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Relationship in Adsorption and Absorption of Cations by Plant Roots from Salt Solutions

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Drake *et al.* (1961) have explained differential cation uptake by plant species on the basis of variable root cation-exchange capacities. Elgabaly and Wiklander (1949) emphasized that both root colloids and soil colloids compete for ions. Cation uptake by plants depends on the relative cation-exchange capacities of root and soil colloids. But no one has yet explained how cation-exchange of roots plays a direct role in differential uptake of cations by plants. In this study, an attempt was made to establish relationships between cations adsorbed and absorbed by roots.

Materials and methods: Pineapple (*Ananas comosa*; Var. Cyenne) and Kaimiclover (*Desmodium canum*; Var. H5335) were grown in 1/8 Hoagland solution which was aerated continuously. The nutrient solution was changed weekly. After approximately six weeks, roots were excised, thoroughly washed with distilled water and used for the following investigation.

Adsorption and absorption of cation by excised roots: Excised roots were centrifuged for 5 minutes at 65×g to remove entrained water. Three grams of roots were placed in three litres of salt solution. The roots were in contact with the continuously aerated solutions for a period of 24 hours. All experiments were performed at 24°C.

At the end of the sorption period, roots were collected on a nylon net and washed for a total period of 10 seconds in two beakers, each containing 100 ml of distilled water. Exchangeable cations (adsorbed cations) on the root were determined before and after the sorption period by desaturating roots in a series of three beakers, each containing 100 ml N HCl. The times of root contact with desaturating solutions in beakers 1 to 3 were 10, 50 and 60 seconds, respectively. Solutions from the three beakers were composited for chemical determinations. The cations adsorbed on the roots at the end of the sorption period were called final adsorbed cations. After desaturation in acid, roots were washed with distilled water, dried at 70°C, and analysed for Al, Ca, and K before and after the sorption period. The difference in initial and final determinations were reported as net absoption of cations in me per 100 g dry roots.

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Results and Discussion : Two series of bi-cationic solutions were prepared. One series contained three levels each of Al and Ca, and the other series consisted of three levels each of Al and K, making 9 treatments for each series. The cations were added as chloride in these solutions. Suitable pH values for Al solubility are between 4.0 and 4.8. Therefore all solutions were brought to pH 4.0 with HCl. Nielson and Overstreet (1955) have reported that pH 4.0 did not injure roots. Final adsorption and net absorption of Al and Ca or K by pineapple (CEC 6 9 me per 100 g dry roots) and Kaimiclover (CEC 20.0 me per 100 g dry roots) and cation concentrations are reported in Tables 1 and 2.

The amounts of cations (Al and Ca or K) adsorbed by roots were lower than root cation-exchange capacities. Apparently, some of the exchange sites on roots were occupied by H ions. Graham and Baker (1951) found that plants had measurable amounts of H ions on their root surface. Cations which were not present in the external medium diffused out of roots into external medium giving rise to the negative values of Tables 1 and 2 The amounts of Al and Ca adsorbed and absorbed were conditioned by their concentrations in solution (Table 1). There was mutual competion between

TABLE 1. *Sorption of Al and Ca by plant roots from the bi-cationic solution (pH 4.0)*

Plant species	Treatment me. per litre		me. per 100 g dry roots *			
			Final adsorption		Net absorption	
	Al	Ca	Al	Ca	Al	Ca
		0	0.16	0.00	-0.26	-0.05
	0	5	0.10	0.15	-0.44	0.22
		25	0.13	1.10	-0.26	1.37
		0	0.89	0.00	1.39	-0.04
Pineapple	0.1	5	0.62	0.09	0.68	0.11
	25	25	0.24	0.20	0.10	0.40
		0	1.65	0.00	2.89	-0.04
	1.0	5	1.09	0.00	1.65	0.05
		25	0 94	0.04	1.12	0.28
		0	0.38	0.00	-0.11	-0.02
	0	5	0.24	4.16	-0.25	4.28
		25	0.39	6.32	-0.28	6.64
		0	2.93	0.00	3.96	-0.04
Kaimiclover	0.1	5	1.08	3.42	1.37	3.50
		25	0.54	5.75	0.20	6.01
		0	3.80	0.00	5.72	-0.03
	1.0	5	2.99	1.94	3.57	2.02
		25	1.84	4.46	1.90	5.75

* Values are averages of two replications

Al and Ca for adsorption and absorption. If the concentration of Al was kept constant then Al adsorption and absorption decreased with increasing concentration of Ca in the solution. Aluminum had the same effect on Ca.

Aoki and Morita (1966) reported that the CEC ratio of orange to peech was 3 with a corresponding Ca adsorption ratio of 3.2. In the experiment reported here, Kaimiclover roots (high CEC) adsorbed and absorbed more Al and Ca them did pine apple roots (low CEC). The CEC of Kaimiclover roots was three times more than pineapple roots; however, the ratios of Al adsorption by Kaimiclover roots to Al adsorption by pineapple roots varied from 1.7 to 3 3 and Al absorption ratios varied from 1.7 to 2.8. On the average, these values were quite close to the CEC ratios as far as adsorption was concerned, but were slightly lower for absorption. The ratios of Ca adsoption and absorption by Kaimiclover roots to Ca adsorption and absorption by pineapple roots were much greater than the CEC ratio.

The results in Table 2 demostrate that Al adsoption and absorption were decreased by increasing K concentration. Exception to the generalization

TABLE 2. *Sorption of Al and K by plant roots from the bi-cationic solution (pH 4.0)*

Plant species	Treatment me. per litre		me. per 100 g dry roots *			
			Final adsorption		Net absorption	
	Al	Ca	Al	K	Al	K
Pineapple	0	0	0.07	0.38	-0.26	-4.48
		0.1	0.19	0.68	-0.22	-1.52
		1.0	0.09	1.04	-0.43	2.22
	0.1	0	1.39	0.50	0.50	-0.14
		0.1	1.19	1.02	0.22	4.10
		1.0	0.85	1.21	0.06	9.09
	1.0	0	2.38	0.40	0.90	-0.60
		0.1	1 61	0.80	0.51	3.44
		1.0	1.29	0.97	0.23	5.98
Kaimiclover	0	0	0.23	4.49	-0.14	-0.29
		0.1	0.45	11.18	-0.20	1.08
		1.0	0.24	13.31	-0.08	1.76
	0.1	0	3.29	9.80	2.32	-0.06
		0.1	2.80	13.83	2 14	2.23
		1.0	2.14	15.77	1.62	3.68
	1.0	0	5.20	8.76	4.30	-0.12
		0.1	4.62	12.75	3.34	1.78
		1.0	4.16	14.19	2.50	3.09

* Values are averages of two replications

were seen for both species when no Al had been added. Viets (1944) reported increased uptake of K when Ca or Al was supplied in addition to K in the external medium. In the experiment reported here, Al level of 0.1 me increased K adsoption and absoption by both plant species. However, the amount of K adsorbed and absorbed again decreased, if Al concentation was increased from 0.1 to 1.0 me (Table 2). The primary effect of polyvalent cations may be either on plasma membranes or on surface metabolism, intimately related to the permeability of protoplasm. This may be a possible explanation for the stimulating effect of Al on the K adsorption and absorption by roots.

It is interesting to note that although K adsorption on Kaimiclover roots exceeded adsorption on pineapple roots, the reverse was true for K absorption. Overstreet and Jacobson (1952) proposed a working hypothesis that a membrane or region exists in the cytoplasm of root cells which is impermeable to free ions, but permeable to complexes formed by the reaction of ions with metabolically produced compounds. It may be that each type of carrier combind a specific type of cation and that Kaimiclover compared with pineapple roots.

Simple correlations between the amounts of a cation adsorbed and absorbed are reported in Table 3. The correlation coefficients were highly

TABLE 3. *Simple correlations among the amount of a cation adsorbed and absorbed by a given plant species*

Cation absorbed	Cations adsorbed							
	Bi-cationic solution (Al+Ca)				Bi-cationic solution (Al+K)			
	Al	Ca	Al	Ca	Al	K	Al	K
Al	0.994**		0.991**		0.981**		0.986**	
Ca		0.978**		0.992**				
K						0.903**		0.926**

** Significant at P=0.01

significant and r values indicate that 80 to 98% of the variability in cation uptake within a species was accounted for by variations in cation adsorption within that species. These data suggest that cation absorption is related to the adsorption of that cation.

Conclusions : Aluminum depressed the adsorption and absorption of Ca by excised pineapple and Kaimiclover roots, but the low concentration of Al stimulated the adsorption and absorption of K. The K adsorption was higher on Kaimiclover than on pineapple, but the order was reversed for its absorption. A highly significant correlation was observed between adsorption and absorption of individual cations within each plant species. But there was little or no relationship between adsorption and absorption when several species were compared. This suggests that absorption of cations may be related to adsorption but the amount of an appropriate carrier produced by roots is the factor most immediately related to absorption.

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