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AGRONOMY

Effect of zinc and organic matter on nutritional composition of seeded rice

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Abstract

A field experiment was conducted to assess the effect on nutritional composition of Rice crop and zinc content in plant and post harvest soils af er the application of zinc alone and zinc in combination with organic mat ers i.e farm yard manure (FYM), poultry manure (PM) and piggery manure (PiM). Zinc was applied at the rate of 1.25, 2.5 and 5 kg ha^{-1} with 10 t FYM, 5 t PM and 5 t PiM ha^{-1}. Grain yield of rice showed increase of 31.2% with the combined application of 5 kg Zn + 5 t PM ha^{-1}. Total Zn uptake and its concentration in grain and straw increased significantly with the increasing levels of Zn and Organic Manures application. Total uptake of nutrients i.e. Zn, Cu, Fe, Mn, N, P, K and S by rice crop, increased significantly with the application of Zn alone or in combination with FYM, PM, or PiM irrespective of the effect of these treatments on the concentrations, as a result of increasing effect on grain and straw yield.

Highlights

- 5 Kg Zn ha^{-1} and 5 t Poultry manure ha^{-1} was found best treatment for nutritional composition of rice.
- Zinc application with manure in rice show positive effect on nutrient content.

Keywords: Zinc, organic mat er, nutritional composition, rice

Rice (Oryza sativa L.) is one of the major staples, feeding more than half of the world population. It provides 21% of energy and 15% of protein requirements of human populations globally (Depar *et al.* 2011). Low yield and poor nutritional quality of plant produce has been reported from plants grown on soils low in available Zn (Welch and Graham 1999). A significant decrease of 80% in grain Zn concentration was observed in cereals grown on soils with low plant-available Zn (Cakmak *et al.* 1997). This decrease in grain Zn also reduces its bioavailability in humans and may contribute to Zn deficiency in susceptible human populations (Hussain *et al.* 2012). Indeed, Zn deficiency is becoming one of the major public health problems in many countries, especially where people rely on cereal-based food (Welch 1993). Zinc deficiency symptoms in rice were observed for the first time in calcareous soils of northern India (Nene 1966; Yoshida and Tanaka 1969).

Manures are a good source of plant nutrients, and their application improves micronutrient availability by changing soil chemical, physical and biological properties (Eghball *et al.* 2004). They contribute to Zn accumulation through N supply and organic acids decreasing soil pH and improving mobilization of soil Zn in calcareous soils (Marschner 1995). Decomposition of organic materials releases fluvic and other organic acids (Marschner 1995) that form complexes with inorganic Zn and increase its solubility and availability to plants (Maqsood *et al.* 2011). Neither of these strategies has been tested sufficiently regarding Zn nutrition in rice systems for improving grain Zn, warranting further research.

Materials and Methods

A field experiment was conducted on rice crop (*Oryza sativa* var. JR 201) with 16 treatments of Zn, FYM, poultry manures (PM) and piggery manures (PiM) in Randomized block design with 3 replications. Some of the physico-chemical properties of clay soil (0-15cm) are Soil pH (1:2): 7.3, Electrical conductivity: 0.2 ds m^{-1}, Calcium carbonate: 19 g kg^{-1}, Organic carbon: 3.5 g kg^{-1}, Nitrogen 223 kg/ha, Phosphorous 25 kg/ha, Potassium 565 kg/ha sulpur 13.4 mg/kg and DTPA extractable Zn: 0.41mg kg^{-1}. Treatments were applied before sowing of rice crop in each replication as in Table 1. N:P:K (100 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1}, 40 kg K_2O ha^{-1}) dose was common in each treatment. Half of N and, full dose of P and K were applied in each plot before sowing. Remaining half i.e. 25 + 25kg N ha^{-1} was applied as top dressing during crop growth. Soil pH was determined in a soil – water suspension of 1:2.5 with a pH meter as described by Jackson (1973). Electrical conductivity was determined in the clear supernatant solution of 1:2.5 soil to water suspension using EC meter (Chopra and Kanwar, 1982). Organic carbon was determined by Walkley and Black's (1934) chromic acid digestion rapid titration method. Available zinc, copper, iron and manganese content in soil determined by were extraction with by 0.005M DTPA, 0.01 M $CaCl_2$ and 0.1 M Triethanol amine (TEA) adjusted to pH 7.3 and analysed on atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Plant material was digested in diacid (10:4 of AR grade HNO_3: $HClO_4$ respectively) (Jackson 1965). The data obtained from the laboratory studies were analysed by statistical procedure as outline by Fischer (1950). The simple correlations were also analysed by the standard methods (Snedecor and Cochran, 1967).

Nitrogen content in the plant sample was determined by the Kjelahal method (A.O.A.C., 1955). The concentration of P in the digestate was determined by vanadomolybdate yellow colour method of Koeing and Johnson (1942) on spectrophotometer. The K content in the digestate was determined by using EEL flame photometer. The concentration of sulphur was determined by the turbidimetric method, using blue filter on Klet -Summerson colorimeter (Chesnin and Yien, 1950).

N, P, K, and S, contents were 1.0, 0.5, 1.0 and 0.71% in FYM; 1.5, 1.5, 0.8 and 0.74 in poultry manure whereas 0.5, 0.5, 0.4 and 0.33 in piggry manure, respectively. While Cu, Fe and Mn contents were 70.2, 2599.6 and 568ppm in FYM; 202.7, 34.7, 2419.8 and 542.6 in poultry manure whereas 30.6, 2234.1 and 3172.2 ppm in piggry manure, respectively.

Results and Discussion

Growth and Yield Parameter

At 60 days growth of rice with application of 5 kg Zn ha^{-1}, plant height and number of tillers increased by 6.7 and 23.3%, respectively whereas due to application of poultry manure the increase was 7.2 and 10.1 per cent, respectively (Table 1). The data on length of panicle, average number of grain per panicle showed the same behavior as recorded in case of plant height and number of tillers in rice crop. However, the effect of piggery manure was lowest amongst the various organic manures. Similarly Verma *et al.* (2001) found that yield attributes increased significantly due to application of organic manures. Dry matter yield at 60 days increased by 15.5, 14.0, 11.8, and 11.2%, due to application of 5 kg Zinc ha^{-1} poultry manure, FYM and Pig manure respectively, Peda Babu *et al.* (2007) also found significantly increase in dry matter production of rice due to the application of zinc.

Grain yield increased with the graded doses of zinc by 5.1, 14.7 and 23.1% at 1.25, 2.5, and 5.0 kg Zn ha^{-1} level, respectively. Among the organic manures maximum response was observed with the application of PM (19.8%) followed by FYM (16.5%) and PiM (14.8%). Similarly, in case of straw yield response varied from 4.9 to 16.2% at various zinc levels (Table 1). Maximum response was observed due to application of PM (28.1%), followed by PiM (17.2) and FYM (13.8%). Nagarajan and Manickam (1986) found that the yield of rice increased from 3.93 to 4.12 tha^{-1} by the application 25 kg $ZnSO_4$ ha^{-1} but did not increase further with increased Zn levels to 50 and 75 kg Zn ha^{-1} Sharma *et al.* (1996), Sajwan and Lindsay (1987), Devarjan and Ramanathan (1995) and Prasad *et al.* (2002) obtained increased yield of rice due to application of Zinc, FYM and other organic manures.

The increase in yield of rice may be due to the beneficial effect of Zn and various organic manures on yield attribute like plant height, number of tillers, panicle length and number of grains per panicle which ultimately resulted in the from of increased production. Significant and, positive correlation (r= 0.89**) was found to exist between the yield and length of panicle.

The positive significant influence of application of Zinc and organic manures (FYM, PM, PiM) was noticed on yield attribute like height of plant, dry matter production, number of tillers, length of panicle, number of grain per panicle and yield of grain and straw of Rice.

Maximum increase in all attribute as well as in grain yield was observed as an effect of 5 kg Zn ha^{-1} with FYM, PM, Pig.M. Maximum grain yield (5.84t ha^{-1}) of Rice was recorded in the plots receiving application of 5 kg Zn ha^{-1} with 5t PM, while it was minimum (4.45 t ha^{-1}) at control.

Straw yield was also increased with the application of 2.5 and 5.0 kg ha^{-1} Zinc but the differences between two consecutive doses were non-significant. In case of organic manures the straw yield increased significantly over control due to application of FYM and Piggery manure, both of these remain at par with each other, whereas Poultry manure was found significantly superior over FYM and Piggery manure as well.

Nutritional Composition

The content of zinc in grain and straw and total Zn uptake by rice increased significantly with the increasing levels of zinc as well as application of organic manures over control (Tables 2, 3). Zinc content was more in straw as compared to grain. The results are in agreement with evidence presented by Varshney *et al.* (2008). Similar results have also been reported by Sajwan and Lindsay (1987), Shukla and Lynagadoh (1990). Significant correlation (r = 0.89**) exhibited between the Zn concentration and grain yield of rice.

The application of graded dose of zinc produces a retarding effect on Cu, Fe and Mn, concentration in grain as well as in straw. These finding are in close agreement with the result reported by Naik and Asana (1961). According to Maskina *et al.* (1980), Zn and Fe compete at absorption sites of the plant roots because of the same ionic radii. Sajawan and Lindsay (1987) have also reported decrease in Mn content with the Zn application which may be due to the competition between two divalent in plant system. Concentrations of Cu, Fe and Mn in rice grain as well as straw were not influenced significantly due to the application of Zn where as organic manures exerted positive effect.

The N content in grain as well as in straw, increased due to application of Zn and organic manures in comparison to their respective control. The N content was comparatively less in straw as 0.394 to 0.370% at control which increased to 0.407% at Zn_5 and 0.414% at 5 t poultry manure, respectively. The content of P in rice grain as well as in straw increased due to application of organic manures, whereas the Zn application did not affect the P concentration, there was no significant effect of either Zn or organic manures on the K content. Sulphur content in rice grain and straw increased significantly due to the application of organic manures but the application of zinc did not affect, significantly. Increasing effect of various secondary and micro nutrients may be attributed to the content of these nutrients in organic manures and their capability to increase the availability of these nutrient in soil. Sharma and

Table 1. Agronomic traits of rice plant

Treatment			Plant height 60DAS	No. of Tiller 60DAS	Dry matter 60DAS (t ha^{-1})	Av. Length of Panicle	Grain per panicle	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
	Zn (Kgha^{-1})	OM (t ha^{-1})							
T_1	0	0	73.9	450.3	3.00	20.1	97.8	3.85	4.00
T_2	1.25	0	79.0	468.5	3.24	22.0	101.3	4.07	4.49
T_3	2.5	0	82.0	539.3	3.34	23.7	110.7	4.45	4.72
T_4	5.0	0	82.7	572	3.57	24.9	115.0	5.03	5.18
T_5	0	10	82.5	493	3.36	22.0	120.9	4.72	4.84
T_6	1.25	10	83.5	531.7	3.60	23.0	125.5	4.77	5.00
T_7	2.5	10	84.1	593.7	3.81	24.2	132.3	5.21	5.33
T_8	5.0	10	85.1	619.7	3.94	25.9	137.5	5.61	5.75
T_9	0	5	83.5	506.7	3.48	23.3	128.0	4.70	5.69
T_{10}	1.25	5	82.9	541	3.60	23.6	130.3	4.92	5.85
T_{11}	2.5	5	85.2	560.7	3.78	25.5	136.9	5.40	6.03
T_{12}	5.0	5	88.6	626.3	4.13	26.1	141.3	5.84	6.00
T_{13}	0	5	78.7	497.3	3.30	21.5	115.7	4.44	4.97
T_{14}	1.25	5	80.2	545.3	3.66	22.1	123.9	4.85	5.12
T_{15}	2.5	5	82.7	571	3.76	23.3	126.6	5.24	5.75
T_{16}	5.0	5	84.2	584.3	3.90	24.7	132.0	5.32	5.71
CD at 5%			4.14	40.80	0.324	1.44	NS	0.409	0.486

T_1(control), T_2:(1.25 kg Zn ha$_{-1}$ +0 t FYM ha$_{-1}$), T_3:(2.5 kg Zn ha$_{-1}$+ 0 t FYM ha- 1), T_4:(5 kg Zn ha$_{-1}$ +0 t FYM ha- 1), T_5:(0 kg Zn ha$_{-1}$ +10 t FYM ha$_{-1}$), T_6:(1.25 kg Zn ha$_{-1}$ +10 t FYM ha$_{-1}$), T_7:(2.5 kg Zn ha$_{-1}$ +10 t FYM ha$_{-1}$), T_8: (5 kg Zn ha$_{-1}$ +10 t FYM ha$_{-1}$), T_9: (0 kg Zn ha$_{-1}$ +5 t PM ha$_{-1}$), T_{10}: (1.25 kg Zn ha$_{-1}$ +5 t PM ha$_{-1}$), T_{11}:(2.5 kg Zn ha$_{-1}$ +5 t PM ha$_{-1}$), T_{12}:(5 kg Zn ha$_{-1}$ +5 t PM ha$_{-1}$), T_{13}:(0 kg Zn ha$_{-1}$ +5 t PiM ha$_{-1}$), T_{14}:(1.25 kg Zn ha$_{-1}$ +5 t PiM ha$_{-1}$), T_{15}:(2.5 kg Zn ha$_{-1}$ +5 t PiM ha$_{-1}$) and T_{16}:(5 kg Zn ha$_{-1}$ +5 t PiM ha$_{-1}$).

Table 2. Elemental content in rice grain

	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	N(%)	P(%)	K(%)	S(%)
T_1	11.1	3.6	67.2	13.0	0.784	0.240	0.8	0.067
T_2	12.0	3.5	65.2	13.5	0.789	0.236	0.81	0.075
T_3	13.2	3.7	65.9	12.9	0.790	0.240	0.81	0.072
T_4	13.8	3.5	67.4	13.0	0.791	0.236	0.82	0.080
T_5	12.2	3.8	79.9	14.3	0.819	0.261	0.81	0.085
T_6	12.5	3.8	75.7	13.9	0.827	0.254	0.82	0.087
T_7	13.8	3.8	75.8	13.6	0.833	0.254	0.83	0.075
T_8	14.0	3.7	72.2	13.2	0.833	0.247	0.83	0.081
T_9	12.7	3.9	76.0	14.3	0.846	0.245	0.81	0.084
T_{10}	13.1	3.8	74.9	13.6	0.873	0.263	0.81	0.081
T_{11}	14.2	3.7	74.1	13.3	0.901	0.261	0.81	0.078
T_{12}	14.8	3.7	73.6	13.3	0.907	0.261	0.82	0.088
T_{13}	11.9	3.7	75.4	13.5	0.847	0.256	0.81	0.087
T_{14}	12.5	3.6	74.4	13.1	0.866	0.254	0.81	0.080
T_{15}	13.4	3.5	73.1	13.0	0.884	0.251	0.82	0.087
T_{16}	14.6	3.5	74.2	13.1	0.897	0.254	0.83	0.087
CD at 5%	0.762	NS	3.51	NS	0.044	0.014	NS	0.006

Table 3. Elemental content in straw

	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	N(%)	P(%)	K(%)	S(%)
T_1	15.3	7.8	32.3	73.2	0.365	0.072	1.74	0.079
T_2	6.8	8.0	225.5	72.1	0.369	0.074	1.7	0.082
T_3	18.5	7.7	230.4	70.8	0.366	0.072	1.71	0.079
T_4	21.1	7.5	218.9	70.7	0.377	0.080	1.81	0.076
T_5	17.3	8.4	261.0	80.3	0.397	0.085	1.76	0.092
T_6	18.6	8.2	258.8	79.0	0.396	0.080	1.76	0.088
T_7	21.9	7.83	251.7	78.0	0.415	0.078	1.78	0.088
T_8	22.2	7.80	246.5	75.8	0.423	0.074	1.8	0.087
T_9	17.4	7.8	253.3	79.2	0.414	0.085	1.78	0.090
T_{10}	19.2	7.9	245.0	78.3	0.421	0.085	1.82	0.086
T_{11}	21.2	7.7	236.4	75.5	0.407	0.084	1.73	0.081
T_{12}	23.0	8.1	229.3	73.8	0.412	0.080	1.78	0.088
T_{13}	17.3	8.0	253.0	77.5	0.398	0.077	1.75	0.091
T_{14}	18.6	7.9	241.4	74.2	0.417	0.076	1.8	0.090
T_{15}	21.5	7.9	235.7	74.7	0.398	0.074	1.79	0.086
T_{16}	23.1	7.8	229.7	73.3	0.417	0.074	1.78	0.084
CD at 5%	1.076	NS	13.61	4.22	0.010	0.005	NS	0.008

Table 4. Total uptake by rice

	Zn(g/ha)	Cu(g/ha)	Fe(g/ha)	Mn(g/ha)	N(kg/ha)	P(kg/ha)	K(kg/ha)	S(kg/ha)
T_1	103.9	45.1	1,189.6	341.4	44.74	12.11	100.6	5.67
T_2	123.4	49.5	1,268.6	378.0	48.67	12.92	109.5	6.76
T_3	146.0	53.0	1,386.7	391.1	52.71	14.19	116.9	6.96
T_4	178.4	56.4	1,475.4	430.9	59.31	16.09	134.9	7.99
T_5	141.7	58.3	1,641.0	457.9	57.85	16.42	123.7	8.48
T_6	152.4	59.0	1,654.3	465.4	59.31	16.07	127.2	8.50
T_7	183.7	61.2	1,739.5	486.7	65.59	17.41	137.9	8.59
T_8	206.1	65.3	1,822.5	511.1	71.00	18.07	150.1	9.58
T_9	158.7	62.6	1,792.9	518.9	63.40	16.34	139.0	9.04
T_{10}	177.3	64.4	1,801.8	524.7	67.56	17.98	146.1	8.90
T_{11}	203.9	66.2	1,818.4	524.2	73.26	19.1	147.6	9.09
T_{12}	224.3	70.2	1,804.7	520.7	77.97	20.03	154.6	10.46
T_{13}	138.5	55.9	1,607.9	445.7	57.15	15.17	122.9	8.37
T_{14}	155.9	57.7	1,601.5	442.5	63.31	16.11	131.8	8.38
T_{15}	193.4	64.0	1,733.3	498.3	69.33	17.44	145.4	9.54
T_{16}	209.3	63.7	1,705.7	482.5	71.55	17.72	145.3	9.52
CD at 5%	13.174	4.50	156.98	45.12	5.17	1.483	10.51	0.72

Table 5. Elemental content in soil after rice

	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	N(kg/ha)	P(kg/ha)	K(kg/ha)	S(kg/ha)
T_1	0.57	1.45	11.0	8.2	268.0	14.89	314.3	7.83
T_2	0.70	1.30	11.4	7.5	277.8	15.90	375.7	7.63
T_3	0.90	1.28	11.0	7.4	285.3	16.51	343.0	7.63
T_4	1.21	1.26	11.1	7.5	290.4	16.82	411.7	7.63
T_5	0.67	1.53	12.7	8.7	308.7	16.83	550.7	7.60
T_6	0.78	1.48	12.3	8.2	304.4	16.95	414.3	7.63
T_7	1.05	1.45	11.5	7.8	307.4	17.05	359.7	7.77
T_8	1.39	1.37	11.3	7.4	309.1	17.27	369.0	7.60
T_9	0.74	1.53	12.0	8.7	278.6	17.40	369.3	7.67
T_{10}	1.02	1.68	12.0	8.5	288.4	17.53	313.7	7.57
T_{11}	1.15	1.48	11.9	8.1	289.7	17.03	299.0	7.70
T_{12}	1.84	1.47	10.9	7.5	275.5	17.86	300.0	7.63
T_{13}	0.62	1.64	12.1	7.8	288.4	17.45	507.7	7.77
T_{14}	0.75	1.56	11.6	7.8	275.7	16.98	289.3	7.63
T_{15}	0.94	1.48	11.4	7.5	287.8	16.78	387.7	7.77
T_{16}	1.38	1.42	11.3	7.3	289.5	17.24	289.3	7.70
CD at 5%	0.087	0.132	NS	NS	19.82	2.099	16.64	NS

Misra (1997) have also obtained the increased nutrient content and uptake in rice with the application of organic manures.

Nutritional Uptake

The uptake of nutrient is a function of yield and its concentration in crop, as the application of Zn increased the yield as well as Zn concentration ultimately the Zn uptake was also increased. Zinc uptake increased by 50.7% with the application 5 kg Zn ha^{-1} and 38.5, 26.4 and 24.0% with the application 5 t PM, 5 t Piggery manure and 10 t FYM ha^{-1}, respectively over control. Similar findings have been reported by Khamparia *et al* (1984) and Singh and Shukla (1985). Zn uptake was linearly correlated with the grain yield of rice (r=0.98**).

In this study total Cu uptake increased by 15.1% due to application of 5 kg Zn ha^{-1} and among the organic manures maximum uptake (29.2%) was found with the application of poultry manure followed by FYM (19.6%) and Pig manures (18.2%) (Table 4). In case of Fe uptake, application of Zn has no significant effect but Fe uptake increased significantly by 35.7, 28.9 and 25% due to application PM, FYM and Piggery manure, respectively. Similar trends were observed in total Mn uptake by rice crop. Shukla and Lynagadoh (1990) found increased uptake of Fe and Mn due to application of Zn. The yield of rice grain as well as straw increased significantly with the application of different Zn levels, hence the total uptake of Cu, Fe as well as Mn increased significantly as an effect of Zn application. Total uptake of N,P,K and sulphur also increased significantly with the application of zinc and organic manure. These findings are in close agreement with the result reported by Bisht and Chandel (1996), Babu and Reddy (2000) and Singh *et al.* (2006).

Nutrient Status of Post Harvest Soils

The Zn in post harvest soils increased with the increasing level of Zn from 0.65 at control to 1.45 mg kg^{-1} at Zn_5 (Table 5). Amongst the organic manures application, the order of increasing effect on Zn content in post harvest soils was Poultry manures > Form yard manure > Piggery manure. Chideshwari and Krishnamurthy (1998) also observed that the application of Zn increased the DTPA-Zn in soil. Similarly Hans Raj and Gupta (1985) found significant role of organic manures on the availability of Zn in post harvest soils. Similar findings have been reported by Prasad and Singh (1980), Nambiar and Abrol (1989), Meena *et al* (2006).

Application of zinc decreased the DTPA- Cu content while organic manures had increasing effect. There was no significant effect of either Zn or organic manures on the Fe and Mn content in the post harvest soils although decreasing trend with Zn levels and increasing trend with organic manures were observed.

Levels of Zn did not affect the N content in post harvest soils whereas FYM exhibited the residual effect in terms of increased N content in post harvest soils, which was obvious due to content of organic carbon in FYM and ultimately the increased N content in soils. All treatments could not exert any significant effect on the residual P content. The K content in post harvest soils increased due to the alone application of Zn, FYM, PM and PiM, but combined application of Zn with various organic manures decreased the K content.

Conclusion

From this study it can be concluded that grain yield of rice showed maximum response of 31.2% with the combined application of 5 kg Zn + 5 t PM ha^{-1}. Zn concentration in grain and straw increased with the increasing levels of Zn. Organic manures also increased the Zn content in grain as well as straw; however they did not differ significantly with different types of organic manures. Content of Cu, Fe, Mn, N, P and S increased due to the application of various organic manures but there was no significant effect of Zn doses. Total uptake of nutrients i.e. Zn, Cu, Fe, Mn, N, P, K and S by rice crop, increased significantly with the application of Zn alone or in combination with FYM, PM, or PiM, and as a result grain and straw yield increased.

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