RESEARCH ARTICLE

TO STUDY THE EFFECT OF ZN, FE AND FYM ON YIELD, ECONOMICS AND NUTRIENT UPTAKE OF DIFFERENT RICE (*ORYZA SATIVA* L.) VARIETIES

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Abstract: A field experiment was carried out at research farm Institute of Agricultural sciences, BHU, Varanasi for two consecutive years during kharif seasons of 2006-07 and 2007-08. Testing variables consisting of two varieties i.e. NDR-359 and HUBR 2-1, two sources of fertilizer application i.e. 100% 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 yield, economics and NPK uptake of rice than HUBR 2-1, while Zn and Fe uptake were significantly increased in HUBR 2-1. Fertilizer source as application of 75% RFD through inorganic and rest through FYM recoded significantly higher yield, economics and N, P, K, Zn and Fe uptake of rice than 100% RFD through inorganic source. Among the different micronutrient treatments, soil application of Zn-EDTA @ 1 kg ha^{-1} recorded significantly higher Zn uptake in rice whereas application of Fe-EDTA @ 0.5 kg ha^{-1} recorded significantly higher Fe uptake by rice as compared to other micronutrient treatments.

Keywords: RFD, FYM, Varieties, Yield attributes, Economics, N, P, K, Zn, Fe uptake

INTRODUCTION

Rice is considered back bone of food security in India and 70% of Asian country of globle lebel. Rice production constitutes the major economic activity and key sources of livelihood for the rural households of the Punjab, Hariyana, Uttar Pradesh, Bihar, Bengal and plain, where growing rice during the kharif season is a physio graphic compulsion. In Asia 90% rice is produced and consumed and the rest (10%) in USA, Africa, Australia and Europe (Tiwari, 2002). Rice is the most important cereal crop in India but its productivity is very low, particularly in eastern U.P. 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 to improve 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 is 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 keeping this view in mind it was thought 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 Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University Varanasi during *kharif* seasons of 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 (0.898 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 (V_1-NDR-359 and V_2 - HUBR2-1) and two fertilizer sources (F_1-100% recommended fertilizer dose (RFD), F_2-75% RFD+25% N through FYM and 9 sub plot treatment combinations M_0 (control), M_1 (Zn as soil application through Zn-EDTA @ 1.00 kg ha^{-1}), M_2 (Zn as foliar application through Zn-EDTA @ 0.5 kg ha^{-1}), M_3 (Fe as soil application through Fe- EDTA @ 1.00 kg ha⁻

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^{1}), M_4 (Fe as foliar application through Fe-EDTA @ 0.5 kg ha^{-1}), M_5 (Zn as soil application through Zn-EDTA @ 1.00 kg ha^{-1} + Fe as soil application through Fe-EDTA @ 1.00 kg ha^{-1}), M_6 (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}), M_7 (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}), M_8 (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 on a spacing of 20 × 10 cm with 2 seedling $hill^{-1}$. Observations on various yield parameters (number of panicle m^{-2}), grains/panicle,test weight (g) , grain and straw yield (qha^{-1}), cost off cultivation (Rs/ha^{-1}), net returns (Rs/ha^{-1}), benefit cost ratio) and nutrient uptake (N, P, K, Zn, and Fe) were done at harvest after transplantation (DAT). Estimations of N, P, K, Zn, and Fe were done by the methods given by, N (Subbiah and Asija, 1973), P and K (Jackson, 1973), Zn and Fe (L'vov, B.V, 2005), respectively. Yield and yield attributes of different treatments ha^{-1} were recorded and computed. As effect of different treatments during two years showed similar trends, pooled means of two years data were presented.

RESULTS AND DISCUSSION

Effect of varieties

Data revealed that variety NDR-359 produced significantly higher yield parameters (number of panicle m^{-2}), test weight (g), grain and straw yield (qha^{-1}) over HUBR 2-1 whereas, grains/panicle, significantly higher over NDR-359 during crop seasons (Table 1).

The cost of cultivation of aromatic and non aromatic rice (fine and coarse rice grains) varied from 29202.48 to 29577.54 Rs/ha. Owing to transplanted of different nature type of rice varieties.The cost of cultivation was the lower under V_1 (NDR-359) for variety treatment, whereas it was higher V_2 (HUBR 2-1) for variety treatment of rice. Owing to production of grain yield and comparatively lower cost (V_1), net returns (55312.55 Rs/ha) and benefit cost ratio (1.87) were the significantly highest under the V_2 (HUBR 2-1) varietal treatment during both the years.

light varietal differences were observed in N, P and K uptake of grain and straw. Variety NDR-359 recorded significantly higher N, P and K uptake than HUBR 2-1. In case of non-aromatic rice varieties, about 73% of N was translocated to grain and rest remaining in the straw while in aromatic cultivars translocation of N to grain was only 47% (De *et al.*, 2002). The results of the present study are in agreement with the findings of Subrahmanym and Mehata (1974). 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, micronutrients (Zn and Fe) content or uptake of variety HUBR 2-1 proved significantly superior over NDR-359 (Table 2). Varieties, HUBR 2-1 recorded maximum zinc and iron in grains and straw because it is aromatic in nature which supported the fact that zinc and iron concentrations remain higher in grains due to aromaticity of the variety. These findings are strongly supported by Graham *et al*. (1997) and (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 might be due to increase of aroma and nutrient content synthesizing in grain with combined use of organic and inorganic sources of nutrients as compared to 100% RFD through inorganic fertilizers. These findings are strongly supported by (Sahu *et al.,* 2007).

Effect of fertilizers

The Application of 75% RFD through inorganics + 25% N through FYM produced significantly higher yield attributes of number of panicle m^{-2}, number of grains $panicle^{-1}$, test weight (g) and grain yield of 54.06 qha^{-1} over 100% RFD through inorganics (49.75 qha^{-1}). Application of F_2 sources of fertilizers also produced relatively higher straw yield (75.41 qha^{-1}), as compared to F_1 sources of fertilizers at crop harvest. (Table 1). 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 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 has also been reported by Gupta *et al*., (2009).

The cost of cultivation of aromatic and non aromatic rice varieties varied from 28960.05 to 29819.97 Rs/ha. Owing to use of different doses and sources of fertilizers. The cost of cultivation was the lowest for 100% RFD through inorganic fertilizers applied to rice, whereas it was highest when 75% RFD through inorganic+25% N through FYM. Owing to production of grain yield and comparatively lower cost (F_1), net returns (46296.48 Rs/ha) and benefit cost ratio (1.55) were the significantly highest under the application of 75% RFD through inorganic+25% N through FYM (F_2).

Application of 75% RFD through inorganic sources + 25% N through FYM proved significantly superior in increasing P, K, Zn and Fe uptake in grain and straw over F_1-100% RFD through inorganics during both the years (Table 2). The present results are in agreement with the findings of Srivastava *et al*. (2008) and Chandrapala *et al.* (2010). Organic sources also improved the uptake 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 and straw 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] (2010).

Effects of Zn and Fe

Micronutrients in various mode of application produced significant variation on yield attributes, yield, economics and nutrient uptake. Incorporation of Zn and Fe either individually or in combination significantly increased the yield attributes, yield, economics and nutrient uptake over control in both the year of experimentation. The combined application of M_7 (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 yield attributes, yield, economics and nutrient uptake. Application of Zn and Fe in combination with FYM and recommended dose of N, P, K significantly influenced the yield attributes, yield, economics and nutrient uptake (Table 1 and 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, number of grains panicles^{-1},grain and straw yield over the single or combined application of Zn-EDTA and Fe-EDTA. Test weight (g) remained statistically at par with the treatment $M_{6,}$ M_8 $M_{1.}$ 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.

The effects of treatments were also observed significan in respect of net return and benefit cost ratio (Table 1). The magnitude of incease due to application of Zn and Fe to both in rice. Owing to net returns and benefit cost ratio were the significantly highest under the application of M_7 (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) in rice was found to be net return (49120..43) and benefit cost ratio (1.64) significantly higher over to all treatments during both the years. M_1 (Zn as soil application through Zn-EDTA @ 1.00 kg ha^{-1}) and M_4 (Fe-EDTA @ 0.5 kg ha^{-1}applied in two splits at 15 DAT and at 50% panicle initiation) applied alone resulted both on par during both the years. Husain *et al.* (2009) also reported similar results.

In general, nutrient removal by rice crop was recorded mainly due to higher yield of rice and depend on nature of rice varieties, fertility and field management and practices. Incorporation of micronutrient (Zn-EDTA and Fe-EDTA) proved significantly superior to control in increasing N, P, K uptake by rice (Table 2). 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 uptake of rice and proved superior over other treatments. 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 followed by M_2, M_7, M_5, M_6, $M_{8,}$ M_4. 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). 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 higher yield and nutrient uptake 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).

Foliar application of Fe in two splits (M_4) 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 obsiously 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. Therefore, overall findings 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.

Uptake by grain and straw

The results of the present study indicated that zinc and iron content in grains and straw favourably influenced due to different treatments. Nutrient content of rice significantly increased over control due to Zn, Fe and FYM application. Zn, Fe and FYM showed synergistic effect on N, P, K, Zn and Fe content. However slight varietal differences were observed in N, P and K content of plant at flowering stage, grain and in straw. Variety NDR-359 recorded higher uptake and N content than HUBR 2-1 at flowering stage and in grain and straw, but it remained significantly higher in straw of NDR-359 during both the years. The results of the present study are in agreement with the findings of Subrahmanym and Mehata (1974).They reported that Fe application significantly increased the N content of rice. Phosphorous content and uptake at flowering stage of plant, grain and straw increased markedly in NDR-359. Similarly K content and uptake of variety NDR-359 remained significantly superior to HUBR 2-1 at flowering stage, and in grain and straw during both the years. Micronutrient (Zn and Fe) content and uptake of variety HUBR 2-1 proved significantly superior to NDR-359 during both the years due to varietal differences and recorded maximum zinc and iron in grains than HUBR 2-1. Since this variety is aromatic in nature which supported the established fact that zinc and iron concentration in grains are related to aromaticity of the variety. These findings are strongly supported by Graham *et al.* (1997), Qui *et al*. (1993) and Babu *et al.* (2005).

Table 1. Effect of Zn, Fe and FYM on yield attributes and yield of rice (pooled data).

Treatments	**Yield attributes and economics**							
Varieties	**Panicle m^{-2} (No.)**	**Grains/ panicle**	**Test wt. (g)**	**Grain yield (qha^{-1})**	**Straw yield (qha^{-1})**	**Cost of cultivation (Rs/ha)**	**Net returns (Rs/ha)**	**Benefit: Cost ratio**
V_1: NDR – 359	385.99	124.61	31.33	55.05	75.01	29202.48	31906.08	1.09
V_2: HUBR 2-1	365.39	140.15	20.05	48.75	72.34	29577.54	55312.55	1.87
SEm±	4.59	1.58	0.27	1.06	0.70	-	1244.75	0.05
CD (P = 0.05)	15.87	5.44	0.94	3.66	2.42	-	4307.35	0.15
Fertilizers								
F_1: 100% RFD through inorganics	361.19	128.51	25.47	49.75	71.96	28960.05	40922.15	1.41
F_2: 75% RFD through inorganics + 25% N through FYM	390.19	136.52	25.91	54.06	75.41	29819.97	46296.48	1.55

SEm±	4.59	1.58	0.27	1.06	0.70	-	1244.75	0.05
CD (P = 0.05)	15.87	5.44	0.94	3.66	2.42	-	4307.35	0.15
Micro-nutrient (Zn and Fe)								
M_0: Control	335.05	115.05	24.26	43.49	65.83	26744.01	34686.01	1.30
M_1: Zn-EDTA @ 1.00 kg ha^{-1} (S)	372.31	133.63	26.28	53.25	74.65	29635.76	45118.47	1.52
M_2: Zn-EDTA @ 0.5 kg ha^{-1} (F)	361.92	130.09	25.56	51.60	73.11	29295.76	43282.41	1.48
M_3: Fe-EDTA @ 1.00 kg ha^{-1} (S)	359.82	126.10	25.43	50.71	72.28	29635.76	41739.90	1.41
M_4: Fe-EDTA @ 0.5 kg ha^{-1} (F)	378.95	132.43	25.64	52.72	74.39	29295.76	44948.41	1.53
M_5: Zn-EDTA @ 1.00 kg ha^{-1} (S)+Fe-EDTA@1.00kg ha^{-1} (S)	387.41	135.33	25.66	52.85	74.92	30315.76	43966.06	1.45
M_6: Zn-EDTA @ 0.5 kg ha^{-1} (F) fb Fe-EDTA @ 0.5 kg ha^{-1} (F)	395.75	137.21	25.68	53.48	75.58	29635.76	45575.07	1.54
M_7: Zn-EDTA @ 1.00 kg ha^{-1} (S) fb Fe-EDTA @ 0.5 kg ha^{-1} (F)	407.78	146.87	26.25	56.27	78.52	29975.76	49120.43	1.64
M_8: Fe-EDTA @ 1.00 kgha^{-1}(S) fb Zn-EDTA @ 0.5 kg ha$^{-1(}$F)	382.21	135.73	26.80	52.76	74.77	29975.76	44047.08	1.47
SEm±	4.23	1.53	0.26	0.83	0.65	-	1187.41	0.04
CD (P = 0.05)	11.96	4.31	0.74	2.35	1.84	-	3354.65	0.11

***RFD –Recommended Fertilizers Dose, S – Soil application, F – Foliar application, fb – Followed by, NS – Non-significant**

Table 2. Effect of Zn, Fe and FYM on total uptaket of rice grain (pooled data).

Treatments	**Nutrient uptake (kg/ha)**				
Varieties	**N**	**P**	**K**	**Zn**	**Fe**
V_1: NDR – 359	121.38	29.22	167.61	2.44	1.55
V_2: HUBR 2-1	108.56	26.98	157.54	2.56	2.11
SEm±	1.80	0.44	0.51	0.02	0.01
CD (P = 0.05)	6.23	1.51	1.75	0.08	0.03
Fertilizers					
F_1: 100% RFD through inorganics	108.75	24.22	152.70	2.34	1.64
F_2: 75% RFD through inorganics + 25% N through FYM	121.20	31.97	172.45	2.66	2.02
SEm±	1.80	0.44	0.51	0.02	0.01
CD (P = 0.05)	6.23	1.51	1.75	0.08	0.03
Micro-nutrient (Zn and Fe)					
M_0: Control	91.48	20.36	134.92	1.77	1.18
M_1: Zn-EDTA @ 1.00 kg ha^{-1} (S)	117.94	29.31	167.47	2.80	1.67
M_2: Zn-EDTA @ 0.5 kg ha^{-1} (F)	109.84	27.09	156.56	2.55	1.54
M_3: Fe-EDTA @ 1.00 kg ha^{-1} (S)	107.29	25.96	153.15	2.35	1.82
M_4: Fe-EDTA @ 0.5 kg ha^{-1} (F)	116.88	28.53	164.23	2.36	2.32

M_5: Zn-EDTA @ 1.00 kg ha^{-1} (S)+Fe-EDTA@1.00kg ha^{-1} (S)	118.72	28.92	167.86	2.64	1.81
M_6: Zn-EDTA @ 0.5 kg ha^{-1} (F) fb Fe-EDTA @ 0.5 kg ha^{-1} (F)	124.26	31.00	173.14	2.72	2.07
M_7: Zn-EDTA @ 1.00 kg ha^{-1} (S) fb Fe-EDTA @ 0.5 kg ha^{-1} (F)	131.71	33.00	180.93	2.85	2.16
M_8: Fe-EDTA @ 1.00 kgha^{-1}(S) fb Zn-EDTA @ 0.5 kg ha^{-1}(F)	116.62	28.72	164.92	2.48	1.89
SEm±	1.44	0.34	0.37	0.02	0.01
CD (P = 0.05)	4.08	0.94	1.05	0.05	0.02

***RFD –Recommended Fertilizers Dose, S – Soil application, F – Foliar application, fb – Followed by, NS – Non-significant**

Regarding source of fertilizer treatment 75% RFD through inorganic sources + 25% N through FYM proved superior over 100% RFD through inorganics in increasing NPK content and uptake during both the years. Nitrogen content in plant at flowering stage and in grain though increased due to 75% RDF through inorganics + 25% N through FYM over 100% RFD through inorganics but failed to touch the level of significance. However it proved significantly superior in respect of N content in straw, P and K content of plant at flowering stage and in grain and straw over 100% RFD during both the years. Application of 75% RFD + 25% N through FYM also remained significantly better over 100% RFD in respect of uptake of N, P and K in grain and straw. The present results are in agreement with the findings of various workers (Srivastava *et al.*(2008) and Chandrapala *et al.* (2010). Application of organic manures along with macro and micronutrients might have enriched the soil fertility due to increased micronutrient availability due to formation of plant available organic-metal complexes with decomposition of organic materials and thus brought about variations in the grain yield of cereal crops through direct influence on the yield attributes and grain yield. Increase in nutrient uptake with the increase in fertility levels could be attributed to the better availability of nutrients and their transport to the plant from the soil, which enhanced the uptake of nutrients by plant. Similar results have also been reported by Singh *et al.* (2002) and Kumar and Kumar (2009). Micro-nutrient (Zn and Fe) content and uptake significantly increased due to 75% RFD through inorganics + 25% N through FYM over 100% RFD through inorganics at flowering stage and in grain and straw during both years. Highest Zn content and uptake was recorded under treatment receiving 10 tonne organic manure+5 kg Zn ha^{-1} by Pandey *et al,* (2007), Sridevi *et al.* (2010) and Satish *et al.*,(2010). Use of organic manure with the optimum level of zinc reduced its requirement upto 50%. Beneficial effect of organic manures may be attributed to the formation of organometallic complexes with zinc, which resulted in the increase of its efficiency. These results are in accordance with findings of several workers Gupta and Handore (2009). Organic sources also improved the content of Fe by supplying chelating agents, which helps in maintaining the solubility of micro-nutrients including Fe. In addition, organic matter improves soil structure which provides better soil aeration resulting into increased availability of Fe. The response of organic matter showed profound influence on the solubility of Fe in waterlogged soil by providing resistance to Fe chlorosis visual indices, increasing foliar content of chlorophyll and which enabled to excrete reduced compounds from the roots (Singh *et al.*, 2010). Organic matter in the soil exerts a positive effect on solubility of Fe through its reductive effect out of proportion with the amount of Fe contained in the biomass. Adding organic matter to a soil deficient in available Fe exerts a positive effect on the plants. Biological degradation of the organic matter contributes negative electron and other reducing agents which lowers the redox potential of the soil, creating reducing microenvironments in the soil where the concentration of Fe (II) available to the plants increased. It is thus apparent that application and maintenance of organic matter in the soil translates adequate long term availability of Fe as has been observed in present investigation and are in agreement with the findings of various workers (Lindsay, 1991). Mishra *et al.* (2004) reported that application of organic manures to rice fields increased the Fe concentration and its uptake in rice and suggested that their regular addition is the best way to avoid Fe deficiency. Improving N nutrition of plants may contribute to increase Zn and Fe concentration in grain 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 Ismail Cakmak[A] (2010).

Content and uptake of Zn and Fe in grains and straw markedly increased due to Zn and Fe application over control during both the years of investigation. Combined and sequential application of zinc and iron slightly decreased zinc and iron concentration in grains, when compared with their separate application. The results are in conformity with the findings of Hemantaranjan and Garg (1988), and Zhang *et al.* (1991) who reported that single application of these micro-nutrients improved their concentration in grains, but when applied simultaneously antagonized to each other. Incorporation of Zn-EDTA @ 1.00 kg ha^{-1} as soil application showed significant superiority over all treatments in increasing Zn content. Chandrapala *et al.* (2010) and Naik and Das (2008), reported increased uptake of Zn in grain and straw due to application of Zn-EDTA and concluded that the greater affectivity of Zn-EDTA over other sources of Zn in terms of growth and its utilization by plants which might be due to less retention greater transport and movement of chelated Zn to plant roots. 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 CA is closely related to zinc content in C_3 plants. Under extreme zinc deficiency, CA (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 (Pearson and Rengel, 1995). About Zn re-translocation little is known regarding its transport from roots to leaves and from leaves to other plant organs. Enhanced translocation of zinc from root to shoot meristems and its re-translocation from senescing to growing organs under deficient cereals is well known. The enhanced capacity of genotypes for zinc translocation from root to shoot and its utilization under deficient Zn supply has been shown to contribute to Zn deficiency in cereal genotypes. Cakmak *et al.* (1996) and Hajiboland *et al.* (2001) found that zinc deficiency tolerance of Zn- efficient rice genotypes is related to its ability to re-translocate zinc from older to growing emerging leaves. Incorporation of Fe and Zn-EDTA @ 0.5 kg ha^{-1} each as foliar application recorded their more concentration and uptake over other combinations. Similar results have been reported by Seilsepour. El-Ghamry *et al*. (2009) and Habib, (2009). Sperotto *et al.* (2010) reported that foliar application of Zn+Fe at tillering and heading stage increased Zn and Fe concentration and its uptake. 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. However for Zn uptake application of Zn-EDTA @ 1.00 kg ha^{-1} as soil application followed by Fe-EDTA 0.5 kg ha^{-1} as foliar application at 15 DAT and at 50% panicle initiation proved significantly superior over all other treatments during both the years.The present results are in agreement with the findings of various workers Subrahmanyam and Mehata (1974) and Varshney *et al*. (2008).

Fe content and uptake significantly increased due to foliar application of Fe-EDTA @ 0.5 kg ha^{-1} at 15 DAT and at 50% panicle initiation (M_4) overall other treatments. Fe is shown to be transported from the root to areal plant organs in the xylem as a ferric citrate complex (Tiffin, 1966). Fe^{2+} is the main form absorbed by rice leaf and Fe^{3+} reduction is prerequisite for its absorption in grains. Fe accumulation trend in rice grains at grain filling stage of rice crop reflects that at anthesis Fe concentration in grains remains down from first 20 days after anthesis. Contrary to this Fe density in grains remains up, from first 20 days after anthesis but decreases thereafter. This suggests the speed of Fe accumulation in grains per unit time is lower markedly than down loads of the carbohydrate, but the content of Fe per grain certainly increased slowly. Generally, Fe concentration decreased initially even though their rate of accumulation was highest during this period. Fe accumulation and dry matter down load in rice grains are not synchronous which show the mechanism of Fe and the carbohydrate uptake by grains is different. Results thus indicated the use of Fe would be more effective when it applied 20 days after anthesis. These results were supported by Singh *et al.* (2002), Kulandaivel (2004). However, the spraying with micronutrients showed marked increase uptake as compared to other treatments. In plants utilizing strategy (I), chlorophytum under iron deficiency remains associated with rhizophere acidification, whereas considerable amounts of apoplasmic Fe in the roots are mobilized and translocated to the shoots (Bienfait *et al*.,1983). Accordingly, the translocation of Fe to the shoots increased steeply in Fe-deficient plants after onset of the light period and continued thereafter more or less continuously. This discrepancy between timing of phytosiderophore release and Fe translocation is probably the result of the experimental conditions. Additionally, the continuous translocation of Fe to the shoots during the light period could be derived from a pool formed within the roots after onset of the light period. The chemical nature of this Fe pool in roots is not known. It is also not clear whether Fe (III) phytosiderophores are involved in Fe translocation from roots to the shoot (Marschner, 1991).

Experimental evidence is lacking on a role of nicotianamine in long distance transport of Fe from roots to the shoots. Microbial siderophores may maintain a continuous and substantial supply of soluble Fe to the root surface. Depending on their chelate stability, they make an important contribution to the apoplasmic Fe pool and thus the source of Fe readily mobilized by phytosiderophores in graminaceous species (Zhang *et al*., 1991). The similar result was found by Yassen *et al.* (2010). However, Fe content improved due to application of N through organic sources. Organic materials supply chealating agents, which helps in maintaining the solubility of micronutrients including Fe and Mn. In addition organic matter improves soil structure which provides better soil aeration resulting in to increase in the availability of Fe (Das *et al.*, 2010). The presence of organic matter showed a profound influence on the solubility of Fe in waterlogged soils. The uptake of zinc or iron was reduced in combined soil application as well as foliar of Zn and Fe but their uptake increased when applied to soil individually indicating antagonism between these two micronutrients.Chandrakumar *et a.l*(2004) also reported that application of these micronutrients improved their uptake in rice when applied separately, but when supplied simultaneously antagonized to each other.

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