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Transport of Sodium in Plant Tissue

Abstract. *Two mechanisms are implicated in the absorption of alkali cations by barley roots. Mechanism 1 has a high affinity for potassium, but its affinity for sodium is so low that, in the presence of even a low concentration of potassium (1* mM*), sodium absorption by this mechanism is all but abolished. Mechanism 2 has a much lower affinity for alkali cations and is not highly selective; it transports sodium as well as potassium.*

Roots of barley, *Hordeum vulgare*, absorb potassium ions through the operation of two clearly distinguishable transport mechanisms, one highly specific for potassium (and rubidium) and indifferent to sodium, the second one competitively inhibited by sodium (*1*, *2*). In the work described here, we demonstrated that the second mechanism effects the absorption of sodium by this tissue. We shall first recall our earlier findings concerning the transport of potassium.

Mechanism 1 of potassium transport is effective at very low external potassium concentrations. It has an apparent Michaelis constant of about 0.02 m*M* and operates at nearly the maximum theoretical rate at a potassium concentration of 0.2 m*M* (*1*). Sodium competes very ineffectually with potassium in this process. At an external potassium concentration of 1 m*M* (at which concentration mechanism 1 operates at the maximum velocity) sodium even in 20-fold excess fails to compete significantly with potassium (*2*).

At higher concentrations of potassium, up to 50 m*M*, a second mechanism with much less affinity for potassium comes into play (*1*). It differs in several respects from mechanism 1; one important difference is that sodium strongly and competitively inhibits the absorption of potassium in mechanism 2 (*1*).

On the basis of these findings we made two tentative predictions. (i) In the presence of 1 m*M* potassium (enough to saturate mechanism 1), the absorption of sodium from solutions of low sodium concentrations (less than 0.2 m*M*) should be almost eliminated. Under such conditions, both mechanisms 1 and 2 would be unavailable for sodium transport. Mechanism 1 would be transporting potassium at maximum velocity and since sodium fails to compete it would fail to occupy the potassium-transporting sites of this mechanism (*1*, *2*). As for mechanism 2, its affinity for alkali cations is much too low for it to make an appreciable contribution to sodium transport at low sodium concentrations (less than 0.2 m*M*). (ii) The second prediction was that at high sodium concentrations (more than 0.2 m*M*) sodium in the presence of 1 m*M* potassium would be transported because in the high concentration range mechanism 2 comes into play, and the finding that in mechanism 2 sodium competitively interferes with potassium absorption indicates that it has affinity for the transport sites of mechanism 2 and might be transported by them.

Figure 1 shows that these predictions, based mainly on the inhibition of potassium transport by sodium, are borne out when the absorption of sodium itself is examined. In the presence of potassium at 1m*M* concentration, sodium absorption from dilute solutions (less than 0.2 m*M*) is all but eliminated. At higher concentrations sodium is absorbed; and this absorption occurs at rates which are comparable with those at which potassium (*1*) and chloride (*3*) are absorbed at the same concentrations. The sodium absorbed is not readily exchangeable with external sodium. When roots containing radioactive sodium are transferred to a solution containing nonradioactive sodium, isotopic exchange occurs very slowly.

Our second prediction was based on the finding that the increment of potassium absorption due to mechanism 2 was competitively inhibited by sodium (*1*). Although this showed that the potassium-carrying sites of mechanism 2 have affinity for sodium ions, the possibility remained that sodium ions, while displacing potassium from these sites, would not themselves be transported. Sodium might be a competitive inhibitor of potassium transport without being an alternative substrate for the transport mechanism. However, the results bear out the prediction: sodium competes with potassium and is itself absorbed.

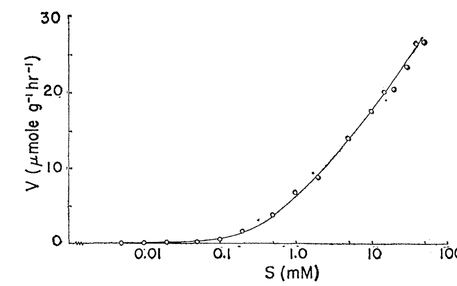

Fig. 1. Rate of absorption, *v*, of sodium labeled with Na^{22}(Na^*) by excised roots of barley, *Hordeum vulgare* var. Arivat, as a function of the external concentration of Na^*Cl (*S*), plotted logarithmically over the range 0.005 to 50 m*M*. Roots were cultured as described (*2*). Experimental solutions, 0.5 m*M* $CaCl_2$, 1.0 m*M* KCl, and Na^*Cl as indicated, pH 5.7, 30°C, aerated. Absorption period, 20 minutes, discontinued by a 30-minute exposure to a cold (7°C) aerated solution of 0.5 m*M* $CaCl_2$, 5 m*M* NaCl (nonlabeled). The experimental technique was described in an earlier paper (*5*).

Thus we have confirmed the existence of two mechanisms which effect the transport of alkali cations by barley roots. Since the present work was completed we have found that mechanism 2 is itself heterogeneous. The evidence indicates the operation of a number of transport sites in mechanism 2, with different affinities for any given cation (*4*).

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