Calvert:

The size (area) of the cotyledons is reduced when temperature is increased, but the area of the true leaves increases with temperature.

Woods:

In past planting stage – at what temperature did yield fall off, was it at 68°F or at higher temperatures ?

Verkerk :

Yield increased with temperature up to 68°F and decreased above that level. Higher temperatures increased early but not total yield.

Siddall :

In Guernsey temperatures of 60°F and 70°F day or 65 night and day had given similar but earlier yields than 60/65, and higher yields than 65/70. Commercially 60/65 was too late; 65/70 reduced yields too much.

THE CALCIUM SUPPLY OF FRUITS AND STORAGE TISSUES IN RELATION TO WATER TRANSPORT

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Introduction

A number of crops can suffer from a type of diseases usually referred to as physiological disorders. Examples of these are bitter pit in apples, blossom-end rot in tomatoes and marsch spot in peas. The result of numerous investigations has been that these disorders can be best characterized as being the result of a local mineral deficiency or disbalance. Furtheron, however, the attention will be mainly focussed on blossom-end rot of tomatoes.
As far as blossom-end rot is concerned it has become clear that it is correlated with the calcium supply of the plant (3,8). Not only the calcium status of the substrate but the K/Ca ratio also seems to be important. An important fact is that the fruits of the plant demonstrate a very low calcium content in comparison to stem and leaves (5) and that the acropetal part of the fruit (10), where the tissue necrosis occurs, is even poorer than the basal part.
Even under soil conditions conducive to the occurrence of this disease the incidence usually is very variable from grower to grower. Factors favouring manifestation of the disease can be high nitrogen supply (6, 12), insufficient soil moisture (4, 6) and glasshouse climate.
Taking the knowledge concerning transport in the plant into account it seems possible that some of these factors act by means of their influence on calcium distribution in the plant. The investigation to be reported was undertaken to elucidate the principles governing the calcium distribution in the plant and the reason for the poor supply of the fruits or other affected organs.

Experiments on modification of the disease incidence of a susceptible crop.

Five sets of 5 tomato plants (cultivar Renova) were grown with intervals of 3 weeks in a period between April and October in a glasshouse. The substrate consisted of a mixture of 1 part sand 3 parts peat mull. Lime, macro- and micronutrients had been added in advance and during the growth period additional N and P was given weekly. The plants were well watered. As expected the plants were susceptible to blossom-end rot.
The plants were detopped after formation of the sixth truss and all trusses reduced to 5 fruits. Five different treatments were imposed:
1 restricted transpiration, all six trusses enclosed in translucent plastic bags.
2 alternating, free and enclosed trusses alternating on the same plant
3 enhanced growth, only 1 truss remaining on the plant
4 control, normal with 6 trusses of 5 fruits in the air
5 restricted growth, only 1/3 of the foliage left on the plant carrying 6 trusses, each with 5 fruits.
The treatments designed to alter the growth rate proved to be effective as can be seen from the data derived from the weekly recordings on increase in diameter of the fruits (table 1). The moist atmosphere in the bags will certainly have reduced transpirational water loss by the fruits.

The effect of the treatments on disease incidence is summarized in the table. The results confirmed our expectations. Both restricted transpiration or enhanced growth rate of the fruits resulted in a higher incidence of blossom-end rot. Slower growth rate was accompanied by a reduced occurrence of the disorder.
Chemical analysis of the fruits (table 1) gives evidence of the very close correlation between disease incidence and the K/Ca ratio. Restricted transpiration of the fruits has resulted in a definitely lower calcium content, while retarted growth rate is accompanied by the highest calcium content. Enhanced growth rate mainly results in a raised potassium influx. Fruits containing less than 800 p.p.m. calcium were always affected, while fruits having more than 1200 p.p.m. on dry matter were always healthy.
For an explanation of these results the possible pathways of calcium transport will have to be considered. Transport from cell to cell can be left out of consideration as being far too slow in regard to the distances involved. The two pathways of importance for supply of the fruits with nutrients are the phloem and the xylem. Taking into account the very low calcium content of the phloem exudate (11) and the immobility of calcium in the sieve tubes (1, 2, 7, 13) attention must be focussed on the stream of water in the xylem.
Calcium absorbed by the roots is first translocated across the root tissues and then enters the xylem. It is then transported to the above-ground parts of the plant along with water. On

Table 1. : The average effect of treatment on rate of fruit growth, percentage blossom-end rot and K/Ca ratio.

Treatment	bagged (1) and (2)	1 truss (3)	control (4) and (2)	1/3 leaf (5)	Differences
mm diameter increase/day	–	1.20	1.06	1.00	highly significant
% blossom-end rot	47.5	40	6.7	0	significant
K/Ca ratio	17.2	15.8	14.0	9.7	highly significant

its way upward the calcium in the woodvessels is in continuous exchange with the surrounding tissues. During transport, loss by absorption into surrounding tissues will dominate, but exceptionally calcium release may lead to a gain. As a result of these processes no strict correlation between water consumption and calcium supply can be expected. However, a poor supply of water over the xylem to a certain part of a plant must restrict its supply of calcium. The treatments imposed in the experiment described above were aimed at modifying this water supply via the woodvessels. As we have seen the reduced transpiration indeed resulted in a diminished calcium content.

Experiments on the linkage of calcium supply and water transport through the xylem.

Tomato plants (cultivar Moneymaker) carying 3 - 4 trusses were used in these experiments The plants were taken out of their pots, the roots washed free of soil and then the greater part of the smaller roots was cut off. The plants were then placed in a vessel containing a dilute nutrient solution to which about 10 μ C Ca^{45} had been added. The dye Light Green was added to the water to act as a tracer for water distribution in the plant. The experiments were performed in the laboratory and lasted 3 - 4 days.
The results demonstrated a very close relation between the distribution of the colour and that of radiocalcium.
Blue colouring of the xylem and even other tissues was clearly evident in most plant parts: stem, leaves, flowers, pedicels and even the fruit calyx. In the larger fruits, more than about 1½ cm in diameter no blue colouration could be detected, except for an occasional single vein. As can be seen from the reproduced autoradiogram (fig. 1) the Ca^{45} distribution is exactly the same. Two conclusions can now be drawn. Distribution of Ca^{45} in the plant correlates with the amount of water flowing to the separate parts by way of the xylem. The other evidence is that hardly any water and calcium or none at all seems to enter the tomato fruit as soon as it arrives in its stage of fast expansion growth by means of the xylem.

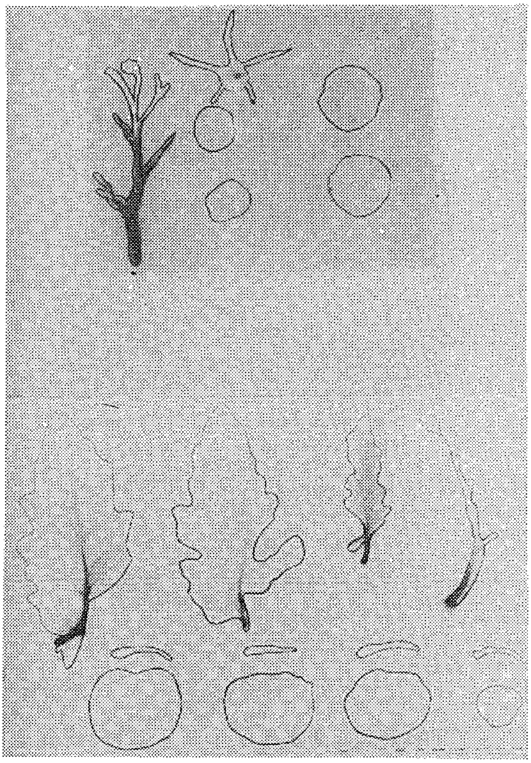

Fig. 1. The distribution of Ca^{45} in the tomato plant.
Blackening of the film occurs in the leaves, truss-stem and calyx, not in slices cut from the fruits.

Explanation of the results.

The demonstrated evidence that during the period of fast growth of the fruits hardly any water and calcium enters the fruits need further elucidation. It will be evident that in this period of expansion in size a large amount of water is needed. There must thus be another means of supply.
For this other means of water supply reference can be made to a hypothesis concerning the mode of transport in the sieve-tubes. Derived from the original suggestion made by Münch (9) a concept of mass-flow as the mode of transport in the phloem is now adhered to by numerous investigators (2, 15, 16). This conception considers that the solutes in the sieve-tubes are

displaced along the vessels along with the water in which they are dissolved. This means that all plant parts where large amounts of assimilates are deposited will receive a large supply of water. Münch himself already suggested that this supply of water could even be in excess of the needs for some parts if their transpirational losses were low.

The scheme depicted in fig. 2 may be used to explain the situation in an expanding tomato fruit. The following equilibrium should hold for water:

phloem influx + xylem influx = consumption in growth + transpiration loss.

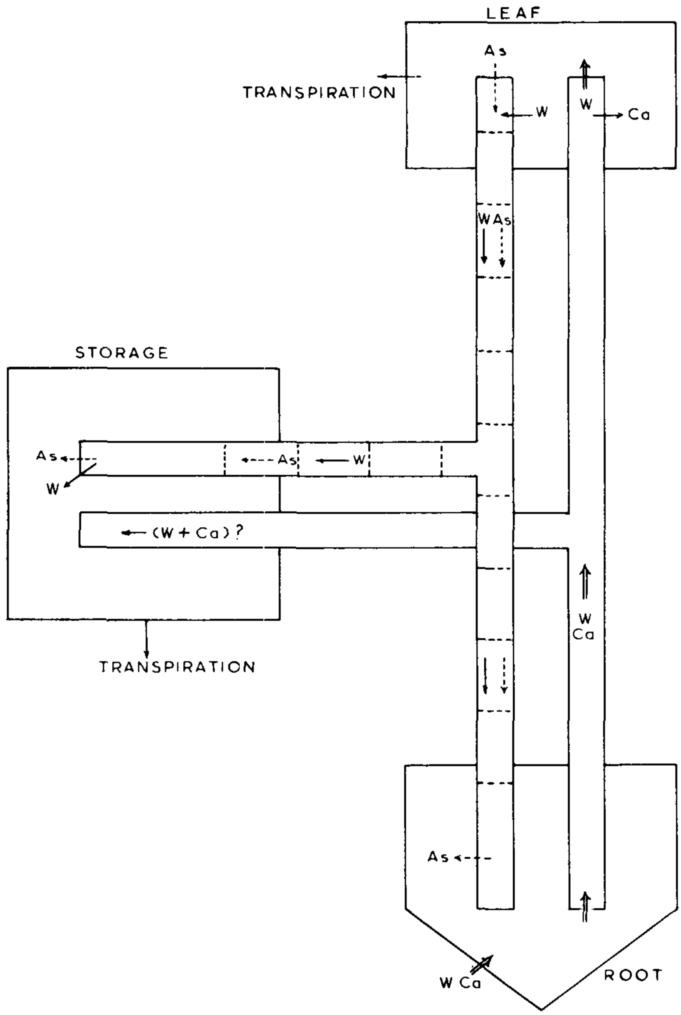

Fig. 2. Schematical drawing of the transport systems in the plant and the pathways of water movement.

W = water As = assimilates

Our first mentioned experiments fit in perfectly with this explanation. Reduced transpiration should result in less necessity for additional water supply over the xylem. Retarded growth should lower the amount of water entering over the phloem and thus enhance the xylem water influx, which supplies the calcium.

Additional remarks

The interpretation given above concerning the low calcium supply of the tomato fruit has a far wider applicability. Transport experiments conducted with the same technique have demonstrated that the same dye and Ca^{45} distribution is obtained in potatoes, broad bean seeds and also in a slightly less strict manner in apples. So the same explanation can be given to describe the low calcium content of apples and potatoes. Even a more extreme case is demonstrated in the pods of Arachis (13). With this fact is linked the susceptibility to bitter pit or poor keeping quality in storage. As manganese is also more or less phloem immobile the results with broad bean suggest that the low manganese content inducing Marsch-spot in peas is linked to this phenomenon.

The knowledge derived from these experiments should be useful to understand some of the factors causing so much variation in the incidence of these disorders. It seems likely that the best calcium supply of the fruits would be warranted if growth is not too fast and under conditions where short periods of waterstress alternate with periods of easy availability of water. Experiments to test this supposition will be performed.

Summary

By means of treatments affecting either transpiration or the growth rate of tomato fruits the incidence of blossom-end rot could be varied. A high disease incidence correlates with a high K/Ca ratio, while a higher content of calcium reduces the amount of affected fruits. It is demonstrated that only small amounts of water enter the tomato fruit via the xylem. As calcium has to be transported by this water-flow the observed low supply results, as could be demonstrated in the experiments using radio-calcium.

Taking into account the conception of transport in the phloem occurring as mass-flow, the main water supply of the fruits would be over the sieve-tubes. This flow of solution, however, hardly transports any calcium at all.

Calcium content of these fruits and other storage tissues will depend on the additional amount of water entering these organs by way of the xylem.

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SEASONAL VARIATION IN THE WATER LOSS FROM GLASSHOUSE TOMATOES

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Introduction

Using a weighing machine in a small glasshouse (0.01 acre). Morris *et al* (1953 and 1957) found that the rate of water loss from crops of tomato, lettuce and carnation, together with the associated soil, was closely correlated with the intensity of the incident solar radiation. This applied both to hourly values within a day and to daily values within a month. With tomatoes the proportion of the radiation used in evaporating water increased with increasing stem length, possibly because of corresponding increases in the leaf area and in the amount of solar radiation intercepted by the vertical sides of the plant array.

Rothwell and Jones (1961) used drainage lysimeters to find the quantitative relation between water loss and radiation for December-sown tomatoes grown on a commercial scale in a 0.1 acre single-span glasshouse, orientated N-S, at Fairfield Experimental Horticulture Station. The proportion of radiation used in evaporating water again became greater as the length of the stems increased during March, April and May, but in this larger glasshouse the proportion of solar radiation intercepted by the vertical sides of the plant array was relatively small.

As all these tomato crops were planted out in early Spring, it remains possible that the change in the ratio of water loss to radiation was partly due to a seasonal change in some other weather factor.

Lake *et al* (1965) used weighing machines to