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Studies on $^{42}K^+$, $^{24}Na^+$ and $^{32}PO_4^{-3}$ mobility in the strawberry receptacle

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INTRODUCTION

The character of the forces responsible for the directional transport of nutrient substances to the receptacle as well as the nature of the "distribution key" of assimilates and mineral salts in the plant are so far unknown (Górski 1962; Penot 1965; Nitsch 1965; Starck 1965).

Investigations were, therefore, undertaken on the mechanism of directional transport of nutrient substances to the receptacle, with the purpose of elucidating the nature of what is known as the "physiological sink", under the assumption that the fruit and other accumulating organs are good examples thereof. It has been demonstrated in the previous paper that osmotic pressure cannot be the main factor controlling the distribution of nutrient substances in the strawberry (Antoszewski, Szymański 1967).

The aim of the present work was the study of the behaviour of the receptacle towards such components as K, Na and P. Sodium and potassium are characterized by a high mobility in biological systems and do not form stable chemical compounds, neither are they incorporated into macromolecules. It has been demonstrated that transport of P compounds in a definite organ may be controlled by factors producing a "physiological sink" (Mothes 1963).

MATERIAL AND METHOD

The investigations were made on strawberries of the variety 'Talisman' and 'Senga Sengana' (*Fragaria grandiflora* Duch . cv. Talisman, Senga Sengana) cultivated the year round in a glasshouse with additional light supply.

^{42}KCl, $^{24}NaCl$ and $NaH^{32}PO_4$ (Institute of Nuclear Research, Świerk) were used in the investigations in aqueous solution containing the inorganic components of White's medium; in some cases carrier-free preparations were used. The treatment of the plant material is described separately for each experiment. The outset radioactivity of the preparations used was for K about 0.4—0.8 mCi/ml and 70—130 mCi/g K, for Na 2.8 mCi/ml and 700 mCi/g Na and for P 5.2 mCi/ml.

When the site of drop application had to be localized, the radiocative preparation was coloured with methyl blue. After a suitable time period, the strawberry peduncle and receptacle were cut into 1—3 mm slices, placed on planchets and their radioactivity was determined (Geiger-Müller BAH-55 counter and type PEL-5 scaler). The material on the planchets was dried and weighed. In the further calculations the short half-life of the preparations was taken into account (for ^{42}K 12.5 hrs, for ^{24} Na 15 hrs). When the migration of ^{24}Na or ^{42}K injected into the plant was followed, the counter was screened with lead blocks.

RESULTS

a) Potassium, sodium and phosphorus introduction through the cut peduncle

The strawberry peduncle was cut under water with care not to let any air into the vascular system. Radioactive sodium or potassium salts were introduced through the section in nutrient solution (fig. 1).

The gradient of potassium and sodium content in the stem was then determined.

The experiments proved that both sodium and potassium travel freely in the vascular system both towards the receptacle and towards the mother plant when the preparations are introduced through the section of the peduncle. Noteworthy is the extremely rapid appearance of the radioactivity in the just mentioned organs. The receptacle becomes radioactive several score of seconds after inserting the stem into the radioactive solution. The preparation applied to the plant through the "open" stem is distributed over the whole plant. It is one of the most effective ways of labelling the whole strawberry plant. Analogous experiments were made with $Na_2H^{32}PO_4$ yielding similar results.

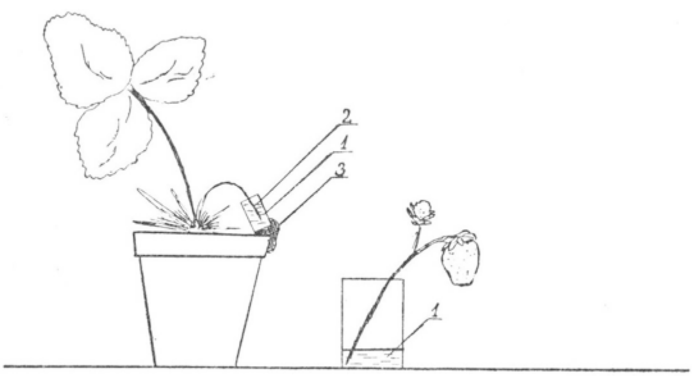

Fig. 1. Application of radioactive compound through cut stem.
1 — Solution of radioactive compound; *2* — cut stem; *3* — plasticine.

It may be concluded from these data that, in the vascular system of the strawberry, under normal transpiration conditions, hypotension exists. Therefore, the solution rapidly penetrates both into the plant and the receptacle after transection of the vascular system. The same has been observed also in many other plants (Strebeyko 1956).

In order to establish the direction of transport of the radioactive preparations in dependence on the site of their application, experiments were made with introduction of the preparation into the stem and into the receptacle by injection.

b) Injection of potassium, sodium and phosphorus into the stem and the receptacle

The behaviour of radioactive sodium, potassium and phosphorus injected to the strawberry was investigated in two series of experiments. In the first 15—30 μl of the preparation were injected into the stem at a considerable distance from the receptacle and the Geiger-Müller counter was set close to the latter (fig. 2). In this scheme of the experiment the first experimental group is denoted by a dashed line, and the second by a continuous line.

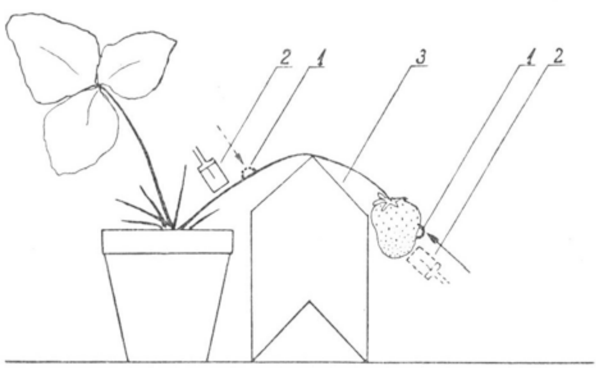

Fig. 2. Unit for studying the movement of radioactive sodium and potassium in strawberry plant. *1* — The place of dropping or injection of radioactive substance; *2* — Geiger-Müller counter; *3* — lead scree.

In no case did the radioactive preparation pass from the receptacle to the peduncle even after as long as 52 hrs, on the contrary, when injected into the stem, it very rapidly (after several score of seconds, and at latest after a few minutes) appeared in the receptacle. The preparation was injected in all the experiments into well developed green or whitish-green fruits (stage Z_2 and B have been described in the preceding paper (Antoszewski, Szymański 1967).

The appearance of radioactivity in the receptacle after injection of the label into the stem was consistent with the results of the previous series of experiments. It is, however, difficult to explain why the preparations introduced into the receptacle do not pass into the peduncle. This prompted the authors to start another experiment.

c) Behaviour of potassium, sodium and phosphorus applied onto the surface of transection of the receptacle

The above described finding that the preparation applied into the receptacle by injection does not pass into the peduncle may be interpreted in various ways. Either the hypotension observed does not extent to the vascular bundles of the receptacle, or the stem exhibits an asymmetry of conduction when intact, or also the label did not reach the conducting system being absorbed by the parenchyma. To elucidate this problem experiments were undertaken in which maximum contact of the radioactive preparation with the vascular system of the receptacle was ensured. The physiological properties of the stem were investigated in a separate study.

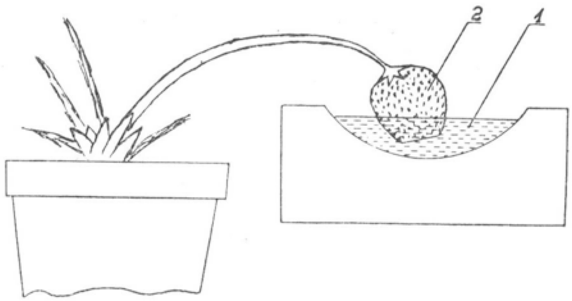

Fig. 3. Application of radioactive substance through cut receptacle.
1 — Radioactive substance; *2* — receptacle with the top cut on.

A wedge of the receptacle was excised or a larger part was cut off and the label was applied on the incision. When a larger part was cut off, the exposed surface was immersed into a highly radioactive solution (fig. 3).

After a suitable time (15—20 hrs) the radioactivity of the receptacle parenchyma, the core, the achenes which did not contact the radioactive solution, was investigated. The peduncle was sliced and the gradient of radioactivity in it was determined.

In all cases the label penetrated through all the tissues of the receptacle. It is noteworthy that the achenes of the more mature receptacle exhibited always a lower relative radioactivity as compared to that of the younger receptacle. In Table 1 exemplary data of ^{42}K, ^{24}Na and ^{32}P distribution in the receptacle and peduncle are shown.

Under the given conditions, sodium and potassium did not penetrate into the peduncle, only the first 2—3 mm section shows very slight radioactivity. This section contains numerous vascular bundles supplying directly the receptacle, it would seem, therefore, that the sodium or potassium solution fills the vascular bundles of the receptacle and flows down to the point of their branching without penetrating further into the peduncle. Phosphorus, on the contrary, is detectable in the peduncle sometimes even at large distances from the receptacle (when green). It should be noted here that methyl blue which does not penetrate into the receptacle through the epidermis, passes into the peduncle to large distances along the course of the damaged vascular bundles of the receptacle.

Some objections might be raised as to these results, since both injection and transection involve tissue injury and disturbances in the hypotension relations prevailing in the receptacle. In order to exclude these conditions, a further experiment was made in which the label was applied through the epidermis.

Table 1

Distribution of ^{42}K, ^{24}Na, ^{32}P applied to the receptacle through out surface

Tissue	activity in imp/min above background		
	^{24}Na	^{42}K	^{32}P
Fragment of tissues from the pith of the receptacle	3418	8600	4009
1-st fragment of the peduncle (3 mm)	49	100	310
2-nd fragment of the peduncle (3 mm)	0	0	74
3-rd fragment of the peduncle (3 mm)	0	0	35

d) Behaviour of potassium, sodium and phosphorus introduced into the receptacle through the epidermis

The preparation was placed dropwise on the surface of the receptacle in the amount of 15 μl. It was established in preliminary experiments that the preparation does not spread on the surface of the receptacle but permeates through the epidermis. After 20 hrs radioactivity was measured in parenchyma sections, in the

Table 2

Distribution ^{42}K, ^{24}Na and ^{32}P applied on the surface of the receptacle

Tissue	activity in imp/min above background		
	^{24}N	^{42}K	^{32}P
Fragment of receptacle tissue	472	324	54
calyx	100	54	—
5 achenes	—	0	13
1-st fragment of the peduncle (3 mm)	4	23	5
2-nd fragment of the peduncle	0	0	0

tissue opposite to the site on which the preparation was placed and in the achenes from the opposite side of the receptacle. Care was taken to choose fragments which could not have been superficially contaminated (as shown earlier, some splashes of sodium and potassium solutions applied on the surface may occur during drying) (Antoszewski, Lis 1967).

It was found that the surface-applied sodium, potassium and phosphorus solutions are taken up by the receptacle and distributed to all its tissues, they do not, however, pass to the peduncle. Illustrative data are listed in table 2.

The mobility of potassium and sodium in green receptacles was higher than in the reddening ones. A similar tendency was observed in the activity of the achenes. Young achenes exhibited a higher activity as compared to the older ones. This is understandable, since in the mature achenes the process of storage of nutrient substances is ended and the biochemical contact with the receptacle is limited (Tsinger 1958; Nitsch 1952).

DISCUSSION

The existence of hypotension in the conducting system of plants has long been known. It may be the result of water loss by transpiration and of its limited supply by the root system (Strebeyko 1956; Górski 1962; Crafts 1949). However, the question, in what degree is this hypotension responsible for water and nutrient substances distribution to the particular organs is not simple. In the present experiments radioactive potassium applied through the transected stem appeared very soon in the roots although they had a sufficient supply of water. Thus it is not only transpiration that controls potassium transport.

The problem of the relations between transpiration and distribution of nutrient substances is the subject of separate investigations.

It is worth pointing out that the so frequently used method of injection in studies on the conduction rate in the plant organism, may in the light of the above discussed results give quite erroneous results.

It should be stressed particularly that none of the labels applied passed from the receptacle to the peduncle (only phosphate administered after a definite interference with the hypotension system passes out of the receptacle). It might be hence concluded that either the hypotension system does not involve the region of the receptacle, or that the parenchyma of the receptacle has the ability of capturing the ions introduced, forming a kind of "physiological trap" as the storing organ might be called. The first version is unacceptable in view of the patency of the conducting system within the receptacle which is easy to demonstrate, e.g. by means of methyl blue. Staining with this dye vizualizes also the autonomy of the particular vascular bundles as also observed in other plants (Biddulph 1965).

One of the reasons why investigations were performed on sodium, potassium, and phosphorus is the fact that each of these components represents a physiologically different group. The opposed behaviour of potassium and sodium in various vital processes is known. Potassium uptake by the cell is generally associated with sodium excretion and vice versa (Troshin 1956; Giese 1959; Kylin 1966). In the present experiments, however, both sodium and potassium behaved analogously. The greater facility with which phosphorus passes out of the receptacle may be due to the low pH of the strawberry sap (Ładyżyński, Pieniążek 1955). It should finally be stressed that the experimental results obtained and the general considerations concern only strawberry fruits rather advanced in development, i.e. green or whitish-green.

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SUMMARY

The behaviour of ^{42}KCl, $^{24}NaCl$ and $Na_2H^{32}PO_4$ introduced into the receptacle and the peduncle of the strawberry was investigated. The hypotension existing in the vascular system of the strawberry allows to label effectively the whole plant. On the other hand, the radioactive preparations introduced into the receptacle (by three methods: injection, dropping on the epidermis and application on the receptacle transection) do not penetrate to the peduncle of the stem. Only phosphorus penetrates into the peduncle when it is applied on the receptacle transection surface.

It may be concluded on the basis of the results obtained that the receptacle constitutes a kind of "physiological trap" for the nutrient substances which reach it.

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STRESZCZENIE

Badano zachowanie się ^{42}KCl, $^{24}NaCl$ i $Na_2H^{32}PO_4$ podawanych do dna kwiatowego truskawki jak i do łodygi. Wykorzystanie podciśnienia panującego w systemie przewodzącym truskawki pozwala na bardzo wydajne wyznakowanie całej rośliny. Natomiast wymienione preparaty promieniotwórcze podane do dna kwiatowego (wypróbowano trzy metody aplikacji: injekcje, nakraplanie na powierzchnię oraz podawanie na przecięcie dna kwiatowego) nie przenikają do szypułki ani do łodygi. Jedynie fosfor penetruje do szypułki, o ile podawać go przez przecięcie dna kwiatowego.

Na podstawie wyników sądzić można, iż dno kwiatowe truskawki stanowi niejako „pułapkę fizjologiczną" dla substancji pokarmowych, które doń dotrą.

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