Pakistan J. Sci. Ind. Res., Vol. 24, Nos 5–6, October – December 1981

EFFECTS OF IRON AND MANGANESE ON THE GROWTH AND NUTRIENT CONTENTS OF RICE PLANTS, GROWN UNDER FLOODED AND UNFLOODED CONDITIONS

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(Received June 1, 1980)

Experiments with rice plants growing on loamy soil, supplied with variable levels of Fe and Mn, and subjected to two moisture regimes, made it clear that under waterlogged (anaerobic) condition the dry matter yield, plant height and contents of Mn, Fe and P in rice plants increased considerably indicating that soil submergence enhanced the availabilities of Fe, Mn and P in the growth medium. It was also observed that Mn content in rice plants under submerged condition was always higher than that of Fe under the similar condition. Aerobic condition (unflooded) showed lesser growth and nutrient contents in rice plants than the anaerobic condition (flooded).

INTRODUCTION

Submergence of the soil during the growth period of lowland rice has long been considered essential for successful rice culture. Dry matter yield and grain production have been observed to be consistently higher when rice plant was grown under waterlogged soil conditions [1–3]. The increased availability of some plant nutrients under reduced conditions brought on by waterlogging has been cited as one of the primary beneficial effects of soil submergence for production of lowland rice [4,5].

On flooding, the concentration of Fe, Mn, Cu, Mg, P. HCO_3 and total soluble salts in soil solution were reported to increase [2,6,7,8]. The constant availability of water and the control of weeds by the flood water are also considered as beneficial effects of excess water. Aoki [9] observed that the behaviour of phosphate in the flooded paddy soil is quite different from its behaviour in the upland condition. Under waterlogged condition the plants absorb more phosphate than under upland soil moisture condition. The reason may be the solubility of fertilizer phosphorus and its ready availability to plant because flooding helps in the reduction of phosphate associated with ferric iron to more soluble ferrous phosphate. In order to study the effect of flooded and unflooded soil conditions on the dry matter yield and nutrient content of rice plants, a pot culture experiment was carried out using rice seedlings cv. dular as a test crop.

MATERIAL AND METHODS

A bulk soil sample from the surface horizon was collected, air-dried, powdered and screened through a 2mm sieve and then mixed thoroughly. Some of the physical and chemical properties of the soil are given in Table 1. To the uniformly mixed soil basic doses of N, P and K fertilizers were given at the rate of 90 kg N/ha as ammonium sulphate, 67.3 kg P_2O_5/ha in the form of potassium dihydrogen

Table 1. Mechanical and chemical properties of soil samples (% of air dry).

Sand %	Silt %	Clay %	Soil texture
44.04	30.30	25.66	Loamy soil

pH	%O.M	%Org.C	%N	Total Fe %	Extractable Fe (ppm)	Total Mn%	Extractable Mn (ppm)	Ca%	Avail-able P ppm ($NaHCO_3$)
6.6	1.16	0.67	0.072	1.90	17.23	0.51	8.95	0.042	12.01

phosphate and 67.3 kg K_2O/ha as muriate of potash to each pot. Proper amounts of Fe and Mn were then thoroughly mixed with 1.5 kg of the soil and placed in tin pots internally painted with asphalt. Fe and Mn were each added at the levels of 0,10,20, and 40 ppm as sulphates of Fe and Mn.

4-week-old rice seedlings were transplanted at the rate of three seedlings per pot. The pots were kept flooded and unflooded conditions after 10 days of transplanting. The water in the pots receiving continuous flooding were maintained at a level of 5 cm above the surface of the soil and in case of unflooding soil, sufficient water was added as and when needed to keep the soil just moist. These conditions were maintained throughout the experimental period. The experiment was arranged into a randomized complete block design with four replications.

All the plants were harvested after 7 weeks of growth and collected in brown paper bags. The samples were washed, dried in an oven at 70^{o} and weighed. The dry plant material was ground in the Wiley mill and a known weight from the respective treatment was taken in a conical flask and ashed in a mixture containing sulphuric, nitric and perchloric acids mixture. Fe and Mn were analyzed colorimetrically using orthophenanthroline and periodate methods respectively [10]. P from the digest was also determined colorimetrically with the vanadate method [10].

RESULTS AND DISCUSSION

Results on the dry matter yield, plant height and nutrient contents of rice plants are presented in Table 2. It can be observed from the data that with the increased levels of Fe and Mn the dry matter yield increased progressively both under flooded and unflooded conditions.

Significant differences between the treatments were found in almost all cases under both the growing conditions. The dry matter yield under flooded condition was about 1–2 times higher than that recorded under unflooded condition. Similarly dry matter yield and the plant height also increased under flooded and unflooded conditions with increased levels of Fe and Mn, but the increase was more in submerged soil than in unflooded soil. It has generally been observed that under waterlogged conditions some important plant nutrients are reduced to soluble forms and render them available to plants. This usually helps in the better growth of rice plants under this condition. Under well-aerated soil conditions most of the plant nutrients remain in oxidized state and exist in unavailable forms and are not sufficiently utilized by plant roots and this caused in less plants growth than the lowland soil condition. The findings of various workers [2,12,17], have revealed that the dry matter yield have been observed to be consistently higher when rice plant was grown under waterlogged soil conditions than when grown under well-drained conditions.

Table 2 shows that the high Fe and Mn levels caused a significant increase in Fe content under waterlogged condition. But a reverse trend was observed under unflooded condition where significantly low uptake of Fe was observed with increased Fe and Mn levels when compared with control. It has been observed that under upland condition Fe remains mostly in oxidized state which seems to be unavailable to plants and also the presence of high P level under this condition decreases the amount of available Fe in the growth medium and active Fe in the plant body. The Annual Reports of the International Rice Research Institute [11] in the Philippines for the period 1964–73 contain informations on Fe and Mn contents of leaves of rice grown on soils varying in a number of characteristics, among others low and upland soil conditions. Rice was grown on these soils under both aerobic (upland) and an-

Table 2. Effect of different levels of Fe and Mn on the plant parameters and nutrient content of rice plant grown under flooded and unflooded conditions.

Fe and Mn levels each in ppm	Flooded condition					Unflooded condition				
	Fe ppm	Mn ppm	P %	Dry matter yield g/pot	Plant height (cm)	Fe ppm	Mn ppm	P %	Dry matter yield g/pot	Plant height (cm)
0,0	223b	2730c	0.175c	6.02c	88b	210a	979a	0.158a	3.29d	73b
10,10	232b	2763bc	0.212b	6.25b	90b	145c	2133b	0.135b	3.98c	88a
20,20	273a	3092a	0.228a	6.27b	84b	156b	1836c	0.128bc	4.12b	77b
40,40	267a	2813b	0.201b	6.40a	103a	150bc	1809d	0.121c	4.32a	76b
LSD 5% level	12.93	58.77	0.011	0.112	7.66	9	15	0.008	0.09	7.78

Values followed by same letter are not significant at the 5% level.

aerobic (lowland) condition. It was observed that high levels of either one of the two elements in rice leaves are always accompanied by relatively low levels of the other element, which phenomenon could be considered as indicative of a mutual antagonism between the two elements, either during uptake by the roots, or during translocation from the roots to the leaves. In this experiment the high Fe content in rice plant is possibly due to high availability of Fe in soil under waterlogged condition. Literature reveals that the chemical change that takes place when a soil is flooded is the reduction of iron and accompanying increase in its solubility. This helps in more utilization of Fe by plants [3,12].

The manganese content in rice plant increased with increased Fe and Mn levels under both flooded and unflooded conditions, and the treatments differed significantly. This indicated that Mn availability in soil and uptake by plant is enhanced by flooding the soil. The results are in agreement with several other investigators, [13,14], who have shown that flooding reduces the higher oxides of manganese in soil releasing Mn^{++} to the soil solution and therefore increasing the concentration of soluble manganese in the soil. Under oxidizing conditions (unflooded) Mn is present in soil in the form of insoluble oxides. Plants absorb water soluble and exchangeable manganese more readily than other forms present in the soil [15]. It was also noted that the Mn content in rice shoots under the two moisture conditions was relatively higher than that of Fe. Literature reveals that Mn is more readily reduced and rendered soluble than iron [16]. The release of Mn into soil solution, therefore, precedes that of Fe. The findings of some workers [16] have revealed that rice plants absorb Mn in relatively large amounts and Mn requirement of rice is very much higher than of other microelements. Clark *et al.* [17] observed that tissues of rice plant sometimes contain as much as 4000 ppm manganese and that under flooded conditions Mn uptake is high.

It was observed that the content of P in rice plants increased significantly with increasing concentration of Fe and Mn under flooded soil condition (Table 2). On the other hand P content in plants significantly decreased with increased Fe and Mn levels under unflooded soil condition. Thus it was observed that the uptake of P was relatively higher under flooded than unflooded conditions. The higher content of P in the plants grown under waterlogged soil condition may be due to iron reduction with the subsequent release of phosphate [5]. The occurrence of a marked increase in the availability of native and added phosphates in flooded soils as compared to well drained soils have been well established [9]. These increases in phosphate have usually been attributed to the reduction of ferric phosphate to the more soluble ferrous forms and the beneficial effects of flooding on phosphate availability depended on the intensity of reduction and the iron content of the soil. In this experiment it was also observed that at high Fe and Mn levels, P content slightly decreased in rice plants under waterlogged soil condition. It has been reported that after a long period of waterlogging, phosphate became less available, probably due to fixation [18].

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