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Ca-CONTENT OF THE PHLOEM SAP IN RELATION TO Ca-STATUS OF THE PLANT

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SUMMARY

Sieve tube exudate was obtained from *Ricinus communis* plants grown on nutrient solutions with varying K:Ca ratio. The K:Ca ratio of the leaves and that of the exudate both appeared to be correlated with the ratio of the nutrient solution. The observed correlations explain the generally observed linkage between the Ca-level in transpiring green plant parts and the degree of severity of Ca-deficiency disorders sometimes observed in fruits, seeds or other carbohydrate sink regions.

1. INTRODUCTION

A number of physiological disorders have been related to an insufficiency of calcium at the sites of the symptoms. The explanation for this local low content of calcium, mainly in seeds, fruits or enclosed young tissues, is related to the fact that they require a large influx of organic matter. This large flow of organic matter occurs through the phloem and carries along so much water, that influx of water through the xylem is restricted. The calcium content is thus partly related to the input via the phloem, which has a very low calcium content. This very low calcium content of the phloem sap, which can be considered to be part of the symplast (WIERSUM 1974), has recently again been stressed by RAVEN (1977). Its incapacity to carry much more than is usually present was demonstrated by VAN GOOR & WIERSMA (1974).

Nevertheless, these disorders are certainly not the rule, and numerous plants remain unaffected. This means that the calcium supply to these tissues is not necessarily inadequate. Well nourished plants with a sufficiently high calcium status are apt to remain free from symptoms. The incidence of the bitter pit disorder shown to be inversely related to Ca-content or Ca:(K + Mg) ratio of the leaves of apple trees by VAN DER BOON (1972) is in line with earlier observations.

A sufficient supply of Ca to the susceptible parts in plants well provided with Ca can be ascribed to a sufficient influx by means of the xylem and also to the fact that the phloem provides more or less adequate amounts. If this occurs, it would suggest that the Ca-content of the phloem is variable and related to the content of the whole plant. As sufficient amounts of phloem sap can be obtained by tapping Ricinus stems (MILBURN 1971, 1974), this possibility was investigated.

2. MATERIALS AND METHODS

For the experiments a series of plants of *Ricinus communis* var. "Gibsonii" (with brown leaves) was used. For the main experiments the germinated young seed-

Table 1. Composition of the four nutrient solutions used in the experiments with *Ricinus*, in g/l.

K:Ca	70:20	60:30	20:70	20:70 (Cl)
KNO_3	0.7705	0.6203	–	–
KH_2PO_4	0.1238	0.1272	0.143	0.143
K_2SO_4	0.2323	0.2382	0.196	0.196
$Ca(NO_3)_2$ 4 aq	0.388	0.5985	1.487	1.000
$MgSO_4$ 7 aq	0.4547	0.4679	0.529	0.529
$CaSO_4$ 2 aq	–	–	0.068	0.068
$CaCl_2$ 2 aq	–	–	–	0.500

lings were placed on 10 l plastic buckets, filled with a continuously aerated nutrient solution. The plants were cultivated in a glasshouse, with day temperatures usually above 17 °C. (290 °K) Tapping, to collect sievetube sap was usually started when the stems at the base exceeded 1 cm diameter, at which stage at least five leaves had been formed and often an inflorescence started emerging.

Tapping was done by making two incisions in the bark in a flat V-shape with a sharp scalpel and draining off the exuded sap through a tube with a very thin end into a collecting vial (*fig. 1*). The amounts collected during a number of hours that exudation lasted could be very variable. The collected amount would often be 1–2 ml per day, in exceptional cases about 5 ml. The plants were often tapped each day by making a new cut just above the older one, thus working upwards towards the source.

The variable outflow might have resulted in sap samples, more or less diluted by osmotically attracted water. As this would influence the concentrations of minerals and other substances, a check was made. Successive small samples of sap, collected during a few hours of exudation, did not show more than an irregular, small variation in Brix index in a simple refractometer. This indicates that the dry matter content – mainly sugars – is more or less constant. Total dry matter content was in the range of 15%. Thus it can be concluded that during exudation no dilution occurs.

Analyses of the sap were made for K and Ca. Ca-content was measured by means of atomic absorption spectrophotometry (using a Techtron AA-100), after adding $SrCl_2$ to a concentration of 1.6%. Potassium was measured by flame-photometry on diluted sap.

In order to obtain a large variation in Ca-status of the experimental plants, four nutrient solutions were used. They were made according to the recipes given in *table 1*, and had K:Ca ratios of 70–20, 60–30 and 20–70. In the fourth solution the K:Ca ratio was also 20–70, but part of the $Ca(NO_3)_2$ was given as $CaCl_2$. This was done because it was expected that chloride entering the sievetubes would allow more Ca to enter the phloem, as it can act as a counter-ion.

Plant analysis was performed on leaf samples, including the large petiole.

3. RESULTS AND DISCUSSION

In preliminary experiments a certain correlation between the K:Ca ratio of the

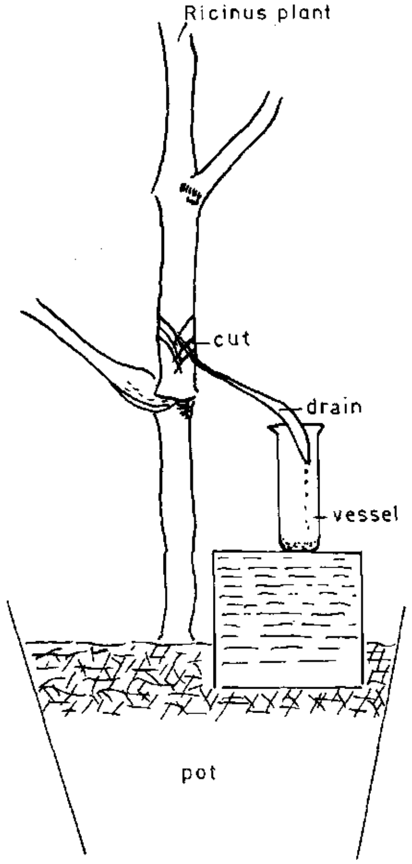

Fig. 1. Three successive cuts and drainage tube to collect phloem sap from *Ricinus* stems.

leaves and phloem sap of the same plant was observed. In a larger experiment the data shown in *table 2* were obtained during a period of about two months. From these data the following phenomena are evident. The K : Ca ratio in the phloem sap is about 40–150 times higher than in the leaves, which is mainly due to the nearly 650–950 times lower Ca-content in the sap, compared with that in the leaves. The increasing age of the plants is evident in the lower K : Ca leaf ratio in successive samples, on account of decreasing K and accumulating Ca.

The effects of treatment are clear, and it is interesting to observe that the $CaCl_2$ indeed results in a noticeable increase in Ca-content of the sap. On the average the Ca in the phloem sap rises from 7.6 to 8.6 ppm by substituting part of the Ca-nitrate in the nutrient solution by Ca-chloride. A statistical analysis of the data shows that there is a significant response to the treatments and that the K : Ca ratios of leaf and sap are also significantly correlated. As a result of the treatments to induce a higher Ca-content of the plant, the phloem content responds by changing from an average of 5.2 to an average of 8.6 ppm.

Table 2. The K- and Ca-content and its ratio in leaves and phloem sap of Ricinus at four successive samplings from November to January.

Treatment leaf (in percent of dry matter)				Sap (in ppm)		
	K	Ca	K/Ca	K	Ca	K/Ca
70:20	6.51	0.31	21.0	3795	4.5	843
	5.47	0.32	17.1	4487	5.8	774
	5.07	0.38	13.3	4026	4.8	839
	4.52	0.38	11.9	4026	5.8	694
60:30	6.11	0.38	16.1	4013	3.6	1115
	5.74	0.39	14.7	3615	4.0	904
	5.67	0.40	14.2	4243	6.4	663
	4.63	0.47	9.9	4051	10.1	401
20:70	5.18	0.59	8.8	3526	5.4	653
	4.04	0.66	6.1	4000	10.8	370
	3.49	0.65	5.4	3769	7.6	496
	2.33	0.79	2.9	3513	6.4	549
20:70 (Cl)	4.51	0.72	6.3	3256	4.9	665
	3.68	0.73	5.0	3897	12.1	322
	3.03	0.83	3.7	3718	6.9	539
	2.74	1.00	2.7	3513	10.4	338
			$P<0.01$			$P<0.05$

As VAN GOOR & WIERSMA (1974) had already demonstrated that some small amounts of Ca can be added to phloem sap before precipitation occurs and this investigation shows that the Ca-content of the phloem may vary, there seems to be good ground to surmise a reasonable Ca-import by the phloem into susceptible parts in many cases if the Ca-status of the plant is sufficiently high.

The results also suggest that the presence of Cl in the medium enhances the relative uptake of Ca, as both leaf and phloem Ca-content increases.

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