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Effects of iron and manganese on the growth of rice and on the contents of these elements in rice plants

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SUMMARY

A glasshouse experiment was conducted to study the influence of Fe and Mn applications in lowland alluvial soil on the growth of paddy rice and the concentration of Fe and Mn in leaves and stems. The application of Mn alone up to 10 ppm increased the dry matter yield of rice, whereas yield decreased with further increase in Mn levels. Similarly addition of Fe alone up to 30 ppm increased the dry weights but decrease was observed beyond that level. The application of Mn up to 10 ppm in the presence of Fe however, increased yields at all Fe levels. The maximum dry matter yield was recorded when 10 ppm Mn was supplied with 30 ppm Fe.

Manganese concentration in leaves and stems increased with increase in Mn levels but in the absence of Fe. Its concentration also increased with Fe level up to 30 ppm. With further addition of Fe, the Mn content decreased in both plant parts.

The increased application of Fe increased the Fe content of leaves and stems with and without Mn application. The application of 10 ppm Mn generally increased Fe concentration in both plant parts, but higher Mn levels decreased the Fe content in plant parts.

Low levels of Fe and Mn were essential for better plant growth and efficient utilization of these nutrients by rice plants. Antagonistic effects were observed only when one of the nutrients was applied in higher quantities in the growth medium.

Additional key word : *Rice nutrition*

RÉSUMÉ

Effets du fer et du manganèse sur la croissance du riz et teneurs en ces éléments dans les plantes

L'influence d'apports de fer et de manganèse à des sols alluviaux sur la croissance du riz et sur la concentration en ces éléments dans les feuilles et les tiges est étudiée en serre.

Le rendement en matière sèche augmente par l'apport de Mn seul jusqu'à 10 ppm ; au-delà, il décroît. Il en est de même pour le fer seul jusqu'à 30 ppm. Cependant, l'apport de Mn jusqu'à 10 ppm augmente le rendement quelle que soit la dose de Fe appliquée. Le rendement maximum en matière sèche est atteint pour 10 ppm Mn et 30 ppm Fe.

La concentration en Mn dans les feuilles et les tiges augmente, en l'absence de Fe, avec le niveau de l'apport, ainsi qu'en présence de Fe jusqu'à un apport de 30 ppm pour cet élément ; au-delà, la teneur en Mn décroît. La concentration en Fe dans les feuilles et les tiges augmente lorsque l'apport de Fe augmente, avec ou sans apport de Mn ; elle augmente généralement après apport de Mn jusqu'à 10 ppm mais décroît au-delà.

De faibles apports de Fe et de Mn sont donc essentiels pour une meilleure croissance du riz et pour une utilisation plus efficace de ces éléments. Les effets inverses s'observent seulement lorsque l'un d'eux est apporté en trop fortes quantités.

Mot-clé additionnel : *Nutrition riz*

I. INTRODUCTION

Research work on iron and manganese in soils and plants has been conducted for many years. Many conflicting results have been reported due to different soil types and plant species investigated. Many research workers (DEKOCK, 1955 ; TISDALE & NELSON, 1975) have reported that the absolute level of iron and manganese in the rooting medium may not be the most important factor in relation to plant growth. The re-

lationship of the amount of one element to another may be more important than its absolute level.

Iron and manganese are essential micronutrients for the growth and development of plants (DEKOCK, 1955 ; VLAMIS & WILLIAMS, 1964 ; PRICE, 1968 ; TERRY, 1980 ; BENNET *et al.*, 1982 ; DATIN & WESTERMAN, 1982). Both of these nutrients are required for chlorophyll synthesis (GAVALAS & CLARK, 1971 ; OHKI, 1975) and for the activities and function of numerous enzymes in the plant root systems (EVANS

& SORGER, 1966 ; DEL RIO *et al.*, 1978). Interaction in the absorption and utilization of Fe and Mn by plants (SCHMID & GERLOFF, 1961 ; LINGLE *et al.*, 1963 ; RICKELS & LINGLE, 1966 ; TIFFIN, 1972) has later been interpreted as a result of an antagonism between both these micronutrients which may be operative inside the plant when Fe and Mn compete for certain positions in enzyme systems (EVANS & SORGER, 1966 ; PRICE, 1968).

Several workers have reported that the combined role of Fe and Mn in plant nutrition is much more important than their individual roles (KARIM & MOHSIN, 1964). Response to both Fe and Mn in the growth and nutrition of the rice plant has been reported (CHIU, 1967 ; PATEL *et al.*, 1977 ; ALAM, 1982). Some researchers (RICKELS & LINGLE, 1966 ; DAHIYA & SINGH, 1976 ; ALAM, 1981) have reported that $\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$ decreases Mn availability in soils. LINGLE *et al.* (1963) reported that Mn interfered with Fe uptake and transport when Fe and Mn were at equimolar concentrations. OLSEN & WATANABE (1979) stated that Mn reduced the physiological effectiveness of Fe in plants, whereas others have found increased Mn concentrations and uptake with increasing iron levels in the growth medium (BEAUCHAMP & ROSSI, 1972). At lower Mn concentrations, Mn stimulated Fe absorption. Soil pH also affects the solubility of micronutrients and with the exception of Mo increased soil pH decreases solubility. These studies have indicated the possibility of interaction between Fe and Mn in plants and as such more information is needed on this subject. Therefore, keeping the above view, the present work was undertaken to see the effects of Fe and Mn on the growth of and content of these elements in rice plants.

II. MATERIALS AND METHODS

A glasshouse experiment was set up using plastic pots of 20 cm surface diameter filled with 4 kg of alluvial soil of pH 7.6, organic matter 0.75 %, total N 0.05 %, total P 0.04 % total K 0.50 %, available P (Truog's) 2.51 ppm, available Fe 1.5 ppm and citric acid soluble K 5.93 ppm. Standard methods of soil analysis were followed for determination of the above soil properties. The treatments were comprised of five levels of Fe 0, 10, 30, 60 and 90 ppm as $\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$ and five levels of Mn 0, 5, 10, 20 and 40 ppm as $\text{MnSO}_4 \cdot 4 \text{H}_2\text{O}$. Each pot received a basal application of N, P and K at the rate of 80, 60 and 30 ppm respectively through reagent grade $(\text{NH}_4)_2\text{SO}_4$, KH_2PO_4 and KCl. Four plants per pot of rice variety 'IR-8' were grown in the glasshouse under proper care. The pots were randomized and the treatments replicated three times. The conditions in the glasshouse were : day temperature 30 °C ; humidity 55 % ; night temperature 20 °C ; humidity 85 % ; the photoperiod was 16 h. The plants were harvested after 7 weeks of growth, washed several times in distilled water, separated into leaves and stems and then dried in an oven at 70 °C for 48 h. The dry weight of plants was recorded and the samples were then chopped into small pieces with a stainless steel scissors and mixed uniformly for further analysis. One gram portions of dried plant material were digested in a nitric, per-

chloric and sulphuric acid mixture. Iron and manganese in the digest were determined using phenanthroline and periodate methods respectively (JACKSON, 1958).

III. RESULTS AND DISCUSSION

The application of Mn alone up to 10 ppm increased the dry matter yield of rice plants, whereas it decreased with further increase of Mn application (table 1). The dry matter yield with 40 ppm Mn was even less than that of the control (0 Mn, 0 Fe). On the other hand, the dry matter yield increased with Fe alone upto 30 ppm, but it decreased considerably with 90 ppm Fe, though it was more than that of the control. Similarly the application of Mn up to 10 ppm along with Fe increased the dry weight of rice plants at all levels of iron. Maximum dry matter yield was recorded when 10 ppm Mn was applied together with 30 ppm Fe. The application of more than 10 ppm Mn in the growth medium decreased the dry matter yield at Fe levels beyond 30 ppm. The above results indicated that a proper balance between Fe and Mn is necessary for maximization of dry matter production.

TABLE 1
Effect of variable levels of Fe and Mn on the dry weight of rice (g/pot).
Effet d'apports variables de Fe et Mn sur le poids sec du riz (g/pot).

Mn levels (ppm)	Fe levels (ppm)					Mean
	0	10	30	60	90	
0	1.97	2.41	2.76	2.42	2.12	2.33
5	2.10	2.73	3.54	2.96	2.56	2.76
10	2.86	3.93	4.29	3.19	2.84	3.42
20	2.62	3.15	3.29	2.92	2.60	2.92
40	1.74	2.62	2.85	2.23	2.09	2.30
Mean	2.26	2.97	3.34	2.73	2.44	

LSD (0.05) ; Fe & Mn 0.11 ; Fe × Mn 0.24.

Both these nutrients responded well when they were applied individually or together at low levels in the growth medium. The lower yield response observed at the higher levels indicates that a synergistic effect between Fe and Mn exists.

Manganese concentration in the leaves and stems increased up to 10 ppm Mn level in the absence of Fe (table 2). The proportionate increase was more in the leaves than in the stems. The application of 30 ppm Fe generally increased Mn concentration both in leaves and stems while addition of Fe above 30 ppm decreased Mn concentration in plant parts but their contents at higher levels were more than that of the control. The results thus indicated reduced uptake of Mn by rice plants in the presence of higher Fe levels. The decrease in Mn concentration in plant parts was attributed to a possible antagonistic reaction between Fe and Mn in the plant root system (TWYMAN, 1951 ; KANNAN & JOSEPH, 1975 ; WALLACE & MULLER, 1980). However, the results also indicated that low levels of Fe were essential for absorption and utilization of Mn by rice plants. These findings are in

TABLE 2

Effect of variable levels of Fe and Mn on the Mn concentration in leaves and stems of rice.

Effet d'apports variables de Fe et Mn sur la concentration en Mn des feuilles et des tiges de riz.

Mn levels (ppm)	Fe levels (ppm)					Mean
	0	10	30	60	90	
Mn concentration in leaves (ppm)						
0	60	117	139	134	122	114
5	83	124	160	129	127	124
10	117	153	192	156	134	150
20	88	105	133	130	110	113
40	84	68	112	87	70	84
Mean	86	113	147	127	112	

LSD (0.05); Fe & Mn 4.40; Fe × Mn 9.85.

Mn levels (ppm)	Fe levels (ppm)					Mean
	0	10	30	60	90	
Mn concentration in stems (ppm)						
0	49	69	85	78	75	71
5	65	108	135	124	116	109
10	91	133	138	122	117	120
20	83	81	87	86	72	82
40	67	68	61	71	59	65
Mean	71	92	101	96	88	

LSD (0.05); Fe & Mn 3.61; Fe × Mn 8.06.

agreement with the results of BEAUCHAMP & ROSSI (1972), who reported that increasing Fe supply does not reduce Mn availability or concentration in barley plants when Mn supply ranges from below to optimum but may do so when the Mn supply is above the optimum level.

Iron concentration in plant leaves and stems increased up to 30 ppm of Fe level, in the absence of Mn (table 3) and beyond this level, Fe concentration in plant parts decreased. Iron concentration also increased with Mn application up to 10 ppm. However, the concentration decreased with a further increase in Mn levels up to 40 ppm regardless of Fe levels. The reason for this decrease in Fe concentration at higher Mn levels could be the interaction between Fe and Mn in the plant root system. The findings of some workers have revealed that Mn interfered with the transport of Fe from roots to shoots (KANNAN & JOSEPH, 1975; ALVAREZ-TINAUT *et al.*, 1977). Such effects may be operative inside the plant when Fe and

TABLE 3

Effect of variable levels of Fe and Mn on the Fe concentration in leaves and stems of rice.

Effet d'apports variables de Fe et Mn sur la concentration en Fe des feuilles et des tiges de riz.

Mn levels (ppm)	Fe levels (ppm)					Mean
	0	10	30	60	90	
Fe concentration in leaves (ppm)						
0	61	75	108	101	94	88
5	132	153	168	141	143	147
10	215	333	383	272	167	274
20	201	214	265	206	150	207
40	192	167	187	140	123	162
Mean	160	188	222	172	135	

LSD (0.05); Fe & Mn 5.37; Fe × Mn 12.00.

Mn levels (ppm)	Fe levels (ppm)					Mean
	0	10	30	60	90	
Fe concentration in stems (ppm)						
0	44	70	83	71	83	69
5	94	140	154	129	105	126
10	140	186	212	183	123	168
20	118	135	149	131	109	129
40	108	106	125	113	108	111
Mean	102	128	144	125	104	

LSD (0.05); Fe & Mn 4.32; Fe × Mn 9.66.

Mn compete for certain positions in the enzyme systems (LABANAUSKAS, 1979; AGARWALA *et al.*, 1982). The interaction of these nutrients inside the plant and or at the absorption sites could be physiological in nature as low Mn levels were apparently necessary for efficient utilization of Fe by rice plant and vice versa.

From the above results it was concluded that maximum dry matter yield was obtained at lower levels of Fe and Mn than at the higher levels. This may be due to the fact that at the higher levels these nutrients interact in the plant root system, inhibiting their utilization by the rice plant and resulting in the reduced dry matter yield. Higher application of Fe reduced the uptake of Mn by plant parts and vice versa. The low levels of Fe and Mn were essential for better plant growth and efficient utilization of these nutrients by rice plant.

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