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Effect of levels of zinc and iron and their chelation on yield and soil micronutrient status in hybrid rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during rainy and winter seasons of 1999–2000 and 2000–2001 to evaluate the levels and mode of application of zinc and iron on grain yields of hybrid rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crops and also the changes taking place in the micronutrient status in the soil. The levels and mode of application of zinc and iron considerably increased the growth, yield attributes and yield of rice–wheat cropping system and also improved the soil status of these micronutrients after harvest of each crop over the control. Application of 30 kg $ZnSO_4$+ 5 kg $FeSO_4$/ha through chelating with FYM was found to be the best combination for rice. However for hybrid rice–wheat cropping system, application of 40 kg $ZnSO_4$ + 10 kg $FeSO_4$ was found to be the most appropriate combination to maximize the grain yields of this system and improve the zinc and iron status of soil.

Key words : Rice–wheat cropping system, Zinc, Iron, Chelation

In recent times, the rice–wheat cropping systems has been experiencing stagnation or decline in productivity (Bhandari *et al.*, 2002) due to low organic matter content of soils and low indigenous nutrient supply (Adhikari *et al.*, 1999). The increasing dependence on high-analysis straight fertilizers as against the ordinary supperphosphate that contains handsome quantities of micronutrients and high harvests in rice–wheat cropping system has resulted in gradual appearance of Zn and Fe deficiencies (Takkar, 1996) especially in highly permeable coarse textured soils of Punjab. Application of these nutrients has became inevitable for realizing potential yield of this cropping system. Chelation of zinc with manures enhances the yields of rice (Devarajan and Krishanasamy, 1996). Further, to meet the food need of the growing population, the system productivity needs not only maintenance but also enhancement. Since yield potential of the exiting cultivars has been harnessed and there lies little scope on this front, efforts have been made to develop hybrids in rice and these hybrids show 15-20% higher yields over the existing varieties (Mahaveappa *et al.* 1996). There is little information on productivity potential of hybrid rice–wheat system and on the effect of combined application of zinc and iron and their mode of application. Therefore present study was carried out to evaluate effect of zinc and iron levels and their mode of application on yield and micronutrient status in hybrid rice–wheat system.

MATERIALS AND METHODS

A field experiment was conducted during 1999–2000 and 2000–2001 (rainy–winter season) at the farm of Indian Agricultural Research Institute, New Delhi, with hybrid rice 'pro Agro 6207' and wheat 'HD 2329'. The soil of the experimental field was sandy clay loam, low in total N (0.04%), medium in available P_2O_5 and K_2O (23.4 and 165 Kg/ha), low in DTPA-Zn and Fe (0. 68 and 3.9 ppm) with 8.1 pH. The incubated $ZnSO_4$ and $FeSO_4$ were prepared by mixing well-rotten FYM with calculated quantities of $ZnSO_4$ and $FeSO_4$ based on the treatments and kept for 60 days under anaerobic conditions. These incubated (chelated) manure + micronutrient mixture were applied to the plots as per the treatments. The non-incubated $ZnSO_4$ and $FeSO_4$ was applied to the plots just before transplanting. All the treatments were given only to hybrid rice and their residual effects were studied on succeeding wheat. All other input management practices were carried out as per the crop recommendations. Samples of rice and wheat grain and straw and post-harvest soil sample of both the crops were taken and the Zn and Fe content were analysed using atomic absorption spectrophotometer. At harvest the grain and straw yields were recorded and uptake was calculated as a product of micronutrient content

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and yield.

RESULTS AND DISCUSSION

Hybrid rice

Growth attributes of rice, viz., number of tillers, dry-matter production, leaf-area index and crop growth rate, increased due to levels and modes of $ZnSO_4$ and $FeSO_4$ application over the control (Table 1). The effect was more prominent in the plot treated with 30 kg $ZnSO_4$ and 5 kg $FeSO_4$/ha. Yield attributes of hybrid rice such as panicles/m^2, grains/panicle and weight of panicle, perceptibly improved by the use of various levels and modes of application of zinc and ferrous sulphate over the control (Table 1). The best treatmental effect was recorded with the application of 30 kg $ZnSO_4$/ha. The other rice yield attributes like panicle length, fertility percentage and test weight were not improved by the levels and mode of application of Zn and Fe. Similar findings were reported by Chauhan (1995).

Application of 30 kg $ZnSO_4$/ha recorded significantly higher grain yield (mean 62.0 q/ha) over its lower levels, but it was at par with application of 40 kg $ZnSO_4$/ha (Table 1). Within levels of $FeSO_4$ and 2 modes of applications of micronutrient sources, no significant effects were noticed. But levels of $FeSO_4$ and its mode of application resulted in significant increase in rice yield over the control. Prasad and Umar (1993) also reported similar results.

Residual effect on wheat

Among the yield attributes of wheat, only the number of ear-bearing shoots was significantly influenced by residual effect of the treatments. Grain yield of wheat enhanced significantly by the residual effect of levels of zinc and ferrous sulphate and their mode of application over the control. The mean increase in grain yield of wheat owing

Table 2. Yield attributes and yield of wheat as influenced by residual effect of levels and mode of application of zinc and iron to hybrid rice (pooled data)

Treatment	Ear-bearing shoots/m^2	Yield (q/ha)	
		Grain	Straw
$ZnSO_4$ (kg/ha)			
10	341.1	41.1	49.7
20	348.1	41.8	50.5
30	371.4	43.0	51.9
40	381.1	43.8	52.7
CD (P=0.05)	16.1	1.3	1.7
$FeSO_4$ (kg/ha)			
5	356.9	42.2	51.4
10	365.6	42.7	51.9
CD (P=0.05)	NS	NS	NS
Mode of application			
Incubated	363.8	42.6	51.4
Non-incubated	356.2	42.2	51.1
CD (P=0.05)	NS	NS	NS
Control	329.7	40.0	45.6
CD (P=0.05) (Control vs. rest)	23.0	2.7	3.3

Table 1. Growth attributes and yield of hybrid rice as affected by levels and mode of application of zinc and iron (pooled data)

Treatment	Tillers/m row at heading	Dry matter (q/ha)		Leaf-area index		Crop growth rate (g/m^2/day)		Panicles/ m^2	Grains/ panicle	Panicle weight (g)	Yield (q/ha)	
		Heading	Harvest	Heading	Harvest	Heading	Harvest				Grain	Straw
$ZnSO_4$ (kg/ha)												
10	18.65	119.1	148.7	7.46	6.71	19.45	9.75	499.5	108.8	3.57	57.0	92.0
20	20.70	124.0	154.9	8.27	7.57	21.70	10.15	536.7	110.6	3.72	59.3	96.6
30	22.40	128.5	160.6	8.97	8.20	22.20	10.85	585.8	113.1	3.95	62.0	110.9
40	22.60	129.5	162.8	9.00	8.23	23.00	11.15	591.5	113.4	3.97	62.9	101.7
CD (P=0.05)	1.08	5.3	7.3	0.41	0.33	0.96	0.50	28.5	2.8	0.21	2.4	3.8
$FeSO_4$ (kg/ha)												
5	20.88	124.5	155.6	8.35	7.59	21.15	10.43	542.4	111.1	3.63	59.6	96.1
10	21.22	125.9	157.3	8.48	7.74	21.55	10.65	549.4	111.9	3.67	60.3	97.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mode of application												
Incubated	21.23	125.6	156.9	8.47	7.70	21.30	10.50	578.1	112.7	3.67	60.2	96.9
Non-incubated	21.02	124.8	156.0	8.40	7.63	21.45	10.20	546.2	110.2	3.64	59.8	96.2
CD (P=005)	NS	NS	NS	NS	NS	NS	NS	NS	1.0	NS	NS	NS
Control	16.45	112.2	142.8	6.58	6.21	17.97	8.99	455.2	105.7	3.48	54.2	89.0
CD (P=0.05) (Control vs. rest)	1.77	7.4	8.6	0.24	0.14	1.40	0.38	23.9	5.2	0.12	4.8	7.8

to residual effect of 40 kg $ZnSO_4$/ha, 10 kg $FeSO_4$/ha and incubated mode of application were 9.5, 6.8 and 5.5%, respectively, over the control. The maximum yield (mean 43.8 q/ha) was recorded with 40 kg $ZnSO_4$/ha, while the minimum (mean 40.0 q/ha) was with the control (Table 2). Ferrous sulphate levels and its mode of application did not show any significant impact on wheat yield. Almost similar trend was observed with straw yield of wheat. However, all the treatments failed to influence the harvest index of wheat.

Zn and Fe uptake

Application of different levels and modes of zinc and ferrous sulphate to hybrid rice had significant influence on Zn and Fe uptake over the control. Among levels of zinc and ferrous sulphate and their mode of application, 40

Table 3. Zn and Fe uptake (g/ha) by hybrid rice and wheat as influenced by levels and mode of application of zinc and ferrous sulphate to rice

Treatment	Hybrid rice				Wheat			
	Zinc		Iron		Zinc		Iron	
	1999	2000	1999	2000	1999	2000	1999	2000
$ZnSO_4$ (kg/ha)								
10	640	718	2,377	2,672	271	192	1,037	1,105
20	785	883	2,523	2,848	326	348	1,081	1,152
30	937	1,023	2,609	2,996	374	408	1,133	1,205
40	975	1,052	2,668	3,004	396	433	1,147	1,225
CD (P=0.05)	42	41	96	124	12	15	58	47
$FeSO_4$ (kg/ha)								
5	818	880	2,278	2,563	335	394	984	1,051
10	853	958	2,711	3,195	349	377	1,215	1,293
CD (P=0.05)	27	28	63	66	9	10	55	33
Mode of application								
Incubated	860	976	2,544	2,993	353	385	1,138	1,220
Non-incubated	791	762	2,400	2,766	331	355	1,059	1,124
CD (P=0.05)	27	28	63	66	9	10	55	33
Control	460	441	1,881	1,752	228	218	718	753
CD (P=0.05) (Control vs. rest)	27	22	158	152	3	7	40	27

Table 4. Zinc and Fe content (ppm) of soil of harvest as influenced by levels and mode of application of zinc and ferrous sulphate

Treatment	After harvest of rice				After harvest of wheat			
	1999		2000		1999		2000	
	Zinc	Iron	Zinc	Iron	Zinc	Iron	Zinc	Iron
$ZnSO_4$ (kg/ha)								
10	0.71	4.57	0.78	4.75	0.66	4.07	0.72	4.33
20	0.78	4.56	0.87	4.74	0.68	4.05	0.75	4.04
30	0.87	4.54	0.96	4.72	0.71	4.04	0.79	4.30
40	0.94	4.53	1.04	4.71	0.75	4.03	0.83	4.29
CD (P=0.05)	0.04	NS	0.05	NS	0.03	NS	0.04	NS
$FeSO_4$ (kg/ha)								
5	0.87	4.33	0.93	4.47	0.70	3.94	0.78	4.08
10	0.86	4.77	0.91	4.98	0.70	4.16	0.77	4.54
CD (P=0.05)	NS	0.16	NS	0.15	NS	0.16	NS	0.14
Mode of application								
Incubated	0.84	4.68	0.93	4.84	0.71	4.14	0.79	4.42
Non-incubated	0.80	4.42	0.89	4.61	0.68	3.95	0.74	4.25
CD (P=0.05)	0.03	0.16	0.03	0.15	0.02	0.16	0.03	0.14
Control	0.65	3.84	0.722	3.92	0.63	3.75	0.70	3.86
CD (P=0.05) (Control vs. rest)	0.002	0.08	0.003	0.07	0.002	0.07	0.002	0.06

kg $ZnSO_4$/ha and 10 kg $FeSO_4$/ha with incubated mode of application registered maximum total Zn uptake (1,016, 906 and 908 g/ha respectively), and total Fe uptake (2,836, 2,953 and 2,769 g/ha respectively), whereas the minimum uptake was observed in control (451 g/ha of Zn and 1,818 g/ha of Fe). These results are in agreement with the findings of Kasana and Chaudhury (1983).

Application of different levels and modes of zinc and ferrous sulphate to hybrid rice had significant influence on Zn and Fe uptake of succeeding wheat. Among levels of zinc and ferrous sulphate and their mode of application, 40 kg $ZnSO_4$/ha and 10 kg $FeSO_4$/ha through incubated mode recorded maximum total Zn uptake (415, 363 and 368 g/ha respectively) and total Fe uptake (1,186, 1,257 and 1,179 g/ha respectively), whereas the minimum uptake was observed in control (223 g/ha of Zn and 735 g/ha of Fe). Application of ferrous sulphate had positive influence on Zn uptake and similarly application of zinc sulphate increased the Fe uptake of wheat.

Zn and Fe status of soil

An appreciable improvement in the Zn and Fe content of the soil after the harvest of hybrid rice and wheat crops was observed. At all the levels of zinc sulphate, there was significant increase in the Zn content of soil both after rice and wheat. The maximum Zn content (0.988 and 0.793 ppm after rice and wheat) was recorded with application of 40 kg $ZnSO_4$/ha. On the contrary, lower content of Zn was recorded from the control. The soil Fe content after rice and wheat in general increased significantly due to iron application over the control and this increase has been significant up to application of 10 kg $FeSO_4$/ha. Further incubated mode of micronutrient application has recorded significantly more iron content than non-incubated ones. In general, the values of post-harvest Zn and Fe contents recorded were less after harvest of wheat compared to those recorded after rice.

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