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CATIONIC ACTIVITIES AND THE EXCHANGE PHENOMENA OF PLANT ROOTS

RELATIONSHIP TO PRACTICAL PROBLEMS OF NUTRIENT UPTAKE[1]

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The feasibility of measuring cationic activities in systems of plant roots was indicated in a preliminary report on this general subject (4). The energy with which a cation is bonded to the exchange seats of the root surface can then be computed from the cationic activities. The present study has been conducted in an attempt to find whether these mean that free-bonding energies have any significance in practical problems involving nutrient uptake.

Some plants utilize Na as a partial replacement for K needs. Such plants accumulate large amounts of Na. Other plants do not absorb Na to any appreciable extent. It seemed worthwhile to determine whether the ability to accumulate Na by a plant would be reflected in the relative bonding energies of plant roots for Na.

The maintenance of grass/legume pastures and meadows has become a difficult task because of diversity of nutrient requirements by the grass as compared to the legume. Some work has indicated that the relative cationic exchange capacities of the roots of the different species was important in this problem (1), hence it seemed likely that the mean free-bonding energies of the cations to the roots might be important also.

The diverse ability of different plants to utilize phosphorus from insoluble sources such as rock phosphate has long perplexed agronomists. Could it be that the plants' ability to break up the tricalcium phosphate molecule in rock phosphate is related to the ability of the roots to bond calcium?

EXPERIMENTAL

Since the previous report in this series, the determination of cationic activities and mean free-bonding energies for various cations has been extended from soybean and alfalfa roots to those of Reed canary grass, red top, lespedeza, corn, oats, and another variety of alfalfa. The plants were grown in level cultures of 1/5 Hoagland's solution as has been described (4) (5). The plants were grown for various lengths of time as follows: Cereals, 15 days; legumes, 30 days; and grasses, 50 days. The procedure for determination of cation activities was exactly as previously described. The uptake of Na by several plants is being determined by replacing with NaO, 1/4, 1/2 and 3/4 of the K in the 1/5 Hoagland solution and growing the plants in quadruplicate in No.2 tin cans of gravel bathed with these solutions.

In other studies reported elsewhere (6), the uptake of phosphorus from soil treated with various phosphates by several of these same plant species was determined.

DISCUSSION OF RESULTS

As these studies are still in progress, the results reported in tables 1, 2 and 3 are in some cases incomplete. However, it is believed that sufficient progress has been attained to justify inclusion here. It appears from the data of Table 1 that some relationship does exist between the tendency to take up Na and the bonding energy of Na to the plant root; however, there is need for completion of two key determinations before definite conclusions can be drawn.

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Journal of the Arkansas Academy of Science, Vol. 8 [1955], Art. 7

Table I. Mean Free-Bonding Energies of Plant Roots for Na in relation to Na Uptake by These Different Plants.

Plant	ΔF_{Na} (Calories/mole)	Tendency to take up Sodium*
Corn	0	nil
Reed canary grass	55	†
Oats	559	Moderate
Alfalfa	599	Moderate
Celery	†	Excessive

* As recently reported in Soil Sci., 76:1 (1953)
† Values being determined but not yet available.

Table 2. Mean Free-Bonding Energies of Legume and Grass Roots for Ca and K in Relation to Their Relative Competition for These Cations.

Plant	ΔF (Calories/equivalent) Calcium	ΔF (Calories/equivalent) Potassium	$\frac{\Delta F_{Ca}}{\Delta F_K}$	Cation for which Competition is Keenest
Legumes:				
Alfalfa (K.C.)	775	672	1.16	Calcium
Alfalfa (B.)	590	642	0.92	Calcium
Soybean	827	711	1.16	Calcium
Lespedeza	815	705	1.16	Calcium
Grasses:				
Red Top	509	861	0.59	Potassium
Reed Canary Grass	329	648	0.51	Potassium

The data of Table 2 appear to give excellent support to the work of Gray, et al (3). They showed that certain grasses are so competitive with clovers grown with them that it is near impossible to maintain sufficient K in the soil to meet the needs of the clover. The relatively high values of the F_{Ca}/F_K ratio for the legumes and the relatively low values for the grasses would seem to offer some explanation as to why legumes tend to accumulate Ca while the grasses tend to accumulate K even to the detriment of the legumes.

Evidently there is a definite relationship between the ability of a plant to utilize phosphorus from rock phosphate and the relatively high mean free-bonding energy of the roots for Ca (Table 3). Graham (2) showed that the free energy change in the exchange of Ca for H on various colloids correlated with the abilities of the acid colloids to weather rock phosphate and render phosphorus available to a test crop. This might suggest that the ability of buckwheat and similar crops to utilize phosphates of low solubility may be related to this relatively high mean free-bonding energy for Ca. Perhaps the latter is a formidable weathering force in attacking rock phosphate much in excess of that of certain other types of plant roots. Truog (7) indicated many years ago that plants' abilities to take phosphorus from low solubility materials was related to their calcium content in the tissues.

Table 3. The Mean Free Bonding Energy Ratios as Indices for Determining the Ability of a Plant to Utilize Rock Phosphate.

Plant	$\frac{\Delta F_{Ca}}{\Delta F_K}$	Ability to Utilize Rock Phosphate*
Buckwheat	1.67	High
Alfalfa	1.16	Moderate
Soybean	1.16	Moderate
Lespedeza	1.16	Moderate
Red Top	0.59	Low
Reed Canary Grass	0.51	Low

* In part based on studies reported (6) and in part based on general knowledge of the relative abilities of these crops to utilize rock phosphate.

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