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Kinetics of Magnesium Uptake by Rice Plants

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Abstract. Uptake of magnesium was studied by continuous flow technique for 82 days old rice plants in nutrient solution over a range of 0.2 to 1 ppm or 8.2 to 41 μM magnesium concentration. Uptake of magnesium followed a Michaelis-Menten kinetics with a Michaelis constant, K_m of 0.2×10^{-4}M and V_m 156 $\mu g\ g^{-1}\ h^{-1}$. With increasing flow rate, the rate of magnesium absorption was increased.

The rate of uptake of ions by plant tissues as a function of external concentration has frequently been examined in an attempt to gain an understanding of the mechanism of nutrient absorption (EDWARDS 1968, FAGERIA 1974a, b, and KANNAN 1971). The results have led to the suggestion that for any given ion, the kinetics of uptake in plant cells agree closely over limited concentration ranges with classical enzyme kinetics (EPSTEIN and HAGEN 1952, and FAGERIA 1974c). This is widely taken to indicate that uptake occurs through a carrier.

In the present study the uptake of magnesium by intact rice plants is examined in the light of latest enzyme kinetics. Rice has been selected as a test plant for this study, because it is an important food crop and provides about 21 per cent of the total food calories consumed by the people of the world (BROWN 1963).

Materials and Methods

Rice (*Oryza sativa* L. cv. 'IR 8') was used as a test plant in this study. Seeds were germinated in dilute calcium sulphate (2×10^{-4}M) solution on cheese cloth.

When seedlings attained the age of one week, five healthy seedlings were transferred to a solution vessel of 5 litre capacity containing a solution of different magnesium concentrations. The solution was changed every day in order to keep the magnesium concentration constant. The composition of the nutrient solution is given in Table 1. The pH of the solution was 5.6 ± 0.2 as reported optimum for nutrient uptake study in solution culture for rice crop (TANG *et al.* 1972). The temperature of the growth chamber was 30 ± 1 °C in the daytime and 22 ± 1 °C at night. Relative humidity was $80 \pm 2\%$ in the daytime and $85 \pm 2\%$ at night. Light was supplied for 12 h at an illuminance of 12 klx with the help of phototubes. No aeration was found necessary as sufficient oxygen was supplied through the nutrient solution (TANG and LAUDELOUT 1966).

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When the plants were 82 days old, the rate of uptake was studied by continuous flow technique. Details of this technique is given elsewhere (TANG and LAUDELOUT 1966). For computation of results, concentration change of the nutrient solution, Co (original concentration) and Cs (change in concentration due to absorption) were determined by the atomic-absorption spectrophotometer. This gives the values of Co and Cs for a given flow rate and for each concentration the ratio Cs/Co was computed. Absorption of magnesium was expressed by the ratio Cs/Co as a function of residence time (RT) as well as absorption in $\mu g\ g^{-1}\ h^{-1}$ root dry weight (Fig. 1). From

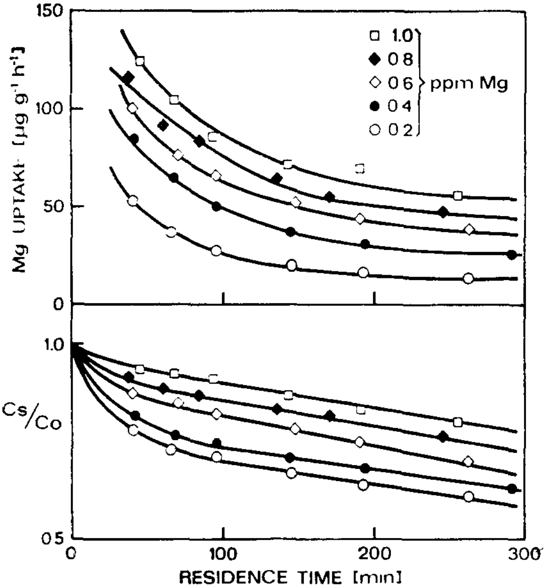

Fig. 1. Rate of uptake of magnesium as a function of residence time for different concentrations of magnesium and Cs/Co as a function of residence time in min for different concentrations of magnesium.

results of rate of uptake we plotted rate of uptake as a function of concentration (Fig. 2) at a residence time of 60 minutes. From this plot biological constants Vm (maximum velocity of uptake) and K_m (concentration at which the absorption mechanism reaches half maximum velocity) were calculated from Lineweaver-Burk (double reciprocal) plots of the data. $1/S$ and $1/V$ (reciprocal of concentration and uptake respectively) plot of the data is given in Fig. 2.

During the experimental period four samples were taken for each concentration and the mean value of Cs/Co as well as the standard error were computed. Standard errors were not allowed to exceed 5% of the mean relative depletion, otherwise the experimental results were rejected.

The residence time (RT) — the time necessary for complete renewal of the nutrient solution in the vessel, in minutes, was computed as follows:

$$RT = \frac{60\pi r^2 l}{\text{Flow rate}}$$

Where: r is the radius of the culture vessel.[cm], and l, the length of roots [cm].

Results and Discussion

The kinetic analysis of the experimental data was used to resolve the absorption mechanism and to calculate the biological constants. The isotherm for magnesium absorption over a range of 0.2 to 1 ppm or 8.2 to 41 μM magnesium concentration follows Michaelis-Menten kinetics (Fig. 2). The biological constants calculated with the help of Lineweaver-Burk plot are K_m, 0.2×10^{-4} M and V_m, 156 μg $g^{-1}h^{-1}$ root dry weight. Therefore, at this K_m value (magnesium concentration) the carrier sites effective were half saturated.

Results presented in Fig. 1 show that Cs/Co ratio as well as the rate of uptake decreased with an increase in the residence time. The increase under flow

TABLE 1
Composition of the nutrient solution

Salt	Molarity $\times 10^6$
KCl	179
$Ca(NO_3)_2 . 4H_2O$	125.0
$(NH_4)_2SO_4$	227.0
KH_2PO_4	32.0
H_3BO_3	9.7
$MnCl_2 . 4H_2O$	2.0
$ZnSO_4 . 7H_2O$	0.17
$CuSO_4 . 5H_2O$	0.2
Fe(EDTA)Na	9.7
$(NH_4)_6Mo_7O_{24} . 4H_2O$	0.004
$MgSO_4 . 7H_2O$	(1) — 8.2
	(2) — 16.4
	(3) — 24.6
	(4) — 32.8
	(5) — 41.0

rate may be because the flowing solution did not permit the formation of the concentration gradient around the roots (BARBER 1962), thus facilitating the contact of ions with the surface of roots and probably increasing even the whole sorption area of the roots. SABET and SALAM (1966) also reported

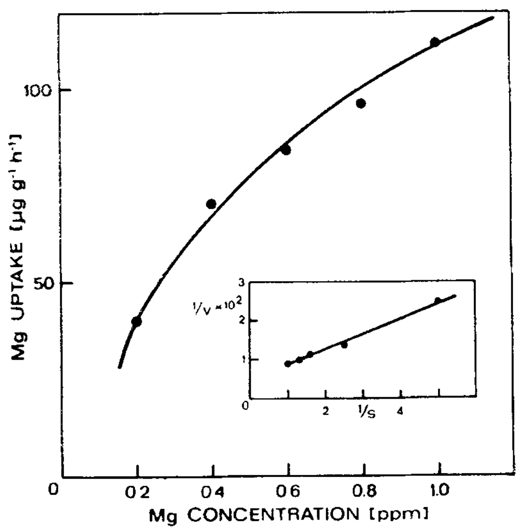

Fig. 2. Magnesium uptake as a function of magnesium concentrations at 60 min residence time and double reciprocal plots *i.e.* $1/S$ and $1/V$.

an increase in the uptake of calcium with increasing flow rate. It is also clear from Fig. 1 that with increasing concentration and flow rate there is no doubt that uptake was increased but there was a diminishing increase in the uptake of magnesium with the increasing flow rate. This decrease can be explained on the basis of the lesser availability of binding sites or a carrier with increasing ions.

According to the carrier concept, an ion reacts with its carrier at or near the outer surface of the plasmalemma membrane. It forms a carrier complex. This carrier complex moves across the membrane and is deposited on the other side. Here it breaks down, releasing the ion into the internal solution and forming a carrier precursor which is incapable of leaving the membrane, or of reaccepting an ion. This precursor is transported back across the membrane and reconverted to carrier and can again combine with another ion. This reaction can be represented as follows (SUTCLIFFE 1962):

$$M + X \underset{K_2}{\overset{K_1}{\rightleftharpoons}} MX \underset{K_4}{\overset{K_3}{\rightleftharpoons}} X' + M$$

Where: M, X, MX and X′ are the ion, ion carrier, ion-carrier complex and carrier precursor respectively. K_{1-4} are the rate constants of the reaction.

The results of the present study show that absorption of magnesium is influenced by the concentration and rate of migration of ions to the root surface. These results will contribute to an understanding of the magnesium uptake pattern by the plants under soil conditions. Under soil conditions the pattern of uptake will be the same but only magnitude will vary due to soil factors.

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References

BARBER, S. A.: Diffusion and mass flow concept of soil nutrient availability. — Soil Sci. **93** : 39 to 49, 1962.

BROWN, L. R.: Man, Land and Food, Looking Ahead at World Food Needs. — U.S.D.A. Agr. Econ. Report **11**. Washington, D.C. 1963.

EDWARDS, D. G.: The mechanism of phosphate absorption by plant roots. — Trans. 9th Int. Congr. Soil Sci. Adelaide **2** : 183—190, 1968.

EPSTEIN, E., HAGEN, C. E.: A kinetic study of the absorption of alkali cations by barley roots. — Plant Physiol. **27** : 457—474, 1952.

FAGERIA, N. K.: Kinetics of phosphate absorption by intact rice plants. — Aust. J. agri. Res. **25** : 395—400, 1974a.

FAGERIA, N. K.: Absorption of magnesium and its influence on the uptake of phosphorus, potassium and calcium by intact groundnut plants. — Plant Soil **40** : 313—320, 1974b.

FAGERIA, N. K.: Uptake of potassium and its influence on growth and magnesium uptake by groundnut (*Arachis hypogaea* L.) plants. — Biol. Plant. **16** : 210—214, 1974c.

KANNAN, S.: Kinetics of iron absorption by excised rice roots. — Planta **96** : 262—270, 1971.

SABET, S. A., SALAM, M. A.: Growth and ion uptake by maize seedlings in solutions variable in calcium and flow rate. — Plant Soil **24** : 467—472, 1966.

SUTCLIFFE, J. F.: Mineral Salts Absorption in Plants. — Pergamon Press, London 1962.

TANG, V. H., FAGERIA, N. K., LAUDELOUT, H.: Root electrical potential and phosphate uptake of rice as determined by pH. — IAEA-SM-151/3 : 81—86, 1972.

TANG, V. H., LAUDELOUT, H.: Phosphate uptake by intact rice plants by the continuous flow method at low phosphate concentrations. — Soil Sci. **101** : 408—417, 1966.