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Effect of foliar application of zinc and iron on growth, yield and quality of rice (*Oryza sativa*) in acid soils of eastern Himalayan region

L K BAISHYA[1], DIBYENDU SARKAR[2], T JAMIR[3] and D J RAJKHOWA[4]

ICAR-Research Complex for NEH Region, Medziphema, Nagaland 797 106, India

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ABSTRACT

A field experiment was conducted at the Research farm of ICAR Research complex for North Eastern Hill Region (NEHR), Manipur Centre, Lamphelpat during *kharif* season of 2014, 2015 and 2016 to study the effect of Zn and Fe content on yield attributes, yield and quality of rice. The experiment was laid out in randomized block design with eight treatment combinations of different foliar dose of Zinc (Zn) and Iron (Fe). The result revealed that foliar application of 2% $ZnSO_4$ (0.5%) at tillering + 0.5% at stem elongation + 0. 5% at booting + 0.5% at grain filling) increased the yield of rice (36.34%) grain, Zn content (up to 48.17 ppm), enhanced the economics of rice production (Return/₹ invested 2.32), crop profitability up to ₹123.54 ha/day over the control (no foliar spray) and recorded better energy budget. On the other hand, foliar application of 1. 5% $FeSO_4$ (0.5% tillering+ 0.5% at booting + 0.5% at grain filling) also recorded increase in rice yield (26.56%), grain Fe content (up to 40.0 ppm), enhanced the economics of rice production (return/₹ invested 2.24), crop profitability up to ₹91.09 ha/day and recorded better energy budget.

Key words: Fe, Foliar application, Rice yield, Zn.

Deficiency of Zn and Fe in food grains is serious a global public health problem affecting more than two billion people and causing aloss of 63 million life-years annually (Myers *et al.* 2014). This is because cereals constitute about two-thirds of theenergy intake of humans particularly in developing countries arelow in Zn and Fe. Fortification of cereal grains with Zn and Fe will be an effective proposition in alleviating Zn and Fe deficiency. Rice (*Oryza sativa* L.) is one of the most important cereals for more than half of the world population andis an important source ofenergy, vitamins, mineral elements, and rare amino acids for people taking this as the staple food grain. Rice is also the most important food grain crop in the eastern Himalayan region of India. It occupies 3.5 million ha in the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, which accounts for more than 80% of the total cultivated area of the region (Baishya and Sarkar 2015). Micronutrient uptake and transport to the edible parts of crops can be enhanced by fertilizer application directly to leaf. Foliar application of micronutrients is, thus, one of the most effective and safest approaches to enrich those micronutrients in crop grain (Fang *et al.* 2008; Jin *et al.* 2008). Foliar-applied micronutrients can enter the leaf either by penetration of the cuticle or *via* stomatal pathway. Foliar fertilization has other advantages over soil application due to lower requirement and immediate crop response (Sarkar *et al.* 2007). Therefore, the present study was undertaken to find out the increase in yield, yield attributes, and quality of rice with foliar application of Zn and Fe in the acidic soil of eastern Himalayan region.

[1]Senior Scientist (lkbicar@gmani. com),[3]YP-II (NICRA) (temjennajamirchumu@gmail.com), [4]Joint Director (djrajkhowa@gmail.com), ICAR RC for NEH Region, Nagaland Centre, Nagaland; [2]Assistant Professor Soil Science (dsarkar04@rediffmail.com) BCKV, Mohanpur, West Bengal.

MATERIALS AND METHODS

The field experimentswere conducted at the Research Farm, ICAR Research complex for North Eastern Hill (NEH) Region, Manipur Centre, Lamphelpat during the *Kharif* seasons of 2014 and 2015. The experimental site is located at 24.49°N latitude and 93.55°E longitudes with an altitude of 760 m amsl. The soil of the experimental plot was sandy loam in texture, acidic in reaction (pH=5.2), low in available nitrogen (112 kg/ha) and available phosphorus (10 kg/ha), but high in available potassium (340 kg/ha). Available Zn (0.23 mg/kg) and Fe (72.6 mg/kg) content in the soil were, low and high respectively. The experiments were laid in randomized block design with different foliar sprays of both Zn and Fe in three replications.

The first experiment consisted of foliar spray of $ZnSO_4$at different critical growth stages of rice, viz. control (no micronutrient spray), 0.5% $ZnSO_4$ (at booting stage),1.0% $ZnSO_4$ (0.5% at booting + 0.5% at grain filling), 1.5% $ZnSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) and 2.0% $ZnSO_4$ (0.5% tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling). The second experiment was conducted with different foliar spray of $FeSO_4$at different critical growth stages of rice, viz. control (no foliar spray), 0.5% $FeSO_4$ (at booting stage), 1.0% $FeSO_4$ (0.5% at booting + 0.5% at grain filling), 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) and 2.0% $FeSO_4$ (0.5% tillering+ 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling)

The recommended doses of 60 kg N + 13.1 kg P + 25.0 kg K/ha, lime (200 kg/ha) and FYM (2.5 t/ha) were applied to all the treatment including the control. The N, P and K contents of FYM used in the experiment were 0.50%, 0.29% and 0.61% respectively. Lime was applied 15 days before planting. One-third of N in the form of urea, full dose of P as single super phosphate and half dose of K as marinate of potash was applied at transplanting. Remaining N was top-dressed in two equal splits—one at mid-tillering (30 days after transplanting-DAT) and the other at heading (55 DAT) and remaining half dose of K was applied at mid-tillering (30 DAT). The crop was sown during the second week of May during both the years. The crop received 1146.9 mm and 1345.2 mm of rainfall in 2014 and 2015, respectively. Temperature during the cropping season ranged from 17.10°C to 32.80°C in 2014 and 19.70°C to 29.40°C in 2015. The relative humidity varied from 64.60 to 91.0% in 2014 and 62.2 to 90.80% in 2015. Observations on growth attributes (plant height, root length, effective tillers/hill, root volume, tillering, crop growth rate and root weight/plant and root growth rate), yield components (length of panicle, number of spikelets/plant, number of filled grain, number of unfilled grain, grain test weight, grain yield and test weight) and crop productivity were recorded. Economics of different treatments were worked out by taking into account the cost of inputs and price of outputs prevailing in the local market. Crop profitability (₹/ha/day) was computed by dividing the net returns (₹/ha) with number of days field was occupied.

RESULTS AND DISCUSSION

Growth, yield attributes and yield of rice: Plant height, tillers number, crop growth rate and root volume of a plant depends on the genotype, environment as well as the plant nutrition. Crop growth rate of rice was found to be significantly influenced by foliar spray of Zn and Fe (Table 1). The highest crop growth rate was recorded with 2.0% of $ZnSO_4$ (0.5% at tillering+ 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling) (0.60 ± 0.01) followed by 1.5% of $ZnSO_4$ (0.5% at tillering + 0.5% at booting + 0.5% at grain filling) and 1.5% $FeSo_4$ (0.5% at tillering + 0.5% at booting + 0.5% at grain filling).

Panicle length, number of spikelet/plant, number of filled grains/panicle, number of unfilled grains/panicle and grain test weight varied significantly due to foliar sprays of Zn and Fe at different growth stages (Table 2). The spraying of different doses of Zn and Fe produced the higher number of panicles/plant in both the years over the control. Among different levels of $ZnSO_4$, 2% of $ZnSO_4$ (0.5% at tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling) recorded the highest panicle length (20.95 ± 0.78 cm), number of spikelet (10.22 ± 0.06), filled grains/panicle (246.00 ± 47.34), grain test weight (30.10 ± 0.17 g) and lower numberof unfilled grains (8.50 ± 0.29), which was closely followed by foliar application of 1.5% of $ZnSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) and significantly superior over control. On the other hand, among different foliar application of $FeSO_4$, 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) recorded the higher number of panicle length (20.68±0.78 cm), number of spikelet (9.00 ±0.01), number of filled grains/panicle (238.00± 45.80), grain test weight (28.50 ± 1.44 g) and lower numberof unfilled grains (12.87 ± 0.93), which were found to be superior over the control (Table 2)

Table 1 Effect of micronutrient spray on growth and yield attributes of upland rice (3 year mean)

Treatment	Plant height (cm)	Root length (cm)	Number of effective tillers/hill	Crop growth rate (g/plant/day)	Root growth rate (g/plant/day)
Control	55.80	3.53	3.83	0.20	0.26
0. 5% $ZnSO_4$ (BT)	56.85	3.63	4.75	0.22	0.27
1. 0% $ZnSO_4$ (BT +GF)	58.09	3.67	4.50	0.29	0.33
1. 5% $ZnSO_4$ (Til + BT + GF)	58.21	3.86	4.92	0.47	0.46
2. 0% $ZnSO_4$ (Til +St E + BT + GF)	59.34	3.30	5.67	0.50	0.47
0. 5% $FeSO_4$(BT)	52.31	3.09	3.83	0.25	0.26
1. 0% $FeSO_4$ (BT+GF)	54.99	3.17	3.67	0.30	0.29
1. 5% $FeSO_4$ (Til+BT+BF)	58.04	4.14	3.83	0.31	0.32
2. 0% $FeSO_4$ (Til +St E + BT + GF)	56.67	3.54	4.09	0.29	0.31
SE(m)±	1.14	0.49	0.63	0.01	0.09
CD (P=0. 05)	NS	NS	NS	0.21	NS

Til= Tillering stage, St E = Stem elongation stage, BT= Booting stage, GF = Grain filling stage, CGR= crop growth rate, RGR= Root growth rate

Table 2 Effect of micronutrient spray on yield attributes and yield of aerobic rice (3 year mean)

Treatment	Panicle length (cm)	No. of spikelets	No. of filled grains/panicle	No. of unfilled grains/panicle	Grain test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
Control	14.83	6.85	167.60	35.62	15.50	1950	2980
0.5% $ZnSO_4$ (BT)	18.47	7.22	210.00	20.62	24.50	2140	3058
1.0% $ZnSO_4$ (BT +GF)	19.10	9.00	211.00	18.50	26.20	2240	2956
1.5% $ZnSO_4$ (Til + BT + GF)	20.72	9.44	240.00	14.12	28.50	2430.	3442.
2.0% $ZnSO_4$ (Til +St E + BT + GF)	20.95	10.22	246.00	8.50	30.10	2650	3520
0.5% $FeSO_4$(BT)	18.67	7.61	187.00	19.37	24.10	2040	3058
1.0% $FeSO_4$ (BT+GF)	20.574	8.78	225.00	22.12	26.30	2290	3324
1.5% $FeSO_4$(Til+BT+BF)	20.68	9.00	238.00	12.87	28.50	2470	3455
2.0% $FeSO_4$ (Til +St E + BT + GF)	19.35	7.67	185.00	15.50	25.75	2250	3259
SE(m)±	0.72	0.08	4.93	1.56	3.33	5.30	5.86
CD (P=0.05)	2.17	0.25	15.09	4.77	NS	16.22	17.95

Til= Tillering stage, St E = Stem elongation stage, BT= Booting stage, GF = Grain filling stage, CGR= crop growth rate, RGR= Root growth rate

in the both years. The foliar application of micronutrients particularly Zn and Fe in small amounts had significant positive effect on plant height, 1000 grain weight, grain yield and harvest index of rice was also reported by Shaygany *et al.* (2012).

The yield of rice is mainly a function of the number of panicles bearing tillers per unit area, panicle length, and number of filled grain. Foliar spray of Zn and Fe at different growth stages of rice significantly increased the grain and straw yield over the control (Table 2). The result reveals that among all the treatment, 2% of $ZnSO_4$(0.5% attillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling) as foliar spray recorded the highest yield of rice grain (2,458.75 ± 67.59 kg/ha) and straw (3,520.78 ± 96.79 kg/ha), which was followed by spraying of 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) and 1. 5% of $ZnSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling). Fang *et al.* (2008) reported the effects of a foliar application of Zn and Fe fertilizers on nutrient concentration and yield of rice grainoever the control (no Zn and Fe application) without any improving growth parameters of rice. Faranak *et al.* (2014) also showed that foliar application Zn, Fe and Cu significantly increased rice yield and yield attributes. This is in conformity with the findings of Suresh and Salakinkop (2016) as photosynthetic pathways depends on enzymes and coenzymes which are synthesized by micronutrients. Zn and Fe are essential for several enzymes that regulate metabolic activities in plants. They involve in auxin production, transformation of carbohydrate and regulation of sugar in plants. Increase in growth attributes was mainly due to Zn and Fe application which are involved in the synthesis of growth promoting hormones and the reproduction process of many plants which are vital for grain formation on the other hand, Zinc is specifically required for development of reproductive organs, pollen fertility and seed formation of maize and mustard (Sharma *et al.* 1990).

Nutrient contents: Spraying of different doses of micronutrients (Zn and Fe) at the critical growth stages of rice had positive effect on the content of N, P_2O_5, K_2O, Zn and Fe in both grain and straw over the control (Table 3). The results reveal that foliar application of Zn and Fe significantly increased the N and K_2O content in rice grain and P_2O_5 content in rice straw. The highest Zn content in rice grain (52.32 ± 3.56 mg/kg) and straw (48.17 ± 0.33 mg/kg) were recorded with the foliar application of 2.0% $ZnSO_4$ (0.5% at tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling) which was closely followed by application of 1.5% $ZnSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling). On the other hand, the foliar application of 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) recorded the highestFe content in rice grain (40.00 ± 1.46 mg/kg) and straw (53.27 ± 3.07 mg/kg) which was closely followed by application of 2.0% $FeSO_4$ (0.5% at tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling). These indicated superiority of both Zn and Fe spray at 2.0 and 1.5% over the lower doses in increasing Zn and Fe content of rice grain and straw. The density of several micronutrients in rice grain can effectively be enhanced by application of appropriate mineral forms (Shaygany *et al.* 2012). On the other hand, foliar fertilization has many advantages over soil application due to lower requirement and immediate crop response. These results are in conformity with the findings of Ram *et al.* (2015).

Economics: Among the different foliar applications of Zn, 2.0% $ZnSO_4$ (0.5% at tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling) recorded higher

Table 3 Effect of micronutrient spray on N, P_2O_5, K_2O, Zn and Fe content in rice grain and straw (3 year mean)

Treatment	Grain					Straw				
	N (%)	P_2O_5 (%)	K_2O (%)	Zn (mg/kg)	Fe (mg/kg)	N (%)	P_2O_5 (%)	K_2O (%)	Zn (mg/kg)	Fe (mg/kg)
Control	1.22	0.17	0.23	18.41	16.44	0.78	0.68	1.20	22.43	16.10
0.5% $ZnSO_4$ (BT)	1.40	0.17	0.27	33.00	24.35	0.95	0.86	1.26	33.85	18.32
1.0% $ZnSO_4$ (BT + GF)	1.42	0.18	0.24	38.77	29.92	0.99	1.06	1.77	44.72	20.60
1.5% $ZnSO_4$ (Til + BT + GF)	1.43	0.19	0.28	47.20	25.40	1.02	1.08	1.77	46.35	21.72
2.0% $ZnSO_4$ (Til + St E + BT + GF)	1.46	0.19	0.27	52.32	27.95	1.03	1.38	1.45	48.17	24.35
0.5% $FeSO_4$ (BT)	1.30	0.17	0.30	19.27	28.85	0.95	0.86	1.56	18.40	35.55
1.0% $FeSO_4$ (BT + GF)	1.34	0.17	0.30	18.05	37.35	1.01	1.00	1.58	20.62	38.35
1.5% $FeSO_4$ (Til + BT + BF)	1.42	0.18	0.21	21.87	40.00	1.12	0.91	1.20	25.12	53.27
2.0% $FeSO_4$ (Til + St E + BT + GF)	1.32	0.17	0.26	20.42	39.00	1.04	1.26	1.50	22.67	51.25
SE(m)±	0.05	0.01	0.01	1.71	0.36	0.07	0.09	0.17	3.62	0.80
$CD_{(0.05)}$	0.17	NS	0.03	5.25	1.10	N/A	0.27	N/A	11.10	2.45

Til= Tillering stage, St E = Stem elongation stage, BT= Booting stage, GF = Grain filling stage, CGR= crop growth rate, RGR= Root growth rate

net return (₹32.62 × 10^3), return per rupees invested (2.32) and crop profitability (₹478.11/ha/day) than the control or other foliar spray of Zn or Fe (Table 4). On the other hand, foliar application of 1.5% $FeSO_4$(0.5% tillering+ 0.5% at booting + 0.5% at grain filling) recorded higher net return (₹29.57× 10^3), return per rupees invested (2.24) and crop

Table 4 Effect of micronutrient spray on economics and energy budget of rice production system (mean of 3 years)

Treatments	Cost of cultivation (×10^3/ha)	Gross return (×10^3/ ha)	Net return (×10^3/ ha)	Return per rupee invested	Crop Profitability (/ha/day)	Input energy (× 10^3 MJ/ha)	Output energy (x10^3 MJ/ha)	Net Energy (MJ/ha) (×10^3 MJ/ha)	Energy use efficiency	Specific Energy (MJ/kg)	Energy productivity (g/MJ)
Control	22.47	42.57	20.10	1.89	354.80	9.71	65.91	56.20	6.79	4.98	200.81
0.5% $ZnSO_4$ (BT)	23.99	46.44	22.45	1.94	387.04	9.80	69.66	59.85	7.10	4.59	218.04
1.0% $ZnSO_4$ (BT + GF)	24.25	48.32	24.06	1.99	402.69	9.90	69.86	59.95	7.05	4.42	225.97
1.5% $ZnSO_4$ (Til + BT + GF)	24.51	52.69	28.17	2.15	439.11	10.00	78.72	68.71	7.87	4.12	242.67
2.0% $ZnSO_4$ (Til + St E + BT + GF)	24.77	57.40	32.62	2.32	478.33	10.10	83.09	72.98	8.22	3.80	263.13
0.5% $FeSO_4$ (BT)	23.79	44.44	20.64	1.87	370.37	9.80	68.19	58.38	6.95	4.81	207.84
1.0% $FeSO_4$ (BT + GF)	23.86	49.83	25.97	2.09	415.32	9.90	75.25	65.34	7.59	4.32	231.39
1.5% $FeSO_4$ (Til + BT + BF)	23.93	53.50	29.57	2.24	445.89	10.00	79.47	69.46	7.94	4.05	246.66
2.0% $FeSO_4$ (Til + St E + BT + GF)	24.00	48.87	24.86	2.04	407.23	10.10	73.78	63.68	7.30	4.49	222.47

Til= Tillering stage, St E = Stem elongation stage, BT= Booting stage, GF = Grain filling stage, CGR= crop growth rate, RGR= Root growth rate profitability (₹ 445.32) over the different foliar spraying practices of Fe.

Energy Budget: The energy budget for different foliar application on micronutrient were also studied (Table 4) and the result reveals that the highest net energy output (72.98 $\times 10^3$ MJ/ha), energy efficiency (8.22), energy productivity (263.13 g/MJ) and lower specific energy (3.80 MJ/kg) were recorded with foliar application of 2.0% $ZnSO_4$ (0.5% at tillering + 0.5% at stem elongation + 0.5% at booting + 0.5% at grain filling), which was closely followed by foliar application of 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling).

From the above study it can be concluded that foliar application of Zn increased rice yield (36.34%), grain Zn content (up to 48.17 ppm), enhanced the economics of rice production, gave better B:C ratio, ICBR profitability upto ₹123.54/ha/day over the control (no foliar spray) and recorded better energy budget. However, foliar application of 1.5% $FeSO_4$ (0.5% tillering + 0.5% at booting + 0.5% at grain filling) also recorded increase in rice yield (26.56%), grain Fe content (upto 40.0 ppm), enhanced the economics of rice production (return/₹ invested 2.24), crop profitability up to ₹91.09/ha/day and recorded better energy budget. The above mentioned practices may be recommended for enhancing productivity and quality of rice in acidic soils of eastern Himalayan region with special reference to Zn & Fe.

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