EFFECT OF THE COUNTER-ION ON THE UPTAKE OF POTASSIUM IN EXCISED BARLEY ROOTS

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SUMMARY

The influence of the counter-ion on K uptake was investigated in excised barley roots.
The effect of the counter-ion on K uptake is restricted to the first three to four hours of the experimental period. The results suggest that the counter-ion influences only the binding of K ions in the cytoplasm and not the accumulation to the vacuole; and fit into the previously developed general scheme of cation uptake, according to which the rate of vacuolar accumulation of K is limited at the tonoplast.

1. INTRODUCTION

It has frequently been observed that potassium uptake is much higher with chloride as the accompanying anion than with sulfate. The present paper reports a study of this phenomenon based on previous results (HOOYMANS 1964, in the press), from which it was postulated that in barley the uptake of alkali cations involves two components, viz. an accumulation to the vacuole on the one hand and on the other a binding to cytoplasmatic constituents as an intermediate phase in the transport to the shoot.

The question posed is which of these components is influenced by the nature of the anion.

It will be demonstrated that when cloride is substituted for sulfate there is no difference in potassium accumulation to the vacuole, whereas binding of potassium to the cytoplasmatic constituents is enhanced.

2. MATERIAL AND METHODS

Excised barley roots were used for these experiments. Seeds of barley *(Hordeum vulgare* L. cultivar "*Arivat*") were germinated as described earlier (HOOYMANS 1964). The seedlings were grown in a solution of 2×10^{-4} M $CaSO_4$ at 25°C in the dark, and after two days were exposed to artificial light (Philips fluorescent lamps $40^{w/33}$ and $40^{w/50}$) for 16 hours a day. When the plants were 8 days old, the roots were excised just below the gauze, washed for 30 minutes in 3 changes (about 4 litres each) of aerated, demineralized water, and centrifuged to remove the adhering water. Equal portions of root material (1 gram) were placed in polyethylene bottles, each containing 5 litres of the experimental solution. The pH of the solution was adjusted to a value of about 7,2 by adding 0.2 me/l CaO to the solutions on the previous day and bubbling air through during the night. The temperature was kept at 25° C by means of a water thermostat.

At the end of the experiment, the roots were washed with running demineralized water for one minute, dried at 100° C, and ashed at 560° C.

For the estimation of K the ash was dissolved in dilute HCl and transferred to volumetric flasks. K was then determined with a Beckman Model DU flamephotometer.

In experiments with Cl, the ash was dissolved in cold dilute HNO_3 and titrated with a Cotlove Aminco chloride titrator.

3. RESULTS

A time curve of K uptake gives information concerning the rate of steady-state K accumulation to the vacuole and the amount of K ions bound in the cytoplasm, as previously discussed (HOOYMANS 1964). The uptake during the first three hours is supposed to represent the sum of accumulation to the vacuole and binding of K ions to cytoplasmatic constituents, the latter being completed after about three hours, as indicated by a more or less abrupt change in the over-all rate of absorption. The rate of uptake prevailing after three hours is assumed to be completely accounted for by the accumulation of K to the vacuole.

In the first experiment the time curve for K was determined both with Cl and with SO_4 as the anion. The experimental solution contained 0.1 me/l K_2SO_4,

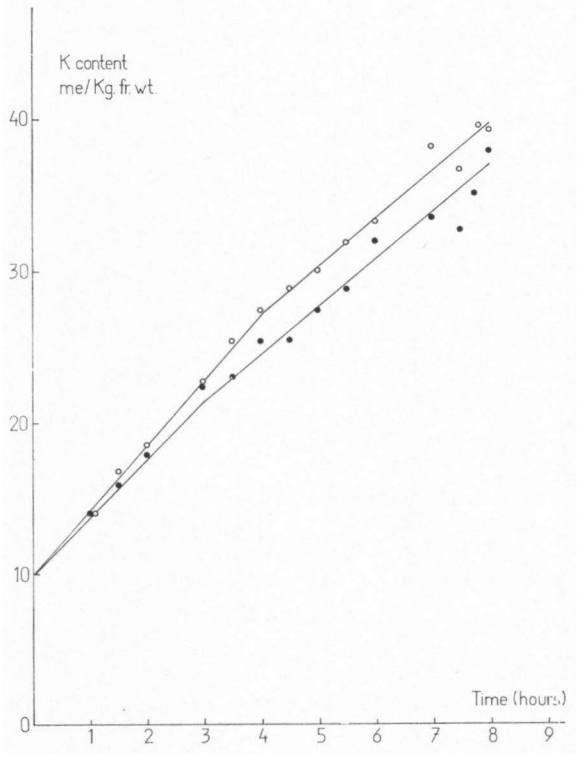

Fig. 1.
K absorption from a 0.1 me/l K_2SO_4 solution in the presence of 10 me/l $CaCl_2$ (○) or 10 me/l $CaSO_4$ (●) during an absorption period of 8 hours.

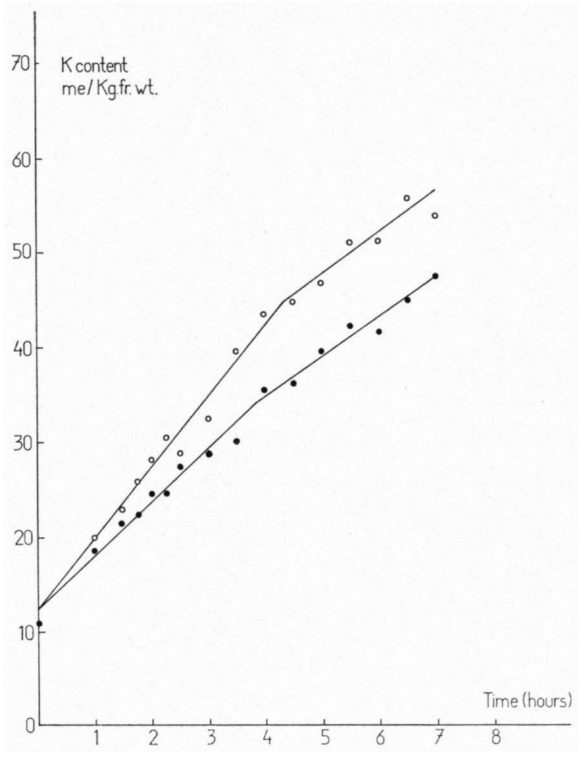

Fig. 2.
K absorption from a 10 me/l K_2SO_4 solution in the presence of 10 me/l $CaCl_2$ (○) or 10 me/l $CaSO_4$ (●) during an absorption period of 7 hours.

to which either 10 me/l $CaCl_2$ or 10 me/l $CaSO_4$ had been added. The results are given in *fig. 1.* The amount of K taken up during the first four hours is higher with chloride than with sulfate as the accompanying anion. After four hours the rate of K uptake is the same with both anions. This behaviour is even more distinct when the experimental solution contains 10 instead of 0.1 me/l K *(fig. 2).*

A time curve for Cl uptake from an identical solution remains linear during the whole experimental period of eight hours *(fig. 3).*

The following experiment was designed to elucidate the relation between the uptake of K ions and the Cl concentration in the experimental solution. The time curve of K uptake was determined at a constant K concentration of 10 me/l, whereas the Cl concentration was varied from 0 to 10 me/l by supplying adequate mixtures of K_2SO_4 and KCl, 10 me/l $CaSO_4$ being present in all cases. The results are given in *fig. 4.* An increase of the Cl concentration in the experimental solution enhanced the amount of K ions taken up during the first four hours of the experimental period, but not in direct proportion to the Cl concentration in the experimental solution, as shown by *fig. 5.* This curve resembles the relationship between the rate of Cl absorption and Cl concentration *(fig. 6).*

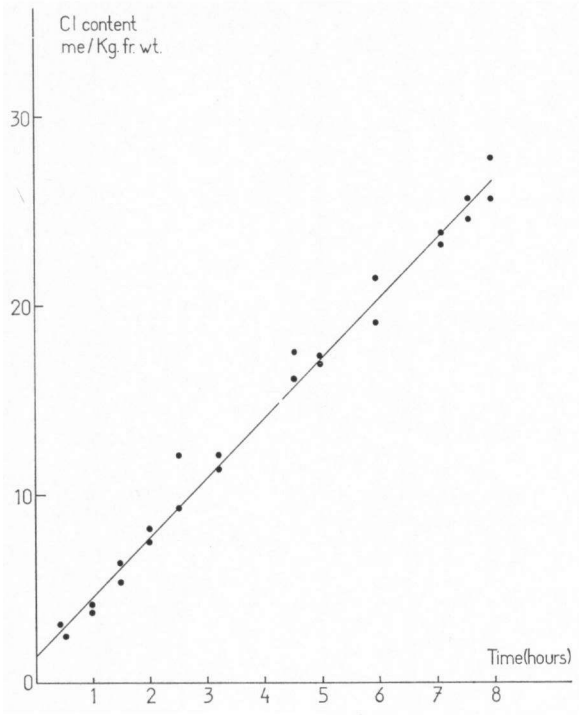

Fig. 3.
Cl absorption from a 10 me/l KCl solution in the presence of 10 me/l $CaSO_4$ during an absorption period of 8 hours.

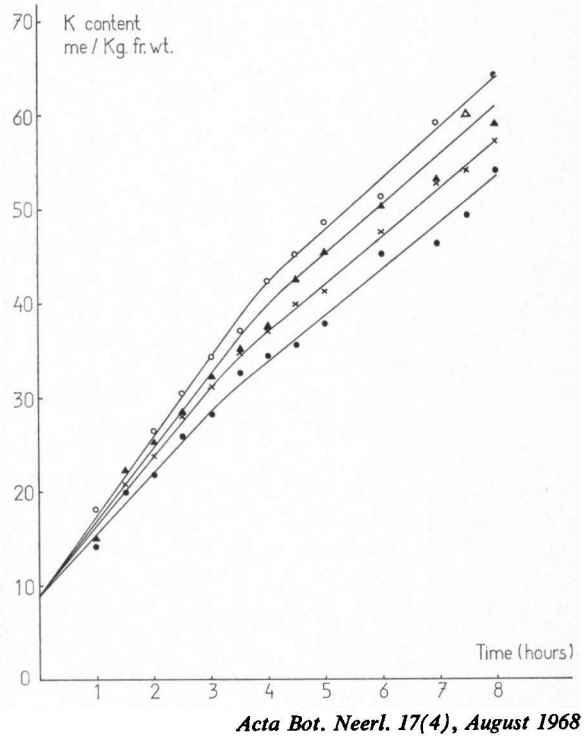

Fig. 4.
K absorption form various solutions (containing 10 me/l K_2SO_4 ●, 1 me/l KCl + 9 me/l K_2SO_4 ×, 3 me/l KCl + 7 me/l K_2SO_4 ▲ or 10 me/l KCl ○ and 10 me/l $CaSO_4$) during an absorption period of 8 hours.

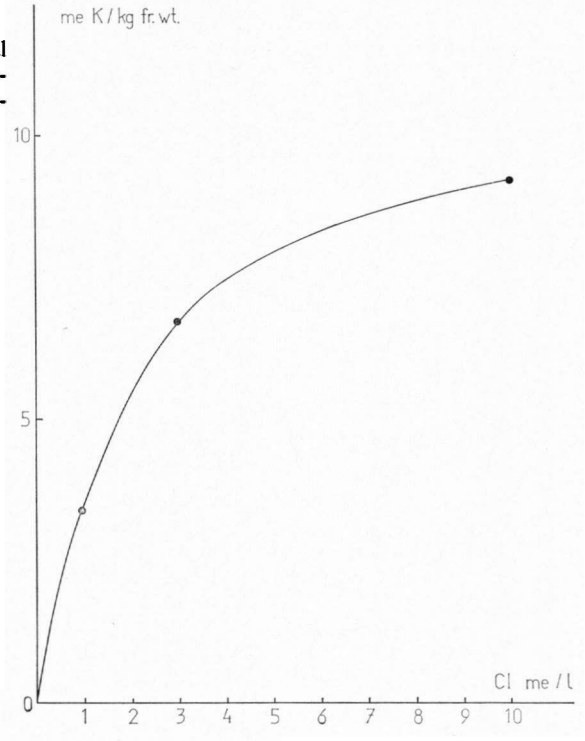

Fig. 5.
Relation between the additional amount of K uptake in the presence of Cl and external Cl concentration.

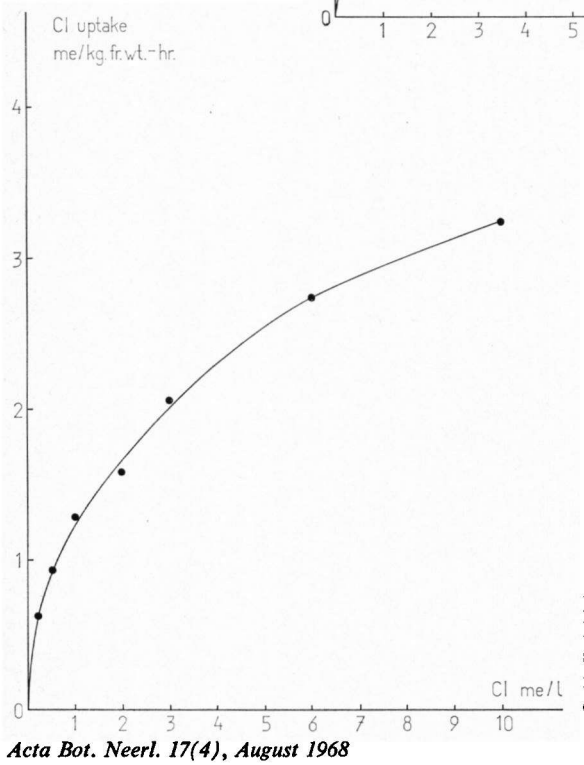

Fig. 6.
Rate of Cl absorption from KCl solutions in the presence of 10 me/l $CaSO_4$ as affected by concentration.

4. CONCLUSIONS

The results of these experiments clearly demonstrate that in our material the difference in the rate of K uptake observed when Cl is substituted for SO_4 in the experimental solution is restricted to the first three to four hours of the experimental period.

According to our previous assumptions (HOOYMANS 1964), this means that only the binding of K in the cytoplasm and not its accumulation in the vacuole is enhanced by the presence of Cl ions as compared to SO_4 ions.

The similarity of the Cl concentration curve and the curve representing the relation between additional cytoplasmatic K binding and external Cl concentration suggests that there may be some relation between the amount of K bound in the cytoplasm and the absorption of Cl ions. Presumably, the capacity of the cytoplasm to bind K is enhanced by the Cl ions present in the cytoplasm, but at present it is not clear how this is realized. Interstitial ion pair formation in the cytoplasm, according to the ideas of LING & OCHSENFELD (1966) could be involved here.

The hypothesis of EPSTEIN *c.s.* (1963) that the Cl effect is restricted to a K uptake mechanism with low affinity for K and operating at high K concentration is not supported by our data. In the first place, our results indicate a Cl effect on the K uptake rate at concentrations lower than 0.5 me/l K, and in the second place, at all concentrations the effect of Cl on the K uptake rate disappeared after an experimental time of about four hours. The short experimental periods used by these authors, together with the fact that in their experimental solutions the K and Cl concentrations were varied concomitantly by the use of KCl may underlie this divergence.

Furthermore, neither the data presented in this paper nor the results of previous work seem easily reconcilable with the views of TORII & LATIES (1966), who postulate that at low K concentrations the limiting factor in the uptake process lies at the plasmalemma whereas at high concentrations the limiting locus shifts to the tonoplast. The present data seem to fit very well, however, into the general scheme of cation uptake developed previously by HOOYMANS *(in the press)* and BANGE & HOOYMANS (1967), in which the rate of vacuolar accumulation of K is limited at the tonoplast. The observation that at low Rb concentrations there is no competition for the incoming Rb between the processes of vacuolar accumulation and upward transport (HOOYMANS, in the press) also seems to exclude unequivocally a limiting role of the plasmalemma.

ACKNOWLEDGEMENTS

The author is indebted to Dr. G. G. J. Bange for valuable discussions and to Miss C. J. E. Logman for skillfull technical assistance.

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