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Effect of Zn, Fe and FYM application on growth, yield and nutrient content of rice

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ABSTRACT

A field experiment was carried out at Banaras Hindu University, Varanasi during wet season, 2006-07 and 2007-08. Testing variables consisted of two varieties i.e. NDR-359 and HUBR 2-1, two sources of fertilizer application i.e. 100% recommended dose of fertilizer (RFD) of NPK through inorganic source and 75% RFD through inorganic and rest 25% through FYM. Two micronutrients, Zn and Fe through Zn-EDTA and Fe-EDTA were tested in different combinations either on soil or as foliar application or both @ 0.5 and 1.0 Kg ha^{-1}. Amongst varieties, var. NDR-359 recorded significantly higher growth, yield and NPK content of grain than HUBR 2-1, while Zn and Fe content were significantly increased in HUBR 2-1. Fertilizer source as application of 75% RFD through inorganic and rest through FYM recoded significantly higher growth, yield and N, P, K, Zn and Fe content of grain than 100% RFD through inorganic source. Among the different micronutrient treatments, soil application of Zn-EDTA @ 1 Kg ha^{-1} recorded significantly higher Zn content in grain, whereas application of Fe-EDTA @ 0.5 Kg ha^{-1} recorded significantly higher Fe content in grain as compared to other micronutrient treatments.

Key words: *rice, growth attributes, harvest index, N, P, K, Zn, Fe content, yield*

Rice productivity is very low, particularly in eastern Uttar Pradesh. Out of many factors, fertilizer is still an important and inescapable input in increasing the production of rice. However, increasing cost of fertilizers has necessitated improving the efficiency of applied fertilizers, which depends on adequate availability of most essential plant nutrients in a balanced proportion throughout the crop growth period. In recent year's use of fertilizers coupled with intensive cropping have accelerated the exhaustion of micro-nutrient reserves of soils. It has, thus, become imperative to use the matching doses of required NPK and micro-nutrients along with FYM.

Besides, increasing the productivity of rice, supplementation of micro-nutrients in fertilizer schedule also is a significant factor to improve the quality of grain to overcome certain malnutritional problems in dietary system of human beings. Accordingly its productivity, quality and profitability have become an integral part of our National Food System. Micro-nutrient malnutrition in rice is a common phenomena due to deficiency of iron, zinc, Fe, iodine and vitamin A (FAO and WHO, 2002). Rice is an especially poor source of two important minerals, calcium and iron (Welch and Graham, 1999) which are known to play significant role in formation of hemoglobin and transport of oxygen in human body. Micro-nutrients have attained a greater significance in intensive farming system with increased crop productivity for nutritional security (Rattan *et al.,* 1998). In India, among micro-nutrients, Zn deficiency is the most widespread under the area of high yielding crop varieties particularly in low land rice (Singh *et al.,* 2010). Therefore, it was worthwhile to study the effect of Zn, Fe and FYM on growth, yield and the content of NPK, Zn and Fe in grains of different rice varieties.

MATERIALS AND METHODS

A field experiment was conducted at the Banaras Hindu University Varanasi during wet season, 2006-07 and

2007-08. The soil of experimental field was alluvium, neutral, having pH (7.3), low in available N (190.56 Kg ha^{-1}) medium in available P (20.58 Kg ha^{-1}) and exchangeable K (223.87 Kg ha^{-1}) while Zn (0.89 Kg ha^{-1}) and Fe (20.67 Kg ha^{-1}) were deficient. The treatments consisting of 4 main plot treatments, with combination of two varieties (NDR-359 and HUBR2-1) and two fertilizer sources (100% recommended fertilizer dose (RFD), 75% RFD+25% N through FYM and 9 sub plot treatment combinations control, Zn as soil application through Zn-EDTA @ 1.00 Kg ha^{-1}, Zn as foliar application through Zn-EDTA @ 0.5 Kg ha^{-1}, Fe as soil application through Fe- EDTA @ 1.00 Kg ha^{-1}, Fe as foliar application through Fe-EDTA @ 0.5 Kg ha^{-1}, (Zn as soil application through Zn-EDTA @ 1.00 Kg ha^{-1} + Fe as soil application through Fe-EDTA @ 1.00 Kg ha^{-1}, Zn as foliar application through Zn-EDTA @ 0.5 Kg ha^{-1} followed by Fe as foliar application through Fe-EDTA @ 0.5 Kg ha^{-1}, Zn as soil application through Zn-EDTA @ 1.00 Kg ha^{-1} followed by Fe as foliar application through Fe-EDTA@ 0.5 Kg ha^{-1}, Fe as soil application through Fe-EDTA @ 1.00 Kg ha^{-1} followed by Zn as foliar application through Zn-EDTA @ 0.5 Kg ha^{-1} allotted in split plot design replicated three times. The duration of NDR-359 and HUBR2-1 were 130-135 days and 125-130 days, respectively which were taken as a test crop and planted at a spacing of 20 × 10 cm with two seedling hill^{-1}. Observations on various growth parameters (plant height, number of leaves hill^{-1}, leaf area index, dry matter accumulation and number of tillers m^{-2}) and nutrient contents (N, P, K, Zn, and Fe) were done at 90 days after transplantation (DAT). Estimations of N was done by the methods given by Subbiah and Asija (1973), P and K (Jackson,1973), Zn and Fe (L'vov, 2005). Yield and yield attributes of different treatments were recorded and computed.

RESULTS AND DISCUSSION

Data revealed that variety NDR-359 produced significantly higher plant height, number of leaves hill^{-1}, leaf area index, number of tillers over HUBR 2-1, whereas dry matter accumulation hill^{-1} remained

Table 1. Effect of Zn, Fe and FYM on growth attributes of rice at 90 DAT

Treatments	Growth attributes				
	Plant height (cm)	No. of leaves hill^{-1}	LAI	DMA hill^{-1}	No. of tillers m^{-2}
	90 DAT	90 DAT	90 DAT	90 DAT	90 DAT
Varieties					
NDR – 359	112.51	37.02	4.34	42.60	422.71
HUBR 2-1	104.95	35.45	3.29	40.41	404.44
CD (P < 0.05)	5.61	1.18	0.16	NS	13.05
Fertilizers					
100% RFD through inorganics	107.91	34.82	3.64	40.49	398.39
75% RFD through inorganics + 25% N through FYM	109.56	37.65	4.00	42.52	428.25
CD (P < 0.05)	NS	1.18	0.16	1.47	13.05
Micro-nutrient (Zn and Fe)					
Control	104.94	27.99	3.04	37.97	360.95
Zn-EDTA @ 1.00 Kg ha^{-1} (S)	109.70	36.81	3.89	41.91	421.23
Zn-EDTA @ 0.5 Kg ha^{-1} (F)	108.66	34.24	3.34	41.16	401.72
Fe-EDTA @ 1.00 Kg ha^{-1} (S)	108.58	32.13	3.19	40.73	396.31
Fe-EDTA @ 0.5 Kg ha^{-1} (F)	109.05	37.25	3.86	41.67	416.23
Zn-EDTA @ 1.00 Kg ha^{-1} (S)+Fe-EDTA@1.00Kg ha^{-1} (S)	108.95	38.10	4.07	41.85	424.94
Zn-EDTA @ 0.5 Kg ha^{-1} (F) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	109.39	40.04	4.19	42.55	432.45
Zn-EDTA @ 1.00 Kg ha^{-1} (S) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	110.55	42.56	4.65	43.57	445.96
Fe-EDTA @ 1.00 Kgha^{-1}(S) fb Zn-EDTA @ 0.5 Kg ha^{-1} (F)	108.93	36.98	4.09	42.15	420.09
CD (P < 0.05)	3.93	1.01	0.12	1.09	10.38

*RFD -Recommended Fertilizers Dose, S - Soil application, F - Foliar application, fb - Followed by, NS - Non-significant, LAI-Leaf area index, DMA - Dry matter accumulation statistically at par in their effectiveness at 90 DAT during crop season (Table 1). The variety NDR-359 produced also significantly higher number of panicle m^{-2}, more panicle weight, test weight, grain yield, straw yield and harvest index (Table 2). Slight varietal differences were observed in N, P and K content of grain. Variety NDR-359 recorded higher N and P content than HUBR 2-1, but it recorded significantly higher K content in grain. In non-aromatic rice varieties, about 73% of N was translocated to grain and rest remainedg in the straw while in aromatic cultivars translocation of N to grain was only 47% (De *et al.,* 2002). Application of N, P, K with micronutrients Zn and Fe are known to increase the uptake or content of N, P, K, Zn and Fe (Ganghaih *et al.,* 1999). However, micronutrient (Zn and Fe) content of variety HUBR 2-1 proved significantly superior to NDR-359 (Table 3). Variety, HUBR 2-1 recorded maximum zinc and iron in grains because it is aromatic in nature which supported the fact that zinc and iron concentrations remain higher in grains due to aromatic nature of the variety. These findings are strongly supported by Babu *et al*., 2005).

It is well known that the application of N,P,K, micronutrients along with FYM in proper combinations might increase and synthecize, various volatile aromatic compound found in rice, responsible for its aroma. Among which 2-Acetyle-1-Pyrroline (2-AP) is the most significant. Considerable improvement in grain quality of aromatic rice was recorded under combined use of organic and inorganic fertilizers as compared to 100% RFD through inorganic fertilizers (Sahu *et al.,* 2007).

Application of 75% RFD through inorganics + 25% N through FYM recorded significantly higher number of leaves $hill^{-1}$, leaf area index m^{-2}, dry matter accumulation $hill^{-1}$, number of tillers m^{-2} over 100% RFD through inorganics but plant height, remained statistically at par with fertilizer sources of 100% recommended fertilizer dose at 90 DAT during both the years of investigation (Table 1). These results corroborated the findings of Kalyanasundaram *et al.* (2003). Incorporation of 25% N through FYM at initial stage coupled with 75% through inorganic fertilizers brought about effective and congenial nutrient

Table 2. Effect of Zn, Fe and FYM on yield attributes and yield of rice

Treatments	Yield attributes					
	Panicle no. m^{-2}	Panicle wt.(g)	Test wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Varieties						
NDR – 359	385.99	4.48	31.33	5.50	7.50	42.32
HUBR 2-1	365.39	3.56	20.05	4.87	7.23	40.25
CD (P < 0.05)	15.87	0.14	0.94	0.36	0.24	2.42
Fertilizers						
100% RFD through inorganics	361.19	3.94	25.47	4.97	7.19	40.85
75% RFD through inorganics+25% N through FYM	390.19	4.10	25.91	5.40	7.54	41.74
CD (P < 0.05)	15.87	0.14	0.94	0.36	0.24	NS
Micro-nutrient (Zn and Fe)						
Control	335.05	3.66	24.26	4.34	6.58	39.63
Zn-EDTA @ 1.00 Kg ha^{-1} (S)	372.31	4.07	26.28	5.32	7.46	41.63
Zn-EDTA @ 0.5 Kg ha^{-1} (F)	361.92	3.97	25.56	5.16	7.31	41.37
Fe-EDTA @ 1.00 Kg ha^{-1} (S)	359.82	3.91	25.43	5.07	7.22	41.23
Fe-EDTA @ 0.5 Kg ha^{-1} (F)	378.95	4.04	25.64	5.27	7.43	41.48
Zn-EDTA @ 1.00 Kg ha^{-1} (S)+Fe-EDTA@1.00Kg ha^{-1} (S)	387.41	4.05	25.66	5.28	7.49	41.36
Zn-EDTA @ 0.5 Kg ha^{-1} (F) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	395.75	4.15	25.68	5.34	7.55	41.56
Zn-EDTA @ 1.00 Kg ha^{-1} (S) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	407.78	4.28	26.25	5.62	7.85	41.77
Fe-EDTA @ 1.00 $Kgha^{-1}$(S) fb Zn-EDTA @ 0.5 Kg ha^{-1}(F)	382.21	4.05	26.80	5.27	7.47	41.41
CD (P < 0.05)	11.96	0.11	0.74	0.23	0.18	1.69

*RFD –Recommended Fertilizers Dose, S – Soil application, F – Foliar application, fb – Followed by, NS – Non-significant environment in soil improving both the intensity as well as capacity factors of soil. This enabled continued supply of required nutrient for longer period covering total growth stage in balanced quantity in addition to the enhancement in micro-nutrient content of soil due to decomposition of FYM mineralizing micro-nutrient and production of organic acids responsible for forming micro-nutrient complexes (Mandal *et al.*, 2009). In initial stage, inorganic sources remain instrumental for proper growth and development of plants, whereas in later stages, plants depend on organic sources and remained devoid of any nutrient stress at any stage of growth and development (Mandal *et al.*, 2009).

Application of 75% RFD through inorganics + 25% N through FYM produced significantly higher number of panicle m^{-2}, more panicle weight, test weight and grain yield of 5.40 t ha^{-1} over 100% RFD through inorganics (4.97 t ha^{-1}) (Table 2). Application of 75% RFD+25% N through FYM sources of fertilizers also produced relatively higher straw yield (7.54 t ha^{-1}) and harvest index (41.74%) as compared to 100% recommended fertilizer dose sources of fertilizers at crop harvest. (Table 2). Lower sterility under the 75% RFD through inorganics + 25% N through FYM producing bolder grains thus increased the test weight due to slow release of nutrients for a longer period after decomposition of FYM, which favoured better plant growth and improved the yield components of rice. Improvement in all above yield attributes and yield have also been reported by Gupta *et al*., (2009).

Application of 75% RFD through inorganic sources + 25% N through FYM proved significantly superior in increasing P, K, Zn and Fe content in grain over 100% RFD through inorganics whereas N content remained statistically at par with 100% recommended fertilizer dose (Table 3). The present results are in agreement with the findings of Srivastava *et al*. (2008) and Chandrapala *et al.* (2010). Organic sources also improved the content of Fe by supplying chelating agents, which helps in maintaining the solubility of micro-nutrients including Fe.The response of organic matter showed profound influence on the solubility of Fe in waterlogged soil by providing resistance to Fe chlorosis (Singh *et al.,* 2010 and Das *et al*., 2010). It is thus apparent that application and maintenance of organic matter in the soil translates adequate long term availability of Fe. Improving N nutrition of plants may contribute to increase Zn and Fe concentration in grain

Table 3. Effect of Zn, Fe and FYM on content of rice grain

Treatments	Nutrient content				
	N%	P%	K%	Zn (ppm)	Fe (ppm)
Varieties					
NDR – 359	1.261	0.282	0.374	155.555	53.308
HUBR 2-1	1.252	0.275	0.360	171.955	62.567
CD ($P < 0.05$)	NS	NS	0.012	4.987	1.743
Fertilizers					
100% RFD through inorganics	1.252	0.260	0.349	157.025	52.153
75% RFD through inorganics + 25% N through FYM	1.262	0.295	0.385	170.490	63.722
CD ($P < 0.05$)	NS	0.009	0.012	4.987	1.743
Micro-nutrient (Zn and Fe)					
Control	1.216	0.247	0.336	148.368	39.087
Zn-EDTA @ 1.00 Kg ha^{-1} (S)	1.261	0.281	0.381	176.078	44.348
Zn-EDTA @ 0.5 Kg ha^{-1} (F)	1.247	0.269	0.352	169.843	58.088
Fe-EDTA @ 1.00 Kg ha^{-1} (S)	1.244	0.259	0.348	158.513	48.018
Fe-EDTA @ 0.5 Kg ha^{-1} (F)	1.254	0.278	0.354	161.806	80.144
Zn-EDTA @ 1.00 Kg ha^{-1} (S)+Fe-EDTA@1.00Kg ha^{-1} (S)	1.262	0.281	0.382	168.227	58.389
Zn-EDTA @ 0.5 Kg ha^{-1} (F) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	1.273	0.303	0.390	166.279	64.807
Zn-EDTA @ 1.00 Kg ha^{-1} (S) fb Fe-EDTA @ 0.5 Kg ha^{-1} (F)	1.283	0.306	0.394	169.618	66.977
Fe-EDTA @ 1.00 Kgha^{-1}(S) fb Zn- EDTA @ 0.5 Kg ha^{-1}(F)	1.257	0.277	0.363	156.092	61.579
CD ($P < 0.05$)	0.025	0.006	0.008	3.611	1.352

*RFD -Recommended Fertilizers Dose, S - Soil application, F - Foliar application, fb - Followed by, NS - Non-significant by affecting the levels of Zn or Fe-chelating nitrogenous compound, required for transport of Zn and Fe within plants, which increased Zn and Fe transporters needed for its uptake by root and phloem loading. It indicates that nitrogen management is an effective agronomic tool to enhance grain Zn and Fe concentrations. The present results are in agreement with the findings of Cakmak[A] I (2010).

Micronutrients in various mode of application produced significant variation on plant growth. Incorporation of Zn and Fe either individually or in combination significantly increased the growth attributes at 90 DAT over control in both the year of experimentation (Table 1). The combined application of Zn as soil application through Zn-EDTA @ 1.00 Kg ha^{-1} followed by Fe as foliar application through Fe-EDTA@ 0.5 Kg ha^{-1}applied in two splits at 15 DAT and at 50% panicle initiation produced significantly higher plant height, number of leaves hill^{-1}, leaf area index and number of tillers m^{-2} over all single or combined application of Zn-EDTA and Fe-EDTA whereas, dry matter accumulation hill^{-1} (g) remained statistically at par with the treatment Zn-EDTA @ 0.5 Kg ha^{-1}+Fe-EDTA @ 0.5 Kg ha^{-1} both applied as foliar in two splits. Chandrapala *et al.* (2010), Naik and Das (2008) concluded that the greater affectivity of Zn-EDTA over other sources of Zn in terms of growth and its utilization by plants might be due to less retention and greater transport and movement of chelated Zn to plant roots. Fe as foliar through Fe-EDTA recorded relatively larger plant height (cm) over Fe as soil through Fe-EDTA at all the stages of plant growth, probably due to higher Fe uptake through aerial portion of plant under foliar spray (Sarangi *et al*., 2006). Evaluation of Fe salts as foliar spray under different conditions showed greening effect associated with increased chlorophyll and Fe content. Subsequently, application of non-charged or negatively charged Fe-chelates for foliar sprays seems to be the most effective alternative as suggested by Fernandez *et al*. (2005).

Application of Zn and Fe in combination with FYM and recommended dose of N,P,K significantly influenced the yield attributes (Table 2). Similarly combined application of Zn-EDTA @ 1.00 Kg ha^{-1} followed by Fe-EDTA@ 0.5 Kg ha^{-1}applied as foliar recorded significantly higher number of panicles m^{-2}, panicle weight, grain and straw yield over the single or combined application of Zn-EDTA and Fe-EDTA. Test weight and harvest index remained statistically at par with the treatment Zn as foliar application through Zn-EDTA @ 0.5 Kg ha^{-1} followed by Fe as foliar application through Fe-EDTA @ 0.5 Kg ha^{-1}. Participation of Zn in biosynthesis of indole acetic acid (IAA) and its role in initiation of primordial reproductive parts and partitioning of photosynthates towards them are responsible for increased yield (Takaki and Kushizaki, 1970). The favorable influence of applied Zn on yield may be due to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants (Mandal *et al.,* 2009). Iron as a constituent of the electron transport enzymes, like cytochromes and ferredoxin are actively involved in photosynthesis and mitochondrial respiration. It is also a constituent of the enzymes catalase and peroxidase, which catalyze the breakdown of H_2O_2 (peroxide released during photorespiration) into H_2O and O_2, preventing H_2O_2 toxicity. Iron along with molybdenum, is an element of the nitrite and nitrate reductase enzymes. Thus, iron helps in the utilization of nitrogen. All these physiological processes proved instrumental in increasing yield by application of iron.

Incorporation of micronutrient (Zn-EDTA and Fe-EDTA) proved significantly superior to control in increasing N, P, K content in grains of rice (Table 3). Application of Zn-EDTA @ 1 Kg ha^{-1} in soil followed by Fe-EDTA @ 0.5 Kg ha^{-1} as foliar spray in two splits recorded maximum N, P and K content in grain of rice and proved superior over other treatments whereas, it remained at par with Zn-EDTA @ 0.5 Kg ha^{-1} followed by @ 0.5 Kg ha^{-1} Fe-EDTA as foliar application. Rest of the treatment combinations remained almost on par. Increase in nutrient uptake with the increased fertility levels could be attributed to better availability of nutrients and their transport to the plant from the soil.

Incorporation of Zn-EDTA @ 1.00 Kg ha^{-1} as soil application showed significant superiority over all treatments in increasing Zn content in grain. The zinc and iron content in rice grains were recorded maximum with their separate application and minimum under control, whereas combined and sequential applications of Zn-EDTA and Fe-EDTA slightly decreased Zn and Fe concentrations in grains as compared to their separate applications reported by Verma and Tripathi (1983). Jana *et al.* (2010) also observed that soil application of Zn-EDTA led to higher content and uptake of N,P,K and Zn in grain and straw of rice. Alvarez *et al.* (2001) reported that when Zn was added as Zn-EDTA, the amounts of the most labile fractions (water-soluble plus exchangeable and organically complexed Zn) increased throughout the entire soil profile column, which enhanced the root-cell membrane function. Activity of carbonic anhydrase (CA) is closely related to Zn content in C_3 plants (Pearson *et al.,* 1995). Under extreme Zn deficiency, carbonic anhydrase activity remained almost absent. The labeled Zn rapidly accumulated in the roots of cereal crops upon immersion into the isotope solution. Root uptake and root-to-shoot transport of zinc and particularly internal utilization of zinc are equally important mechanism involved in the expression of zinc efficiency in cereal crops varieties. Since flag leaves are one of the sources of remobilized metals for developing seeds, the identification of the molecular players that might contribute to the process of metal transport from flag leaves to the seeds may be useful for biofortification purposes in relation to Zn and Fe (Sperotto *et al.*, 2010).

Foliar application of Fe in two splits produced highest Fe content in grain and proved significantly superior to all other combinations. Concurrently, incorporation of Zn-EDTA @ 1 Kg ha^{-1} in soil and foliar application of Fe- EDTA @ 0.5 Kg ha^{-1} showed next best affectivity in increasing Fe content over other treatments. Uptake of Zn or Fe, however, was reduced in combined soil as well as foliar applications of Zn and Fe which remarkably increased when applied to soil individually. This indicated antagonism between these two micronutrients when applied in combination. Further, Fe content improved due to application of N through organic sources which might be due to maintenance of better soil aeration and the solubility of micronutrients. Based on overall findings, it may be concluded that Zn-EDTA as soil and Fe-EDTA as foliar applied in rice contributed marked increase in yield associated with grain micronutrient content (Zn and Fe) along with their uptake as compared to other treatments and finally significantly balancing in ionic composition.

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