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Yield and economics of direct seeded rice (*Oryza sativa* L.) as influenced by the zinc nutrition

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Abstract

The field study was conducted to evaluate the “Response of direct seeded rice (*Oryza sativa* L.) to zinc nutrition in sub-montane zone of Maharashtra during kharif 2021. The field experiment was laid out in randomized block design with three replications and eleven treatments replicated thrice. The growth, yield and yield attributing characters of direct seeded rice recorded significantly highest with the application of RDF (100:50:50 kg NPK ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA Zn. Soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application 0.2% EDTA Zn + RDF and Vermicompost recorded maximum gross returns, net monetary returns and benefit cost ratio.

Keywords: Zinc, yield attributes, B: C ratio, net monetary returns

Introduction

Rice (*Oryza sativa* L.) is the world's leading staple food grains and premier cereal crop for above 60 per cent world's population, belonging to family Poaceae. India has over 45 million hectares of land devoted to rice farming in the year 2021. Rice is the food grain that is most widely cultivated in South Asian Nations (Anonymous, 2022^a)^[1]. Next to China, India is the world's second-largest producer and consumer of rice. In the year 2021, India produced 122 million metric tonnes of rice. The first projection for 2022 is 107.04 million metric tonnes, which represents a further decline (Anonymous, 2022^b)^[2]. The direct seeding is time and labour saving method, constitutes both wet and dry seeding. The upland paddy is mostly dry-seeded and found in parts of Bihar, Assam, Chhattisgarh, Gujarat, Kerala, Karnataka, West Bengal, Uttar Pradesh and Maharashtra. The upland rice grown in India is about 13 per cent of area under cultivation; it helps in feeding numbers of poor farmer from its limited resources in India. Direct seeded rice (DSR) reduces 11.2 per cent of the total cost of production over the transplanting method (Dongarwar *et al.*, 2018)^[4].

In DSR, the input requirements and total investment are much less than transplanted rice. Kumar and Ladha (2011)^[8] recorded higher benefit cost ratio in direct seeded rice as compared to manual transplanted rice. Integrated use of synthetic fertilizers with organic sources of nutrients helps in maintaining higher productivity and greater stability in crop production. Micronutrients are crucial for the growth and development of plants as well as for boosting crop productivity. In locations where consumption of rice is significant, a zinc deficit can lead to decreased yields, deteriorated crop quality and zinc malnutrition or covert hunger in humans. According to experts, two billion peoples worldwide are micronutrient malnourished. (Verma, 2015)^[11] Zinc (Zn) acts as an essential component of many enzymes and control plant biochemical processes (IRRI, 2000)^[6]. In the world more than 30 per cent of the cultivated soils are zinc deficient and about 50 per cent of the soils used for cereal crop production are low in available zinc. Nearly half of the world population suffers from zinc deficiency (Cakmak, 2008)^[3]. In India, about 26 per cent populations and about 54 per cent childrens are suffering from Zn deficiency (Verma *et al.*, 2015)^[11]. Zinc is moderately mobile in plants and immobile in soil. Continues flooded soil prevent zinc uptake by the rice crop and root respiration ability become very poor. The most economic way to alleviate zinc deficiency in the rice is application of zinc fertilizers and improves productivity and zinc concentration in grains. In addition to specific zinc fertilizers, organic manures are good source of zinc and other nutrients.

Materials and Methods

The experiment was conducted at the Post Graduate Research Farm, Agronomy Section of Rajarshree Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur (M.S), India, during *kharif*, 2021. The field experiment was laid out in randomized block design with three replications and eleven treatments replicated thrice. The treatment comprises of T₁: Absolute control, T₂: RDF (100:50:50 kg NPK kg ha⁻¹), T₃: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹), T₄: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 10 kg ha⁻¹, T₅: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 20 kg ha⁻¹, T₆: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Foliar application of 0.1% EDTA Zn., T₇: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Foliar application of 0.2% EDTA Zn., T₈: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 10 kg ha⁻¹ + Foliar application of 0.1% EDTA Zn., T₉: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 10 kg ha⁻¹ + Foliar application of 0.2% EDTA Zn., T₁₀: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 20 kg ha⁻¹ + Foliar application of 0.1% EDTA Zn., T₁₁: RDF (100:50:50 kg NPK kg ha⁻¹ + Vermicompost @ 2.5 t ha⁻¹) + Soil application of ZnSO₄ @ 20 kg ha⁻¹ + Foliar application of 0.2% EDTA Zn. The variety used for the experiment is Indrayani (IET-12897) (Amb-157× IR-8).

Fertilizers were applied at the time of paddy sowing as a basal dose. Basal dose comprises 40 per cent of nitrogen, and full dose of P₂O₅ and K₂O. The remaining 60 per cent nitrogen was applied in two split doses; 40 per cent at maximum tillering stage i.e. 30 DAS and 20 per cent at initial panicle initiation stage i.e. 60 DAS. Nitrogen was applied through urea, P₂O₅ through single super phosphate, K₂O through muriate of potash. Soil application of ZnSO₄ @ 10 and 20 kg ha⁻¹ was done by mixing with sandy soil at the time of sowing as per treatment and foliar spray of chelated Zn-EDTA @ 0.1% and 0.2% at initial panicle initiation stage and late growth stage i.e., one week after flowering as per treatment wise.

The experimental soil was sandy clay loam soil. The pH and electrical conductivity values were 7.80 (slightly alkaline in

reaction) and 0.45 dSm⁻¹ (normal-low saline), respectively. The status of soil organic carbon content (0.51%) was medium. The plot was low in available N (168.27 kg ha⁻¹), relatively very high in available P₂O₅ (30.02 kg ha⁻¹), medium in available K₂O (339.88 kg ha⁻¹) and deficient in available Zn (0.25 ppm). The five representative plants were selected randomly from each net plot for studying the effects of various treatments on plant character of rice. The periodical biometric observations were recorded at an interval of 14 DAS up to harvest.

Results and Discussion

Details of results observed from the present investigation have been summarized under suitable heading and subheading.

Yield and harvest index

Data on mean grain yield, straw yield, biological yield and harvest index ha⁻¹ for different treatments is given in table 1. Grain, straw, biological yield (q/ha) and harvest index of DSR as affected by various treatments have been mentioned below in table 1.

Yield studies

The significantly highest grain and straw yield of 48.97 q/ha and 69.71 q/ha respectively, biological yield of 130.24 q/ha, economic yield of 46.42 q/ha and harvest index of 46.51 was recorded in T₁₁ which is soil application of ZnSO₄ @ 20 kg/ha + foliar spray of 0.1% EDTA zinc. The mean value for the harvest index was estimated to be 46.48 percent. The highest harvest index of 46.51 was observed under the treatment [T₁₁] soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA Zn and [T₅] soil application of ZnSO₄ @ 20 kg ha⁻¹. However, it had the record of lowest harvest index value 46.42 which was of direct seeded rice by giving absolute control treatment. Both the studies of Ghasal *et al.* (2015)^[5] and Shivay *et al.* (2015)^[10] have concluded almost same result regarding harvest index. It could be due to the combined method of application of zinc had a positive impact on root development and therefore nutrient uptake by plant from the soil and transport to the aerial parts of the plant and provided direction towards more yield attributing characters like vegetative growth parameters that cumulatively make up the yield.

Table 1: Grain, straw, biological yield (q ha⁻¹) and harvest index of DSR as influenced by various treatments

Treatments	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Biological yield (q ha ⁻¹)	Harvest Index
T ₁ – Absolute control	21.55	24.87	46.42	46.42
T ₂ – RDF (100:50:50 kg NPK ha ⁻¹)	34.70	39.96	74.66	46.48
T ₃ – RDF + Vermicompost @ 2.5 t ha ⁻¹	39.50	45.46	84.96	46.49
T ₄ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹	51.42	59.16	110.58	46.50
T ₅ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹	53.94	62.02	115.96	46.51
T ₆ – (RDF + Vermicompost) + Foliar application of 0.1% EDTA Zn	50.31	57.89	108.20	46.50
T ₇ – (RDF + Vermicompost) + Foliar application of 0.2% EDTA Zn	52.48	60.37	112.85	46.50
T ₈ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹ + Foliar application of 0.1% EDTA Zn	56.61	65.29	121.90	46.44
T ₉ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹ + Foliar application of 0.2% EDTA Zn	57.64	66.39	124.03	46.47
T ₁₀ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + Foliar application of 0.1% EDTA Zn	59.94	69.11	129.05	46.47
T ₁₁ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + Foliar application of 0.2% EDTA Zn	60.53	69.71	130.24	46.51
S.Em±	0.353	0.409	0.878	1.56
C. D. at 5%	1.043	1.208	2.593	NS
General mean	48.97	56.39	105.36	46.48

Economic Studies

The economic indices of direct seeded rice with reference to Mean Gross Monetary Returns (MGR), Net Monetary Returns

(NMR), Cost of Cultivation (COC) and Benefit Cost Ratio (BCR) in terms of zinc nutrition treatments are presented in Table 2.

Table 2: Economics of direct seeded rice as influenced by various treatments

Treatments	Cost of cultivation (₹. ha ⁻¹)	Gross returns (₹. ha ⁻¹)	Net returns (₹. ha ⁻¹)	Benefit: Cost ratio
T ₁ – Absolute control	38031	55450	17419	1.46
T ₂ – RDF (100:50:50 kg NPK ha ⁻¹)	43651	89274	45624	2.04
T ₃ – RDF + Vermicompost @ 2.5 t ha ⁻¹	68251	101619	33368	1.49
T ₄ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹	69050	133052	64001	1.93
T ₅ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹	69551	138759	69208	2.00
T ₆ – (RDF + Vermicompost) + Foliar application of 0.1% EDTA Zn	72169	129428	57259	1.79
T ₇ – (RDF + Vermicompost) + Foliar application of 0.2% EDTA Zn	73086	135008	61921	1.85
T ₈ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹ + Foliar application of 0.1% EDTA Zn	72998	145658	72659	2.00
T ₉ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 10 kg ha ⁻¹ + Foliar application of 0.2% EDTA Zn	73887	148295	74408	2.01
T ₁₀ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + Foliar application of 0.1% EDTA Zn	73689	154223	80534	2.09
T ₁₁ – (RDF + Vermicompost) + Soil application of ZnSO ₄ @ 20 kg ha ⁻¹ + Foliar application of 0.2% EDTA Zn	74287	155729	81442	2.10
S.E.m±	--	6382	4738	--
C. D. at 5%	--	18827	13977	--
General mean	66241	126045	59804	1.89

Cost of Cultivation (₹. ha⁻¹)

In general, the average cost of cultivation was ₹. 66241 ha⁻¹. The highest cost of cultivation (₹. 74287 ha⁻¹) was recorded with soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA zinc along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₁₁] followed by treatment T₉, T₁₀ and T₇ as compared to other treatments due to higher cost of foliar application of 0.2% EDTA Zn and higher cost of Zn-EDTA in comparison to ZnSO₄.7H₂O (Table 2). Lower cost of cultivation (₹. 38031 ha⁻¹) was noted under absolute control treatment. Similar findings were reported by Ghasal *et al.* (2015) [5] and Saha *et al.* (2020) [9].

Gross Monetary Returns (₹. ha⁻¹)

Information on mean gross monetary return (₹.ha⁻¹) of direct seeded rice regarding various zinc nutrition treatments are depicted in Table 2. mean gross monetary return was ₹. 126045 ha⁻¹. The gross monetary returns were significantly influenced by various methods and levels of Zn application. The treatment soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA zinc along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₁₁] recorded highest gross monetary return (155729 ₹. ha⁻¹) of direct seeded rice due to higher yield and it was found at par with soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of Zn EDTA @ 0.1% along with recommended dose of fertilizer NPK 100:50:50 kg ha⁻¹ and Vermicompost @ 2.5 t ha⁻¹ [T₁₀], soil application of ZnSO₄ @ 10 kg ha⁻¹ + foliar application of 0.2% EDTA Zn along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₉], soil application of ZnSO₄ @ 10 kg ha⁻¹ + foliar spray of 0.1% EDTA Zn along with RDF and Vermicompost [T₈] and only soil application of ZnSO₄ @ 20 kg ha⁻¹ with RDF and Vermicompost [T₅]. However, it was found significantly superior over treatments T₇, T₄, T₆, T₃, T₂ and T₁. The lowest gross monetary returns were recorded in treatments [T₁] absolute control (55450 ₹. ha⁻¹). The combined zinc application methods (soil + foliar) and soil application @ 20 kg ZnSO₄ recorded

highest gross returns due to highest grain yield. Like these authors Kumar *et al.*, (2020) [7] Saha *et al.* (2020) [9] too pointed out the similar sort of results.

Net Monetary Returns (₹. ha⁻¹)

Table 2 shows the NMR of DSR as influenced by various treatments and mean NMR was recorded ₹. 59804 ha⁻¹. Among the different zinc nutrition treatments the soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA zinc along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₁₁] recorded the highest net monetary returns (₹. 81442 ha⁻¹) of direct seeded rice which was significantly superior over all the treatments of zinc application. However it was [T₁₁] remained at par with soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.1% EDTA zinc along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₁₀], soil application of ZnSO₄ @ 10 kg ha⁻¹ + foliar application of 0.2% EDTA zinc [T₉], soil application of ZnSO₄ @ 10 kg ha⁻¹ + foliar application of 0.1% EDTA zinc [T₈], soil application of ZnSO₄ @ 20 kg ha⁻¹ with RDF (100:50:50 NPK kg ha⁻¹) + Vermicompost @ 2.5 t ha⁻¹ [T₅]. The lowest net monetary return was recorded in absolute control treatment. The combined (soil + foliar) zinc application method and alone soil application recorded higher net monetary returns due to higher grain yield and low cost of ZnSO₄. Singh *et al.*, (2021) also found that on the basis of monetary return, highest net monetary return was recorded in the case of soil application of zinc due to similar yield with slightly low cost of cultivation. Ghasal *et al* (2015) [5] and Saha *et al* (2020) [9] also reported similar observations.

Benefit: Cost Ratio

Data on average benefits: cost ratio of DSR was 1.89 presented in Table 2. The highest benefit: cost ration 2.10 was recorded with soil application of ZnSO₄ @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA zinc along with RDF (100:50:50 NPK kg ha⁻¹) and Vermicompost @ 2.5 t ha⁻¹ [T₁₁]. Here the combined application of zinc nutrition (soil + foliar) and alone soil

application ZnSO_4 recorded higher B: C ratio while, lowest benefit: cost ratio of 1.46 was recorded under absolute control treatment [T₁]. Similar findings were reported by Ghasal *et al.* (2015)^[5] and Kumar *et al.* (2020)^[7].

Conclusion

An economical analysis demonstrated that grain yield (60.53 q ha⁻¹), straw yield (69.71 q ha⁻¹) and biological yield (130.24 q ha⁻¹) were significantly maximum when ZnSO_4 at rate 20 kg ha⁻¹ was applied through soil + 0.2% EDTA Zn through foliar spray with RDF and Vermicompost [T₁₁], which was at par with soil application of ZnSO_4 @ 20 kg ha⁻¹ + foliar application of 0.1% EDTA Zn with RDF and Vermicompost [T₁₀] (59.94 q ha⁻¹, 69.11 q ha⁻¹) and (129.05 q ha⁻¹), respectively. The gross and net monetary returns (155729 ₹. ha⁻¹ and 81442 ₹. ha⁻¹) were significantly maximum with soil application of ZnSO_4 @ 20 kg ha⁻¹ + foliar application of 0.2% EDTA Zn along with RDF and Vermicompost [T₁₁] and at par with combined method of zinc application i.e. soil + foliar [T₁₀, T₉ and T₈] and alone soil application @ 20 kg ZnSO_4 ha⁻¹ [T₅] in terms of gross monetary returns. Whereas, in terms of net monetary returns zinc application through combined method (soil + foliar) [T₁₀, T₉ and T₈] and soil application of zinc @ 10kg ZnSO_4 ha⁻¹ and 20kg ZnSO_4 ha⁻¹ along with RDF and vermicompost [T₄ and T₅] found at par with superior treatment [T₁₁]. When ZnSO_4 at a level of 20 kg ha⁻¹ was applied to the soil, 0.2% EDTA Zn was applied to the foliage, RDF and vermicompost were also added [T₁₁]. This resulted in a higher B: C ratio of 2.10.

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