https://doi.org/10.29321/MAJ.10.A02900

Madras agric. J. 67 (11): 751 – 757 November 1980

Effect of Various Levels of Aluminium on the Dry Matter Yield, Content and Uptake of Phosphorus, Aluminium, Manganese, Magnesium and Iron in Maize.

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Solution culture trials were carried out to study the influence of increasing doses of aluminium on the uptake of Al, P, Mg, Mn, Fe and dry matter yield of maize crop. The results revealed that excessive doses of aluminium accumulated in the roots. The uptake of P by the roots was actually enhanced by Al application. The indications were that phosphorus gets precipitated with aluminium in the roots. Al-application did not increase Al concentration in the shoot, whereas the phosphorus concentration gradually increased. Poor growth beyond 25 ppm of Al was clearly seen. This was partly due to direct injury of Al on the root hairs and partly due to poor uptake of essential nutrients like Fe and Mn.

One of the major effects of aluminium toxicity in plants is the disturbance of phosphorus assimilation. Wright (1943) observed greater percentage of phosphorus accumulation in the roots of aluminium toxic plants of beans than in the normal plants. Many investigators (Burgers and Pember. 1923, Pierre Stuart 1933 and Rogland and Coleman, 1962) believe that the main action of large amounts of phosphate lies in correcting aluminium found soluble in acid soils. Lohse and Ruhnke (1933) studied the beneficial action of large amounts of phosphorus in reducing aluminium toxicity in solution culture. The results definitely showed that the problem of aluminium toxicity and phosphate availability were very closely inter related. Clarkson (1967) showed that in roots treated with 0.001 M aluminium sulphate, 85 to 95 percent of the total Al taken up by the root was located in the cell wall fraction and he suggested that the Al assimilated by roots became strongly bound to negative adsorption sites in the cell wall.

Randall and Vose (1963) stated that although aluminium promotes the uptake of P, it subsequently binds it or causes it to be bound within the plants, mainly within the roots and thus causing symptoms of P deficiency. The above observations show that heavy doses of soluble phosphate application to acid soils directly precipitate the active aluminium which may be contained therein. Mc Cormick and Bordon (1972) reported that Al was responsible for an increase in phosphate concentration along the root surface and within the epidermal and cortical regions. Mc Cormick and Borden (1974) have demonstrated that Al-PO_4 interaction does occur in plant roots and results in the apparent formation of an Al-PO_4 precipitate. The interaction occurs primarily outside the cell membrane.

In view of the importance of phosphate fertilization of acid soils where soluble aluminium is found to occur in high amounts, it was thought desirable to study further the aluminium toxicity problem taking maize as the test crop. The objectives of the study were as follows.

To study the addition of different doses of aluminium on the uptake pattern of Aluminium, Phosphorus, Magnesium, Iron and Manganese.

MATERIAL AND METHODS

With maize as the test crop, an experiment was conducted in nutrient solution. The pH of the solution was 4.8. Maize seedlings were grown in saw dust medium. When the seedlings grew to a height of 5-8 cm, seedlings of uniform growth were transferred to a complete nutrient solution (Crone's solution) consisting of KNO_3, $CaSO_4.2H_2O$, $MgSO_4.7H_2O$, $Ca_3(PO_4)_2$ at the rate of 1.0, 0.5, 0 5, 0.14, 1.0 gm per litre respectively. All micronutrients Viz. Fe, Mn, Cu, Zn, Mo and B, were added. In a four litre glazed pot seven healthy plants per vessel were maintained. Aluminium as aluminium sulphate $Al_2(SO_4)_3.18H_2O$ solution was prepared and added to the pots to provide the following treatments.

1. 0 aluminium
2. 1 mg Al/pot of 4 lit. capacity
3. 5 mg Al/pot ,,
4. 10 mg Al/pot ,,
5. 25 mg Al/pot ,,
6. 100 mg Al/pot ,,

All the treatments were replicated four times. The solution was renewed at weekly intervals and the volume was kept constant by addition of distilled water. After eight weeks the plants were cleaned with deionised water and blotted. The plants were divided into roots and shoots, dried at 75°C for 24 hours; dry matter weights recorded. The samples were ground and wet digested with H_2SO_4, HNO_3 and $HC1O_4$ mixture and analysed for iron, magnesium and manganese by atomic absorption spectrometer. Phosphorus was estimated in the triple acid extract colorimetrically by the Vanadomolybdate method (Jackson, 1967). Aluminium was estimated in one gram of the sample after ashing and digesting with nitric acid and hydrogen peroxide mixture and developing colour with 0.5 per-cent thioglycolic acid and aluminium in boiling water. The intensity was measured after 6 hours.

RESULTS AND DISCUSSION

Data on dry matter yield of maize crop is presented in Table 1. The plants were observed periodically for the development of roots. As the concentration of aluminium increased the roots tended to cluster and the root colour turned brownish. The intensity of clustering and colouring increased as the concentration of aluminium increased. But beyond 25 ppm the root hairs were damaged.

The final dry yield of maize plants increased with increased application of aluminium up to 25 ppm. When compared to control pots, the increase in dry weight of shoot was 44 percent and roots 34 percent. At the next higher dose tried, namely 100 mg per pot, the dry matter of shoot was reduced to 69 percent and the roots reduced to 67 percent. It was observed that the response of the shoot growth was more than the roots.

Aluminium

As the concentration of aluminium was increased, correspondingly the concentration of aluminium in the roots increased (Table 2). The concentration in the roots increased 8.51 fold at the highest dose of application and inspite of lower dry-matter yield at the highest level, the uptake of Al increased 3.66 times more, than the control. A perusal of the table revealed that as the concentration of aluminium in the solution was increased, the concentration of aluminium in the shoots progressively decreased. When the concentrations of aluminium in the control plants were reckoned as 100, the concentration at 1 ppm level rose to 111, when progressively decreased to 34 at the highest dose. Presence of Al in the 0-Al treated plants might be due to aluminium of the seeds themselves. Similar observations were made by Mullette (1975). Inspite of the fact that the shoot weight increased with higher doses of aluminium up to 25 ppm, the aluminium concentration decreased. It was thus seen that though the total uptake of aluminium by the whole plant increased with increase in aluminium concentration, it got accumulated in the root portions. Foregoing observations indicated that aluminium did not influence the dry-matter yield directly.

Phosphorus

Both concentrations and uptake of P by the root portions of maize increased with increased dose of aluminium except the highest dose of 100 ppm Al where it registered a decrease (Table 3). An increase of three fold in the uptake of P was observed. In the shoot portions the concentration of P increased progressively. An increase of 33 percent was obtained at the higher level when compared to the control. This observation was in confirmation with the results of Viets (1944) that aluminium stimulated the P uptake, but the total uptake increased by 74 percent at 25 ppm concentration, beyond which there was a decrease in uptake.

Increased uptake of aluminium and phosphorus by the roots by increasing the concentration of aluminium in the nutrient solution, but a decreased amount of aluminium taken up by the shoots suggested that aluminium got precipitated as aluminium phosphate and its translocation to the shoots were restricted. However this did not adversely effect the phosphorus translocation to the shoots. This was in line with the observations made by Clarkson (1967) that aluminium assimilated by roots become strongly bound in the cell wall of roots.

Magnesium and iron

The content and total quantity of Mg and Fe taken up by the crop increased with increasing dose of aluminium (Table 4 and 5). The increase was more in the roots than in the shoots. At the highest dose, Mg content decreased. A similar trend was observed in the case of iron also. An interesting observation was that when the concentration of aluminium in the solution was increased, the iron uptake by roots was reduced. But the translocation of iron from the roots to the shoots was not hindered. There was no such variation in the Fe content of the shoots though the total quantity removed by the shoots increased. This might be due to increased dry-matter yield.

Manganese

The content of manganese in the roots as well as the shoots decreased with increasing aluminium concentration of the nutrient solution (Table 6).

The observations tended to indicate that up to 25 ppm concentration of aluminium there was no detrimental effect though aluminium accumulated in the root protions with increased aluminium concentration of the nutrient solution which was not translocated to the shoots. The more the aluminium removed by the roots the more was the uptake of phosphorus by the roots. Al-application did not increase Al-concentration in the shoot, whereas the phosphorus concentration gradually increased. Subsequently aluminium got precipitated with phosphorus and its movement to the shoot was very much reduced. Iron and manganese uptake by the roots were adversely affected by increased aluminium concentration. But inside the plants the movement of iron and manganese was not affected. Magnesium uptake was aided by aluminium application up to 25 ppm.

LITERATURE

BURGERS, P. S. and Pember, L. R. 1923. Active aluminium as a factor detrimental to crop production in many acid soils. *Rhode Island Agri. Expt. Sta. Bull.* 194.

CLARKSON, D. T. 1967. Interactions between aluminium and phosphorus on root surfaces and cell wall material. *Plant and Soil.* **27**: 347-356.

JACKSON, M. L. 1967. *Soil Chemical Analysis.* Constable and Co. Ltd. London, 1958.

LOHSE, H. W. and RUHNKE, G. N. 1933. Studies on readily soluble phosphate in soils. III. The effect of phosphate treatment. *Soil Sci.* **36**: 33-38.

Mc CORMICK, L. H. and BORDON, F. Y. 1972. Phosphate fixation by aluminium in plant roots. *Soil Sci. Soc. Amer. Proc.* **36**: 799-802.

Mc CORMICK, L. H. and BORDON, F. Y. 1974. The occurrence of Aluminium phosphate precipitate in plant roots. *Soil Sci. Soc. Amer. Proc.* **38**: 931-934.

MULLETTE, K. J. 1975. Stimulation of growth in Eucalyptus due to aluminium. *Plant and Soil.* **42**: 495-493.

PIERRE, W. H. and STUART, A. D. 1933. Soluble aluminium studies IV. The effects of phosphorus in reducing the deterimental effects of soil acidity on plant growth. *Soil Sci.* **36**: 211-227.

RANDALL, P. J. and VOSE, P. B. 1963. Effect of Al on uptake and translocation of P 32 by perennial Ryegrass. *Plant Physiol.* 38 : 403-409.

ROGLAND, J. L. and COLEMAN, N. T. 1962. The influence of Al on P uptake by snap bean roots. *Soil Sci. Soc. Amer. Proc.* 26 : 88-90.

VIETS, P. G. Jr. 1944 Calcium and other polyvalent cations as accelerators of ion accumulation by excised barley roots. *Plant Physiol.* 19 : 466-80.

WRIGHT, K. E. 1943. Interval precipitation of P in relation to Al toxicity. *Plant Physiol.* 18 : 708-12.

TABLE 1 DRYMATTER YIELD IN g/Pot

Treatments	Shoot		Root	
	Content at 75°C (g/Pot)	(When Control=100)	Content at 75°C (g/Pot)	(When Control=100)
O-Al	7.93	100	2.68	100
1 mg/Pot Al	8.62	109	2.75	102
5 mg/Pot Al	9.77	120	2.89	108
10 mg/Pot Al	10.13	128	3.04	113
25 mg/Pot Al	11.42	144	3.58	134
100 mg/Pot Al	5.49	69	1.80	67

TABLE 2 ALUMINIUM CONTENT

Shoot				Root			
Content		Uptake		Content		Uptake	
ppm	When control =100	mg/ Pot	When control =100	mg/100 g	When control =100	mg/ Pot	When Control =100
17.24	100	0.137	100	21.73	100	0.058	100
19.12	111	0.165	120	22.15	102	0.061	104
16.67	97	0.163	119	32.68	151	0.090	155
12.99	75	0.132	96	47.10	217	0.143	245
7.19	42	0.082	60	52.64	242	0.189	323
5.77	34	0.032	23	185.00	851	0.214	366

TABLE 3 PHOSPHORUS CONTENT

Shoot				Root			
Content		Uptake		Content		Uptake	
mg/100 gm	When control =100	mg/ Pot	When control =100	mg/100 gm	When Control =100	mg/ Pot	When control =100
720	100	57.16	100	1404	100	37.76	100
760	102	65.54	115	1414	101	38.94	103
824	115	80.54	141	1744	124	50.49	134
844	117	85.45	150	2152	153	65.48	173
868	121	99.17	174	3088	220	110.80	293
960	133	52.71	92	1848	132	33.31	88

TABLE 4 MAGNESIUM CONTENT

Shoot				Root			
Content		Uptake		Content		Uptake	
mg/100 gm	When control =100	mg/ Pot	When control =100	mg/100 gm	When control =100	mg/ Pot	When control =100
202	100	16.04	100	170	100	4.57	100
215	106	18.54	116	170	100	4.68	102
222	110	21.70	132	204	120	5.91	129
228	113	23.09	134	212	125	6.45	141
234	116	26.72	167	234	138	8.40	184
204	101	13.40	73	82	48	1.48	32

TABLE 5 IRON CONTENT

Shoot				Root			
Content		Uptake		Content		Uptake	
mg/100 gm	When control =100	mg/ pot	When control =100	mg/100 gm	When control =100	mg/ pot	When control =100
25	100	1.99	100	284	100	7.64	100
26	104	2.24	113	270	95	7.44	97
26	104	2.54	128	254	89	7·35	102
26	104	2.63	133	238	84	7.24	95
25	100	2.86	144	138	49	4.95	65
24	96	1.32	66	135	47	2.43	32

TABLE 6 MANGANESE CONTENT

Shoot				Root			
Content		Uptake		Content		Uptake	
mg/100 mg	When control =100	mg/pot	When control =100	mg/100 mg	When control =100	mg/pot	When control =100
6	100	0.476	100	36	100	0.968	100
5	83	0.431	91	22	61	0.605	63
4	67	0.391	82	20	56	0.551	57
3	50	0.304	64	14	39	0.426	44
2	33	0.228	48	10	28	0.359	37
2	33	0.110	23	8	22	0.144	15