ION UPTAKE IN RELATION TO SALT EFFECT AND SOIL MOISTURE

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INTRODUCTION

Donnan system represents a colloidal phase surrounded by an inner solution containing mainly exchangeable cations, and an outer solution containing only free diffusible ions. The equilibrium condition of Donnan system is characterized by the fact that the free energy of any pair of ions are constant throughout the system.

It is well established that the root surface carries fixed negative charge related to pectic and polyuronide groups and therefore, we can talk about Donnan distribution of ions between the root surface and soil solution. This distribution will naturally affect the uptake of ions by plant roots since the inner active protoplasmic should feed on ions of the outer membrane and only indirectly upon the ions of the soil solution.

It must be noted that the free diffusible anions would not enter the Donnan system unless the negative charge of the nondiffusible anions are neutralized by cations. Thus, raising the ionic strength by adding salt to outer solution will suppress the electrical negative potential of root surface so that anions move throughout the cell wall of root to the active sites of absorption with much less resistance. The suppression is greater the higher the cation valence and smaller the higher the anion valence of the added salt. Such suppression is also affected by cation exchange capacity of plant roots. The positive effect of salt on ion uptake is usually referred as "salt effect".

Also one of the essential characteristics of the Donnan system is that dilution of this system i.e. by increasing moisture content of the soil favours the adsorption of polyvalent cations and the desorption of polyvalent anions. Thus, the ratio of anion activity inside/anion activity outside is smaller in dilute system and the differences is suppressed at a given solution activity, being greater the higher the cation valence and smaller the higher the anion valence.

The aim of this investigation was to study the "salt effect" as well as "dilution effect" in relation to anion uptake according to Donnan system in view of Mattson's theoretical curves using different ratios of cation and anion valences. Experimental data presented in this investigation will discuss the validity of such theory in sand culture and soil system as indicated by the uptake of some anions for macro- and micro-nutrients namely, nitrate, phosphate and borate.

II REVIEW OF LITERATURE

The effect of salt on anion uptake by plants was investigated by many workers. The literature concerning this subject will be reviewed under the following headings.

1. Anion uptake in relation to salt effect:

Minotti et al (1968) found that calcium salts have a beneficial influence on initial nitrate uptake by roots, while the continual potassium was apparently beneficial in nitrate transport. El-Gabaly and Wiklander (1962) reported that the uptake of nitrate was influenced by the concentration of soil solution. Moustafa (1974) studied the effect of different salt treatments on nitrogen content of both barley and broad bean plants grown in sand culture. He found that the uptake of nitrogen generally increased with increasing the concentration of salt treatments up to 3×10^{-3} N. In all salt treatments the concentration of 10^{-3} N $CaCl_2$ gave the highest increase in N-uptake by plants. The effect of different salt treatments on N-uptake was generally related to their effect to decrease the negative potential of plant roots.

Ali et al. (1971) reported that nine calcium salts (calcium carbonate, dicalcium phosphate, calcium oxide, calcium sulphate, calcium sulphide, calcium sulphite, calcium nitrate, calcium acetate and calcium citrate) increased the availability of soil nitrogen. In highly acid soil, the application of calcium carbonate gave the maximum availability of soil nitrogen whereas the addition of calcium acetate has been found to give maximum availability of nitrogen in slightly acid soil.

Mattson et al. (1949) reported that the addition of neutral salts increase absorption of phosphate by plants. This effect is explained on the basis of the Donnan distribution of ions. The presence of salts makes possible a higher concentration of phosphate in the electronegative pecting root membrane, which has strong acidoid properties and a high cation exchangeability. The protoplasm membrane is nourished directly from the outer root membrane and the uptake of nutrients depends on the composition of this outer membrane. Moukhtar (1972) reported that the uptake of phosphate by barley plant generally increased with increasing the absorption of various tested cations relative to that accompanied anions.

Ferguson and Hedlin (1963) found that phosphorus uptake by barley increased with increasing salt concentration. They attributed, however, this relationship to the effect of salt on the physiology of plant rather than salt effect on P solubility.

Mattson (1966) established some theoretical curves showing the relation between the ratio of anions activity in the inside soil solution to its activity in the outside solution as a function of solution concentration. These curves show that the anion activity ratio (y/x) i.e. the ratio of the anion activity in the inside soil solution to that in the outside solution is suppressed by increasing activity of solution. The suppression being greater the higher the cation valence and the lower the anion valence.

Mattson (1967) studied the effect of increasing calcium chloride activity added to the soil on phosphate uptake by plant. The uptake of phosphate was higher with increasing calcium chloride concentration. These results were explained as a "salt effect" which tends to even out the difference between the phosphate activity in the soil solution and the inside solution associated with the plant root.

Moustafa (1974) studied the effect of potassium chloride, potassium sulphate and calcium chloride on Donnan distribution of phosphate in sand culture. Results showed that the uptake and percentage of phosphate in roots and shoots of several plants increased with increasing salt concentration from 10^{-4} to 3×10^{-3} N. This effect was greater the higher the cation valence and smaller the higher the anion valence. The increase in phosphorus uptake was higher in broad bean than in barley plant.

Abdou et al. (1972) studied the effect of two salt levels of each of chloride, sulphate and carbonate of calcium, magnesium, potassium and sodium on the phosphate content of rye grass. They found that increasing salt level increased phosphorus content of the roots, with exception of magnesium salts. The increase being greater the higher the cation valence and smaller the higher the anion valence. The effect of salt treatments on the phosphorus content of the shoots was different from that on the roots. They also found that only calcium salts gave measurable increase in the phosphorus content, while magnesium sulphate and magnesium carbonate showed slight increase; magnesium chloride reduced the phosphorus content. Other salts used either reduced phosphorus content or had no effect. It was suggested that the increase in phosphorus content of roots was mainly due to the increase in phosphorus concentration in Donnan free space.

Robson et al. (1970) found that differences in behaviour of divalent cations from that of monovalent, regarding the phosphate uptake by investigated plants, to be due to variations in the more screening of electronegative charges near the sites of absorption for divalent cations, thus increasing their number of sites accessible to the anions.

Franklin (1971) found that the excised roots of ten plant species pretreated with calcium chloride or alomonium chloride absorbed large amounts of chloride and sulphate than potassium chloride pretreated roots; the mean increase in uptake for all species was over 800% for sulphate and about 65% for chloride and was correlated with total uptake of sulphate and chloride by the polyvalent cation pretreated roots. He also found that P uptake increased with increasing ionic strength of the absorption solution with KCl to

10^{-3}. Effect of ionic strength and Ca^{++} and Al^{+++} were thought to be associated with a reduction in the negative charge on root surface and the resulting effect on ion diffusion through the cell wall.

El-Gabaly (1962) studied the effect of the valence of the associated cation on Cl uptake by excised barley root grown in $CaSO_4$. He found that the uptake of chloride relative to that of the associated cation increased in the order, trivalent > divalent > monovalent. These results were explained on the expected effect of the cation on the negative charge and potential of root surfaces. A lyotropic order was observed in case of monovalent cations, whereas divalent cations showed no such order. The order observed in Cl uptake from chloride solutions of monovalent cations is associated with the ability of the absorbed cation to remove Ca and Mg from the roots. El-Gabaly and Handley (1962) found that a greater Cl uptake from the resin NaCl system than from the NaCl filtrate and little or no difference between the resin $CaCl_2$ system and $CaCl_2$ filtrate. These results are explained on the basis of an interaction between the negative root surfaces and the positively charged resin