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Influence of K/Ca ratio and drought on physiological disorders in tomato

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Summary

The effects of two K/Ca ratios and of four short drought periods on the quality of the tomato fruit were studied in two pot experiments. The drought periods were imposed at stages, in which the fruits of the successive clusters to be sampled were at comparable physiological age.

Drought lowered the calcium concentration and raised the K/Ca ratio in the fruit. After a drought period, the total amount of calcium in the fruit was lower than that of the control. The temporary drought treatment had a lasting effect, noticeable even in the ripe fruits. Blossom-end rot only occurred at the higher K/Ca ratio, and was then slightly aggravated by drought. The effect of the latter can be wholly explained by the reduction in calcium content.

At the high K/Ca ratio incidence of blotchy ripening was lower than at the low K/Ca ratio. In contrast with the interaction in the case of blossom-end rot, drought had now only an additional effect, which was favourable.

No clear influence was found of the K/Ca ratio and of drought on the incidence of green-back.

Introduction

Physiological disorders in fruits, although associated with a disturbance in the calcium and potassium supply as in the case of blossom-end rot in tomatoes and bitter pit in apples, often seem to occur at random. Practical experience indicates that weather conditions play an important role. Water stress in the plant during dry periods seems to be a contributing factor. The question may be posed whether water stress influences the incidence of the quality disorders directly, or indirectly via the mineral supply to the fruit.

Therefore two experiments with tomato (Exp. VP 677 and VP 753) were conducted to study the influence of a temporary drought period on the mineral composition of the leaf and fruit and on the incidence of quality disorders in the fruit. During the development of the plant four drought periods were imposed to determine the differences in susceptibility to moisture stress of the successive clusters. Detailed analyses of the leaf and fruit should reveal to which extent water shortage of the soil influences the uptake of potassium and calcium and whether or not any appearing quality disorders could be explained by changes in the mineral composition of the fruit (more details in van der Boon, 1971).

Lay-out of the experiment

The tomatoes (variety Renova) were grown in a glasshouse in plastic pots (15 litres), filled with a sand-peat mixture (1 : 3).

The experiment was a factorial combination of two K/Ca levels and five drought treatments, consisting of the control and four successive drought periods. These four periods were imposed as follows: the first at the moment that five fruits of the first cluster had reached a diameter of (at least) 1 cm, the second period when fruits of the second cluster of an other group of plants had a diameter of 1 cm and so on (for outline, see Table 5). As soon as the chosen fruits had the required size, water was withheld. The drought period was considered to have become effective when the plants were wilting already at 10 h 00. The effective period lasted four days in the first experiment (VP 677) and six days in the second experiment (VP 753). By means of small water injections into the sand-peat mixture further drying-out during this last part of the drought period was prevented as much as possible. The amount of water given in the whole drought period was in the first experiment 19% and in the second 28% of the consumption of the control, which at this moment of full growth and fruit bearing was for the two experiments 1.4 and 1.0 litre/day, respectively. This difference was due to the fact that temperature and humidity in the experimental glasshouse were not standardized. The drought was established very gradually without extra ventilation, so as to get only a disturbance in the mineral supply of the fruits and as little as possible in the growth of the plant.

Two K/Ca ratios (high and low) were maintained, both in the basal dressing and weekly topdressing. The higher K level approached the borderline of K excess and Mg deficiency, the lower level was selected in such a way that direct K deficiency did not occur and fruit size was not affected. Excessively low or high Ca levels, which could cause growth abnormalities, were also avoided. The following ratios for topdressing were intended: in the high-K/Ca treatment 5 : 1 and in the low-K/Ca treatment 1 : 5; the ratio of the two K levels was 5 : 1. Frequent periodical soil sampling revealed, however, that without adaptation of the topdressing the nutrient levels of the soil and the difference in nutrient levels between the two treatments could not be maintained, especially in the stage of rapid growth and first fruit-set. Differences in growth rate between the two treatments added to

Table 1. Quantities of basal and topdressing in g/pot.

	Low K/Ca			High K/Ca		
	N	K_2O	CaO	N	K_2O	CaO
Exp. VP 677						
Basal dressing	2.00	0.15	100.0*	2.00	0.75	25.0*
Total dressing	16.14	8.69	114.6	18.59	28.71	29.3
Weekly topdressing (on average)	0.54	0.33	0.6**	0.64	1.08	0.2**
Exp. VP 753						
Basal dressing	2.00	0.15	100.0*	2.00	3.00	17.5*
Total dressing	14.30	13.20	117.0	19.75	34.25	17.7
Weekly topdressing (on average)	0.49	0.50	0.8**	0.68	1.30	0.0**

* as $CaCO_3$
** as $Ca(NO_3)_2$

this difficulty. Table 1 shows the amounts of fertilizer that were ultimately applied.

Immediately before and after a drought period, recently matured leaves and the first five fruits from the first three clusters were taken as samples from the treated and from the control plants. Later, recently matured leaves and the first five ripe fruits on the corresponding clusters were taken from identically treated and non-treated plants. Leaf and fruit samples were analysed for dry matter, ash and total K and Ca content. The fruits were macerated, homogenized and filtered. Of the juice the K content and the total sugar content (refractometer method) were determined.

During harvest, quantity and size of fruit were recorded and quality disorders as blossom-end rot (dying-off of fruit apex), blotchy ripening (uneven ripening, browning of vascular strands) and green-back (areas of hard, green or yellow tissue around calyx) were rated as to severity.

The experiment was carried out with six pots per treatment, each pot containing one plant as a replication. Extra pots, however, were added, as sampled plants were discarded. Composite leaf samples were taken from each treatment. Duplicate fruit samples were taken, i.e. from each treatment, two separate samples, each from three plants, were collected.

Results

On the whole, the measured criteria of the leaves and the fruits of the first three clusters reacted mostly the same way for the four drought periods, so only the average results are given, unless there are clear deviations.

The analysis figures of the recently matured leaves, sampled before and immediately after the drought period in the unripe fruit stage and after the drought period in the ripe fruit stage are given in Table 2, as averages over the four successive drought periods. In the older plants, the K content of the leaf decreased, the calcium and ash content increased, and so the K/Ca ratio decreased.

The fact that fruit analysis was performed on two samples made statistical evaluation possible without the need to regard higher-order interactions as error. The effects reported below are for the most part statistically significant. In Table 3 the levels of minerals and sugar are given. As a change in concentration of a nutrient element does not necessarily mean a gain or loss of this element in the fruit, the total nutrient quantity in the fruit has been calculated (Table 4). Of course the dry-matter percentage of the unripe fruit was increased by the drought period, but that of the ripe fruit also increased, though to a smaller degree. This influence was lasting, notwithstanding the short period, while the total dry-matter quantity of the fruit did not clearly change, which is exactly as was intended. Changes in the nutrient levels due to drought, calculated on a dry-matter basis, could therefore not be explained without postulating a change in translocation of nutrients into or out of the fruit. During the development of the fruit the dry-matter content and the K/Ca ratio decreased, whereas the calcium and ash contents of the dry matter, and the calcium content of the ash increased.

The main effects of the drought period on the mineral composition of leaf and fruit were as follows. Drought decreased the Ca level in the leaf, but there was no consistent influence upon the K level. An increase in the K/Ca ratio of the leaf at the unripe fruit stage was apparent in both experiments; in Exp. VP 753 this effect could be noted at the ripe fruit stage. In the late fruit stage there was a small decrease in ash content in leaf dry matter, but not immediately after the drought period.

Table 2. Influence of a drought period on the mineral composition of the leaves of tomato plants in dependence of the K/Ca ratio.

	K/Ca ratio	Experiment VP 677, sampling in					Experiment VP 753, sampling in				
		unripe fruit stage			ripe fruit stage		unripe fruit stage			ripe fruit stage	
		before drought period	after drought period		control	treated plants	before drought period	after drought period		control	treated plants
			control	treated plants				control	treated plants		
K_2O (% d.m.)	low	2.86	1.71	1.70	0.69	0.64	3.07	0.76	1.35	1.40	1.52
	high	6.83	5.57	5.22	3.10	2.85	7.97	5.78	6.24	5.81	6.15
CaO (% d.m.)	low	4.88	6.09	5.25	12.71	12.76	5.27	5.65	5.41	12.32	11.03
	high	2.38	2.73	2.50	9.44	9.19	2.11	2.13	1.91	5.07	4.20
K_2O/CaO	low	0.62	0.29	0.34	0.06	0.05	0.60	0.14	0.27	0.12	0.14
	high	2.92	2.18	2.24	0.33	0.31	3.78	2.88	3.32	1.15	1.44
Ash (% d.m.)	low	12.8	12.5	13.2	23.3	22.5	13.1	10.3	11.0	20.8	19.8
	high	13.9	12.4	12.2	18.7	18.7	16.4	13.1	13.6	17.6	16.7

Table 3. Influence of a drought period on the mineral composition of tomato fruits in dependence of K/Ca ratio.

	K/Ca ratio	Experiment VP 677, sampling in					Experiment VP 753, sampling in				
		unripe fruit stage			ripe fruit stage		unripe fruit stage			ripe fruit stage	
		before drought period	after drought period		control	treated plants	before drought period	after drought period		control	treated plants
			control	treated plants				control	treated plants		
% dry matter	low	5.92	5.18	5.84	4.15	4.30	5.91	5.29	6.31	4.37	5.21
	high	5.85	5.27	5.99	4.38	4.60	5.97	5.21	6.38	4.90	5.67
K_2O (% d.m.)	low	3.82	3.37	3.24	3.52	3.55	3.24	2.81	2.73	3.15	2.94
	high	5.20	5.15	5.01	5.47	5.38	4.60	4.57	4.40	4.95	4.64
CaO (% d.m.)	low	0.27	0.25	0.20	0.35	0.31	0.21	0.26	0.18	0.35	0.31
	high	0.14	0.15	0.11	0.18	0.18	0.10	0.10	0.09	0.13	0.10
K_2O/CaO	low	14.9	13.5	16.6	10.2	11.7	15.6	11.4	16.1	9.3	9.9
	high	38.5	36.2	46.4	30.8	30.4	46.4	46.5	51.2	38.2	44.7
Ash (% d.m.)	low	6.30	6.17	5.96	6.73	6.68	5.91	5.19	5.17	6.11	6.10
	high	8.97	8.57	8.42	9.73	9.64	8.63	8.37	7.89	8.90	8.61
CaO/ash %	low	4.4	4.2	3.4	5.3	4.6	3.7	5.1	3.5	5.9	5.1
	high	1.6	1.8	1.4	1.9	1.9	1.3	1.3	1.1	1.5	1.3
K_2O % of juice	low	0.21	0.16	0.18	0.14	0.15	0.17	0.14	0.19	0.13	0.16
	high	0.30	0.26	0.28	0.23	0.26	0.32	0.25	0.31	0.25	0.29
Sugar % of juice	low	4.24	3.82	4.21	3.55	3.65	4.41	3.83	4.78	3.74	4.21
	high	3.58	3.81	4.38	3.94	4.31	4.25	3.87	5.01	4.20	5.07

Table 4. Quantities of nutrients and dry matter in tomato fruits before and after a drought period.

Quantities per fruit	K/Ca ratio	Experiment VP 677, sampling in					Experiment VP 753, sampling in				
		unripe fruit stage			ripe fruit stage		unripe fruit stage			ripe fruit stage	
		before drought period	after drought period		control	treated plants	before drought period	after drought period		control	treated plants
			control	treated plants				control	treated plants		
g dry matter	low	1.37	2.39	2.39	2.90	3.38	2.33	3.47	3.32	4.06	4.26
	high	1.74	2.87	2.83	3.32	3.33	2.73	4.06	3.77	4.33	4.24
mg K_2O	low	50	79	77	104	122	71	98	92	128	127
	high	92	146	144	186	180	124	186	167	214	194
mg CaO	low	3.7	5.9	4.9	9.9	10.0	5.3	9.0	6.0	13.8	12.6
	high	2.4	4.1	3.2	5.9	6.0	3.0	4.2	3.3	5.7	4.6
g ash	low	0.09	0.15	0.14	0.20	0.22	0.14	0.18	0.17	0.25	0.26
	high	0.16	0.25	0.24	0.33	0.32	0.24	0.34	0.30	0.39	0.36

In the fruit the dry-matter percentage was increased by drought, independent of the K/Ca level. In more than half of the cases the K content of the fruit decreased, but mostly the effect was not statistically significant. In the unripe fruits the Ca concentration and total Ca amount were decreased by drought, the decrease in Ca concentration in VP 753 being greater for the high-Ca fruit of the low-K/Ca treatment than for that of the high-K/Ca treatment. The Ca concentration of the ash also decreased, especially in the case of the low-K/Ca treatment. In the ripe fruit drought lowered the Ca concentration, the influence on the total Ca amount being indistinct. The K/Ca ratio in the unripe fruits increased clearly as a result of drought and mostly also in the ripe fruits. In most cases the ash content decreased after the period of water shortage, especially for the high-K/Ca treatment and in the first drought period. Drought had little effect on the amount of ash.

As mentioned before, the drought periods were imposed in such a way that the plants received a temporary shock, which could cause a disturbance in the nutrient supply to the fruit without decreasing the yield appreciably. This indeed occurred: there was no systematic difference in fruit production between the treated plants and the control, except in VP 753 where the average fruit weight was lower for the drought-treated plants. The high-K/Ca treatment gave not only a higher yield, but also a substantially higher percentage of healthy fruits than the low-K/Ca treatment. Drought affected the health of the fruit not unfavourably and improved to a greater or lesser extent the overall quality of the fruits of the plants which were growing luxuriously, possibly too luxuriously, at a low salinity level in the potting soil, consisting largely of peat.

As for the separate quality disorders, in the little susceptible variety Renova no blossom-end rot occurred at the low K/Ca ratio, but at the high K/Ca ratio blossom-end rot did appear and was aggravated by drought at certain stages: the first drought period influenced the first and second cluster and the following drought periods the second and third cluster (Table 5). Blotchy ripening occurred largely at a low K/Ca ratio, especially in the higher clusters. Drought tended to diminish the incidence of the disorder at the high K/Ca ratio (Table 6). Many of the ripe fruits had been attacked by green-back, but nutrition level and water supply had no clear influence on its occurrence.

Whether or not drought influences the incidence of physiological disorders in relation to the calcium and potassium status of the plant, can be judged from the graphs, relating the percentage of affected fruits and the mineral composition of the fruit. A negative correlation exists between blossom-end rot percentage and the calcium content of the

Table 5. The occurrence of blossom-end rot at a high K/Ca-level as affected by drought periods at various stages of development of the tomato plant.

	Percentage of fruits affected by blossom-end rot		
	1st cluster	2nd cluster	3rd cluster
Control	10.1	10.7	8.5
Drought*			
1st period 23 April - 5 May	21.7	21.2	4.8
2nd period 29 April - 17 May	7.2	9.2	12.6
3rd period 6 May - 24 May	5.8	14.0	15.5
4th period 20 May - 1 June	0.0	7.6	9.6

* The four successive drought periods started when the fifth fruit of the 1st, 2nd, 3rd and 4th cluster, respectively, had reached a diameter of 1 cm.

Table 6. The occurrence of blotchy ripening as affected by the level of K nutrition and by a drought period.

			Percentage of fruits affected by blotchy ripening	
			Exp. VP 677	Exp. VP 753
K/Ca	low	control	36.3	70.7
		drought	45.1	60.2
K/Ca	high	control	19.5	34.1
		drought	9.3	11.6

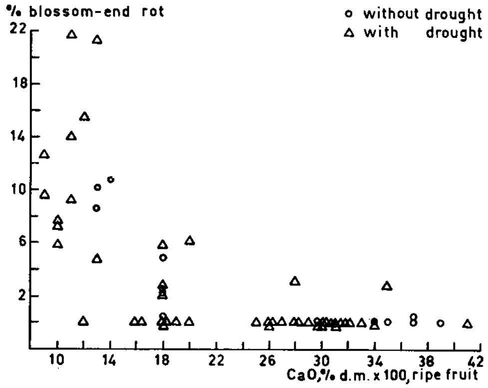

Fig. 1. The relationship between percentage blossom-end rot and the calcium content of ripe tomato fruits.

fruit, but there is no clear difference between the positions of the points plotted for the droughttreated plants and the control plants (Fig. 1). Although other properties of the fruit were also changed by drought, the decrease in calcium content itself could already explain the increase in blossom-end rot. The calcium content of the dry matter, below which blossom-end rot generally occurred in this experiment, was for unripe fruits 0.12% CaO and for ripe fruits 0.20%. Expressed as a fraction of the ash content of the fruit the figures were 1.5 and 2.5% CaO, respectively.

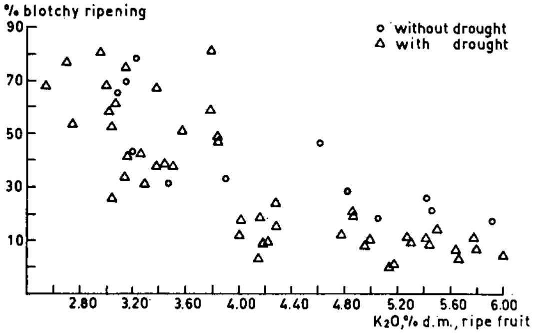

Fig. 2. The relationship between percentage blotchy ripening and the potassium content of ripe tomato fruits.

A negative correlation existed between blotchy ripening and the potassium content of the fruit (Fig. 2). At high potassium levels the control plants showed more boltchy ripening than the plants that had received a drought treatment. Drought lowered the potassium content slightly, but reduced rather than enhanced the incidence of blotchy ripening. When instead of the data on K content of the dry matter, the data on K content of the fruit juice are plotted along the abscissa, no discrepancy exists between the positions of the points for treated and control plants. For an interpretation of the influence of drought there should be no need now to invoke other mechanisms, which in reality probably are operating.

Discussion

Blossom-end rot often appears to occur at random; it is known, however, that weather conditions and low Ca levels in the fruit are associated with the incidence of this disorder. The question arises, if weather conditions act directly on the incidence of this disease, or indirectly through a partial or complete shift of the calcium level to the critical zone. To investigate this problem, of the complexity of weather conditions, only one indirect factor was varied, namely soil moisture content. The soils were allowed to dry out over a period of time, short enough to avoid growth retardations and changes in the leaf/fruit ratio.

Drought influenced the mineral composition of leaf and fruit. The calcium content of leaf and fruit decreased. Gerard and Hipp (1968) also found a somwehat lower Ca content of the fruit and a higher K/Ca ratio after the flowering stage on plots without irrigation, and Riggleman (1964) reported an increased calcium content of the fruit after irrigation.

The lower calcium contents in leaf and fruit after drought can be a result of a diminished calcium supply to the fruit, but also of an unchanged calcium supply at the start of the drought period, followed by withdrawal of calcium from the fruit in the latter part of the drought period. Calcium can be withdrawn from the fruit, as Wilkinson (1968) has found for apples in a dry summer. Daily sampling could have shown whether or not this also was the case in the present experiment.

The larger reduction in the quantity of calcium relative to potassium contained in leaves and fruits can also be due to changes in the rate of uptake of these nutrients by the roots, as well as to changes in distribution of the nutrients in the plant.

Concerning the first possibility, the effect of drought on the calcium availability in the soil is rather complex. A lower water content means a higher salt concentration in the soil solution. A higher Ca concentration in the soil solution can then be expected as a result of exchange phenomena at the adsorption sites ,but according to Geraldson (1957) a higher salt concentration decreases the relative activity of divalent ions in the soil solution more than that of monovalent ions resulting in a lower calcium uptake. Wiersum (1969) argues that the availability of calcium, supplied by mass flow, is less dependent on moisture stress, if not too severe, than is the availability of potassium, which is governed by diffusion and directly dependent on water content of the soil. Hence, soil moisture content may not only affect Ca uptake directly, but also indirectly through its effect on the availability of K, which may compete with Ca for absorption. The same applies to other ions in the soil (Wadleigh and Richards, 1951). Thus the possible conclusion that the decrease in calcium level in fruit and leaf in this experiment after drought may be attributable to a change in root uptake, does not seem to be generally valid.

Concerning the distribution in the plant, it can be postulated that during drought the water supply from the roots to the fruits may be more restricted than the water transport via the phloem. Since translocation of both calcium and potassium proceeds through xylem vessels, whereas phloem vessels were found to contain potassium, but only minute quantities of calcium a rise in the K/Ca ratio in fruits might result from a restricted water availability (Wiersum, 1966).

Only more intensive sampling could have revealed to what extent the results of the present experiment could be explained by a change in Ca uptake by the roots, by an altered distribution of Ca in the plant, or by Ca withdrawal from the fruit.

The effect of a reduced water availability was not a temporary one. Also in the ripe fruits more or less distinct influences of drought were still apparent. This is in accordance with the findings of Woodham and Kozlowski (Kozlowski, 1964) in a tomato experiment of a (more or less) similar design. The carbohydrate metabolism of plants, subjected to moisture stress, changed in their experiment already before wilting. During the gradual water loss there was a decrease in reducing sugars, non-reducing sugars and starch in the vegetative parts. After irrigation there was no return to the state of the check plant. In the present experiment, drought increased lastingly the sugar content of the fruit juice in dependence of the K/Ca ratio.

The effect of the drought periods on the incidence of blossom-end rot was small, especially in comparison with the effect of the K/Ca ratio. Drought alone did not produce blossom-end rot at the low K/Ca ratio. Water stress is possibly only dangerous to the health of the fruit at a low Ca level. Fig. 1 shows that high percentages of blossom-end rot occurred only at low Ca contents in the fruit and that at high levels little or no blossom-end rot was present. There is no systematic difference between treatment and control points. The critical level for the incidence of blossom-end rot appears to be 0.15-0.20% CaO, which agrees with the results of Geraldson (1957). Raleigh and Chucka (1944) indicate that plants with less than 0.38% CaO in the fruit generally produced fruits with blossom-end rot. The small effect of the reduced water availability in the potting soil agrees with the data of Jumelet and van Koot (1945), who did not find any effect on blossom-end rot of short fluctuations in water supply, brought about by watering of tomatoes every other day instead of daily. Probably of more importance is the water stress in the plant, depending not only on the rate of absorption, but also on the rate of transpiration (Kramer in Kozlowski, 1964). Gerard and Hipp (1968) found only a light attack of blossom-end rot at a low level of calcium if transpiration was suppressed, either by a high relative humidity (70%) in a growth chamber, or by light sprinkler irrigation, twice a day, during periods of high transpiration rates. Blossom-end rot attack was serious under conditions of vapor pressure deficits of more than 15 mm of Hg. Dr B. van Goor (pers. comm.) could not evoke blossom-end rot under 'normal' winter conditions in the glasshouse in spite of very low Ca levels in the fruits. Ca deficiency locally occurring in the fruit seems to make the cell there unstable and susceptible to blossom-end rot (van Goor, 1968), the extent of the incidence of the physiological disorder depending on the water stress in the plant. In the literature the following factors are found to influence the appearance of blossom-end rot: imbalance of nutrients (Raleigh and Chucka, 1944; Fisher, 1967; El-Asdoudi, 1968), low ratio of soluble Ca to total soluble salt (Geraldson, 1957), high salt concentration in the soil (Jumelet and van Koot, 1945; Geraldson, 1957), also after a side dressing (Geraldson, 1957; Riggleman, 1964), a dominating mass flow of assimilates and calcium-deficient water via the sieve tubes, e.g. at a high leaf/fruit ratio and during rapid growth (Wiersum, 1966), and a high transpiration rate resulting in water and calcium loss of the fruit (Gerard and Hipp, 1968). All these factors can be reduced to two 'causal' factors: lowering of the calcium level of the fruit and/or increase in the water stress in the plant. In our experiment drought seems to have worked only by way of the first mechanism, while the high-transpiration conditions in the experiments of Gerard and Hipp (1968), which, to some extent, also prevented the movement of Ca into the fruit, gave water loss from the small, permeable fruits with, as a consequence, the collapse of the sensitive unstable tissue.

For the four successive drought periods, the susceptibility to blossom-end rot of the fruits of the first three clusters was estimated. As can be seen from Table 5, the susceptibility of the small fruits with a diameter of 1 cm is high. A drought period, imposed much earlier or later, clearly had a less strong effect. The susceptible period lies, according to Spurr (1959), before 12 to 15 days after anthesis, at which time the first stages of disorder were found. Gerard and Hipp (1968) showed that the small fruits are more permeable and liable to loss of water. In this experiment with a nutrient supply controlled in the best possible way, no large differences in blossom-end rot among the three clusters occurred. Under practical circumstances, the first cluster is often more attacked than are the following ones. This may be a consequence of the high leaf/fruit ratio in the early stage of growth (Wiersum, 1966), but it may also be caused by a high basal dressing with consequently a high concentration of total soluble salt in the soil. Jumelet and van Koot (1945) found that a decrease in blossom-end rot incidence ran parallel with a decrease in salt concentration. Van Goor (1966) connected the appearance of the disorder with an increasing K/Ca ratio in the soil.

Blotchy ripening was found more at the low than at the high K/Ca ratio (Table 6), which is in agreement with observations made in fertilizer experiments that a high potassium dressing tends to prevent the incidence of the disorder (van den Ende, 1962; Minges and Boutonnet, 1966; Roorda van Eysinga, 1966; Winsor, 1966; Ozbun et al., 1967). In other experiments reported on in the literature, however, this decrease in blotchy ripening due to potassium was not distinct (Woods, 1966). In the present experiment, drought had a favourable influence on fruit colouring, at least at the high K/Ca level (Table 6). In agreement with most experiments described in the literature, water stress suppresses the appearance of colour ripening disorders (Woods, 1966). Fruits with blotchy ripening have a low dry-matter content. To obtain a crop of high quality, a sufficiently heavy basal N, P, K dressing and a timely topdressing are desired while the transpiration rate should not be too low (van der Ende, 1962). Winsor (1966) attributes a part of the favourable response of high potassium dressing to increased salt concentration in the root environment, because more uniform ripening also has been reported in response to sodium and magnesium sulphate. The higher dry matter and sugar contents, found in the present experiment under influence of potassium and drought, are also in accordance with earlier reports in the literature. The fact that drought lowered the K content of the fruit, which in itself promotes the incidence of this disorder, indicates, however, that the former exerts an independent effect on the occurrence of this disorder (Fig. 2).

No systematic influence of the K/Ca level and of drought have been found on the incidence of green-back. Winsor (1966) found a favourable influence of potassium, but it was smaller than that for other ripening disorders. In addition, the occurrence of green-back is also a function of other factors, such as variety susceptibility and abundant light. The high green-back incidence in the present experiment is possibly due to susceptibility of the variety, but also to the fact that a wide plant spacing was used.

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