Original Research Article

Response of Direct Seeded Rice to Iron and Zinc Fertilization Strategies under Middle Gujarat Conditions

ABSTRACT

Directseeded rice (DSR) cultivation has received considerable attention due to its economic and labor-saving benefits. However, inadequate nutrient availability, particularly micronutrients, remains a significant constraint in achieving optimal crop growth and yield in direct seeded rice system. This research paper presents a comprehensive analysis of the impact of iron and zincfertilization on yield, productivity and nutritional quality of direct seeded rice.This experiment was conducted at Experimental Farm, Regional Research Station, Anand Agricultural University, Anand, Gujarat, during *kharif* season of the year 2022with twelve treatments of iron and zinc fertilization strategies *viz.*nutripriming, foliar application and soil drenchingwhich were replicated thrice in randomized block design(RBD).In the treatments of nutripriming, seed were soaked in 0.5% solutions of iron sulphate and zinc sulphate individually and also in combination for 12 hrs. In other treatments, solutions of 0.5% concentration of iron sulphate and zinc sulphate were applied through foliar application at 30 and 50 DAS and soil drenching.Soil drenching was done by adding nutrient solutions (0.5% of ironsulphate and zincsulphate each) directly on the rice sown lines of the plots.Findings demonstrate that targeted application of micronutrients (Fe and Zn) significantly enhanced the DSR performance in form of growth parameters, yield attributes, yield and nutrient content of grain and straw. Among all the treatments, (T_5) nutripriming of direct seeded rice with 0.5% iron sulphateplus0.5% zinc sulphatefor 12 hours before sowing along with recommended dose of fertilizers has been found best in terms ofplant height, panicles per m^2, yield and Fe and Zn content in seed and straw of rice.

Keywords:*Direct seeded rice,Soil drenching, Ferti-fortification, Iron sulphate, Zinc sulphate.*

1. INTRODUCTION

In recent time, the micronutrients deficiencies in cereal crops particularly in rice,have been evolved as a very serious issue which resulted in malnourishment and several other disorders predominantly in developing countries.Rice is the staple food crop for more than half of the world's population, unfortunately is a poor source of many essential micronutrients (Stalin *et al*., 2011). Thus, a rice-based diet is the primary causes of micronutrient malnutrition worldwide mainly in the developing world. Iron and zincdeficiencies are common in rice consuming areas. These micronutrients are required in small amounts but they affect directly or indirectly many vital processes in the plant such asphotosynthesis, respiration, protein synthesis, reproduction phase which in combination affectsthe grain yield as well as straw yield (Clarkson and Marschner, 1995).In the puddled transplanted rice cultivation, a traditional method widely practiced in many rice-growing regions, involves the creation of an anaerobic environment through the continuous submergence of rice fields. While this technique has long been favored for its perceived benefits, recent research has shed light on several drawbacks and adverse effects associated with puddled transplanted rice cultivation like soil degradation,methane emissions, inefficient water use and excessive water consumption*etc*.Also, an alarming rate of ground water depletion and increasing labour scarcity are major threats to future rice production in India. Management strategies that reduce the irrigation amount and labour requirement while maintaining or increasing yield are urgently needed. Direct seeded rice (DSR) is the alternative method to achieve these objectives (Gill*et al*., 2011). The direct seeding offers certain advantages *i.e.,* labour saving, faster and easier planting helps in timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirements, high tolerance to water deficit, often higher yield, low production cost and more profit, better soil physical conditions for following crops and less methane emission (Balasubramanian and Hill, 2002). But direct seeded rice crop suffers from micronutrients deficiencies particularly iron and zinc due to non-reductive conditions. Thus, direct seeded rice crop tends to develop micronutrients deficiency at the vegetative and reproductive stage of growth. The ferti-fortification of micronutrients is an effective way to overcome the nutrients deficiency and enhanceyield and nutrient content of grain (Johnson *et al.,* 2005). Concentration of iron and zincincreased in rice grain and straw due to the application of these nutrients combinedly (Jin*et al.,* 2008, Yadav *et al*. 2021). Nutripriming, foliar application and soil drenching of micronutrients particularly iron and zincare some ofthe effective methods for ferti-fortification. Keeping these facts in the view, the present investigation was undertaken as response of direct seeded rice under iron and zinc fertilization strategies.

2. MATERIALS AND METHODS

The experiment was conducted during the *kharif* season of the year 2022 on plot No. E-15 at Experimental Farm, Regional Research Station, Anand Agricultural University, Anand, Gujarat (situated at 22° 32' 18.672" N latitude, 72° 57' 57.708" E longitude with an average elevation of 39 m above mean sea level). The field experimentsite had an even topography with moderate slope and good drainage. Soil was representative of the soils of the region, popularly known as "*Goradu*" which is sandy loam in texture derived from alluvial parent material. The soil hadbetter physical conditions for optimum growth and development and also had good moisture retentive capacity (Table. 1).

The research experiment was laid out in randomized block design with twelve treatments of iron and zinc application strategies which were replicated three times. Recommended doses of nitrogen, phosphorus and potassium (80:25:00 kg/ha) were applied through diammonium phosphate and urea as a basal and two split of nitrogen. The treatments were applied as seed priming, soil drenching and foliar spray at 30 and 50 days after sowing. Iron and zinc were applied through iron sulphate (heptahydrate) and zinc sulphate (heptahydrate) respectively, as per the treatments. All the standard recommended agronomic practices, except those in treatments, were followed to grow the rice crop. For priming, seeds were placed in distilled water (hydropriming), 0.5% Fe solution (Fe nutripriming), 0.5% Zn solution (Zn nutripriming) and 0.5% Fe plus 0.5% Zn solution (combination) with a 1:5 (w/v) seed to solution ratio. After the removal of seeds from the priming solution, they were thoroughly washed by using distilled water and dried in shade before sowing. Soil drenching was done by adding diluted solution directly on the rice sown lines of plots.

The Mahi Sagar cultivar of rice was sown on 21^{st}June, 2022 and harvested on 22^{nd}October, 2022. From each treatment plot five random plants were selected for non-destructive observations. And at the time of harvest these plants were taken for further analysis. The grains after threshing were weighed and recorded as grain yield per net plot. Further, this net plot grain yield was converted to grain yield per hectare. The experimental data was statistically analyzed by applying "Analysis of Variance" technique for randomized block design. Standard error of mean (SEm±) and Critical difference (CD) at 5% significance level were worked out for each observation as per the method suggested by Steel and Torrie (1982).

Table 1.Physical and chemical properties of experimental soil (0-15 cm)

Particulars	Value	Method	References
Sand (%)	69.66	International Pipette Method	Piper, 1966
Silt (%)	22.14		
Clay (%)	6.20		
Bulk density (Mg/m^3)	1.32	Core Sampler	
pH (1:2.5; Soil: Water)	7.82	Potentiometric method	Jackson, 1973
Electrical Conductivity(dS/m) (1:2.5, Soil : Water)	0.11	Conductivity method	
Organic carbon ($g\ kg^{-1}$)	0.38	Wet oxidation method	Walkley and Black, 1934
Available N (kg/ha)	240	Alkaline KMnO4 method	Subbiah and Asija, 1956
Available P_2O_5 (kg/ha)	38	Spectrophotometric method	Olsen *et al*., 1954
Available K_2O (kg/ha)	365	Flame Photometric method	Jackson, 1973
Available sulphur (mg/kg)	16.24	Turbidimetry Method	Williams and Steinberg, 1959
DTPA Extractable Fe (mg/kg)	7.20	0.005 M DTPA method (pH 7.3)	Lindsay and Norvell, 1978
DTPA Extractable Zn (mg/kg)	0.67		

2.1 Growth and Yield Parameters

2.1.1 Plant Height

Plant height was recorded at 25, 55 DAS and at harvest from the base of plant to the tip of the newly opened leaf from five previously tagged plants and the mean plant height was expressed in centimeters as per plant basis.

2.1.2 Number of Tillers/m^2 and Panicles/m^2

Number of tillers and panicles were counted from the plants which were falling under the sides of iron square having one square meter area and their mean value was recorded on plant basis in plots at the time of harvest.

Table 2. Treatment details

Tr.No.	Treatmentdetails
T_1	Control
T_2	Hydropriming
T_3	Nutripримingwith0.5%$FeSO_4.7H_2O$
T_4	Nutripримingwith0.5%$ZnSO_4.7H_2O$
T_5	Nutripримingwith0.5%$FeSO_4.7H_2O$+0.5% $ZnSO_4.7H_2O$

T_6	Foliarapplicationwith0.5%$FeSO_4.7H_2O$
T_7	Foliarapplicationwith0.5%$ZnSO_4.7H_2O$
T_8	Foliarapplicationwith0.5%$FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$
T_9	Soildrenchingwith 0.5%$FeSO_4.7H_2O$
T_{10}	Soildrenchingwith 0.5%$ZnSO_4.7H_2O$
T_{11}	Soil drenchingwith0.5%$FeSO_4.7H_2O$ +0.5%$ZnSO_4.7H_2O$
T_{12}	Nutripriming(0.5%$FeSO_4.7H_2O$ +0.5%$ZnSO_4.7H_2O$)+Foliarapplication (0.5%$FeSO_4.7H_2O$ +0.5%$ZnSO_4.7H_2O$)

3. Results and Discussion

3.1 Growth Parameters

Direct seeded rice is a highly responsive crop to the micronutrient's application. So, iron and zinc fertilization considerably influenced the growth and yield parameters of direct seeded rice.It is clearly evident from the data (Table. 3) that iron and zinc application increased plant height at all the growth stages of crop growth period. At 25 and 55 DASsignificantly higher plant height (31.50 and 77.30 cm, respectively) was observed with T_{12} which comprises nutripriming (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) and foliar application (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) than rest of the treatments. At 25 DAS the$T_{12}$was being at par with T_3, T_4 and T_5.The treatment T_{12} being on par with T_3, T_5, T_6, T_8 and T_{11}at 55 DAS in terms of plant height.And also, the lowest plant height was registered with control (T_1). The increase in plant height might be attributed to external application of nutrients in adequate amount and balanced proportion which resulted in increase in uptake, better crop establishment with higher root growth. Moreover, Fe and Zn accelerate the enzymatic activity in theplants and also helps in increasing in internodal length. Also, the nutripriming of seeds trigger the germination and further physiological processes and consequently higher plant height. The results are in close vicinity with the findings of Sudhakar *et al.* (2006), Khan *et al.* (2007), Humaira *et al.* (2015), Gill and Walia (2014) and Yadav *et al*. 2021.

3.2 Yield Attributes

In order to assess the yield and other ancillary observations, yield attributing characters like tillers/m^2 and panicles/m^2 were counted was influenced due to the application of iron and zinc fertilization. The data furnished in the Table. 3 revealed that there was a significant difference in number of panicle/m^2 among the treatments. However, changes in tillers/m^2 could not reach to the level of significance. The results revealed that significantly higher number of panicles/m^2 (428) were observed with T_{12} involving nutripriming (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) + foliar application (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) being at par with the treatments $T_5$and T_8.Further, the changes in the test weight were also recorded but could not reach to a level of significance. The highest thousand grain weight (19.19 g) was recorded with T_{12}.As nitrogen is the leading element for the emergence of tillers in plants which was applied common in all the plots and the effect of Fe and Zn is not much observed so the number of tillers/m^2 could not reach to a level of significance. While, the solo or combined application of Zn and Fe whether by nutripriming or foliar spray favored the positive effect on number of panicles/m^2. This might be due to the improved metabolic activity with the application of micronutrients that enhanced the floral primordia development in many tillers. The results were in accordance with the findings of Khanda and Dixit (1996), Jena *et al.* (2006) and Gill and Walia (2014) who reported that micronutrients favour higher production and conversion of vegetative tillers into reproductive tillers(panicles).

3.3 Grain and Straw Yield

Results revealed that iron and zinc fertilization strategies significantly increased grain and straw yield under direct seeded rice.Overall, the response was more evident in the treatment receiving both the strategies viz. nutripriming plus foliar spray of nutrients. Significantly highest grain yield (5163 kg/ha) was obtained in case of T_{12} which was at par with treatments T_5 and T_8. The lowest grain and straw yield were attributed in control (T_1). The increase in yield due to $T_{12}$was 26 per cent over control (Table. 3).This trend could be attributed to the yield parameters due to priming of seed which trigger the germination and helped in better nutrient uptake from soil which led to the higher photosynthates production and resulted higher grain yield. Earlier studies from Sarangi and Sharma (2004) and Ramana *et al.* (2006) reported similar results.
Similarly, the highest straw yield (6868 kg/ha) was also obtained in application of $T_{12}$and increase in straw yield was to the tune of about 22 per cent over control(Table**. 3)**.The lowest straw yield was obtained under control (T_1). The higher improvement in straw yield could be attributed to the yield parameters due to priming of seed which trigger the germination and helped in better nutrient uptake from soil which led to the higher vegetative growth and resulted in higher dry weight production. Moreover, external fertilization of micronutrients in DSR has shown better response due to availability of nutrients at most critical stages for nutrient requirements. So, combined application of Fe and Zn could only avert the possible deficiencies of these two trace elements and can result in prevention of yieldreduction due to the insufficient uptake by aerobic rice (Kumar *et al.* (1997) and Ramana *et al*. (2006)).

3.4 Nutrient concentration

Among the nutrient elements, nitrogen,sulphur, iron and zinc contentsin grain and strawas influenced by application of micronutrients were differed significantly whereas phosphorus and potassium content in grain and straw had not reached to the level of significantdifference (Table. 4).The higher content of N could be attributed to the balanced fertilization. The significantly higher N, S and Zn was found with application of involving nutripriming (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) + foliar application (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) in seed and straw of rice. The significantly higher Fe content in seed of rice was registered with nutripriming with 0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$ and in case of stover the higher Fe content was obtained with nutripriming (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) + foliar application (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$). The lowest nutrients content was obtained under control treatment. Application of NP along with micronutrients helped in better physiological growth of the plant and higher absorption of nitrogen from soil over solo application of NP. Moreover, increase in nitrogen uptake of rice grain and straw could also be due to easy transformation of urea into available nitrogen with addition of Zn (Kumar *et al*., 1999).**I**ncrease in S content was due to Fe and Zn carriers' sulphates in both the treatments viz. T_{12}, T_5 in comparison to rest of the treatments. In case of T_{12}, seed priming with S containing solution followed by foliar spray of sulphates (Fe and Zn sulphates) resulted in highest S availability and higher the absorption and content in grain and straw of direct seeded rice. The results are in close vicinity with the findings of Wei *et al*. (2012) and Bhanuvally*et al*. (2017).

Table 3. Growth, yield and yield attributesof direct seeded rice as influenced by iron and zinc application

Tr. no	Treatment Details	Yield (kg/ha)		Tillers/m^2	Panicles/m^2	Test weight (g)	Periodical plant height (cm)		
		Grain Yield	Straw yield				25 DAS	55 DAS	At harvest
T_1	Control	4088	5589	409	341	18.41	23.30	62.67	90.90
T_2	Hydropriming	4269	5783	416	367	18.48	27.07	67.77	91.00
T_3	Nutripriming with 0.5% $FeSO_4.7H_2O$	4652	6182	428	381	19.02	29.37	74.70	91.83
T_4	Nutripriming with 0.5% $ZnSO_4.7H_2O$	4629	6154	425	385	18.92	27.87	73.30	90.13
T_5	Nutripriming with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	4928	6667	437	415	19.10	30.13	77.07	93.83
T_6	Foliar application with 0.5% $FeSO_4.7H_2O$	4628	6164	419	378	18.83	26.43	69.03	91.07
T_7	Foliar application with 0.5% $ZnSO_4.7H_2O$	4621	6176	416	376	18.60	25.83	67.83	90.83
T_8	Foliar application with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	4815	6592	427	399	19.05	27.07	73.97	92.07
T_9	Soil Drenching with 0.5 $FeSO_4.7H_2O$	4591	6136	414	375	18.81	25.30	67.87	91.00
T_{10}	Soil Drenching with 0.5% $ZnSO_4.7H_2O$	4569	6161	412	370	18.78	24.47	66.20	91.10
T_{11}	Soil Drenching with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	4624	6184	418	386	18.89	26.47	68.80	91.77
T_{12}	Nutripriming (0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$) + Foliar application (0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$)	5163	6868	442	428	19.19	31.50	77.30	94.50
S.Em.±		171	227	20.34	14.15	1.07	1.38	2.98	5.12
C.D.(P=0.05)		**504**	**667**	**NS**	**41.61**	**NS**	**4.04**	**8.75**	**NS**

Table 4. Effect of micronutrient application on nutrients content of direct seeded rice

Tr. no	Treatment Details	Ncontent(%)		P content(%)		K content(%)		S content(%)		Fe content(mg/kg)		Zn content(mg/kg)	
		Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1	Control	1.35	0.69	0.21	0.18	0.78	1.21	0.013	0.029	171	362	23	27
T_2	Hydropriming	1.49	0.77	0.22	0.19	0.81	1.23	0.015	0.030	178	373	24	28
T_3	Nutripriming with 0.5% $FeSO_4.7H_2O$	1.74	0.89	0.26	0.22	0.85	1.30	0.024	0.036	204	421	28	32
T_4	Nutripriming with 0.5% $ZnSO_4.7H_2O$	1.69	0.86	0.25	0.21	0.83	1.29	0.023	0.037	184	396	32	35
T_5	Nutripriming with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	1.74	0.94	0.26	0.23	0.90	1.33	0.027	0.040	216	430	35	38
T_6	Foliar application with 0.5% $FeSO_4.7H_2O$	1.69	0.85	0.25	0.22	0.80	1.27	0.019	0.034	198	413	26	31
T_7	Foliar application with 0.5% $ZnSO_4.7H_2O$	1.65	0.84	0.24	0.21	0.82	1.26	0.020	0.034	186	393	31	33
T_8	Foliar application with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	1.71	0.88	0.26	0.23	0.88	1.31	0.023	0.037	207	422	34	35
T_9	Soil Drenching with 0.5 $FeSO_4.7H_2O$	1.61	0.84	0.24	0.21	0.82	1.27	0.017	0.032	195	398	25	29
T_{10}	Soil Drenching with 0.5% $ZnSO_4.7H_2O$	1.58	0.85	0.24	0.20	0.82	1.25	0.017	0.033	183	388	29	30
T_{11}	Soil Drenching with 0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$	1.68	0.86	0.25	0.22	0.83	1.27	0.020	0.035	198	409	30	32
T_{12}	Nutripriming (0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$)+Foliar application (0.5% $FeSO_4.7H_2O$ +0.5% $ZnSO_4.7H_2O$)	1.82	0.99	0.27	0.24	0.92	1.34	0.029	0.043	215	442	39	40
S.Em±		0.08	0.04	0.01	0.01	0.05	0.06	0.001	0.002	9.2	15.3	1.60	1.70
C.D.(P=0.05)		**0.23**	**0.12**	**NS**	**NS**	**NS**	**NS**	**0.004**	**0.005**	**27.0**	**44.9**	**4.80**	**4.90**

4. CONCLUSION

A field experiment was conducted to evaluate the effects of foliar application of $FeSO_4$ and $ZnSO_4$ on the growth, yield, and nutrient content of direct-seeded rice. The results showed that nutripriming (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$ for 12 hours before sowing) + Foliar application (0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$) at 30 and 55 days after sowing along with the recommended dose of fertilizers (80 N: 25 P_2O_5: 00 K_2O kg/ha), significantly improved all growth parameters, including plant height, panicles plant^{-1}, yield attributes, and yield. The foliar application and nutripriming with Fe and Zn also improve the macronutrient (N, P and S) and micronutrients (Fe and Zn) content in grain and straw of direct seeded rice.

ETHICAL APPROVAL

The corresponding author affirms that this research paper has not been submitted elsewhere.

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