

the reduced form. In the case of vanadium it is probably the reverse in that reduction and subsequent complexation of vanadium reduces its availability. Complexation no doubt prevents accumulation of V^V in the cell where its adverse effects on enzyme systems might cause severe cellular disruption.

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PS7.2 — MO

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THALLIUM UPTAKE BY PLANT ROOTS: COMPETITIVE EFFECTS OF POTASSIUM IONS

INTRODUCTION

Thallium is a rare but toxic element, with a mean crystal abundance of approximately 1 ppm. Biologically, thallium is of interest due to its mimicry of K^+ in many biological systems [1]. Thallium shows many physico-chemico similarities to potas-

sium, with the ionic radius of Tl^+ being very similar to the alkali metal cations Rb^+ and K^+ ($K^+ = 133$ pm, $Tl^+ = 144$ pm, $Rb^+ = 148$ pm). Tl^+ has been shown to be more effective than K^+ , Rb^+ or Cs^+ at activating certain (Na^+/K^+) ATPases [2,3], whilst MULLINS and MOORE [4] have shown that both the kinetics of exchange and the electrochemical influences of Tl^+ and K^+ are virtually identical in the cells of the frog sartorius.

Levels reported in soils vary in the literature, between 0.05 and 0.5 $\mu g.g^{-1}$ dry weight, although recent studies by German workers report levels exceeding this value [5].

Thallium levels in plants have been reported as between 0.01 and 3800 ppm ash weight, with 0.5 ppm being typical for most species [1]. Plants with elevated thallium levels have been found in areas of natural thallium mineralization, and have been reported as toxic to grazing sheep and cattle [6].

The aim of this study is to examine the kinetics of uptake of thallium by excised barley roots, and to compare it with findings for K^+ by other workers.

MATERIALS AND METHODS

Low salt barley roots were grown hydroponically as described by EPSTEIN [7]. Barley seeds (*Hordeum vulgare* c.v. Maris Mink) were soaked in aerated distilled water for 4 hours, germinated and grown in the dark at 25°C for 7 days. Roots were excised, rinsed in distilled water, thoroughly mixed, and placed in aerated 0.5 mM $CaCl_2$ solution, prior to experimental use.

Uptake experiments were carried out as described by HARRISON *et al.* [8]. Roots were placed in aerated thallous acetate solutions at various concentrations, spiked with the isotope ^{204}Tl . After 15 minutes roots were removed, rinsed in chilled distilled water, and placed in chilled (2°C) unspiked thallous acetate solution for 30 minutes, after which they were removed, blotted to remove excess moisture, and weighed into digestion flasks. Samples were digested in 5 ml of a sulphuric acid/hydrogen peroxide mixture as described by ALLEN [9]. Samples were poured into scintillation vials, the flasks rinsed with 5 ml distilled H_2O , and the washings added to the samples. Activity was measured directly by measuring Cerenkov ra-

diation in a Packard Tricarb liquid scintillation counter.

In competition studies K^+ was added as KCl, and the above procedure followed.

RESULTS

The initial uptake velocity of Tl^+ by excised roots showed a hyperbolic profile with respect to the concentration of the ion in the bathing solution (Fig. 1). The maximum velocity was calculated (from the curve) at 27.5 mol/gram fresh wt./hour, and from this the K_m of 80 μM was obtained.

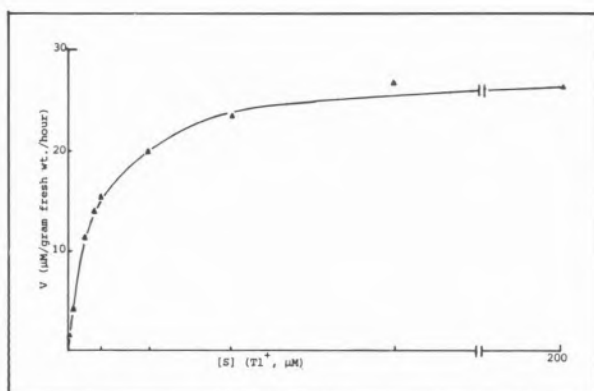


Fig. 1

Initial rate of uptake (V) against concentration of thallium [S].
Uptake for 15 minutes. Desorption 30 minutes.

$V_{max} = 27.5$; $K_m = 80 \mu M$

Competition studies with potassium showed a strongly competitive effect of the cation on thallium absorption (Fig. 2). The results are presented

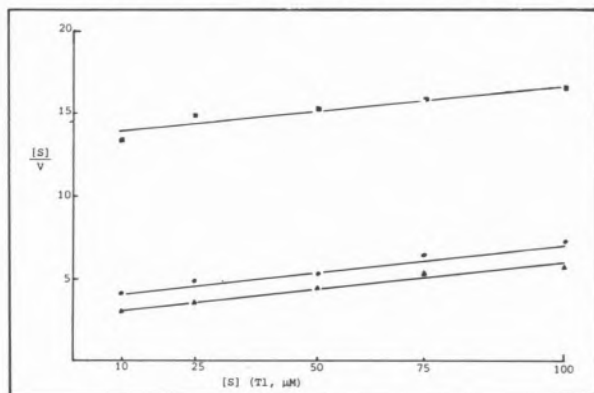


Fig. 2

Hanes plot of uptake of thallium at various concentrations in the presence and absence of inhibitors.

▲ = control; $K_m = 87$; ● = 100 μM K^+ ; $K_m = 106$; ■ = 500 μM K^+ ; $K_m = 414$

in Hanes plot showing S/V against S . The competitive nature of the inhibition is marked by an increase in the apparent K_m value in the presence of the inhibitor, with no overall change in the maximum velocity (K_m control = 87.17; K_m (100 μM K^+) = 106.21; K_m (500 μM K^+) = 414.72 μM . $V_{max} = 30.12 \pm 1.95 \mu M$ Tl /gram fresh weight/hour. The inhibition constant, K_i , was calculated from the graph as 122 μM .

DISCUSSION

The results obtained show a contrasting picture. The competition studies carried out suggest that K^+ is a competitive inhibitor of Tl^+ uptake, possibly indicating that they are both taken up by the same carrier system. The results from thallium uptake studies show that for increasing thallium concentrations a single hyperbola is obtained in accordance with Michaelis-Menten kinetics. Potassium has been shown to deviate from simple Michaelis-Menten kinetics, with a dual pattern of uptake. This involves two mechanisms [10]; mechanism I a high affinity carrier; and mechanism II, a low affinity carrier. The K_m value for K^+ uptake is given as approximately 20 μM [11] which is considerably less than that obtained for Tl uptake (80 μM). This suggests that K^+ has a greater affinity for the carrier than Tl^+ , and would therefore explain why, over the concentration range studied, a single hyperbola describes Tl^+ uptake. It could be concluded that the lower affinity of Tl^+ for the carrier means that saturation kinetics for type I sites are not reached until much higher Tl^+ concentrations, i.e. beyond the range studied here, and that thallium uptake over the range studied is almost exclusively by mechanism I of the potassium carrier system.

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PS7.3 — TH

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THE INFLUENCE OF COMPLEXATION ON MICRONUTRIENT UPTAKE BY PLANTS: A COMBINATION OF COMPUTER SIMULATION AND PLANT GROWTH EXPERIMENTS

Chelation of the micronutrient metal ions (Cu, Fe, Mn and Zn) is known to be an important factor in the efficacy of their uptake by plants [1,2]. Chelation may occur by plant exudates [3], in substances released from decaying organic matter [4], and in bacterial excretions [5]. It is reasonable to postulate that chelation is essential (i) for the solubilization of the metal ions, particularly under alkaline conditions; (ii) for metal transportation; and (iii) for selectivity between the metal ions.

Over the past 30 years there has been a large number of studies on the application of synthetic

chelating agents to overcome plant nutritional problems, most noticeably the use of EDTA and related chelating agents to overcome plant iron deficiencies [6]. In other cases, e.g. with Cu, chelation with EDTA reportedly decreases plant uptakes [7]. In fact, there is little agreement on the influence and mechanism of chelation of the micronutrient metal ions in relation to the subsequent plant growth and health. Many of these conflicts can be attributed to a lack of knowledge or consideration of the metal speciation and to ignoring the mutual influence of one metal upon another.

Fortunately, plants may be grown from aqueous solutions which contain known levels of metal salts and chelating agents. The speciation in such solutions can now readily be calculated via computer simulation, provided the relevant thermodynamic data are available. A number of computer programs are available for assessing metal speciation in multi-metal multi-ligand systems (e.g. ECCLES, GEOCHEM, PSEUDOPLOT), such programs lead to the same results in general [8]. We have begun a series of studies on the influence of complexation upon metal ion uptakes from nutrient solutions and the effects upon plant growth and health. The emphasis is on a multi-metal study. Thus, barley seeds are allowed to germinate under carefully controlled conditions and then grown in nutrient solutions containing EDTA. A «continuous replenishment» method is being used to avoid changes in solution concentrations and pH. The solutions used differ in EDTA level and/or pH. The plants are harvested at set times, washed, weighed, and then the roots and tops separately analysed for all elements with an ICP instrument. The complexation of each metal ion in each of the solutions is determined by computer simulation. By small changes in EDTA and/or pH quite wide variations in the degrees of chelation can be obtained for one or more of the metal ions. In our initial studies solutions of the same nutrient composition (Long Ashton nutrient solutions) and pH but with varying EDTA concentrations were used. The barley plants were grown in these solutions at 20°C under regulated lighting conditions and humidity. The computed speciation of the metal ions is shown in the Table. The data in column 1 show that the assumption that