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Effect of soil application of Fe and Zn on nutrient content and uptake by two rice varieties

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Abstract
An investigation entitled "Effect of soil application of Fe and Zn on nutrient content and uptake by two rice varieties" was carried out during *kharif*, 2014 at Department of Natural Resources Management, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The present pot trial consisting of 20 treatment combinations involving two varieties (V_1: GNR-4, V_2: IET-23833) and ten micronutrient levels (M_0:- Control, M_1:- 2.50 mg Fe kg^{-1}, M_2:- 5.00 mg Fe kg+, M_3:- 7.50 mg Fe kg^{-1}, M_4:- 10.00 mg Fe kg^{-1}, M_5:- 1.25 mg Zn kg^{-1}, M_6:- 2.50 mg Zn kg^{-1}, M_7:- 3.75 mg Zn kg^{-1}, M_8:- 5.00 mg Zn kg^{-1}, M_9:- Grade 5 @ 12.0 mg kg^{-1}) was conducted in FCRD with three repetitions. The experimental results revealed that variety V_2 recorded significantly higher content of Ca (0.211%), Fe (136.5 mg kg^{-1}), Mn (22.5 mg kg^{-1}) and Zn (78.2 mg kg^{-1}) in grains as compared to variety V_1 with an exception of P (0.18%) which was significantly higher in V_1. In case of straw portion also, significantly more content of P, Ca, Zn and Cu was recorded in variety V_2 than V_1, but it was not true for Mg, Fe and Mn content. As far as micronutrient levels are concerned, application of either Fe (M_1 to M_4) or Zn (M_5 to M_8) significantly increased the N, P, Fe and Zn content in all parts (grain, straw and root) of rice as compared to control. With respect to nutrient uptake, significantly higher uptake of N, P, K, Ca, Mg, Fe, Mn and Cu by grain and straw was registered in variety V_1, while variety V_2 registered significantly higher uptake of Zn by both grain and straw of rice. Further, most of the treatments receiving Fe and Zn, removed significantly higher amount of all the determined nutrients from soil, as indicated in higher content in grain and straw of rice as compared to control.

Keywords: effect of soil, micronutrient, *Kharif*, Rice variety, content and uptake

1. Introduction

Micronutrient deficiencies are becoming increasingly common in agriculture as a result of higher levels of removal by ever-more-productive crops combined with breeding for higher yields, at the expense of micronutrient acquisition efficiency (Havlin *et al.*, 2014) [5]. Increasing evidences indicate that food grown by applying adequate NPK fertilizers on soils with low levels of trace elements not only reduce the crop yield but, may also provide insufficient human dietary levels of certain elements, even though the crop plants themselves show no signs of micronutrient deficiency (Karak *et al.*, 2006) [6]. For, all these reasons, increasing attention is directed towards management of micronutrients in the soils.

Among the micronutrients, though, Fe is the second most abundant metal in nature and fourth most abundant element in the earth's crust; about 11.0 per cent Indian soils are deficient in supply of Fe (Ram *et al.*, 2013) [10]. In the case of Gujarat, most of the cultivated soils have been reported to be deficient in Fe and Zn. With respect to plant growth, Fe is the third most limiting nutrient for plant growth primarily due to the low solubility of the oxidized ferric form (Fe^{3+}) in aerobic environment (Yi *et al.*, 1994) [17]. The oxidized Fe^{3+} has a very low solubility at basic pH and high bicarbonate concentration resulting in limited uptake by plant roots because it cannot be absorbed by root cells (Yadav *et al.*, 2013) [16]. The Fe is essential for chlorophyll formation, though it is not a constituent of chlorophyll. It is also essential for respiration, photosynthesis and fixation of atmospheric nitrogen by nitrogen fixing organisms. Iron deficiency is a common nutritional disorder in many crop plants, causing interveinal chlorosis, poor yield and reduced nutritional quality. Besides Fe, Zn is another most important micronutrient essential for plant growth and now it is recognized as the fifth leading risk factor in developing Asian Countries. Zinc deficiency is prevalent worldwide in temperate and tropical climates. Nearly, 47 per cent of Indian soils are deficient in Zn element (Veeranagappa *et al.*, 2010) [15]. Moreover, among the cultivable soils of Gujarat, 24 per cent are Zn deficient.

It is a major component and activator of several enzymes involved in metabolic activities. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country. Zinc deficiency in rice is characterized by brown spots, which appear first on the younger leaves and later in the lower leaves. In case of severe deficiency, burnt dark brown patches of plants appear in rice fields. The availability of Zn to growing plant is governed predominantly by Zn mineral solubility, soil reaction, SOM and Zn adsorbed on exchange complexes of soils. Therefore, the Fe and Zn deficiency is one of the most frequently encountered micronutrient deficiencies besides hidden hungers of other micronutrients in different crops grown across the India.

Micronutrient malnutrition has been designated as the most serious challenge to humanity as two-third of the world's population especially; women and children are at the risk of deficiency in one or more essential mineral elements (Sakal *et al.,* 2001) [12]. Among the essential minerals, Fe and Zn deficiency in human being is a serious threat not only to the health of individuals but also to the economy of developing nations. It is evident that out of the total world's population, 5.0 billion are suffering from iron and 2.7 billion are suffering from Zn deficiency. In India alone, 74 per cent children under three years of age, 43 per cent preschool children, 90 per cent adolescent girls and 50 per cent women are having clinical Fe deficiency (Sahay *et al.,* 1993) [11]. Various physiological diseases, such as anemia and some neurodegenerative diseases are triggered by Fe deficiency. Similarly, only in India, 27.0 per cent of total population is affected by Zn deficiency related disorders such as poor immune system, diarrhea, poor physical and mental growth (Ram *et al.,* 2013) [10]. Zinc deficiency alone claims about 4.4 per cent of the total child deaths in the world whereas anemia is the major reason of post natal death of mothers as well as infants (Chandel *et al.,* 2010). Human health problems caused by Fe and Zn deficiency can be reduced by improving nutritional quality of dietary foods especially rice crops because it is a most important staple food crop in world as well as in India (Veeranagappa *et al.,* 2010) [15].

In micronutrient fertilizer trials conducted on 5,800 fields in India, it has been found that in the 63 per cent of the trials crops responded to micronutrient fertilization with yield increase (Singh, 2007) [13] and efforts are underway for encouraging Fe and Zn fertilization in the view point of getting higher rice yields.

In present investigation, rice variety, GNR-4 was selected which is a bio-fortified fine grain rice variety developed from a cross NAUR-1 x Lal Kada (Anon., 2014). It is a dwarf statured, fine grained culture possessing red colour kernel. Another variety of rice i.e., RP BIO 5477-NH 787 (IET-23833) has a higher micronutrient absorption potential (Babu *et al.,* 2014) [3]. However, the information related to response of these varieties grown on deficient to medium Fe and Zn available soils to applied Fe and Zn nutrients under condition is scanty. Therefore, an experiment was conducted to study the effect of soil application of Fe and Zn on yield of two rice varieties with the objectives on effect of soil application of Fe and Zn on growth and yield of rice varieties.

2. Materials and Methods

For achieving the objective of present investigation, a pot experiment entitled, "Effect of soil application of Fe and Zn on nutrient content and uptake by two rice varieties" was carried out during *kharif* season of 2014. The experiment was conducted in the Poly House of Department of Natural Resources Management, ASPEE College of Horticulture & Forestry, NAU, Navsari. The experiment consists of two varieties of Rice i.e. GNR-4 and RP BIO 5477-NH 787 (IET-23833) and nine level of micronutrients i.e. Fe @ 2.50 mg kg^{-1}, Fe @ 5.00 mg kg^{-1}, Fe @ 7.50 mg kg^{-1}, Fe @ 10.0 mg kg^{-1}, Zn @ 1.25 mg kg^{-1}, Zn @ 2.50 mg kg^{-1}, Zn @ 3.75 mg kg^{-1}, Zn @ 5.00 mg kg^{-1}, Micronutrient fertilizer Grade 5 @ 12.0 mg kg^{-1}. For conducting the pot experiment, the soil from surface layer (0-15 cm) was collected, after collecting the required quantity of bulk fill up the earthen pot and plastic bags (for inside lining of the pots) of ten kg capacity having around 20 and 40 cm diameter and height, respectively, it was air dried and fairly ground to pass through 2.0 mm sieve with wooden mortar and pestle and mixed thoroughly to homogenize the bulk of soil. In each pot, treatment wise four healthy seedlings (24 days) of rice were planted, after successful establishment of seedlings, thinning was done by keeping two healthy seedlings in each pot. The recommended dose of N, P and K @ 100-30-00 mg kg^{-1} to rice crop under pot trial was applied through ammonium sulfate and single super phosphate, respectively. The nutrient content and uptake by paddy was recorded after harvesting. Whole biomass of rice grain and straw from each repetition were sampled separately for recording dry biomass and analyzing nutrient content viz., N, P, K, Ca, Mg, Fe, Mn, Zn and Cu from each portion. The collected samples were washed with distilled water and dried in oven at 65 ^{o}C till constant weight achieved and dry weight of each sample was done. Subsequently, the dried samples were powdered using willey mill and stored in clean polythene zip-bags for chemical analysis. All the data recorded during the study period were statistically analyzed by using standard methods as suggested by Panse and Sukhatme (1967) [8].

3. Result and Discussion

3.1 Nutrient Content

The effect of different micronutrient levels on performance of two varieties of rice was tested under pot trial. With respect to nutrient content, Variety V_2 recorded significantly higher content of Ca, Fe, Mn and Zn in grain as compared to variety V_1. In case of straw portion, significantly more amounts of P, Ca, Zn and Cu were also recorded in variety V_2 than V_1. But reverse was true for Mg, Fe and Mn contents in straw. However, N and K content in all the portions of rice plant did not differ significantly due to genotypes except N content in root. With respect to nutritional quality especially Fe and Zn, grains of variety V_2 recoded significantly higher content of Fe (136.5 mg kg^{-1}) as compared V_1 (113.7 mg kg^{-1}), while reverse trend was true for Fe content in straw. Similarly, variety V_2 recorded the Zn content of 78.2 and 115.1 mg kg^{-1} in grain and straw of rice, respectively, was also recorded with, which was significantly more than V_1. Application of either Fe (M_1 to M_4) or Zn (M_5 to M_8) significantly increased N, P, Fe and Zn content in grain and straw of rice as compared to control. However, the micronutrients were not affected significantly the content of K content in grain and straw of rice plant. Though, higher levels of Fe (M_5) and Zn (M_8) application reduced the P content numerically in grain and straw of rice in comparison to their lower level, yet the differences did not reach to a level of significance. Iron content in grain and straw was increased remarkably as the rate of Fe (M_1 to M_4) or Zn (M_5 to M_8) application increased and it was found to be significantly higher with the treatment of M_4 than the M_0 and M_1. It is also evident from the results that Zn content in grain was statistically higher in all Fe fertilized treatments (M_1 to M_4) than the control. Significantly higher content of Zn of 84.0 and 111.8 Zn kg^{-1} in grain and straw, respectively, was recorded with higher level of Zn application (M_8) than control, but it remained at par with M_7 in case of straw only. An application of micronutrient grade 5 also recorded significantly higher Zn content (59.5 mg Zn kg^{-1}) in grains of rice only in comparison to control (43.0 mg Zn kg^{-1}). Most of the treatments receiving Fe and Zn removed significantly higher amount of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu nutrients through grain and straw of rice as compared to control. Nevertheless, the differences were not significant in case of Ca, Mg and Mn uptake by grains of rice.

3.2 Uptake

In case of nutrient uptake, significantly higher uptake of N, P, K, Ca, Mg, Fe, Mn and Cu through grain and straw of rice was registered in variety V_1 as compared to V_2 with an exception of P uptake by straw. While, reverse was true for Zn uptake. Here, variety V_2 registered significantly higher uptake of Zn by both grain and straw of rice and P uptake by straw only than V_1. In rice grain, significantly higher uptake of N and K was recorded in treatment M_3, while in straw, treatment M_7 removed significantly higher amount of N and K as compared to control. Of course, treatments receiving Fe and Zn were found to be statistically similar in majority of the cases. Whereas, in case of P uptake, lower rate of Fe (M_1 and M_2) and Zn (M_5 and M_6) application recorded significantly more uptake of P. However, their application at higher level significantly reduced the P uptake by both grain and straw portion of rice. The uptake pattern of Ca, Mg, Mn and Cu under different treatments was similar as was observed in case of P uptake by rice.

Table 1: Effect of different treatments on primary and secondary nutrients content (%) in different parts of rice plant

Treatments	N		P		K		Ca		Mg	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Varieties										
V_1:- GNR-4	1.92	1.25	0.18	0.08	0.24	1.26	0.200	0.702	0.072	0.256
V_2 :- IET-23833	1.94	1.23	0.16	0.15	0.23	1.24	0.211	0.743	0.073	0.197
S. Em. ±	0.014	0.017	0.003	0.002	0.004	0.018	0.002	0.006	0.001	0.003
C. D. @ 5 %	NS	NS	0.008	0.005	NS	NS	0.006	0.018	NS	0.009
Micronutrient levels										
M_0 :- Control	1.84	1.15	0.14	0.11	0.22	1.17	0.208	0.691	0.071	0.211
M_1 :- 2.50 mg Fe kg^{-1}	1.93	1.20	0.16	0.12	0.23	1.22	0.205	0.710	0.074	0.216
M_2 :- 5.00 mg Fe kg^{-1}	1.99	1.23	0.19	0.13	0.23	1.25	0.207	0.720	0.075	0.211
M_3 :- 7.50 mg Fe kg^{-1}	2.02	1.24	0.17	0.12	0.24	1.26	0.202	0.730	0.071	0.219
M_4 :- 10.0 mg Fe kg^{-1}	1.96	1.23	0.16	0.11	0.22	1.18	0.198	0.752	0.070	0.228
M_5 :- 1.25 mg Zn kg^{-1}	1.91	1.20	0.19	0.11	0.24	1.29	0.204	0.713	0.073	0.222
M_6 :- 2.50 mg Zn kg^{-1}	1.97	1.25	0.19	0.12	0.24	1.30	0.204	0.738	0.073	0.257
M_7 :- 3.75 mg Zn kg^{-1}	1.92	1.30	0.19	0.14	0.25	1.31	0.205	0.731	0.070	0.243
M_8 :- 5.00 mg Zn kg^{-1}	1.89	1.29	0.18	0.10	0.25	1.30	0.212	0.721	0.074	0.229
M_9 :- G 5 @ 12.0 mg kg^{-1}	1.90	1.31	0.16	0.11	0.23	1.24	0.210	0.718	0.071	0.231
S. Em. ±	0.032	0.038	0.006	0.004	0.008	0.041	0.005	0.014	0.002	0.007
C. D. @ 5 %	0.091	NS	0.018	0.011	NS	NS	NS	NS	NS	0.021
Interaction effect (V × M)										
S. Em. ±	0.045	0.053	0.009	0.005	0.012	0.057	0.007	0.020	0.003	0.010
C. D. @ 5 %	NS	NS	0.025	NS	NS	NS	0.019	NS	NS	NS
C. V. (%)	4.0	7.4	8.8	8.0	8.5	7.9	5.5	4.8	7.2	7.9

Table 2: Effect of different treatments on micronutrients content (mg kg^{-1}) in different parts of rice plant

Treatments	Fe		Mn		Zn		Cu	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Varieties								
V_1:- GNR-4	113.7	223.2	17.8	705.8	38.1	66.5	15.6	23.3
V_2 :- IET-23833	136.5	205.9	22.5	662.4	78.2	115.1	15.5	27.8
S. Em. ±	1.61	2.67	0.19	6.11	0.68	1.31	0.15	0.23
C. D. @ 5 %	4.61	7.63	0.55	17.47	1.94	3.73	NS	0.65
Micronutrient levels								
M_0 :- Control	99.0	189.2	21.0	716.4	43.0	77.7	17.0	27.4
M_1 :- 2.50 mg Fe kg^{-1}	111.2	211.3	20.8	709.0	47.4	82.3	15.9	27.5
M_2 :- 5.00 mg Fe kg^{-1}	138.0	219.8	19.7	694.1	51.5	84.3	15.0	25.7
M_3 :- 7.50 mg Fe kg^{-1}	147.6	239.8	19.1	662.8	53.5	86.2	14.3	24.7
M_4 :- 10.0 mg Fe kg^{-1}	147.2	248.3	18.3	625.5	53.4	80.5	13.7	23.0
M_5 :- 1.25 mg Zn kg^{-1}	111.5	202.5	21.6	716.5	52.1	91.3	16.5	27.0
M_6 :- 2.50 mg Zn kg^{-1}	119.6	207.3	20.7	700.9	64.0	101.2	16.2	25.7
M_7 :- 3.75 mg Zn kg^{-1}	125.0	211.0	19.7	671.9	72.9	107.7	15.9	24.8
M_8 :- 5.00 mg Zn kg^{-1}	129.0	207.4	19.6	633.5	84.0	111.8	14.8	22.8
M_9 :- Grade 5 @ 12.0 mg kg^{-1}	122.9	208.9	21.2	710.0	59.5	84.6	16.3	26.8
S. Em. ±	3.61	5.97	0.43	13.87	1.52	2.92	0.33	0.51
C. D. @ 5 %	10.31	17.07	1.23	39.07	4.35	8.34	0.94	1.44
Interaction effect (V × M)								
S. Em. ±	5.10	8.44	0.61	19.33	2.15	4.13	0.47	0.71
C. D. @ 5 %	NS	NS	NS	NS	6.16	NS	NS	NS
C. V. (%)	7.1	6.8	5.2	4.9	6.42	7.8	5.2	4.8

Table 3: Effect of different treatments on primary and secondary nutrients uptake (g pot^{-1}) by different parts of rice plant

Treatments	N		P		K		Ca		Mg	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Varieties										
V_1:- GNR-4	1.618	1.102	0.154	0.071	0.201	1.113	0.167	0.621	0.060	0.226
V_2 :- IET-23833	1.068	0.822	0.088	0.100	0.128	0.828	0.116	0.480	0.040	0.131
S. Em. ±	0.015	0.016	0.002	0.001	0.003	0.015	0.002	0.006	0.001	0.003
C. D. @ 5 %	0.044	0.044	0.006	0.004	0.008	0.042	0.005	0.017	0.002	0.007
Micronutrient levels										
M_0 :- Control	1.175	0.839	0.092	0.075	0.144	0.857	0.133	0.499	0.045	0.157
M_1 :- 2.50 mg Fe kg^{-1}	1.333	0.918	0.108	0.093	0.161	0.937	0.138	0.536	0.051	0.169
M_2 :- 5.00 mg Fe kg^{-1}	1.437	0.982	0.133	0.101	0.169	1.001	0.148	0.567	0.054	0.172
M_3 :- 7.50 mg Fe kg^{-1}	1.479	0.990	0.121	0.092	0.178	1.019	0.149	0.572	0.053	0.180
M_4 :- 10.0 mg Fe kg^{-1}	1.387	0.955	0.110	0.077	0.159	0.914	0.139	0.574	0.050	0.180
M_5 :- 1.25 mg Zn kg^{-1}	1.328	0.919	0.139	0.083	0.169	0.982	0.141	0.537	0.052	0.173
M_6 :- 2.50 mg Zn kg^{-1}	1.400	0.989	0.136	0.092	0.171	1.017	0.144	0.578	0.052	0.207
M_7 :- 3.75 mg Zn kg^{-1}	1.360	1.033	0.137	0.090	0.173	1.030	0.141	0.572	0.049	0.196
M_8 :- 5.00 mg Zn kg^{-1}	1.259	0.998	0.125	0.077	0.165	1.007	0.141	0.538	0.049	0.179
M_9 :- Grade 5 @ 12.0 mg kg^{-1}	1.273	0.995	0.107	0.076	0.153	0.943	0.141	0.534	0.048	0.178
S. Em. ±	0.034	0.035	0.005	0.003	0.006	0.033	0.004	0.014	0.002	0.006
C. D. @ 5 %	0.098	0.099	0.014	0.008	0.017	0.093	NS	0.039	NS	0.016
Interaction effect (V × M)										
S. Em. ±	0.049	0.049	0.007	0.004	0.008	0.046	0.006	0.019	0.003	0.008
C. D. @ 5 %	NS	NS	0.019	NS	NS	NS	NS	NS	NS	NS
C. V. (%)	6.3	8.9	9.8	9.0	8.9	8.2	6.5	6.1	9.0	7.9

Table 4: Effect of different treatments on micronutrients uptake (mg pot^{-1}) by different parts of rice plant

Treatments	Fe		Mn		Zn		Cu	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Varieties								
V_1:- GNR-4	9.60	19.77	1.49	62.38	3.20	5.88	1.31	2.06
V_2 :- IET-23833	7.54	13.75	1.24	44.15	4.31	7.69	0.85	1.85
S. Em. ±	0.13	0.26	0.02	0.64	0.06	0.12	0.01	0.02
C. D. @ 5 %	0.38	0.74	0.05	1.84	0.17	0.34	0.04	0.07
Micronutrient levels								
M_0 :- Control	6.25	13.96	1.31	52.77	2.52	5.51	1.10	1.98
M_1 :- 2.50 mg Fe kg^{-1}	7.52	16.29	1.40	54.69	3.01	6.06	1.11	2.09
M_2 :- 5.00 mg Fe kg^{-1}	9.77	17.68	1.39	55.90	3.41	6.46	1.08	2.04
M_3 :- 7.50 mg Fe kg^{-1}	10.69	19.52	1.37	53.87	3.61	6.65	1.06	1.97
M_4 :- 10.0 mg Fe kg^{-1}	10.42	19.43	1.28	48.65	3.41	5.96	0.98	1.75
M_5 :- 1.25 mg Zn kg^{-1}	7.62	15.45	1.43	54.75	3.36	6.65	1.15	2.02
M_6 :- 2.50 mg Zn kg^{-1}	8.41	16.50	1.44	55.58	4.23	7.70	1.15	2.01
M_7 :- 3.75 mg Zn kg^{-1}	8.57	16.93	1.35	53.61	4.81	8.30	1.11	1.95
M_8 :- 5.00 mg Zn kg^{-1}	8.36	15.97	1.27	48.85	5.39	8.36	0.98	1.73
M_9 :- Grade 5 @ 12.0 mg kg^{-1}	8.07	15.87	1.42	53.98	3.77	6.18	1.10	2.00
S. Em. ±	0.30	0.58	0.04	1.44	0.13	0.26	0.03	0.05
C. D. @ 5 %	0.86	1.65	NS	4.11	0.38	0.75	0.09	0.15
Interaction effect (V × M)								
S. Em. ±	0.45	0.82	0.06	2.04	0.19	0.37	0.04	0.07
C. D. @ 5 %	1.21	NS	NS	NS	0.53	NS	NS	NS
C. V. (%)	8.6	8.4	7.7	6.6	8.6	9.5	6.7	6.5

4. Conclusion

From the results of present pot study, following inferences are emerged. Variety V_2 recorded significantly higher content of Ca, Fe, Mn and Zn in grains. In case of straw portion also, significantly more content of P, Ca, Zn and Cu was recorded in variety V_2. As far as micronutrient levels are concerned, application of either Fe (M_1 to M_4) or Zn (M_5 to M_8) significantly increased the N, P, Fe and Zn content in grain and straw of rice as compared to control. With respect to nutrient uptake, significantly higher uptake of N, P, K, Ca, Mg, Fe, Mn and Cu by grain and straw was registered in variety V_1, while variety V_2 registered significantly higher uptake of Zn by both grain and straw of rice. Further, most of the treatments receiving Fe and Zn, removed significantly higher amount of all the determined nutrients from soil, as indicated in higher content in grain and straw of rice as compared to control.

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