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RESPONSE OF THE RICE VARIETIES TO FIELD APPLICATION OF MICRONUTRIENT FERTILIZERS

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Abstract. Analysis of leaf samples collected from farmers' fields in 1973 revealed a wide incidence of severe Zn and Cu deficiency in rice in the Punjab. Iron and Mn supply to plants appeared to be optimum.

In 1974, two rice varieties, Basmati-370 and IR-6 were grown on randomly selected 5 and 15 sites respectively with and without the addition of Cu, Fe and B fertilizers. Top most leaves of control plants of both the varieties contained luxury concentration of Mn. Iron concentration also appeared sufficient. Still Fe application marginally increased paddy yield of IR-6 on two and Basmati-370 on seven sites. Leaf concentration of Fe was a poor indicator of Fe deficiency in rice plants.

Application of Cu markedly increased paddy yield of IR-6 on two and of Basmati-370 on six sites. Five p.p.m. applied Cu alleviated its deficiency completely on all the sites. Critical Cu concentration in the leaves of the two varieties were 6.6 and 5.3 p.p.m. respectively. Higher critical Cu level in IR-6 appeared to be caused by higher Fe absorption (low Cu/Fe ratio) by its plants.

Boron increased paddy yield of IR-6 on two and of Basmati-370 on nine sites quite markedly. Interaction between various micronutrients in plants were not consistent but at a few sites, they accentuated deficiency of some elements and depressed paddy yields.

These investigations indicate widespread deficiency of Zn, Cu, Fe and B for rice in the Punjab. Use of their fertilisers appears to be quite profitable.

Application of micronutrient fertilizers to crops have revolutionized agricultural production of many countries of the world. Since the first report by Nene,[16] disorders of flooded rice caused by Zn deficiency has been reported in India,[30] Japan,[25] Philippines, Taiwan,[8] and the United States of America.[20] These reports indicate that in Asia alone, more than two million hectares of flooded rice suffer with Zn deficiency. It occurs more frequently on calcareous soils.[26] Since rice soils of the Punjab are predominantly calcareous, Zn deficiency in rice may be quite severe in this region. Field trials at Kala Shah Kaku Rice Research Farm with IR-8 and IR-184 rice varieties has recently shown the disorder of rice, called 'Hadda', to be Zn deficiency.[21,30] The availability status of rice soils for other micronutrients are not known. However, Zn and Cu deficiency usually occurs simultaneously on many soils.[7] Some preliminary pot trials in our laboratory have also revealed the possibility of Cu deficiency on these soils.[14] Iron chlorosis is a major problem for many plant species on alkaline calcareous soils[27] and rice responds quite markedly to its application.[15] But analysis of leaf samples collected at and around Kala Shah Kaku Rice Research Farm indicated luxury to toxic Fe contents in rice plants.[26] Mangenese and B status of rice soils has never been reported but some studies on B deficiency for upland crops in other calcareous regions[5] indicate the possibility of severe B deficiency in rice especially when Ca concentration, which strongly reduces B contents of plants[9] is usually high in flooded soils.

Basmati-370 is a major fine-grained rice variety of the Punjab. Its micronutrient requirements have never been reported. IR-6 has recently been introduced in this area. It is a high yielder and is considered a high feeder on soil nutrients. Its micronutrient requirements are yet to be known.

The present field trials were, therefore, conducted to establish and compare the need of the two rice genotypes for micronutrient fertilizers on calcareous soils of the Punjab and to establish critical micronutrient levels in their plants for diagnostic purposes.

Materials and Methods

In summer 1973, top most leaves of about 60-days old rice plants (about 15 days before flowering) were collected from randomly selected farmers' fields of important rice growing areas of the Punjab. About 100 leaves were sampled from each 1/2 acre. Deficiency symptoms on the plants were noted and field history, wherever available, was also recorded. Leaves were washed with deionized water, dried at 70°C in a stainless-steel oven for 24hr and ground in a Wiley mill fitted with stainless steel interior parts of the cutting chamber. One g portions of the ground samples were digested with 25 ml diacid mixture

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(redistilled HNO_3 and $HClO_4$ at 4:1 ratio). Zinc, Cu, Fe and Mn in the diluted digest were determined by atomic absorption spectroscopy.[1] Deficiency of various m icronutrients in the samples were predicted using critical values reported by other researchers.[26, 30]

Next year in summer 1974, field trials were conducted on 20 important sites of rice growing areas of the Punjab (Map 1). IR-6 was sown on randomly selected 5 and Basmati-370 on 15 sites. The detailed physiochemical characteristics of soils have been described elsewhere.[14] In brief, the soils were clayey (ranging from clays to heavy clays), calcareous (containing less than 5%$CaCO_3$), moderately alkaline (pH 7.5-8.5), low in organic matter (containing less than 1.0% organic matter), and deficient in nitrogen and phosphorus.

One-month old nursery seedlings raised near the respective experimental sites were transplanted in 9-in apart rows of well puddled 46×12.5 ft plots separated from each other by intermediary buffers. The basal fertilizers applied were 112 kg/ha N as urea and 29.12kg/ha P as superphosphate. Copper (as $CuSO_4$) at 11.2kg/ha, Fe (as $FeSO_4$) at 11.2kg ha and B (as $Na_2B_4O_7$) at 5.6 kg/ha were applied at all the sites with one control treatment (no micronutrient was applied). All the fertilizers were broadcast on the surface of the plots and thoroughly mixed with the upper 9-in soil layer by deep ploughing. The plots remained flooded throughout the growth period.

After 55-day growth, the topmost leaves of 100 random plants were sampled from each plot, washed in deionized water, dried and analysed for Zn, Cu, Mn and Fe contents as described above for farmers' fields samples. Paddy yield was recorded at maturity. Yield response to fertilizer application was satatistically evaluated at 5% probability level ($P<0.05$).

Results and Discussion

Micronutrient Deficiency in the Samples of Farmers' Fields. Critical concentration of various micronutrients for rice reported in other studies were used to evaluate the micronutrient status of leaf samples collected from farmers' fields. They were 20 p.p.m. for Zn,[30] 6.5 p.p.m. for Cu, 20 p.p.m. for Mn, and 50 p.p.m. for Fe.[26] Data given in Table 1 indicate a wide incidence of Zn deficiency for rice in this region. Out of 44 samples collected, 28 suffered with Zn deficiency. It appears to be quite severe since most of the deficient samples contained Zn well below 20 p.p.m. Severe Zn deficiency symptoms characterized by yellow leaves with brown streaks were also present on many samples. These results thus confirm the previous observations on leaf samples[26] and of field trials at Kala Shah Kaku Rice Research Farm[21,29] indicating the possibility of widespread Zn deficiency for rice in the Punjab. Copper deficiency was present in 17 samples. Its deficiency also appeared to be quite severe since most of the deficient samples had Cu contents well below its critical level (Table 1). Iron and Mn were present in luxury concentration in all the samples. No sample contained toxic concentration of any of these micronutrients.[26]

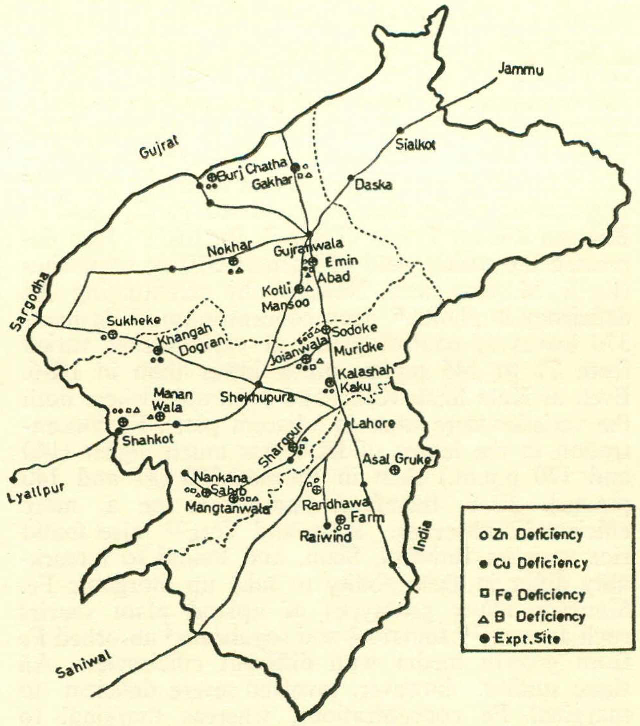

TABLE 1. MICRONUTRIENT DEFICIENCIES IN RICE LEAVES COLLECTED FROM FARMERS DURING SUMMER (1973)

Variable	Zn	Cu	Mn	Fe
No. of samples collected	44	44	44	44
Range of conc. in leaves (p.p.m.)	5.47	3.12	77.622	62.456
No. of samples deficient* in micronutrients	28	17	0	0

*Contained 20 p.p.m. Zn, 6.5 p.p.m. Cu, 20 p.p.m. Mn, and 50 p.p.m. Fe.

During the survey, we noted more severe Zn deficiency in low lying areas which possibly occurred due to continuous reduced soil conditions. Tanksa and Yoshida[26] also indicated soil reduction as a major cause of Zn deficiency in flooded rice since drainage of pots tended to alleviate its deficiency in their experiment. Zinc deficiency was also severe in late sown crops. Such rice crop apparently did not have enough time to recover from Zn deficiency which mainly prevails during the first 40 days of plant growth,[24] possibly due to occurrence of active chemical and electrochemical changes in flooded soil during this period.[18] Later on these changes tend to revert to some extent and alleviate Zn deficiency in plants partially or completely.[24]

Micronutrient Deficiency in Field Trials. Rice response to Zn application (5 p.p.m.) in these field trials has been discussed elsewhere.[6] IR-6 was found to suffer with severe Zn deficiency on all the sites and strongly responded to its application. Basmati-370 responded to Zn application on 55% sites. Critical

Zn concentration in the leaves of two varieties were found to be 25 and 17 p.p.m.[6] respectively.

Application of Fe increased the paddy yield of IR-6 at Eminabad by about 14% ($P<0.05$). Marginal increase also occurred at Nankana Sahib (Table 2). Response of IR-6 to Fe application is quite surprising since its leaves from control plants contained 140–223 p.p.m. of Fe showing its luxury supply to plants.[26] Application of Fe also increased the paddy yield of Basmati-370 on 7 sites (Table 3, $P<0.05$). Iron depressed the paddy yield of Basmati-370 on some sites (Kotli Mansoo and Nokhar) by accentuating Zn deficiency in plants.[6] Iron concentration in Basmati-370 leaves of control plants at various sites varied from 71 to 146 p.p.m. much lower than in IR-6. Even at Kala Shah Kaku and Joianwala where both the varieties were sown in adjacent plots, Fe concentration in the leaves of IR-6 was much higher (140 and 170 p.p.m.) than in Basmati-370 (81 and 140 p.p.m.). IR-6, therefore, appears to be a more efficient Fe absorber. Shim and Vose[23] also found rice varieties Rabifun, Siam, and Paldal to remarkably differ in their ability to take up inorganic Fe. Similarly many genotypes of upland plant species such as corn,[10] tomato,[2] and soyabeans[4] absorbed Fe from growth media with different efficiencies. All these studies, however, involved severe deficient to marginal Fe concentrations, whereas marginal to luxury concentration existed at most of the sites in the present studies. However, many factors such as imbalance of other micronutrients, pH difference in rhizosphere and nature of exudates, that have been interpreted to explain differential Fe absorption by various genotypes, may also be relevant to present investigations and will be the subject of further studies.

Iron concentration in leaves is a poor indicator of Fe supply to plants and thus a critical Fe concentration for any of these two varieties could not be determined. In IR-6, Fe concentration of leaves showed little correlation with yield response. For example, the leaves of control plants at Eminabad were paddy yield increased significantly with Fe addition, contained higher Fe concentration than the other nonresponsive sites. Similarly when leaf concentration of Fe was plotted against yield response of Basmati-370 at various sites, a precise Fe concentration that could distinguish responsive from nonresponsive soils could not be determined (Fig.1). Many nonresponsive soils were scattered among the responsive ones. In both the varieties, Fe deficient leaves often contained higher Fe concentrations than the nondeficient ones (Tables 2 and Fig. 1). This trend is quite marked at Eminabad and Nankana Sahib in IR-6. Similarly in Basmati-370 many Fe-responsive plants contained as high as 140 p.p.m. Fe in their leaves (Joianwala) whereas Fe-sufficient plants contained only 81 p.p.m. Fe (Kala Shah Kaku). Although in many other studies, leaves of Fe-deficient plants contained lower Fe-contents than Fe-sufficient plants[28] making possible the determination of a critical Fe level[26] for plants, serveral studies have shown that chlorotic plants contain higher Fe concentration in their leaves than the green plants.[19]

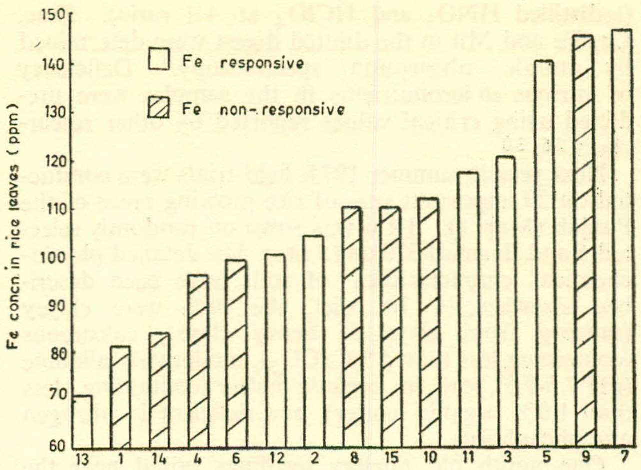

Fig. 1. Iron concentration in leaves of Basmati-370 in relation to Fe response on 15 sites.

Concentration of Fe in leaves in relations to other nutrient ions associated with Fe chloroisis were considered important for the phenomenon. For example high P, Cu, and K and low Ca-induced Fe imbalance in plants[3] were considered the probable causes. Such studies have never been conducted for rice and warrants early attention of researchers. It also appears that concentration of active Fe rather than total Fe may be a better indicator of Fe supply to plants.[17] Use of other plant parts such as stem may perhaps be more useful for diagnostic purposes since Fe tends to accumulate to a greater degree in the margins of plant leaves.[11]

Concentration of Mn in the control plant leaves of IR-6 and Basmati-370 rice varied from 241 to 304 and 234 to 345 p.p.m., respectively. Manganese, therefore, appears to be in luxury supply at all the sites for both the plant varieties.[26] Leaf manganese is a good indicator of its supply to rice plants. Application of B increased paddy yield of IR-6 on two (Table 3, Map 1, $P<0.05$) and of Basmati-370 on 9 sites (Table 3, map 1, $P<0.05$). Increase occurred from 10 (Nankana Sahib) to 16% (Eminabad) in IR-6 and 11 (Ghakhar) to 35% (Sadoke) in Basmati-370. These preliminary results need further studies especially on soil and plant boron-contents in relation to plant yield. Present trials, however, support the other studies showing marked B deficiency for cotton,[5] sweet clover, corn and wheat on calcareous soils of Hyderabad regions. It, therefore, appears that B deficiency may be widespread for a number of crops on calcareous soils of Pakistan since more sensitive crops such as alfalfa, sugarbeet and sugarcane[15] may suffer with B deficiency still more severely.

Copper deficiency of rice on these soils appears to be as strong as that of Fe. Its deficiency symptoms were generally not clear in the two varieties probably due to its moderate deficiency[12] within the range of hidden hunger and to simaltaneous incidence of deficiency of other micronutrients. Bending of leaves and delayed maturity[7] were, however, noted at Eminabad in IR-6 and at Sadoke in Basmati-370.

TABLE 2. MICRONUTRIENT DEFICIENCIES IN RICE LEAVES COLLECTED FROM FARMERS' FIELDS DURING SUMMER (1973)

Site No.	Name of site	Micronutrient applied (p.p.m.)	Paddy yield (kg/ha ×10³)	Zn concn (p.p.m.)	Cu concn (p.p.m.)	Mn concn (p.p.m.)	Fe concn (p.p.m.)	Cu/Fe ratio
1	Kala Shah Kaku	0	3.6	16.1	7.4	275	140	0.053
		5 Cu	3.3	18.3	9.1	282	152	
		5 Fe	3.6	13.2	6.4	289	160	
		2.5 B	3.3	—	—	—	—	
2	Eminabad	0	3.7	25.0	6.6	247	175	0.038
		5 Cu	4.8	20.2	7.3	220	157	
		F Fe	4.2	15.3	5.1	231	195	
		2.5 B	4.3	—	—	—	—	
3	Joianwala	0	3.5	17.0	8.6	253	170	0.051
		5 Cu	3.3	16.6	10.5	272	185	
		5 Fe	3.7	14.1	6.6	248	196	
		2.5 B	3.6	—	—	—	—	
4	Burj Chatha	0	4.3	22.2	6.2	304	223	0.028
		5 Cu	4.8	23.3	8.1	295	210	
		5 Fe	4.5	17.1	6.4	288	240	
		2.5 B	4.7	—	—	—	—	
5	Nankana Sahib	0	2.0	12.8	8.3	241	199	0.042
		5 Cu	2.0	14.3	9.9	261	202	
		5 Fe	2.2	12.2	7.0	256	235	
		2.5 B	2.2	—	—	—	—	

TABLE 3. EFFECT OF MICRONUTRIENT FERTILIZERS ON PADDY YIELD AND LEAF COMPOSITION OF IR-6 RICE.

Site No.	Name of site	Micronutrient applied (p.p.m.)	Paddy yield (kg/ha ×10³)	Zn concn (p.p.m.)	Cu concn (p.p.m.)	Mn concn (p.p.m.)	Fe concn (p.p.m.)	Cu/Fe ratio
1	Kala Shah Kaku	0	2.2	12.5	6.8	272	81	0.084
		5 Cu	1.7	10.1	9.3	290	92	
		5 Fe	2.1	12.6	7.2	266	102	
		2.5 B	1.3	—	—	—	—	
2	Sadoke	0	2.3	14.1	5.1	241	104	0.049
		5 Cu	3.0	14.9	7.2	232	74	
		5 Fe	2.9	12.8	5.2	231	144	
		2.5 B.	3.1	—	—	—	—	
3	Gakhar	0	1.8	14.2	6.8	286	120	0.057
		5 Cu	1.7	12.6	10.9	283	115	
		5 Fe	2.0	17.0	5.2	265	145	
		2.5 B	2.0	—	—	—	—	
4	Motli Mansoor	0	3.0	18.8	4.9	294	96	0.051
		5 Cu	2.5	14.9	8.2	303	106	
		5 Fe	2.7	16.0	5.9	270	128	
		2.5 B	3.3	—	—	—	—	
5	Joianwala	0	2.8	21.0	8.9	275	140	0.064
		5 Cu	3.3	24.6	9.9	250	112	
		5 Fe	3.4	19.3	7.5	245	171	
		2.5 B	3.3	—	—	—	—	
6	Nokhar	0	2.5	20.0	5.3	285	99	0.054
		5 Cu	2.9	16.2	8.6	262	80	
		5 Fe	1.6	25.6	4.1	304	145	
		2.5 B	2.8	—	—	—	—	
7	Shahkot	0	2.0	15.2	4.6	270	146	0.032
		5 Cu	2.4	13.1	8.1	245	158	
		5 Fe	2.4	14.6	4.8	249	176	
		2.5 B	2.2	—	—	—	—	
8	Mananwala	0	1.3	19.9	6.2	279	110	0.056
		5 Cu	1.2	20.3	9.3	269	118	
		5 Fe	0.8	20.1	5.1	295	150	
		2.5 B	1.9	—	—	—	—	

9	Sukheke	0	3.2	20.1	6.3	234	145	0.043
		5 Cu	3.1	22.2	10.4	245	132	
		5 Fe	3.1	21.1	6.2	234	169	
		2.5 B	3.2	—	—	—	—	
10	Khangah Dogran	0	3.1	16.9	5.3	342	112	0.047
		5 Cu	3.5	16.1	7.2	324	80	
		5 Fe	3.0	15.2	6.6	356	138	
		2.5 B	3.0	—	—	—	—	
11	Sharqpur	0	3.2	14.1	4.3	270	117	0.037
		5 Cu	3.6	16.0	8.1	245	120	
		5 Fe	3.6	13.3	4.5	271	148	
		2.5 B	3.6	—	—	—	—	
12	Mangtanwala	0	2.8	15.3	8.0	262	100	0.080
		5 Cu	1.8	12.2	14.2	292	121	
		5 Fe	3.8	12.3	6.5	246	131	
		2.5 B	3.7	—	—	—	—	
13	Randhawa Farm	0	2.9	14.2	14.4	241	71	0.203
		5 Cu	3.1	14.8	16.2	235	82	
		5 Fe	3.4	16.4	12.1	234	89	
		2.5 B	2.9	—	—	—	—	
14	Raiwind	0	3.7	12.8	5.8	345	84	0.069
		5 Cu	3.7	13.3	9.6	334	75	
		5 Fe	2.8	11.0	5.9	375	124	
		2.5 B	3.5	—	—	—	—	
15	Asal Gruke	0	1.8	17.0	8.1	272	110	0.074
		5 Cu	1.7	16.1	12.3	256	92	
		5 Fe	1.7	19.1	9.0	265	135	
		2.5 B	1.6	—	—	—	—	
							Average	0.067

In the absence of applied Cu, leaves of IM-6 contained 6.2-8.6 and those of Basmati-370 from 4.3 to 14.4 p.p.m. of Cu (Tables 2 and 3). Application of Cu raised its concentration in leaves. It markedly increased paddy yield of IR-6 on two (Table 2, map 1, $P<0.05$). and of Basmati-370 on six sites (Table 3, map 1, $P<0.05$). On a few sites such as Kala Shah Kaku and Kotli Mansoo (Table 3) Cu depressed paddy yield mainly by accentuating Zn deficiency in plants. As reported earlier, Cu-Zn antagonism does not seem to occur on all soils and its effect on plant yield highly depend on the relative Cu deficiency in soils.[12] Since leaves of control plants of IR-6 on two responsive sites contained 6.2 and 6.6 p.p.m. of Cu which were lower than those in nonresponsive sites, 6.6 p.p.m. Cu may indicate critical Cu concentration for this variety. Critical Cu level for Basmati-370 leaves appears to be much lower, i. e. 5.3 p.p.m. (Fig. 2). Higher critical Cu level in IR-6 seems to be associated with relatively higher Fe concentration (low Cu-Fe ratio; Table 2) in its leaves. Iron, therefore, may have increased Cu requirement of IR-6 by creating an imbalance between Cu and Fe in plants. This effect of Fe is not specific for Cu only since it also increased Zn requirement of rice plants.[6]

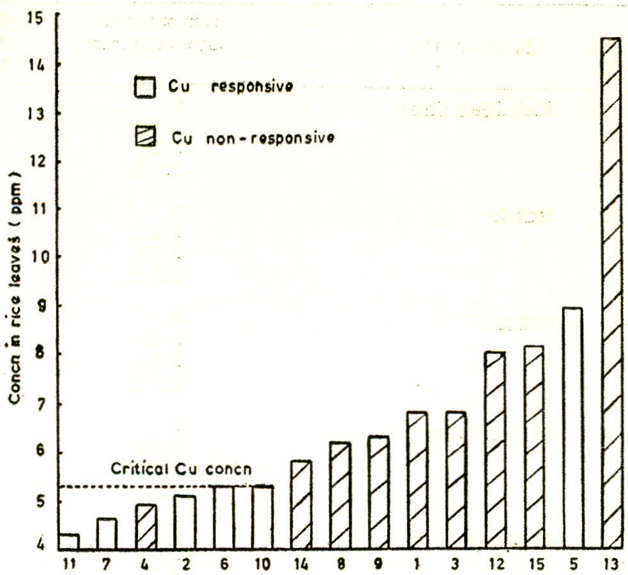

Fig. 2. Copper concentration in leaves of Basmati-370 in relation to Cu response on 15 sites.

Both the leaves and whole shoots can be used for predicting Cu deficiency in rice plants since pot trials on Basmati-370 in our laboratory have indicated a strong correlation between Cu contents in shoots and plant response to Cu additions.[12] The critical concentration for the whole shoots was relatively higher i.e. 6.5 p.p.m. In the present studies, Cu addition at 5 p.p.m. overcame Cu deficiency in both the varieties at all the sites (Cu application raised Cu concentration above critical level). These results thus contrast those of Zn experiments where 5 p.p.m. Zn failed to completely alleviate Zn deficiency in IR-6 at any of these sites.[6] Copper deficiency, however, is less severe.

These experiments indicate that Mn deficiency for rice is not prevalent in the Punjab whereas Zn, B and Cu deficiency is quite severe. Their deficiency is expected to be more severe in the near future as the soils will be further depleted of nutrients. Current trend of heavy application of nitrogenous[21] and phosphatic[22] fertilizers and introduction of high yielding new varieties will also aggravate the problem. Considering the present cost of fertilizers and the price of paddy rice, application of Zn, Cu, Fe and B fertilizers appears to be quite profitable. Further studies should, however, be conducted on the methods of controlling micronutrient deficiencies more economically. Leaf analysis should be adopted on routine basis for diagnosing Zn and Cu deficiency in field rice. Soil tests for this purpose have not proved reliable.[12,13] A suitable soil or plant tissue test for diagnosing Fe deficiency is yet to be evaluated.

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