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PLANT RESPONSE TO MICRONUTRIENTS

II. UPTAKE, DISTRIBUTION AND TRANSLOCATION OF MANGANESE IN MAIZE AND BARLEY PLANTS

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SUMMARY

The uptake, distribution and translocation of manganese in maize and barley plants grown on a deficient soil with high pH were studied. All the manganese treatments increased the manganese content and uptake by plants, but increased the dry matter yield only slightly. The distribution pattern of manganese in maize and barley differed. In maize, blades had the highest manganese content, followed by roots and sheaths. In barley, roots had highest manganese content, blades next highest and sheaths again had the lowest.

The autoradiographs of maize and barley plants showed that nodes and older leaves contained higher concentrations of Mn^{54} than internodes and younger leaves, respectively. Mn^{54} also increased from the leaf base to the leaf tip.

INTRODUCTION

The requirement of plants for micronutrients and the behaviour of these elements in the plants differ widely. Rice, for example, is much more sensitive to added copper than is barley [5]. On the other hand, under conditions where barley shows symtoms of copper deficiency, rice plants growing on the same soil and under upland conditions, show no symptoms [3].

A previous paper reported that maize and barley plants grown on an identical soil differed in terms of zinc deficiency and zinc uptake [9]. The present experiment was, therefore, designed to study the uptakc, distribution and translocation of manganese in maize and barley plants.

9169

METHODS

Planting, harvesting, analytic and autoradiographic procedures and the physico-chemical properties of the soil have been described in a previous paper [9]. Treatments used were 0, 50 and 100 ppm of added manganese and 20 μc of carrier-free Mn^{54} per pot. The solutions containing active and inactive manganese ($MnSO_4 \cdot H_2O$) giving the specific activities of > 100 mc/mg, 0.133 and 0.066 μc/mg of manganese for 0, 50 and 100 ppm treatments, respectively, were manually mixed into the soil. The Mn^{54} activity in digested plant samples was measured by a NaI-scintillation spectrometer. Activity in samples was then compared with standards of known specific activity to determine the amount of manganese drawn from the isotope labelled source added to the soil. Data reported in the tables are on a dry matter basis.

TABLE 1

The effect of manganese application on the total dry matter yield of maize and barley plants

Plant	Harvest	Mn rate ppm	Total dry matter yield (g/pot)			
			Roots	Sheaths	Blades	Total
Maize	Ist	0	1.43	1.54	2.20	5.16
		0a	1,30	1,48	2,29	5.07
		50a	1.04	1.21	2.00	4.25
		100a	1.45	1.66	2.88	6.00
	LSD		—	—	0.55	1.13
	IInd	0	3.62	5.46	5.62	14.70
		0a	3.83	6.15	6.82	16.80
		50a	3.88	5.35	5.81	15.03
		100a	3.85	6.37	7.78	18.00
	LSD		—	—	1.36	—
Barley	Ist	0	0.32	0.60	1.08	2.00
		0a	0.38	0.61	1.15	2.14
		50a	0.38	0.54	1.04	1.96
		100a	0.38	0.60	1.09	2.07
	LSD		—	—	—	—
	IInd	0	0.59	3.24	2.82	6.65
		0a	0.71	3.17	2.59	6.47
		50a	0.66	3.29	2.82	6.77
		100a	0.61	3.45	2.59	6.65
	LSD		—	—	—	—

a = activity of Mn^{54} (20 μc/pot).

RESULTS

None of the manganese treatments significantly affected the total dry matter yield of maize and barley plants. However, numerically superior yields of maize were obtained at 100 ppm level of manganese (Table 1). Manganese deficiency was not observed in either of the plants. Zinc deficiency symptoms were seen in all treatments, but in maize plants only.

Applied manganese significantly increased the Mn^{54} content and uptake in roots, sheaths and blades of maize and barley (Table 2 and Fig. 1). The distribution pattern of manganese in maize and barley plants was different. In maize, blades had the highest Mn^{54} content, roots next highest and sheaths lowest, in both harvests. In barley, highest Mn^{54} contents were found, with one exception, in roots followed by blades and sheaths, in both harvests. At 50 ppm of added manganese there was considerably more Mn^{54} in blades than in roots, in the second harvest.

The distribution of total manganese in maize (Table 3) was very similar to that of Mn^{54}. In barley, the two patterns were similar only when fertilizer manganese was applied. When no manganese was added, blades had the highest manganese content, roots next highest, and sheaths the lowest.

TABLE 2

The effect of manganese application on Mn^{54} content and distribution in maize and barley plants

Mn rate ppm	Plant	Mn^{54} content (ppm)					
		Ist harvest			IInd harvest		
		Roots	Sheaths	Blades	Roots	Sheaths	Blades
0a	Maize	0.1	0.5	1.4	0.1	0.2	0.3
50a		169.5	106.5	271.9	68.6	66.5	94.3
100a		247.6	124.2	317.9	115.3	105.8	116.2
LSD							
0a	Barley	0.5	0.6	1.0	0.4	0.4	1.0
50a		157.5	73.1	121.2	79.1	54.0	156.7
100a		302.6	80.5	153.5	247.8	79.4	222.9

a = activity of Mn^{54} (20 μc/pot).

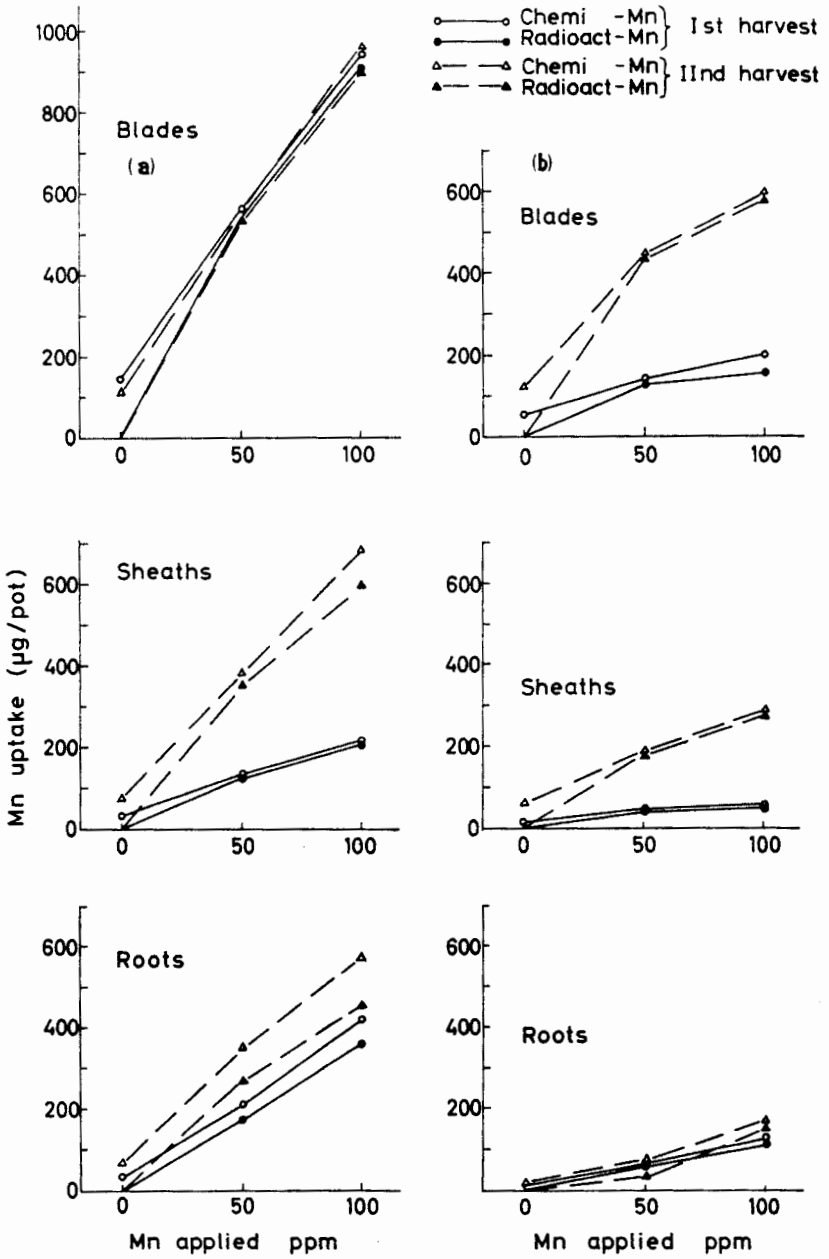
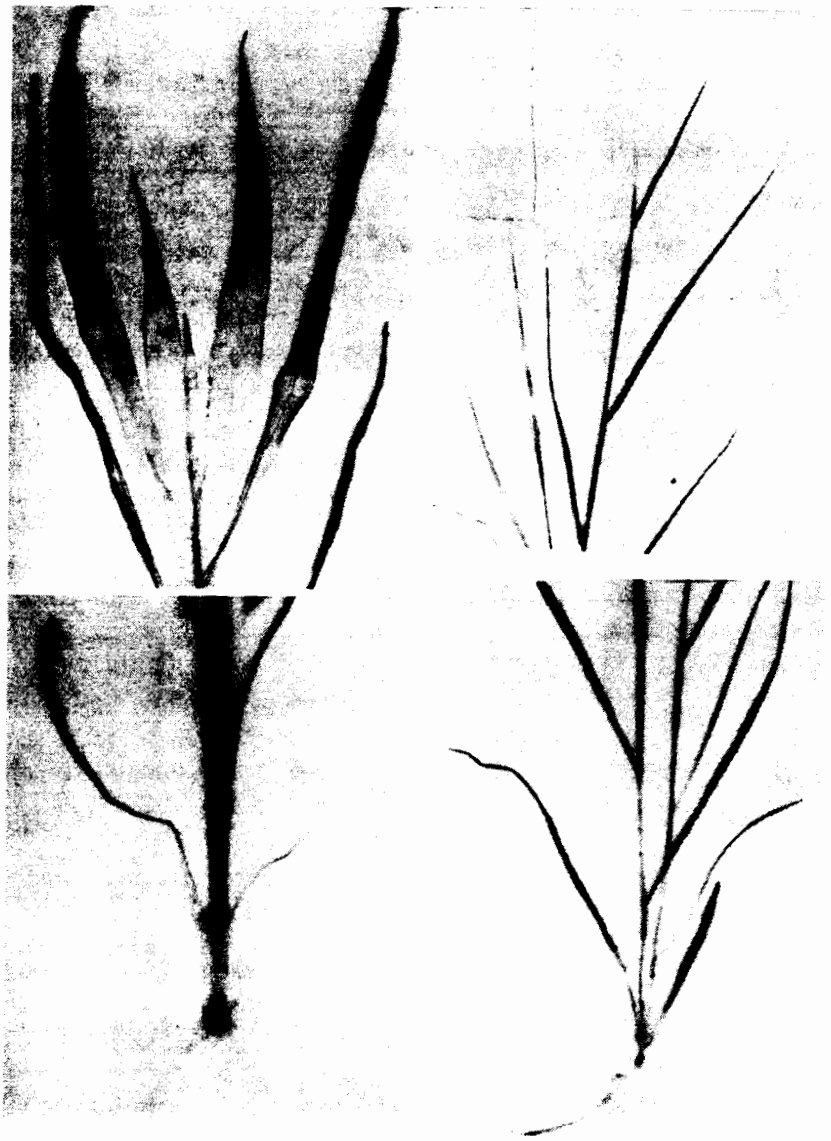


Fig. 1. Effect of manganese application on manganese uptake by maize (a) and barley (b)



(a) (b)

Fig. 2. Autoradiographs of intact maize (a) and barley (b) plants supplied with 20 μc of carrier-free Mn^{54} at 0 ppm level of manganese.

TABLE 3

The effect of manganese application on the total manganese content and distribution in maize and barley plants

Mn rate ppm	Plant	Total manganese content (ppm)					
		Ist harvest			IInd harvest		
		Roots	Sheaths	Blades	Roots	Sheaths	Blades
0	Maize	27.6	24.0	64.6	19.0	15.0	21.4
0a		26.4	23.8	67.9	18.6	11.9	14.2
50a		202.3	109.3	280.7	88.6	71.7	100.6
100a		289.9	129.7	329.1	144.9	109.7	127.9
LSD		45.8	15.5	26.8	43.7	70.2	107.4
0	Barley	31.4	27.8	53.8	26.2	20.5	49.8
0a		31.8	23.6	43.9	26.8	17.6	42.5
50a		158.1	75.5	141.1	92.8	56.4	158.3
100a		342.8	87.0	172.6	277.3	81.5	229.0
LSD		109.3	17.4	11.7	11.3	6.7	22.2

a = activity of Mn^{54} (20 μc/pot).

The autoradiographs in Figure 2 illustrate the distribution of Mn^{54} in maize and barley. (Lighter stripes across some of the plant parts are due to absorption of beta radiation by cellophane tape). In maize, main and auxiliary roots contained very little Mn^{54} except at the root-stem junction, where there was a relatively higher concentration of Mn^{54}. Nodes contained higher Mn^{54} than internodes and, similarly, older leaves had higher concentration than young emerging leaves. Also Mn^{54} increased from the leaf base to the leaf tip. In comparison, differences in Mn^{54} among plant parts of barley were relatively less pronounced.

DISCUSSION

Uptake of manganese by plants depends less on the total amount of nutrient present in the soil than on its availability. Maize and barley plants grown on a soil having 2.3 ppm of reducible manganese and pH 7.3 showed neither manganese deficiency nor response to manganese application in the pot experiment. Mild deficiency symptom of manganese in barley and oats were, however, observed

in the field. The reason for the absence of manganese deficiency in the pot experiment may be that drying the soil transformed some of the unavailable manganese to available form [8]. Farley and Draycott [1], working with sugarbeets, showed that air drying the soil followed by rewetting increased the availability of manganese and resulted in delaying manganese deficiency symptoms.

Addition of manganese to the soil increased Mn^{54} and total manganese content as well as uptake in maize and barley. The distribution pattern of manganese differed in maize and barley plants. Vlamis and Williams [10] in a solution culture experiment found that manganese content in rice leaves was higher than in roots, whereas the situation was reversed in barley. A possible explanation for this variation may be the differential behaviour of plant genotypes in the translocation of manganese within plants. Oulette and Dessureaux [6] demonstrated that four clones of alf-alfa differed in susceptibility to manganese toxicity. At specific concentrations of manganese in the medium, all plants contained approximately the same total amount of manganese. However, the plants least affected by manganese excess showed less ability to translocate manganese from roots to tops. Gerloff [2] suggested that variation in the capacity for transport was at least partially responsible for the observed differences in the susceptibility in the clones. Higher concentration of manganese in barley roots than in blades in the present study may be due to decreased ability of barley to translocate manganese from roots to the blades.

The autoradiographs showed higher concentration of Mn^{54} in nodes and older leaves than in internodes and young emerging leaves, respectively. Millikan [4] found in flax, pea, cabbage and tomato plants that Mn^{54} generally accumulated in the mature leaves rather than in young leaves. Stem tissue contained less Mn^{54} than did leaf tissue. Romney and Toth [7] also found that more Mn^{54} was present in mature than in young leaf of buckwheat, soybean and sunflower plants, and the stem contained less Mn^{54} than did the leaves. Compared to transport of Zn^{65}, as reported in a previous paper [9], these results suggest that Mn^{54} is less mobile in the sieve tubes of plants.

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REFERENCES

1 Farley, R. F. and Draycott, A. P., Manganese deficiency of sugarbeet in organic soils. Plant and Soil **38**, 235–244 (1973).
2 Gerloff, G. C., Comparative mineral nutrition of plants. Ann. Rev. Plant Physiol. **14**, 107–124 (1963).
3 Kurosawa, J., Uchida, S., and Nakano, N., Bulletin of the Iwate Agri. Expt. St. No. **8** (1965).
4 Millikan, C. R., Radio-autographs of manganese in plants. Australian J. Sci. Research Ser. B. **4**, 28–41 (1951).
5 Mitsiu, S., Kumazava, K., and Yazaki, J., Iron and manganese metabolism in crop plants as influenced by copper. I. Study on the chlorosis of rice upland cultivated on copper affected area and the copper accumulation in orchard soils. J. Sci. Soil and Manure Japan **28**, 505–507 (1958).
6 Ouelette, G. I. and Dessureaux, L., Chemical composition of alfalfa as related to degree of tolerance to manganese and aluminum. Can. J. Plant Sci. **38**, 206–214 (1958).
7 Romney, E. M. and Toth, S. J., Plant and soil studies with radioactive manganese. Soil Sci. **77**, 107–117 (1954).
8 Savant, M. K. and Kibe, M. M., Effect of alternate submergence and drying of soil prior to resubmergence of extractable aluminum, iron and manganese in rice soils of Maharastra state, India. Soil Sci. **108**, 440–447 (1968).
9 Singh, B. R. and Steenberg, K., Plant response to micronutrients. I. Uptake, distribution and translocation of zinc in maize and barley plants. Plant and Soil **40**, 637–646 (1974).
10 Vlamis, J. and Williams, D. E., Iron and manganese relations in rice and barley. Plant and Soil **20**, 221–231 (1964).