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Effect of soil application of Iron and zinc on soil available nutrients under two different rice cultivars

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Abstract
Pot experiment was conducted to investigation the effect of soil application of iron (Fe) and zinc (Zn) on available nutrients in soil under two rice varieties at Department of Natural Resources Management, ASPEE College of Horticulture and Forestry, NAU, Navsari. The experiment consists of two varieties of Rice *i.e.* GNR-4 and RP BIO 5477-NH787 (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} in FCRD with three replication. The experimental results revealed that significantly more available K_2O (337.5 kg ha^{-1}) and Fe (5.26 mg kg^{-1}) were registered with variety V_2 (IET-23833) than in V_1 (GNR-4) plots. Exactly reverse trend was observed for available Zn content (0.76 mg/kg) in soil. Among the different micronutrient levels, the available P_2O_5 content in soil after harvest of rice was found to decrease remarkably as the rate of Fe (M_1- 2.50 mg Fe kg^{-1} to M_4- 10.0 mg Fe kg^{-1}) and Zn (M_5- 1.25 mg Zn kg^{-1} to M_8- 5.00 mg Zn kg^{-1}) applications increased and significantly lower available P_2O_5 content was recorded with M_4 and M_8 as compared to control (M_0). The availability of Fe was found to increase significantly with each level increase in Fe application (M_0 to M_4). The same trend was also recorded for Zn availability under the treatments receiving Zn at different rates (M_5 to M_8). In addition to this, the Mn availability was also improved significantly with the application of both Fe (M_4) and Zn (M_8) at higher levels.

Keywords: Available nutrients, Fe and Zn, *Kharif*, rice varieties, soil

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) [8]. 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% Indian soils are deficient in supply of Fe (Ram *et al.*, 2013) [15]. In the case of Gujarat, most of the cultivated soils have been reported to be deficient in Fe and Zn (Patel *et al.*, 2008) [13]. 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) [24]. 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) [23]. 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% of Indian soils are deficient in Zn element (Veeranagappa *et al.*, 2010, Kumar *et al*, 2019) [10].

Moreover, among the cultivable soils of Gujarat, 24% 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) [17]. 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% children under three years of age, 43% preschool children, 90% adolescent girls and 50% women are having clinical Fe deficiency (Sahay *et al.*, 1992) [16]. Various physiological diseases, such as anemia and some neurodegenerative diseases are triggered by Fe deficiency. Similarly, only in India, 27.0% 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) [15]. Zinc deficiency alone claims about 4.4% of the total child deaths in the world whereas anemia is the major reason of post natal death of mothers as well as infants. 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) [22].

In micronutrient fertilizer trials conducted on 5,800 fields in India, it has been found that in the 63% of the trials crops responded to micronutrient fertilization with yield increase (Singh, 2007) [18] 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) [1]. 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) [2]. 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.

Materials and Methods

For achieving the objective of present investigation, a pot experiment entitled, "Effect of soil application of Fe and Zn on available nutrients in soil after harvest of 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-NH787 (IET- 23833) and nine level of micronutrients *i.e.* Fe @ 2.50 mg/kg, Fe @ 5.00 mg/kg, Fe @ 7.50 mg/kg, Fe @ 10.0 mg/kg, Zn @ 1.25 mg/kg, Zn @ 2.50 mg/kg, Zn @ 3.75 mg/kg, Zn @ 5.00 mg/kg, Micronutrient fertilizer Grade 5 @ 12.0 mg/kg. 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 to rice crop under pot trial was applied through ammonium sulfate and single super phosphate, respectively. Soil properties were analyzed from processed initial soils samples as per standard procedures given in Table No. 1. The obtained results furnished in table 1 showed that the experimental soil is heavy textured and alkaline in reaction with normal salt content. It has a high amount of available P_2O_5 (95.32 kg ha^{-1}), K_2O 350.39 kg ha^{-1}), Mn (10.90 mg kg^{-1}) and Cu (2.40 mg kg^{-1}), medium amount of SOC (0.68%) and available N (280.91 kg ha^{-1}) and Zn (0.76 mg kg^{-1}) status while deficient in available Fe content (4.40 mg kg^{-1}). Representative soil sample from each pot was collected by crushing the whole soil mass of pot. After taking soil sample, the soil mass of pot were washed with water to collect plant roots. The representative soil samples from each pot were dried and ground by using wooden mortar and pestle and sieved through 2.00 mm sieve and stored in polythene bag with proper label. The processed soil samples were preserved 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) [25].

Table 1: Initial chemical properties of bulk soil (0-15 cm) used for pot trial

Parameters	Value	Method of analysis	Reference
1. Mechanical			
Coarse sand (%)	3.13	International pipette method	Piper (1996) [14]
Fine sand (%)	17.62		
Silt (%)	21.93		
Clay (%)	57.32		
Textural Class	Clay		
Chemical Properties			

pH (1:2.5)	7.85	Potentiometry	Jackson (1973) [6]
EC (1:2.5) (dS/m)	0.45	Conductometry	
Organic carbon (%)	0.68	Wet oxidation method	Walkley & Black (1934) [9]
Available N (kg/ha)	280.91	Alkaline $KMnO_4$ method	Subbiah and Asija (1956) [19]
Available P_2O_5 (kg/ha)	95.32	Spectrophotometry method (0.5M $NaHCO_3$ extractable)	Olsen *et al*. (1954) [11]
Available K_2O (kg/ha)	350.39	Flame photometry (1 N NH4OAc extractable)	Jackson (1973) [6]
DTPA extractable Fe (mg/kg)	4.40	DTPA extractable Atomic Absorption Spectroscopy	Lindsay and Norvell (1978) [10]
DTPA extractable Mn (mg/kg)	10.90		
DTPA extractable Zn (mg/kg)	0.76		
DTPA extractable Cu (mg/kg)	2.40		

Result and Discussion

The chemical properties *viz*., soil pH and EC of soil did not differ significantly due to effects of varieties. But, fertility parameters *viz*., available K_2O, Fe and Zn were influenced significantly due to varietal effect. Here, significantly lower available K_2O and Fe were recorded with variety V_1 as compared to V_2 (Table 2 and 3). In contrast, available Zn content was significantly lower under variety V_2 than V_1 (Table 3). Application of Fe and Zn at different rates failed to influence the soil chemical properties and also the SOC, available N and P_2O_5 content in soil significantly. On the other hand, available P_2O_5, Fe, Mn, Zn and Cu were affected significantly due to application of different levels of Fe and Zn fertilizers (Table No. 2 and 3). Available P_2O_5 content in soil was significantly higher under control treatment (M_0) and it tended to decrease with each level of increase in Fe (M_1 to M_4) and Zn (M_5 to M_8) application.

The availability of Fe was found to be increased significantly with each level increase in Fe application. The same trend was also true for Zn availability under the Zn fertilized treatments. In addition to this, the Mn availability was also improved significantly under the both high levels of Fe (M_4) and Zn (M_8) fertilized treatments while, available Cu remarkably improved in soil due to application of higher level of Fe and Grade 5 fertilizers as compared to control after harvest of rice. The interactive effect of V x M was not significant on all the chemical and fertility parameters of soil after harvest of rice plant.

All properties of soil determined after harvest of rice when compared with their initial values, the results presented in Table No. 2 and 3 showed that soil pH, SOC and available Fe, Zn and Cu were found to improve remarkably due to application of medium to high amount of micronutrient fertilizers with an exception of available Cu with Zn application. Whereas, remaining available nutrients content was decreased up to certain extent after harvest of rice than their respective initial values under all the treatments. This seems to be due to higher removal of nutrients by rice crop. Jatay *et al.* (2006) [7] and Ananda and Patil (2007) also concluded that available Fe and Zn in soil after harvest of crop were remarkably increased with increasing levels of Fe and Zn, respectively. Whereas, Biswas *et al.*, (2007) [3] reported that continuous submergence had a synergistic effect on the availability of DTPA extractable Fe, Mn and Cu to rice crop. The applied Fe and Zn ions might be react with available P compounds present in soil and formed their insoluble compounds of Fe and Zn (Havlin *et al.*, 2014) [5]. This is a probable reason for decrease in the available P_2O_5 content at harvest of rice.

Table 2: Effect of different treatments on chemical properties in soil after harvest of rice plant

Treatments	pH	EC (ds/m)	OC (%)
Varieties			
V_1:- GNR-4	7.85	0.74	0.69
V_2:- IET-23833	7.85	0.72	0.68
S.Em. ±	0.015	0.006	0.005
C. D. @ 5%	NS	NS	NS
Micronutrient levels			
M_0:- Control	7.89	0.71	0.66
M_1:- 2.50 mg Fe/kg	7.84	0.72	0.68
M_2:- 5.00 mg Fe/kg	7.84	0.72	0.69
M_3:- 7.50 mg Fe/kg	7.83	0.73	0.70
M_4:- 10.0 mg Fe/kg	7.81	0.74	0.68
M_5:- 1.25 mg Zn/kg	7.86	0.73	0.68
M_6:- 2.50 mg Zn/kg	7.86	0.74	0.69
M_7:- 3.75 mg Zn/kg	7.85	0.74	0.70
M_8:- 5.00 mg Zn/kg	7.83	0.75	0.69
M_9:- G 5 @ 12.0 mg/kg	7.86	0.74	0.68
S.Em. ±	0.034	0.012	0.011
C. D. @ 5%	NS	NS	NS
Interaction effect (V × M)			
S.Em. ±	0.048	0.018	0.015
C. D. @ 5%	NS	NS	NS
C. V. (%)	1.1	4.2	3.8

Table 3: Effect of different treatments on available nutrients in soil after harvest of rice plant

Treatments	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)	Av. Fe (mg/kg)	Av. Mn (mg/kg)	Av. Zn (mg/kg)	Av. Cu (mg/kg)
Varieties							
V_1:- GNR-4	272	90	313	4.97	9.63	0.76	2.26
V_2:- IET-23833	269	91	338	5.26	9.78	0.71	2.32
S.Em. ±	1.62	0.90	30.8	0.05	0.08	0.01	0.02
C. D. @ 5%	NS	NS	8.81	0.15	NS	0.03	NS
Micronutrient levels							
M_0:- Control	275	97	331	1.35	9.88	0.65	2.34
M_1:- 2.50 mg Fe/kg	272	96	327	5.22	9.00	0.60	2.23
M_2:- 5.00 mg Fe/kg	268	93	325	5.78	9.57	0.57	2.27
M_3:- 7.50 mg Fe/kg	267	90	322	6.49	10.02	0.56	2.24
M_4:- 10.0 mg Fe/kg	272	86	324	7.28	10.44	0.65	2.52
M_5:- 1.25 mg Zn/kg	271	95	328	4.39	9.33	0.74	2.28
M_6:- 2.50 mg Zn/kg	270	92	324	4.42	9.24	0.87	2.19

M_7:- 3.75 mg Zn/kg	265	88	321	4.30	9.52	0.95	2.11
M_8:- 5.00 mg Zn/kg	273	84	325	4.56	10.65	0.99	2.24
M_9:- G 5 @ 12.0 mg/kg	271	87	323	4.36	9.41	0.80	2.50
S.Em. ±	3.62	2.02	6.89	0.11	0.17	0.02	0.04
C. D. @ 5%	NS	9.78	NS	0.33	0.48	0.006	0.13
Interaction effect (V × M)							
S.Em. ±	5.12	2.86	9.76	0.16	0.24	0.03	0.06
C. D. @ 5%	NS	NS	NS	NS	NS	NS	NS
C. V. (%)	5.3	5.4	5.2	5.6	4.3	7.1	4.8

Further, the application of acid producing Fe and Zn fertilizers along with SSP and AS might have lower down the soil pH at harvest of rice. With respect to soil salinity, the EC of soil was found to increase considerably at harvest of rice plant as compared to initial value. The increase in soluble salt content in soil could be attributed to crops irrigating with water having some extent of dissolved salts throughout the growing period (Patel *et al.*, 2008) [13]. Further, experiment is laid out in pot condition where drainage is not provided during the season. Continuous ponding of water also enhances solubility of some salts which normally under arable conditions are not soluble. These reasons are sufficient enough to explain the results of present study. The findings of present study are also corroborating with those reported earlier by Swarup (1993) [20], Haldar *et al.* (2007) [4], Prasad *et al.* (2010), Varshney *et al.* (2008) [21] and Keram *et al.* (2012) [99] under different soil conditions.

Conclusion
From the results of present pot study, following inferences are emerged.

- After harvest of rice, the soil properties *viz.*, pH, SOC and available Fe, Zn and Cu were found to improve remarkably due to application of medium to high amount of micronutrient fertilizers when compared with their initial values with an exception of available Cu content with Zn treated plots.
- Whereas, available N, P, K, Ca, Mg and Mn content of soil were decreased up to certain extent after harvest of rice than their respective initial values under all the treatments.
- With respect to soil salinity, the EC of soil was found to increase considerably after harvest of rice plant as compared to its initial value.

Further, Soil applications of Fe and Zn also significantly improved respective DTPA-extractable Fe and Zn content in soil after harvest of rice.

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