SALT EFFECT IN RELATION TO SOME ANION CONCENTRATION IN SOIL AND UPTAKE BY PLANT

By

MOHAMED AHMED M. MOUSTAFA

B.Sc. (Agric.), Ain Shams Univ., 1969

THESIS

Submitted in Partial Fulfilment of the Requirements
For the Degree of

MASTER OF SCIENCE

in

SOIL SCIENCE

Soil Science Department
Faculty of Agriculture
Ain Shams University

1974

APPROVAL SHEET

Thesis by Title : Salt Effect in Relation to Some Anion Concentration in Soil and Uptake by Plant

Approved by :

____

____

____

Date : ___ / ___ / 1974

...ooOoo...

بسم الله الرحمن الرحيم

A C K N O W L E D G M E N T

The author wishes to express his appreciation and deepest gratitude to Prof. Dr. A.H. El-Damaty, Professor of Soil, in Soil Science Department, Faculty of Agriculture, Ain Shams University, and Dr. A.I. Metwally, Associate Professor of soil in the same Dept., for suggesting the problem, supervision, progressive criticism, keeping interest, and guidance during the investigation and preparation of this work.

...ooOoo...

C O N T E N T S

...ooOoo...

INTRODUCTION

The soil represents a colloidal system in which the solid or colloidal phase is surrounded by an inner solution containing an excess of one kind of ions, the exchangeable cations, and an outer solution containing the ions of the free electrolytes. Donnan theory demands that at equilibrium the partial molal free energy of any pair of ions (salt) be the same in all parts of the system.

Studies on ion uptake have led to the conclusion that the roots of plants are provided by a physiologically passive, outer membrane consisting of pectic and polyuronic acidoids in addition to cellulose, and that this membrane interacts with the soil solution according to the laws of ion exchange. The inner active protoplasmic membrane must then be assumed to feed upon the ions of this outer membrane and only indirectly upon the ions of the soil solution. It is well known that the uptake of ions is influenced by the exchange capacity of the roots, more particularly by the active hairs, then this influence should express itself in a predictable manner, by the way the uptake is influenced by the composition and concentration of the solution.

According to Donnan distribution, the ratio of the anion activity in the inside root solution to the anion activity in the outside root solution (soil solution or nutrient solution) is small in dilute system. But the difference is suppressed by adding salts. This suppression, at a given solution activity is greater the higher the cation valence and smaller the higher the anion valence of the added salt. Such effect is also affected by the relative C.E.C. of roots and soil. The present work was carried out to discuss validity of such theory in sand culture and soil systems, as indicated by the uptake of phosphate and nitrate. Using different plant species and wide range of salt concentrations would give same light on the limits of application of such theory in relation to anion uptake by plants.

II. REVIEW OF LITERATURE

a) Salt effect on phosphate solubility in soil :

Lehr and Wesemael (1952) reported that all neutral salt decreased the solubility of the phosphate, the effect being more pronounced with higher salt concentration. The anion being the same, the depressing effect increased in the order : Na < K < Mg < Ca. When neutral salt were added to soil phosphate, they did not have the same effect as if added to pure phosphate solutions; this difference can be explained on the basis of interaction between the salt solution and the soil. He also added that the effect of neutral salts on the solubility of soil phosphate was greater with sandy and loamy soils than with river and sea clays. Mattson et al. (1951) indicated that the addition of salt suppresses the solubility of phosphate in the soil under investigation. This is a distribution of ions according to Donnan in which the activity of a buffered ion which has the same kind of charge as the colloid, remains nearly constant at the colloid solution interface. They also added that the OH ions show the same effect as the phosphate ions. Mattson et al. (1951) reported that the phosphate ions are displaced from their fixation by the anions of the added salt. The Donnan distribution of ions is suppressed, the more acidoid content and the greater the acidity. Gorbyleva *et al.* (1968) reported that KCl with lime intensifies the soil P availability even more than dose K_2SO_4 but did not affect the P uptake from fertilizer to a large degree. Peaslee and Phillips (1970) stated that the presence of 7.75 m.e./100 g clay of the NO_3^- , Cl^- or $SO_4^=$ salts of Ca or NH_4 significantly decreased the diffusion coefficients of phosphorus from those of the untreated clay. The self-diffusion coefficients in the presence of the Ca-salt were significantly larger than those in the presence of the NH_4 -salt.

Alberts (1965) concluded that the silicate ion present in large amounts, probably increased the availability of soil phosphate by anion exchange, there was no evidence that silicate substituted for phosphate inside the plant.

El-Nennah (1972) found that all cations and anions except silicate depressed the solubility of soil phosphorus as compared with control and the depressing effect of the different cations followed the order : Ca $>$ Mg $>$ K $>$ and NH_4 $>$ Na. This depressing effect was less marked with the cations associated with sulphate compared with those associated with chloride, concerning the anions, they can be arranged in the following order according to their depressing effect when associated with ammonium, sulphate $<$ nitrate $<$

chloride $<$ carbonate, but when associated with Ca^{++} the order is as follows : sulphate $<$ nitrate $<$ carbonate $<$ chloride. This depressing effect was more pronounced when the anions are associated with the divalent cation (Ca^{++}) compared with those associated with ammonium. Wesemael and Lehr (1955) reported that the Na, K and Ca decreased phosphate solubility, Na producing the smallest and Ca the largest decrease; sulphate has less effect than nitrate and chloride; Na_2SO_4 particularly at higher concentration of 0.5 N and 1.0 N, even increased phosphate solubility in acid lateritic soils.

Mattson et al. (1951) found that the phosphate solubility of the calcium phosphate in alkaline range was less with sodium chloride than with potassium chloride. Bouldin and Sample (1959) indicated that salts tend to increase the solubility of superphosphate and its availability to oats.

Fine and Carson (1954) indicated that relatively high plant response to phosphorus fertilizers occurred on moderately saline soil. They concluded that this was due to the effect of the salts on the solubility of soil phosphorus Sauchelli (1965) reported that the ability of the different anions, when compared as solutions of neutral salts, to replace phosphate from a soil which had been heavily phosphated five years before was found to be as follows : fluoride $>$

oxalate > citrate > bicarbonate > borate > acetate > sulphate > chloride.

b) Salt effect on anions uptake :

The availability, solubility and retention of phosphate have been extensively investigated because of their agriculture importance. The content of neutral salts influence these properties in a way and to an extent which varies with the nature of the soil material.

Salt effect on phosphate absorption had been investigated by several investigators. Mattson (1969) showed that the phosphate uptake by barley from $CaCl_2$ solution was higher than KCl and least in water. He explained his results on the basis of Donnan distribution of ions between the soil solution and the root membrane. Mattson (1966) established some theoretical curves showing the relation between the ratio of the anions activity in the inside soil solution to its activity in the outside solution as a function of the solution concentration, the valences of both cations and anions, and the exchange capacity of the exchanger. 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 small in dilute systems and the difference is suppressed by the increase of the solution activity, the suppression at a given solution activity, being greater the higher the cation valence and the lower the anion valence.

It is well established that plant roots act as cation exchanger and therefore, we can talk about Donnan distribution of ions between the root and the soil solution. This distribution will naturally affect the uptake of these ions by plant roots.

Mattson (1967) studied the effect of increasing the solution activity on the phosphate uptake by plant with the increase of the $CaCl_2$ activity added to the soil, the uptake of phosphate was higher with increasing $CaCl_2$ 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 roots. Mattson et al. (1949) found that the neutral salts increase absorption of phosphate ions 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 and nitrate in the electronegative pecting cellulose 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. The work of El-Gabaly and Wiklander

(1962) and El-Gabaly (1962) showed that the uptake of nitrate and other anions was influenced by the concentration of the soil solution in the same way as the phosphate.

El-Leboudi *et al.* (1973) in their studies on barley plants, which were grown in sand cultures, found that the uptake of phosphate by plants generally increased with increasing the absorption ratio of various tested cations relative to that of accompanied anions. Ferguson and Hedling (1963) indicated that phosphorus absorption by barley increased with increasing salt concentration, they attributed this relationship to the effect of salts on the physiology of the plant rather than the effect of salts on phosphorus solubility. Gausman and Awan (1956) indicated that the chloride ion increased phosphorus absorption by potato tubers at low concentration.

Srivastava and Ali (1971) found that all the calcium salts ($CaCl_2$, CaI_2, $CaBr_2$, $Ca(OAC)_2$, $CaSiO_3$, $CaSO_4$, $CaCO_3$, $Ca(NO_3)_2$, CaO or $Ca(H_2PO_4)_2$), significantly increased available N and P in soil samples under investigation. In the more acid soil, $CaCO_3$ gave significantly higher N and P values than the other salts and in the less acid soil $Ca(OAC)_2$ gave the highest levels of available N and P, with the exception of $CaSiO_3$ which had the smallest effect on available N and P in all treatments; the halides generally had less effect than other salts; the maximum N and P values for all calcium salts were obtained with 8 m.e./100 g soil.

Minotti et al. (1968) concluded from their data that calcium salts have a beneficial influence on initial nitrate uptake by root tissue, while the continual potassium supply was apparently beneficial in nitrate transport. Lewis et al. (1952) reported that sulfate ions increased phosphorus absorption at low concentration.

In (1942) Eaton found that the addition of both chloride and sulfate salts caused little effect on total nitrogen and phosphorus concentration.

On the other hand, Medappa and Dana (1968) found that calcium concentration from zero to 750 p.p.m. had no appreciable effect on the uptake of P^{32} by Cranberry plants in nutrient solution. Alberda (1949) found in his study on plants that the maximum rate of P absorption is reached at low concentration of solution with low salt plants than with high salt plants, growth of plants and absorption are parallel. Absorption of P_2O_5 was independent of the concentration of other ions of the solutions. Howe and Graham (1957) found that the effect of salts on phosphorus availability were small and inconsistent.

c) Effect of cation valence on anions uptake :

El-Kobbia and Omer (1972) reported that the valence of the cation present in the cultural media has no obvious effect on anion uptake. They found that the uptake of the metabolically inactive ion (Cl) was more related to the cation summation values within plant (electroneutrality). On the contrary, the NO_3^- uptake was more related to plant growth rather than cation status within the plant.

Gerola and Gilardi (1955) reported that the apical roots of the pea placed in Knop solution with 10^{-3}M $Be(NO_3)_2$ showed greater increase in weight and absorption of P than the control with $NaNO_3$. Leggett et al. (1965) reported that both studied divalent cations calcium and magnesium were equally effective in the activation of the phosphate absorption by barley plants. Franklin (1971) indicated that the excised roots of ten plant species pretreated with $CaCl_2$ or $AlCl_3$ subsequently, absorbed larger amounts of chloride and sulfate than KCl pretreatment roots; the mean increase in uptake for all species was over 800 percent for sulfate and about 65 percent for chloride and was correlated with total uptake of sulfate and chloride by the polyvalent cation pretreated roots. He also added that the phosphate uptake could be increased by raising the ionic strength of the absorption solution with KCl; responses to KCl, KNO_3 and NaCl were similar