TARC Notes

Antagonistic iron-deficiency of rice plants growing in acid red latosol in Paraná, Brazil

A distinct chlorosis of rice plants growing in acid red latosol was found in upland fields, just after a long rain, in newly developed lowland fields, or even under greenhouse (pot culture) conditions in Paraná, Brazil. A preliminary test on Fe application to the chlorotic leaves indicated that the symptom is a typical Fe deficiency.

Contents of Fe, Mn, and Zn in the soil, extracted with various extractants, are given in Table 1. Based on data already available[1,3,4,6,7], the content of exchangeable Fe extracted with N-ammonium acetate (pH 4.5) was regarded of an adequate level, whereas the contents of exchangeable Mn and easily reducible Mn, extracted with N-ammonium acetate (pH 4.5) and N-ammonium acetate (pH 4.5)+0.2% hydroquinone respectively, were extremely high. Available Zn, extracted with N-ammonium acetate (pH 4.5) or 0.1 N HCl, was also regarded to be at an adequate level.

Since available Mn in soil is influenced by a rise of pH, moisture range, and organic matter content[2,6], a factorial pot experiment was carried out in a greenhouse during a period from August to October 1976 to know the effects of soil pH and application of Fe and Zn on growth of rice plants in upland as well as lowland conditions. Although the content of available Zn in the soil was found to be sufficient, as shown above, Zn application treatments was included in the experiment, because Fe application might cause an antagonistic depression of Zn uptake. The experiment was run with 3 replications.

Table 1. Available Fe, Mn and Zn in soil

Extractants	ppm in soil*		
	Fe	Mn	Zn
H_2O	0.0	4.3	0.0
N-NH_4OAc pH 4.5	14.0	66.8	0.75
N-NH_4OAc pH 4.5+ 0.2% hydroquinone	368	500	—
N-KCl pH 7.0	5.0	57.3	1.65
0.1 N-HCl	80.0	90.0	1.55

* Extracted by adding 100 ml of extractant to 10 g of oven-dried soil, and shaking for 1 hr at room temperature. Atomic absorption spectrophotometer of Perkin-Elmer, Model-503, was used for assays.

IR 305-3-15, one of the varieties which showed severe chlorosis in the field was used. Each pot contained 6 kg of subsurface soil taken from the experimental field of Instituto Agronômico do Paraná with fertilizers (N 1.0g, P_2O_5 1.0 g and K_2O 0.5 g/pot), and 4 plants were grown per pot. Distilled water was used for watering. Plant growth and contents of Fe, Mn, and Zn in plants were determined at 50 days after germination.

In the upland condition, chlorosis occurred in control plots and Zn plots at pH 4.6 and 5.0 at 15 days after germination. It occurred, though slightly, even in Fe and Fe + Zn plots at every pH level from 29 days after germination. Under the lowland condition, chlorosis appeared in control and Zn plots of every pH level at 12 days after germination, and the symptom became severe as the growth

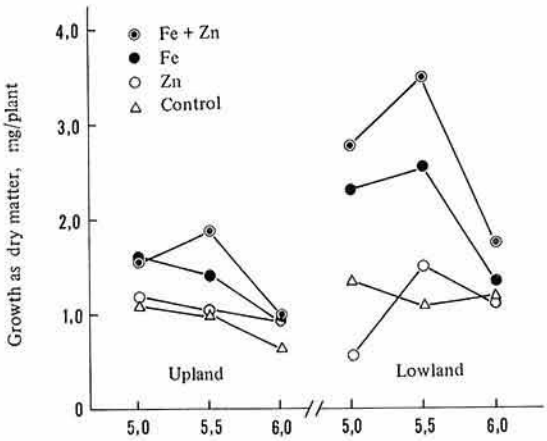

Fig. 1. Effect of soil pH and micro-nutrient application on rice growth in upland and lowland condition.
LSD (5%): condition = 0.21, pH = 0.16, micro-nutrient = 0.32

Table 2. Effect of soil pH and micro-nutrient application on Zn, Fe and Mn concentration of rice leaves (pot culture experiment)

Treatment of pH	Treatment of micro-nutrients											
	Control			Fe			Zn			Fe+Zn		
	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn
	ppm in leaves			ppm in leaves			ppm in leaves			ppm in leaves		
	Upland condition											
pH 4.6	42	141	6310	34	175	4550	161	125	3580	59	152	3150
5.0	55	143	6140	25	128	4830	148	138	4600	50	163	4640
5.6	29	98	4560	22	120	5380	142	105	5940	46	110	5870
	Lowland condition											
pH 4.6	55	152	4100	42	168	4350	161	108	4900	89	158	3890
5.0	52	120	5920	33	137	4800	120	249	4460	48	157	3990
5.6	21	125	3270	21	122	4970	88	147	3480	54	379	3600

Note 1) pH of original soil is 4.6, and amended by $CaCO_3$ application
2) Fe application: 30 ppm as Fe EDTA
3) Zn application: 5 ppm as $ZnSO_4$
4) Stems were excluded to avoid contaminations by soil

advanced. It appeared also, though slightly, in Fe + Zn plot of pH 5.6, Fe plot of every pH, and Fe + Zn plot of pH 4.6 and 5.0 at 19, 26, and 35 days after germination respectively.

Fig. 1 shows top growth of plants as effected by the treatments. Variance analysis indicated the significant differences with a extremely larger extent of varience ratios, among the main effects of water condition, pH, and the application of micro-nutrients, although the interactions of water condition × pH, water condition × micro-nutrient, and pH ×micro-nutrient were also significant.

Effect of Fe and Fe + Zn applications on plant growth was remarkable at pH 4.6 and 5.0 in both upland and lowland conditions. The combined application of Fe and Zn gave better growth than the application of Fe alone at pH 4.6 and 5.0 in lowland condition and at pH 5.0 in upland condition. However, the application of Zn alone gave no clear effect: it rather caused an inhibitive effect at pH 4.6 in lowland condition.

Contents of Fe, Mn, and Zn in leaves are given in Table 2. Under the upland condition, the application of Fe increased the Fe content, but decreased Mn content (except at pH 5.6) and Zn content. The application of Fe + Zn caused increased Zn contents in addition to the increased Fe contents and decreased Mn contents. The application of Zn caused remarkable increases in Zn contents with decreased contents of Fe and Mn (except at pH 5.6). The combined application of Fe and Zn resulted in the Zn contents similar to or higher than those of the control plot, and higher Fe contents with lower Mn contents. Under the lowland condition, the similar trend is observed though it is not so clear as above.

The relations observed among Fe, Mn, and Zn contents suggest the antagonistic absorption of them. It can be considered that the increased plant growth in the Fe plot at pH 4.6 and 5.0 is attributable to an increased Fe absorption in relation to Mn absorption. The better growth in the Fe + Zn plot than the Fe plot can be accounted for by the increased absorption of Zn in addition to the increased Fe absorption and decreased Mn absorption. In other words, the increased growth observed in the Fe plot was still limited by the reduced Zn absorption caused by Fe application, so that the Fe + Zn application could give a further increase of growth.

These results strongly suggest that the chlorosis observed in acid red latosol is caused

by an antagonism between Fe and Mn: Fe-deficiency occurs in the presence of an excess of Mn in the soil containing an adequate amount of available iron.

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Sulphur application and amino acid content of brown rice

Sulphur, an essential element for plant growth, has been rather neglected in rice culture. This is understandable, since traditional fertilizers, ordinary superphosphate, ammonium sulphate and low grade potash salts, contain sulphur.

Recently it was found that sulphur deficiency seems to be widespread in rice areas in Indonesia. Sulphur deficiency was found in Java, Bali, North Sumatra, West Sumatra and South Sulawesi[4,5,6,7,10]. It is not unlikely that more areas suffer from sulphur deficiency. Sulphur applications increased grain yields by 12 to 45% in South Sulawesi under field conditions[10]. Five out of eight sites examined were responsive to sulphur application. Sulphur deficiency in rice was reported also in Brazil[13], India[1], the Philippines[9] and Pakistan[2]. The introduction of high yielding rice varieties and the use of high analysis sulphur free (or low sulphur) fertilizers seem to aggravate sulphur deficiency. It covers a wide range of soil types, from the light sandy regosol to the heavy grumusol.

Sulphur deficiency in rice is easily overcome by the use of elemental sulphur or sulphur containing fertilizers, like ammonium sulphate, potassium sulphate and gypsum. Recent findings indicated that the application of sulphur increased not only grain yield, but also the methionine content of brown rice[4,5,6].

In the 1976–77 wet season a pot experiment (Table 1) was conducted at CRIA to study the effect of sulphur on the yield and the amino acid content of brown rice, using the soil low in sulphur content sampled from Ngawi, East Java. The soil type was grumusol. Sources of sulphur supply were elemental sulphur, ammonium sulphate, potassium sulphate or gypsum.

The elemental sulphur was applied at 1, 2 or 3 weeks before transplanting to the soil which was kept either at the moisture content of the field capacity or at the submerged condition, to know the rapidity of the dynamic change of elemental sulphur to sulphate sulphur as affected by the time of application and different water regimes under the tropical condition. After rice seedlings of 2 week old were planted, all pots were kept submerged under 2 cm of water until one week prior to the harvest. Rainwater was used for watering.

After the harvest, filled grains were separated from empty grains, and were unhusked. The brown rice obtained was ground and used for amino acid analyses.

To 50 mg of brown rice powder taken into

Table 1. Sulphur treatments, using four different sources of sulphur

Treatment*	N	P	K	S	S-source
		g/pot			
A	2	0.4	4	—	—
B	2	0.4	4	0.5	Elemental S (ES)
C	2	0.4	4	0.5	Elemental S (ES)
D	2	0.4	4	0.5	Elemental S (ES)
E	2	0.4	4	0.5	Elemental S (ES)
F	2	0.4	4	0.5	Elemental S (ES)
G	2	0.4	4	0.5	Elemental S (ES)
H	2	0.4	4	0.5	Ammonium sulphate
I	2	0.4	4	0.5	Potassium sulphate
J	2	0.4	4	0.5	Gypsum

* A No sulphur applied.
B ES applied 3 weeks before transplanting, field capacity.
C ES applied 2 weeks before transplanting, field capacity.
D ES applied 1 week before transplanting, field capacity.
E ES applied 3 weeks before transplanting, submerged.
F ES applied 2 weeks before transplanting, submerged.
G ES applied 1 week before transplanting, submerged.
H Ammonium sulphate applied 1 day before transplanting
I Potassium sulphate applied 1 day before transplanting
J Gypsum applied 1 day before transplanting.
The fertilizers used, i.e. urea, ammonium sulphate, triple superphosphate, potassium chloride, potassium sulphate and elemental sulphur were applied by mixing with the soil.

a vacuum reaction tube, 15 ml of 6 N HCl was added. The mixture was cooled in acetone plus dry ice, subjected to a vacuum to remove dissolved air, and hydrolyzed at 110°C for 16 hrs in an Al-block heater (Pierce Reacti-Therm Heating Module). The solution was evaporated to dryness in a vacuum vibrating waterbath evaporator at 45°C. After adding 1 ml of 0.01 N NaOH, the residue was allowed to stand for 4 hrs. Then 1 ml of 0.1 N HCl followed by 3 ml of IPH-DL was added. IPH-DL is a sample diluter, consisted of 0.4 *l* distilled water, 19.7 g sodium citrate, 16.5 ml conc. HCl, 0.1 ml caprylic acid, 20 ml thiodiglycol, and 4 ml BRIJ-35, with a total volume of 1 litre, Na concentration of 0.2 N and pH at 2.2. The solution was centrifuged at 3000 RPM for 10 min and the amino acid content was determined by the Hitachi KLA-5 amino acid analyzer.

Table 2 indicates that sulphur application increased grain yield to about two to three times that of the non-sulphur treatment. Elemental sulphur applied 3 weeks before transplanting at field capacity gave the highest yield. Application of elemental sulphur at field capacity gave higher yields than the application under a submerged condition. Field capacity condition seemed to stimulate the oxidation of elemental sulphur into sulphates, which can readily be absorbed by rice roots.

In addition to increasing the grain yield, sulphur application increased the methionine content of brown rice to 1.7 to 2.5 times that of the non-sulphur treatment. The methionine content was higher with elemental sulphur applied at field capacity than with that applied under submerged conditions. In the former case, the methionine content was the same irrespective of the time of application, while in the latter case, application at one week before transplanting gave the lowest content. The application of elemental sulphur at the field capacity increased the content of most

Table 2. Amino acid content of brown rice of plants treated with and without sulphur

Amino acid % (dry weight basis)	Treatment									
	A	B	C	D	E	F	G	H	I	J
Lysine	0.48	0.51	0.55	0.57	0.43	0.43	0.51	0.55	0.20	0.43
Histidine	0.29	0.36	0.38	0.40	0.33	0.32	0.36	0.42	0.15	0.31
Arginine	1.07	1.16	1.22	0.29	0.96	1.04	1.19	1.27	0.49	1.01
Asparted acid	1.19	0.93	1.11	1.05	1.07	1.11	0.78	0.95	0.86	1.02
Threonine	0.36	0.37	0.46	0.44	0.40	0.42	0.27	0.32	0.29	0.41
Serine	0.50	0.48	0.43	0.58	0.52	0.55	0.27	0.34	0.29	0.53
Glutamic acid	1.86	1.85	2.12	2.06	2.01	2.10	1.49	1.82	1.62	1.98
Proline	0.38	0.44	0.47	0.42	0.59	0.58	0.44	0.52	0.48	0.54
Glycine	0.47	0.47	0.52	0.49	0.50	0.53	0.40	0.47	0.43	0.51
Alanine	0.61	0.59	0.66	0.66	0.59	0.63	0.52	0.63	0.56	0.62
Cystine	0.06	0.17	0.16	0.18	tr	0.17	tr	tr	tr	0.16
Valine	0.58	0.60	0.62	0.61	0.65	0.69	0.54	0.66	0.58	0.68
Methionine	0.13	0.30	0.31	0.30	0.28	0.31	0.22	0.25	0.23	0.32
Isoleucine	0.52	0.54	0.54	0.54	0.41	0.45	0.36	0.44	0.39	0.45
Leucine	1.22	1.17	1.18	1.15	0.86	0.92	0.65	0.80	0.70	0.90
Tyrosine	0.82	0.78	0.79	0.71	0.51	0.58	0.38	0.48	0.41	0.60
Phenyl-alanine	0.81	0.80	0.82	0.79	0.56	0.62	0.45	0.54	0.35	0.22
Grain yield (g/pot)	13.1	43.3	37.9	39.8	26.4	28.0	34.0	28.0	29.0	36.2

tr: trace
treatment: see Table 1.