original Research Article

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Effect of Bio-fortification through Organic and Inorganic Sources of Zinc and Iron on Growth, Yield and Quality of Aromatic Rice

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ABSTRACT

Micronutrients are not only essential for plant growth and development but are also integral to human health. Fe and Zn deficiencies cause serious nutritional problems in human beings. Increasing the micronutrient content of grain by bio-fortification offers great potential to combat micronutrient deficiency and dramatically impact human health. To find out the most suitable and profitable method of bio-fortification in aromatic rice with Zinc and Iron, a field experiment was conducted during *kharij*, 2019 at the Research Farm, Bihar Agricultural University, Sabour, Bhagalpur. The experiment was laid out with Randomized Complete Block Design with treatments comprising of soil and foliar application of Fe and Zn from organic and inorganic sources. Soil application of ZnSO₄ and FeSO₄ each @ 25 kg ha⁻¹ along with RDF recorded significantly higher plant height, number of tillers hill⁻¹, leaf area index and dry matter accumulation, highest grain yield (41.30 q ha⁻¹), straw yield (59.05 q ha⁻¹), net return (65698 Rs. ha⁻¹) compared to control. RDF along with foliar application of ZnSO₄ and FeSO₄ each @ 0.5% at 25 DAT and 1 week after flowering showed similar results as that with soil application of ZnSO₄ and FeSO₄ each @ 25 kg ha⁻¹ along with RDF with respect to growth, yield and economics of aromatic rice. Foliar application of Zinc & Iron through inorganic sources resulted into better biofortification. T₄ (RDF + 2 FS of 0.5% ZnSO₄ at 25 DAT & 1 week after flowering) recorded higher Zn content in grain (35.74 mg kg⁻¹) and straw (37.93 mg kg⁻¹) while T₆ (RDF + 2 FS 0.5% FeSO₄ at 25 DAT & 1 week after flowering) recorded higher Fe content in grain (74.26 mg kg⁻¹) and straw (193.52 mg kg⁻¹) followed by T₈ (RDF + 2 FS of 0.5% ZnSO₄ & 2 FS of 0.5% FeSO₄ each at 25 DAT & 1 week after flowering).

Keywords

Aromatic rice,
Biofortification,
Zn & Fe
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Introduction

Rice (*Oryza sativa* L.) is a grain crop belonging to the family Poaceae with chromosome no. 24. Over two billion people in Asia derive their 80 per cent energy from rice. India is the second largest producer of rice next to China, having the area of about

43.8 m ha with the production and productivity of 112.91 mt and 2578 kg ha⁻¹ respectively (GOI 2018-19). In Bihar, the area under rice cultivation is about 3.17 million ha with the production of 9.04 million tonnes and productivity of 2847 kg ha⁻¹ (Directorate of Statistics and Evaluation, Bihar, 2018-19).

Current trend indicates that about two billion people in developing countries suffer from micronutrient malnutrition (Dipender *et al.*, 2018). Fe and Zn deficiencies are among the most prevalent micronutrient deficiencies in humans, affecting two billion people and causing more than 0.8 million deaths annually (World Health Organization, 2003). Anemia, fatigue, dizziness, reduced work capacity and some pathological consequences (Stoltzfus, 2003; Hentze *et al.*, 2004) have been reported in Fe deficiency. Zn deficiency causes growth retardation, hypogonadism, immune dysfunction, and cognitive impairment (Prasad, 2009). Approximately, five million children die every year due to micronutrient malnutrition (Dipender *et al.*, 2018). Rice is the staple food to almost half of the world's population, especially in Asia and Africa. Increasing Fe and Zn content of rice has a great potential to mitigate widespread Fe and Zn deficiency and alleviating malnutrition problem in human. Biofortification is an effective, most economical and convenient way to combat micronutrient deficiencies, i.e., healthy food, micronutrient supplementation, and food fortification.

This study evaluated agronomic biofortification in aromatic rice by soil and foliar application from different organic and inorganic sources of Zn and Fe. Among the different inorganic sources Zinc sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) containing 21% Zn and Iron sulphate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) containing 19% Fe was used. While in case of organic sources Panchagavya and Vermiwash were used for biofortification of Fe and Zn which were also found suitable for crop improvement in organic agriculture (Sangeetha and Thevanathan, 2010). Panchagavya is an organic liquid fertilizer containing 28 mg Zn and 87 mg Fe per litre of panchagavya (Vajantha *et al.*, 2012). Vermiwash is a liquid obtained during the process of vermicomposting and contains Zn (0.02 ppm) and

Fe (0.06 ppm) (Manpreet *et al.*, 2017). Therefore, the influence of the application of Zn and Fe fertilizer from organic and inorganic sources was evaluated on growth, grain quality and yield potential of aromatic rice.

Materials and Methods

The field experiment was carried out during the *kharij* season of 2019 at the Research Farm, Bihar Agricultural University, Sabour, Bhagalpur, which is located at the South of river Ganges. Soil of the experimental field was sandy loam in texture, slightly alkaline in pH (7.7), low in available Zn (0.148 ppm), high in available Fe (24.294 ppm), low in available N ($194.32 \text{ kg ha}^{-1}$), medium in available P (22.31 kg ha^{-1}) and K ($120.11 \text{ kg ha}^{-1}$). Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and ten treatments. Nitrogen fertilizer was applied in three splits. One third of nitrogen was applied at basal along with full dose of phosphorous and potassium and remaining amount of nitrogen was applied in two equal splits each at 25 DAT and at panicle initiation stage respectively.

The source of nitrogen, phosphorous and potash were urea, DAP and MOP respectively. Soil application of ZnSO_4 (21% Zn) & FeSO_4 (19% Fe) were done as per the treatments at the time of transplanting. Foliar spray of ZnSO_4 and FeSO_4 were done twice as per the treatments at 25 DAT and 1 week after flowering, while foliar spray of Panchgavya (3%) and Vermiwash (1%) were done thrice at 25 DAT, 50 DAT and 1 week after flowering. The plot having absolute control did not receive any fertilizer either as basal, top dressing or as foliar spray. Two hand weeding were done manually at 25 days after transplanting and 40 days after transplanting to control weeds and to facilitate good aeration. For biometric observations five

plants in net plot were randomly selected and tagged for recording at different stages of crop growth. However, for measuring dry matter accumulation, five plants from the border rows were randomly selected.

Yield attributes and yield were studied before and after harvesting as per investigation required. Crop was harvested when grains became hard enough with nearly 15-20 per cent moisture and plants showed physiological maturity. Harvesting was done by cutting the plants from each plots separately. The plants after harvesting were sun dried at the threshing floor.

Threshing was done thereafter by beating the plants. The threshed grains were dried in sun to bring the moisture content to 12-14 per cent and then final weights were recorded. The gross return, net return and benefit-cost ratio of different treatments were worked out on the basis of prevailing market prices. To test the significance, experimental data collected on various aspects of investigation on rice were statistically analysed with procedure described.

Results and Discussion

Growth attributes

Treatment receiving soil application of ZnSO_4 @ 25 kg ha⁻¹ and FeSO_4 @ 25 kg ha⁻¹ (T₇) recorded highest plant height (108.53 cm), number of tillers hill⁻¹ (16.37), leaf area index (3.29) and dry matter accumulation (1001.12 g m⁻²) at harvest which was statistically at par with treatment receiving 2 foliar spray of 0.5% ZnSO_4 & 2 FS of 0.5% FeSO_4 each at 25 DAT & 1 week after flowering (T₈) at all the crop growth stages i.e. at 30, 60, 90 DAT and at harvest (Table 1). The profound increase in these growth characters was probably due to action of Zn in auxin metabolism, which led

to higher hormonal activity at critical crop growth stages (Ghatak, 2005 and Slaton, 2005). Also Fe, which is indispensable for chlorophyll synthesis and involved in the formation of pyrrole ring, a structural component of chlorophyll increased growth characters.

These findings are in close agreement with Sandhu and Bansal (2001) Rakesh *et al.*, (2012), Xiaoyun *et al.*, (2012). Inorganic sources of Zn and Fe aided to the fast growth of the crop compared to organic sources as during vegetative stage the demand of nutrients is quite high and micronutrients from fertilizers are easily available to the plants in sufficient quantity.

Yield attributes and yield

Yield attributes like effective tillers per sq. m and no. of filled grains per panicle increased significantly with soil and foliar application of both zinc and iron fertilizer. T₇ (RDF + SA of ZnSO_4 @ 25 kg ha⁻¹ + SA of FeSO_4 @ 25 kg ha⁻¹) recorded the highest no. of effective tillers per sq. m (363) and no. of filled grains per panicle (113) and was at par with treatment T₈ ((RDF + 2 FS of 0.5% ZnSO_4 & 2 FS of 0.5% FeSO_4 each at 25 DAT & 1 week after flowering) as shown in table 2.

Regular availability of both Zn and Fe micronutrients in treatment T₇ and T₈ enhanced the plant metabolism and chlorophyll synthesis thereby increasing the dry matter accumulation and production of more tillers which in turn enhanced the yield attributing characters of rice plant. Similar results were observed by Ram (2011) and Tabassum *et al.*, (2013). Test weight of treatment T₇ and T₈ showed significantly superior values compared to control but no significant difference was observed among the treatments.

Table.1 Effect of bio-fortification through organic & inorganic sources of Zn & Fe on growth parameters of aromatic rice

Treatments		Plant height (cm)	Number of tillers hill ⁻¹	Leaf area index	Dry matter accumulation (g m ⁻²)
T1	Absolute control	94.13	7.50	1.94	609.66
T2	RDF	106.04	9.81	2.04	823.47
T3	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹	108.04	13.19	2.85	921.29
T4	RDF + 2 FS of 0.5% ZnSO ₄ at 25 DAT & 1 week after flowering	108.04	10.52	2.60	895.68
T5	RDF + SA of FeSO ₄ @ 25 kg ha ⁻¹	106.83	13.41	2.93	882.85
T6	RDF + 2 FS 0.5% FeSO ₄ at 25 DAT & 1 week after flowering	107.26	11.97	2.64	862.58
T7	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹ + SA of FeSO ₄ @ 25 kg ha ⁻¹	108.53	16.37	3.29	1001.12
T8	RDF + 2 FS of 0.5% ZnSO ₄ & 2 FS of 0.5% FeSO ₄ each at 25 DAT & 1 week after flowering	108.38	14.89	3.28	927.60
T9	RDF + 3 FS of 3% Panchgavya at 25, 50 DAT & 1 week after flowering	108.14	12.82	2.71	901.48
T10	RDF + 3 FS of vermi-wash at 25, 50 DAT & 1 week after flowering	107.33	12.50	2.61	903.04
CD (P=0.05)		5.68	1.91	0.99	97.63

Table.2 Effect of bio-fortification through organic & inorganic sources of Zn & Fe on yield and economics of aromatic rice

Treatments		Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Gross return (Rs.)	Net return (Rs.)	B:C ratio
T ₁	Absolute control	24.82	37.02	59499	32445	1.20
T ₂	RDF	33.97	49.07	80955	50078	1.62
T ₃	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹	38.25	55.13	91127	58750	1.81
T ₄	RDF + 2 FS of 0.5% ZnSO ₄ at 25 DAT & 1 week after flowering	36.64	53.64	87547	55834	1.76
T ₅	RDF + SA of FeSO ₄ @ 25 kg ha ⁻¹	36.52	52.95	87107	56055	1.81
T ₆	RDF + 2 FS 0.5% FeSO ₄ at 25 DAT & 1 week after flowering	35.44	51.89	84684	53236	1.69
T ₇	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹ + SA of FeSO ₄ @ 25 kg ha ⁻¹	41.30	59.05	98250	65698	2.02
T ₈	RDF + 2 FS of 0.5% ZnSO ₄ & 2 FS of 0.5% FeSO ₄ each at 25 DAT & 1 week after flowering	38.64	55.25	91922	60174	1.90
T ₉	RDF + 3 FS of 3% Panchgavya at 25, 50 DAT & 1 week after flowering	37.19	54.76	88954	55473	1.66
T ₁₀	RDF + 3 FS of vermi-wash at 25, 50 DAT & 1 week after flowering	37.26	54.51	89009	57178	1.80
CD (P=0.05)		3.07		0.20	6184.17	6184.17

Table.3 Effect of bio-fortification through organic & inorganic sources of Zn & Fe on zinc and iron content of aromatic rice

Treatments		Nutrient content (%)			
		Zn content in grain (mg kg ⁻¹)	Zn content in straw (mg kg ⁻¹)	Fe content in grain (mg kg ⁻¹)	Fe content in straw (mg kg ⁻¹)
T ₁	Absolute control	26.92	30.39	59.24	178.33
T ₂	RDF	29.00	31.67	60.28	180.00
T ₃	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹	35.25	36.06	61.16	181.67
T ₄	RDF + 2 FS of 0.5% ZnSO ₄ at 25 DAT & 1 week after flowering	35.74	37.93	61.81	182.00
T ₅	RDF + SA of FeSO ₄ @ 25 kg ha ⁻¹	29.08	32.08	70.85	190.33
T ₆	RDF + 2 FS 0.5% FeSO ₄ at 25 DAT & 1 week after flowering	29.80	32.52	72.64	193.01
T ₇	RDF + SA of ZnSO ₄ @ 25 kg ha ⁻¹ + SA of FeSO ₄ @ 25 kg ha ⁻¹	32.44	35.53	69.50	191.67
T ₈	RDF + 2 FS of 0.5% ZnSO ₄ & 2 FS of 0.5% FeSO ₄ each at 25 DAT & 1 week after flowering	32.31	36.45	71.67	193.52
T ₉	RDF + 3 FS of 3% Panchgavya at 25, 50 DAT & 1 week after flowering	34.59	35.93	67.71	184.67
T ₁₀	RDF + 3 FS of vermi-wash at 25, 50 DAT & 1 week after flowering	33.10	35.59	66.88	180.00
CD (P=0.05)		3.33	3.78	5.21	6.92

High yield attributing characters positively complemented the grain and straw yield of the rice crop. T₇ (RDF + SA of ZnSO₄ @ 25 kg ha⁻¹ + SA of FeSO₄ @ 25 kg ha⁻¹) recorded the highest grain yield (41.30 q ha⁻¹) and straw yield (59.05 q ha⁻¹) and was found to be significantly superior over all other treatments but was statistically at par with T₈ (RDF + 2 FS of 0.5% ZnSO₄ & 2 FS of 0.5% FeSO₄ each at 25 DAT & 1 week after flowering) (Table 2). Application of ZnSO₄ + FeSO₄ with RDF posed a great increment in yield over rest of the treatments because of adequate availability of major and micro nutrients in soil, which in turn, favourably influenced physiological processes and building up of photosynthates (Tabassum *et al.*, 2013). These findings are similar to the results found by Mattas *et al.*, (2011), Roshan *et al.*,

(2011), Zayed (2011) and Kadam *et al.*, (2018). Moreover, by supplying plants with micronutrient through soil application, there was increased yield and quality as well as macronutrient use efficiency (Imtiaz *et al.*, 2006). Among the different sources used the inorganic source gave better results due to quick solubility of Zn and Fe in soil and their easy absorption by plants. In case of organic sources the nutrients are available in chelated form and their absorption requires energy thereby affecting the plant growth and yield performance.

Economics

Highest gross return (98250 ₹ ha⁻¹), net return (65698 ₹ ha⁻¹) and benefit-cost ratio (2.02) were recorded with the treatment

T₇(RDF + SA of ZnSO₄ @ 25 kg ha⁻¹ + SA of FeSO₄ @ 25 kg ha⁻¹) which was at par with treatment T₈ i.e. foliar application of ZnSO₄ and FeSO₄ each @ 0.5% along with RDF. Although soil and foliar application involved higher cost of cultivation than other treatments because of the fertilizer cost and the spray cost but the increase in yield was high enough to cover the fertilizer and spray cost proving profitable to farmers. Similar results were obtained by Suresh *et al.*, (2015).

Zn and Fe content in grain and straw

The data on micronutrient content in rice plant differed significantly due to soil and foliar application of ZnSO₄ and FeSO₄. Zn content in grain was found highest (35.68 mg kg⁻¹) in T₄ (RDF + 2 FS of 0.5% ZnSO₄ at 25 DAT & 1 week after flowering) while Fe content in grain was recorded highest (72.64 mg kg⁻¹) in treatment T₆ (RDF + 2 FS 0.5% FeSO₄ at 25 DAT & 1 week after flowering) (Table 3). Foliar application of Zn and Fe each @ 0.5% accounted significantly higher zinc content in grain (33.67 Zn and 67.76 Fe mg kg⁻¹) over no foliar spray (30.36 and 64.24 mg kg⁻¹ Zn and Fe respectively) (Suresh *et al.*, 2015). Foliar Zn and Fe spray offers a practical and useful means for an effective biofortification of rice grain. This consistently and significantly contributes to increases in Zn and Fe content of rice grain irrespective of cultivars, environmental conditions and management practices. The results are similar to the findings of Dhaliwal *et al.*, (2010) and Jan *et al.*, (2016) who independently found that foliar application of Zn and Fe respectively was much more efficient in grain Zn and Fe accumulation than the soil application.

In conclusion the improved nutrient practices involving micronutrient application in major crops like rice can aid in mitigating the Zn and Fe deficiency. Bio-fortification is one of

the most potential solutions which is effective, economical and convenient to combat increasing micronutrient deficiencies in humans. Based upon the result of the experiment it may be concluded that for getting higher grain yield as well as for better bio-fortification of rice grain, soil application of ZnSO₄ and FeSO₄ along with RDF (T₇) should be adopted, however foliar application of ZnSO₄ and FeSO₄ along with RDF (T₈) may also be taken as the best alternative. Inorganic fertilizers increase the uptake of micronutrients at the peak demand period in plants but the organic sources used in this study can also be considered useful in present era where organic farming is adopted widely.

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