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Ripening disorders of tomatoes as affected by the K/Ca ratio in the culture solution

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SUMMARY

The effect of the K/Ca ratio in the culture solution on the occurrence of ripening disorders in tomatoes was studied; the various solutions used were of equal osmotic pressure. The symptoms observed on the fruit were yellowish stripes, running radially from calyx to apex, and yellow-green areas near the calyx; the latter probably corresponding to greenback. These disorders lessened with an increasing K/Ca ratio in the culture solution, the increase also causing the K/Ca ratio in the leaves and fruits to rise, both by a decrease in the Ca content and by an increase in the K content.

As the K/Ca ratio in the solution was increased, the Mg content of the leaves at first declined, but then rose, whereas the Mg content of the fruits was increased throughout though less markedly at the higher K/Ca ratios.

An increasing ratio of (K+Mg)/Ca in the leaves and fruits was also accompanied by a lower incidence of ripening disorders. It is not known whether this effect was caused by a decreased Ca content, an increased content of K or Mg or by a combination of these.

Quantitative data on the effect of the K/Ca ratio in the culture solutions on nutrient uptake, the nutrient contents of leaves and fruits and the occurrence of ripening disorders are presented.

TOMATOES sometimes do not ripen uniformly. In the English literature such ripening disorders are called blotchy ripening, graywall, internal or vascular browning and cloud; in The Netherlands a ripening disorder named "waterziek" is known. There is probably some similarity among the various ripening disorders. In general, parts of the outer wall of the fruit remain green or yellow and the tissue associated with the vascular system is brown.

It is likely that certain ripening disorders such as blotchy ripening, internal browning and cloud are "physiological" and are not caused by pathogens; however, viruses such as the tobacco mosaic virus sometimes have an aggravating effect on ripening disorders (Cotter, 1961; Jones and Alexander, 1962; Woods, 1963; Tomkins, 1964).

Generally the occurrence of ripening disorders has been found to decrease with enhanced K nutrition of the plants (Kidson and Stanton, 1953a and b; Cotter, 1961; van den Ende, 1962; Woods, 1964a and b: Winsor, 1966; Ozbun *et al.*, 1967; Winsor and

Long, 1967; van der Boon, 1973; Forster and Venter, 1974) and to increase with rising Ca nutrition (van den Ende, 1962; Collin and Cline, 1966; Ozbun *et al.*, 1967; Winsor and Long, 1967). However, the effects of increasing Ca nutrition were dependent on the K concentration in the medium in which the plants were cultivated. On the whole, Ca and K nutrition are related in such a way that changing one also affects the other.

Furthermore, investigations on the effect of the osmotic pressure of the medium on the occurrence of ripening disorders in tomatoes have mainly been based on changes in the concentration of K, Na or Mg salts (Clay and Hudson, 1960; Kidson, 1963), and these salts (ions) *per se* may also have an effect on ripening disorders. Changes in the Ca and K levels are usually coupled with a change in the osmotic pressure of the medium. It was therefore not possible to separate the effects of K and Ca on ripening disorders from that of osmotic pressure.

The purpose of this investigation was to determine the effect of different K/Ca ratios in culture solutions of equal osmotic pressure on the occurrence of ripening disorders in tomatoes, the composition of the solutions with respect to other constituents also being kept roughly the same. In addition, the effect of the K/Ca ratio in the solutions on the K, Ca and Mg contents of the leaves and fruits, and the relation of these contents to the occurrence of ripening disorders have been studied.

MATERIALS AND METHODS

The experiment was performed with tomatoes cv Yelvic grown in a glasshouse at 16–21°C. The aerated culture solutions (Steiner, 1961) were prepared with different K/Ca ratios but with equal osmotic pressures. The K/Ca ratios in the culture solutions, leaves and fruits, as well as the (K+Mg)/Ca ratios in the leaves and fruits, have been expressed in equivalents.

Plants were transplanted to 1·2-l plastic pots three weeks after sowing on 6 February and were grown in nutrient solution at a K/Ca ratio of 0·80 for five weeks. The plants were then transplanted to 9·5-l plastic buckets (one plant in each) and the treatments were initiated, *viz.* K/Ca ratios in the culture solutions of 3·15, 0·29, 0·12 and 0·04. Nielsen (1972) and Shaykewich *et al.* (1971) found K/Ca ratios of 0·10–0·15 in the soil solution; these ratios are within the range of the K/Ca ratios in our treatments. The culture solutions ranged from Ca deficiency to K deficiency. The composition of the macro-elements in the nutrient solutions used is given in Table I. The solutions in the 9·5-l buckets were replenished

TABLE I

Concentration of the macro-elements in the culture solutions

Equivalent ratio K/Ca	Ion concentration (mg ion l^{-1})						
	NO_3^-	$H_2PO_4^-$	SO_4^{--}	K^+	Ca^{++}	Mg^{++}	Total
3·15	10·62	0·90	3·04	11·02	1·75	1·67	29·00
0·29	12·12	0·98	3·38	3·67	6·41	1·94	28·50
0·12	12·58	1·06	3·35	1·84	7·45	2·02	28·30
0·04	12·92	1·08	3·29	0·62	8·36	2·06	28·33

twice a week during the first two weeks, and three times a week thereafter. Twelve plants per treatment were cultivated in 9·5-l buckets for 19 weeks, at which stage the experiment was ended.

Fruit colour disorders

The tomatoes were harvested 65 days after the date of setting, at which time the fruits are normally ripe, and examined for ripening disorders. Yellowish stripes, running radially from calyx to apex on the fruit, were designated R. Yellow-green areas, mostly occurring around the calyx of the fruit and probably corresponding to greenback, were designated V. Symptoms were rated from 0 to 6, 0 indicating a perfect fruit and 6 a severely affected fruit.

Fruit analysis

After examination, fruits of corresponding size and truss position were collected and frozen. At the end of the experiment samples from the same truss and treatment were combined and, after thawing, ground in a mixer and ashed. The ash was dissolved in 25% HCl and the K, Ca and Mg contents of the fruits of truss 1, and of a mixed sample from trusses 2, 3 and 4, were determined.

Leaf analysis

Samples of the leaves below the fourth truss were taken 172 days after sowing, washed twice for one min in deionised water and then dried at 105°C. The samples were analysed for K, Ca and Mg.

Plant uptake of K, Ca and Mg from the solution

Mineral uptake was determined by sampling and analysing each nutrient solution before and after use. The period of uptake was from 77 to 173 days after sowing.

Methods of analysis

Mg was determined by atomic absorption and K by flame emission spectrophotometry. The Ca content of the leaves and solutions was determined by the oxalate method, and that of the fruits by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Plants in the treatment with the highest K/Ca ratio grew somewhat faster than those in the other treatments; at the end of the experiment the heights were 200 and 175 cm, respectively. Potassium deficiency symptoms were particularly obvious in the leaves of plants grown at a K/Ca ratio of 0·04.

Colour disorders, designated R (Fig. 1) and V, decreased markedly when the K/Ca ratio in the culture solution rose from 0·04 to 0·29; beyond that value the decline was less obvious.

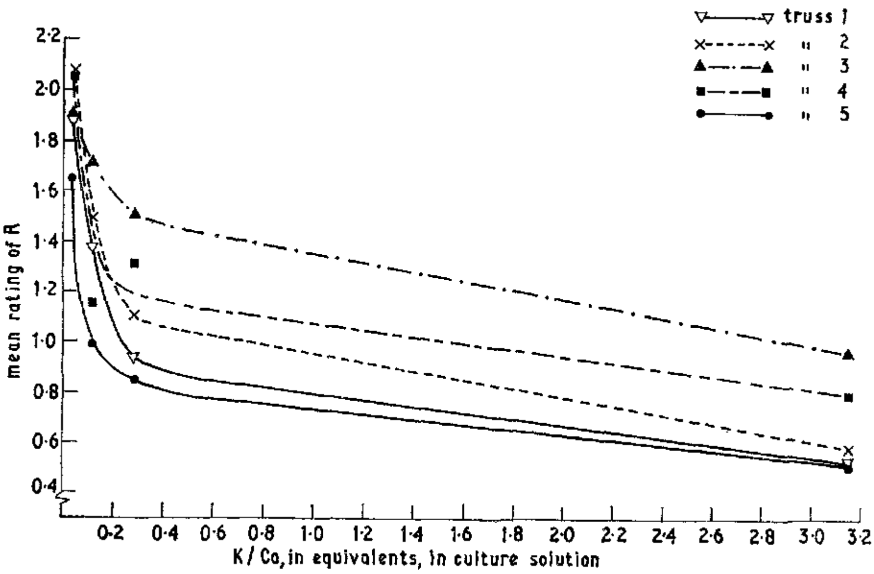

FIG. 1

Relation between the K/Ca ratio (in equivalents) in the culture solution and the occurrence of uneven ripening (R)

Uptake of K, Ca and Mg by the plants and the content of these elements in the leaves and fruits

In general, the plants depleted the culture solutions by not more than one-third, but at K/Ca ratios of 0·12 and 0·04 the depletion of K reached 47% and 65% respectively.

The uptake of K (Fig. 2), K content, and (K+Mg)/Ca ratio in the fruits and leaves all increased markedly with increasing K/Ca ratio in the solution from 0·04 to 0·29, and to a lesser extent up to a K/Ca ratio of 3·15. In contrast to K, the uptake of Ca (Fig. 2) and the Ca content of the fruits and leaves showed the opposite behaviour. The results for K uptake are partly in accordance with data from Hiatt (1970) and Robertson (1958), who found a curve with a maximum and an increase to an asymptotic value, respectively, in the relationship between K in the medium and plant uptake. Mengel (1973) found little effect of Ca supply on K absorption by the plant. In contrast, Hiatt (1970) found a shift of the maximum in the K absorption curve towards higher K concentrations, and a higher value of the maximum, with more Ca. In our experiment it was not possible to determine whether the variations in K absorption were due to changes in K or Ca concentration; the former is, however, more probable.

The uptake of Mg was higher in the treatment with the highest K/Ca ratio than in the other treatments. The Mg content of the leaves fell with increasing K/Ca ratio from 0·04 to 0·29 but rose with a further rise in the K/Ca ratio up to 3·15. The Mg content of the fruits also rose with increasing K/Ca ratio. This different effect on the Mg content of leaves and fruits may have been caused by a specific influence of Ca status on the translocation of Mg *via* the xylem and phloem, by which pathways the leaves and fruits respectively are fed. More detailed investigation of this subject will be undertaken.

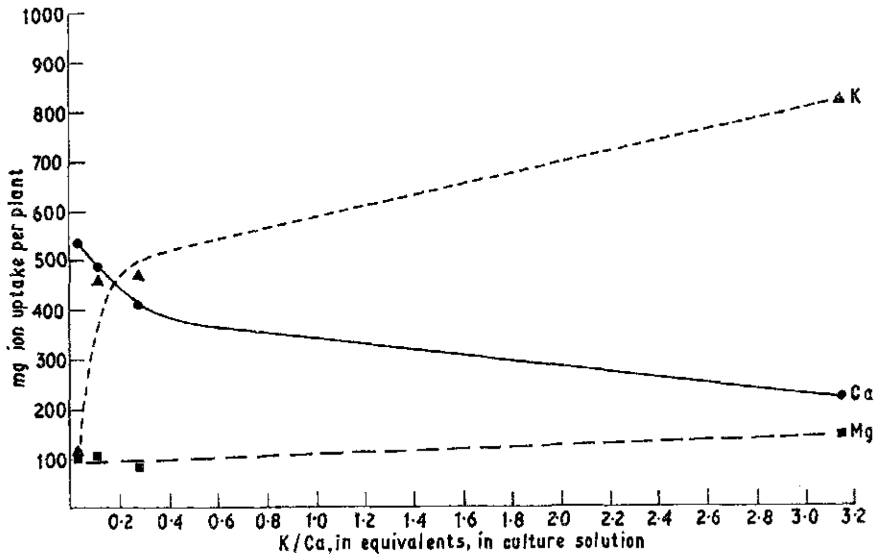

FIG. 2

Relation between the K/Ca ratio (in equivalents) in the culture solution and mg ion uptake of K, Ca and Mg per plant

Effects of the K, Ca and Mg contents and the (K+Mg)/Ca ratio of the leaves and fruits on the occurrence of ripening disorders

A rise in the (K+Mg)/Ca ratio in the leaves and fruits was accompanied by a sharp decline in ripening disorders designated R (Figs 3 and 4) and V; however, the rate of decline of V (not shown) decreased considerably after the (K+Mg)/Ca ratio in the leaves and fruits rose above about 1·4 and 14, respectively.

An increase in the K/Ca ratio in the solution changed the K as well as the Ca and Mg contents of the leaves and fruits. It is thus not possible to decide which element is responsible for differences in the incidence of uneven ripening. There are, however, some indications from the literature that a low K concentration is the main cause of the occurrence of this disorder. Trudel and Ozbun (1970, 1971) found that a decrease in K concentration of the culture medium is accompanied by a reduced carotenoid content. Potassium probably plays a role in the activation of enzymatic biosynthesis of fruit pigments (Trudel and Ozbun, 1970).

Further experiments will be required to distinguish between the effects of K, Ca and Mg on ripening disorders. In such experiments, polymers such as polyethylene glycol should prove useful in keeping the osmotic value of the nutrient solution constant while the concentration of one ion is varied.

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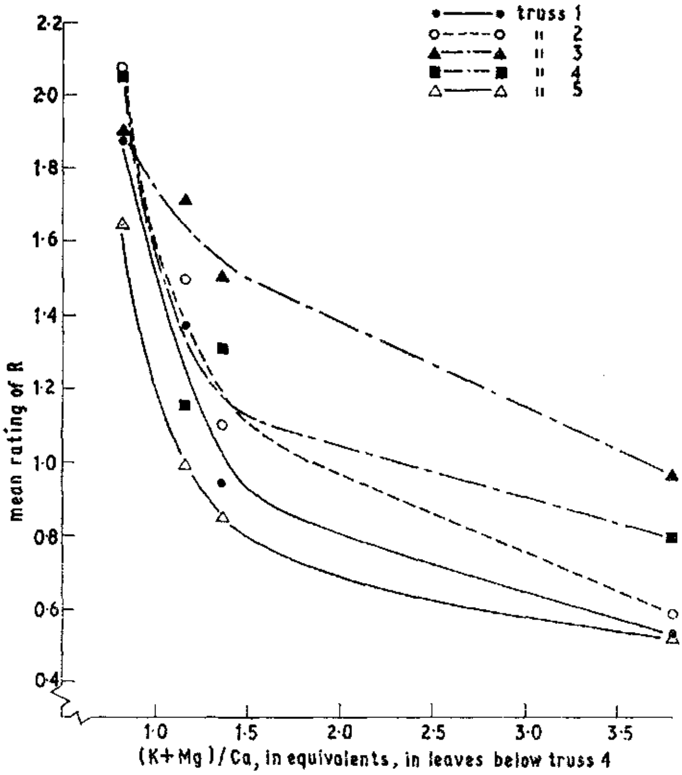

FIG. 3

Relation between the (K+Mg)/Ca ratio (in equivalents) in leaf beneath truss 4 and the occurrence of uneven ripening (R)

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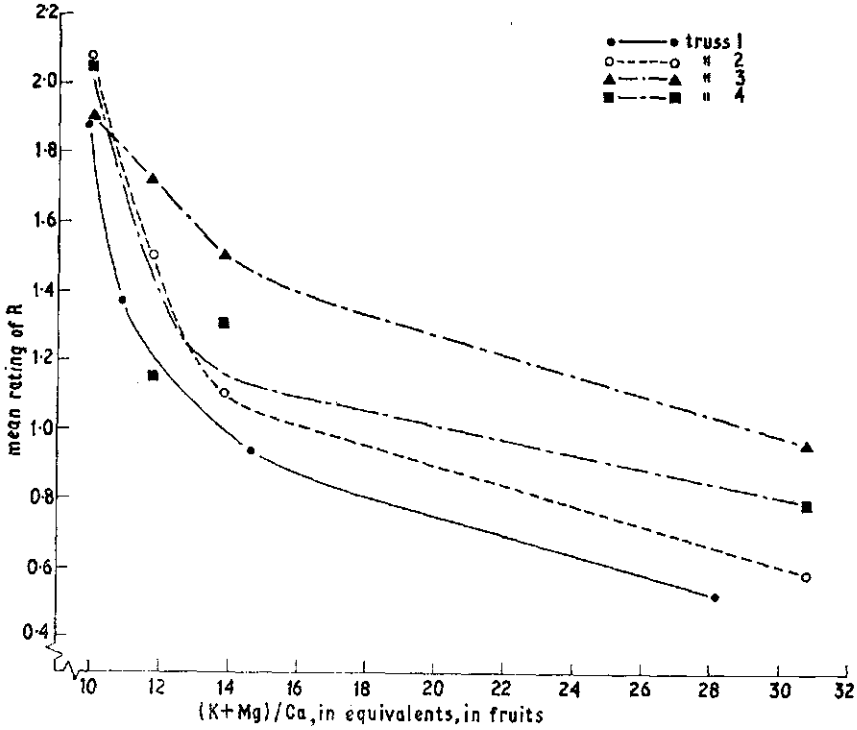

FIG. 4

Relation between the (K+Mg)/Ca ratio (in equivalents) in fruits and the occurrence of uneven ripening (R)

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