THE RELATION OF SOME ENVIRONMENTAL FACTORS AND COMPOSITION VALUES TO BLOTCHY RIPENING IN THE TOMATO

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THESIS

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THE RELATION OF SOME ENVIRONMENTAL FACTORS AND COMPOSITION VALUES TO BLOTCHY RIPENING IN THE TOMATO

By

JAMES ERNEST ELLS

AN ABSTRACT OF A THESIS

Submitted to
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ABSTRACT

THE RELATION OF SOME ENVIRONMENTAL FACTORS AND COMPOSITION VALUES TO BLOTCHY RIPENING IN THE TOMATO

By James Ernest Ells

Blotchy ripening of the tomato fruit has been a serious disorder of tomatoes in certain years, affecting up to 60 percent of the fruit from a single harvest. This disorder is characterized by green or yellow blotches on the walls of red-ripe tomatoes, which customarily are accompanied by a browning of the underlying vascular tissue. This brown coloration is found in a sheath of necrotic parenchyma cells surrounding the vascular bundles.

A primary objective of this study was to induce blotchy ripening experimentally by the manipulation of moisture relations. The initial experiment was designed to differentially influence the diurnal fluctuations in turgor pressure of the tomato plant by the use of lampblack and white talc dusts. Other experiments were designed to differentially influence plant water requirements by early and continuous shading of plants with cheese cloth and shielding of plants with wind barriers, and the use of close, medium, and wide plant spacings. Plant water relations were also influenced by the application of compounds to accelerate and retard transpiration, and by pruning leaves, fruit clusters, and roots. Fruit water relations were influenced by wrapping attached fruit in black plastic and aluminum foil. In some cases these treatments were interacted with a high and low level of fertility. Since none of the treatments were effective in inducing blotchy ripening under the conditions prevailing,

the role of water relations on the induction of the disorder is still in doubt.

Biological assays indicated an increased incidence of blotchy ripening of fruit on plants infected with tobacco mosaic virus, and laboratory analyses indicated a lower level of dry matter, soluble solids, and reducing sugars in blotchy wall tissue, but failed to reveal any consistent differences in mineral composition between blotchy and non-blotchy wall tissues.

Since blotchy ripened tissue has been associated with low dry matter, soluble solids, and reducing sugars, it was suggested that this disorder may be induced by cultural practices which would result in low levels of these constituents in the plant and fruit after the fruit has reached the mature-green stage of development. The cultural practices suggested to produce this effect were reduced light duration and day temperature, and increased soil moisture and night temperature.

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CONTENTS

INTRODUCTION

Blotchy ripening is a disorder of tomato fruit which in early stages is characterized by green blotches on the walls of ripening fruit. In later stages these blotches become yellowish and may eventually turn red. The vascular bundles show a brown discoloration which may radiate out into the adjacent tissue. This disorder may frequently be arrested if the developing fruit is picked at an early stage.

Blotchy ripening usually occurs on the fruits of the lower, shaded clusters of heavily bearing plants. The disorder seldom occurs on the blossom-end of the fruits, but usually appears on the wall area between the junctions of the septa.

Under experimental conditions, the incidence of blotchy ripening has been influenced by several factors. Bewely and White (4) reduced it by application of potassium to the soil. Climatic conditions, however, are probably the dominant influence as the incidence of blotchy ripening varies from year to year on tomatoes grown in a given area. In normal years, blotchy ripening affects only a negligible portion of the crop. In 1958, however, approximately half of the fresh market tomatoes in Michigan showed blotchy ripening during part of the harvest season. At the close of this season the investigation reported herein was initiated.

REVIEW OF LITERATURE

Blotchy ripening is both widespread in its occurrence and in the nature of the factors that have been related to its origin and development in the tomato fruit. Bewley and White (4) first used the term and reported that the disorder was exhibited when tomato fruits displayed an uneven ripening which may be accompanied by necrosis of the vascular bundles and a breakdown of the adjacent tissue with the formation of canals. This adequately describes the other disorders which have been subsequently called internal browning (5, 14, 17, 32, 33, 45, 46, 51), vascular browning (11, 15), cloud (21, 22, 23), graywall (32, 33, 45), and waxy fruit (28).

The possible reason for the application of different descriptive terms to this disorder was the lack of agreement as to the conditions under which the disorder was found, induced, or alleviated.

Studies indicate that blotchy ripening has resulted from innoculation of tomato plants with tobacco mosaic virus when the fruit is at the mature green stage (5, 33), by application of mist with shading (15, 46), or may be due to the occurrence of low light intensities one to two weeks prior to harvest (10).

Blotchy ripening has also been associated with excess transpiration (39), invading root fungi (4), a few days of intense sunlight following a dull period (16), luxuriant foliage growth (11, 21), reduced air movement over the plant (14), reduced light (22), reduced light early in the season with a greenhouse crop (22), high humidity (21), cool weather (22), a wet season with many sunless days (22), and high temperature for a two week period (27).

Blotchy ripening has been associated with soil compaction, heavy watering, soil sterilization, application of raw organic manure or glucose to the soil, or heavy defoliation (21), or deficiencies of nitrogen (4, 21, 52), potassium (4, 19, 21, 52), or boron (46, 47). It has further been shown that the affected portions of the blotchy fruit have low dry matter and sugar contents (22, 28, 47).

Bitter Pit in Apples

A brief review of the factors associated with bitter pit in apples is included because of the apparent similarity to blotchy ripening in tomatoes.

Carne, Pittman, and Elliot (8) observed necrotic cells of apples with bitter pit and found them high in starch. They concluded that these cells had a low osmotic pressure which allowed water to be withdrawn, resulting in necrosis. White (52) observed starch grains in necrotic blotchy ripened cells of tomato, and Seaton (39) believed that the associated necrosis was caused by the withdrawal of water.

Smock (43) related bitter pit with osmotic pressure of leaves and fruit. He showed that the incidence of bitter pit increased as the ratio between the osmotic pressure of the leaves to the fruit increased, and that no bitter pit resulted when the leaves were removed from a limb. He also observed that increases in the soil nitrogen level, heavy thinning, shading, heavy pruning, and ringing all tended to increase bitter pit, and to increase the osmotic pressure ratio between the leaves and fruit.

Smock has observed that apple fruits are particularly susceptible to bitter pit on their lower shaded quarter, which also has the lowest osmotic pressure (43). Blotchy ripened tomatoes have been reported to have a low dry matter content particularly in the fruit walls (19). The leaves of plants which have produced blotchy ripened fruit have also been found to have a low dry matter content (23). Massey and Winsor (28, 29) reported that the total solids, sugars, nitrogenous compounds and acids were lower in the expressed sap and that there was a progressive decrease in sap solids, reducing sugar, and total acidity from red to yellow to green portions of the walls of blotchy ripened fruits. These findings indicate a low osmotic pressure in the blotchy areas.

Postulated Causes of Blotchy Ripening

Bewley and White (4) ascribed the disorder to a potassium and nitrogen deficiency, particularly potassium. They also felt that climatic factors were involved since they could never completely eliminate the disorder by fertilization.

Seaton (39) observed that blotchy ripening increased when greenhouse conditions favored rapid transpiration. He demonstrated a water stress by injecting eosin dye into ripe fruit and allowing it to be drawn from the fruit up into the leaves.

White (52) postulated that blotchy ripening occurs because the blotchy areas are unable to convert starch to sugar. He demonstrated the inferior hydrolyzing powers of juice expressed from the blotchy areas of the fruit by comparing it with normal juice in test tubes containing starch solution, and testing their hydrolyzing power with iodine. Using the same technique, it was shown that green areas from "green back" fruit gave similar results. He also observed that increased sunlight had the same result on the occurrence of blotchy ripening in potassium starved plants as did applications of potassium. Noting that increased sunlight also increased the size of the crop which further depleted the supply of potassium, he postulated that blotchy ripening was not directly due to potassium deficiency, but to metabolic changes which are counteracted by light. He further noted that potassium deficiency caused an acceleration of blossoming and a prolonged ripening period which were also caused by low carbohydrates; and concluded that increased intensity and duration of sunlight increased the carbohydrate level and thereby decreased the incidence of blotchy ripening. He observed that nitrogen deficiency increased the incidence of blotchy ripening and related this to the fact that nitrogen is an essential constituent of protein, and amylase is proteinaceous.

Boyle and Wharton (5) have been successful in inducing blotchy ripening in tomatoes by inoculation with a strain of tobacco mosaic virus. They believed that late infection with this virus shocked the plant when the virus accumulated in fruits where there is a hypersensitive response on the part of the host.

Massey and Winsor (29), and Kidson and Stanton (23) have observed that blotchy fruits are characterized by low dry matter and suggested that practices which increased the dry matter content would alleviate the trouble.

Gilbert (14) has observed that blotchy ripening was most severe during damp calm weather. He suggested that this might have caused "water congestion" in the leaves and thereby initiated a suboxidation injury in the affected tissues. Closs (10) has induced blotchy ripening by reducing light intensity one to two weeks prior to fruit ripening.

Discussion of Postulated Causes of Blotchy Ripening

Since blotchy ripening is characterized by low dry matter content, it is perhaps best to discuss these postulated causes of the disorder from the standpoint of their influence on dry matter. Since carbohydrates are a large constituent of dry matter in the tomato, they will receive special attention.

A study conducted by Went (50) revealed that the sugar content of the stem and petiole of tomato remained fairly constant; but in the leaf blades it increased rapidly during the forenoon, and disappeared during the night, although it could be partially recovered in the roots. The length of the illumination period had the greatest influence on sucrose production, more of which was produced in the upper leaves than in the lower leaves. Since illumination has the greatest influence on sucrose production, it is reasonable that longer light periods might exert an inhibiting effect on blotchy ripening.

Translocation of carbohydrates from the leaves was greater at low than at high night temperatures (18) possibly because reduced respiration rendered more carbohydrates available for translocation (48). Low night temperature is said to accelerate the degradation of starch into sugars (53), and is essential for good fruit yields during winter months (48). High night temperature results in more blossom-end rot, weaker stems, and less fruit and dry matter (48). Maximum efficiency was achieved with warm days and cool nights, while a reversal of this condition resulted in the death of the plant because of its inability to fix a sufficient quantity of photosynthate during the cool day to supply the carbohydrates required for the respiration taking place during the warm night (12).

It is generally recognized that light intensity and duration, influence the carbohydrate accumulation of the plant. Porter (35) has shown that a 75 percent reduction in light intensity resulted in a 40 percent increase in stem elongation, a 50 percent decrease in the weight of fruit produced, and a 33 percent decrease in total dry matter.

Tobacco mosaic virus reduce the dry weight and carbohydrates of the tomato plant (7), and may reduce yields up to 50 percent (1). Transpiration is increased (40) and virus protein multiplies often at the expense of the plant protein production when nitrogen is deficient (3). Therefore, virus infection may help to induce blotchy ripening in fruit by decreasing the carbohydrate and protein levels, which might in turn reduce enzyme activity.

In a study of the organic components of the tomato, starch was found to decrease in the fruit from 16 percent in a 14 day old tomato to 2.5 percent in ripe fruit with the most rapid change occuring during the transition from green to red. An increase in moisture, acids, and sugars; and a decrease in solids, total nitrogen, pentosans, crude fiber, and ash occur during ripening (37).

Fruit size has been reported to have no effect on percent dry matter, or is there any difference between fruits of the first four clusters, but dry matter begins to increase with the fifth cluster (2); however, small fruits have been reported to have higher soluble solids (26). It is also reported that irrigation reduces firmness, soluble solids, and acidity (31).

The influence of mineral nutrition on carbohydrates has generally been recognized. Potassium starved plants accumulate more carbohydrates in the leaves with the dry weight decreasing from the base to the top (52). Potassium deficient plants were higher in solids, reducing sugar, and insoluble nitrogen, and the leaves were higher in starch and dextrins while the stems were lower (34). Potassium functions as a catalyst in the condensation and hydrolysis of inulin and starch (41), and has a more marked effect in increasing the total acid in the ripening fruit than any other element (24). Both nitrogen and boron are related to reducing sugar translocation (46), with sucrose moving less rapidly in plants deficient in boron (42).

PRELIMINARY INVESTIGATION

The 1958 tomato crop had a high percentage of blotchy ripened fruit. Since the disorder was quite general, climatic conditions were implicated.

The study was initiated at the close of the season with the examination of the weather records. The weather data showed that in 1958, July had 55 less hours of total sunlight, which was greater than one standard deviation (34.8) from the mean (328) for the past ten years; and that the number of heat-degree-days below 65°F (1.0) was fewer by nearly a standard deviation (15.5) of the mean (14.5) for the past ten years. This suggested the possibility that a photosynthetic stress may have been placed on the tomato plant during the relatively warm and cloudy days of July, and may have set the stage for blotchy ripening. It is difficult, however, to relate monthly weather records to blotchy ripening because the climatic conditions which may induce the disorder probably need to prevail for only a few days, and these abnormal conditions are not necessarily reflected in monthly averages.

After reviewing the literature pertaining to blotchy ripening in the tomato fruit, the data from two experiments on which blotchy tomatoes had been recorded by weight and number, for several harvests, were analyzed to find possible leads as to the cause of the disorder.

Blotchy Ripening Observations in 1958

Fireball tomatoes were evaluated from an irrigation experiment, and Fireball, Morton Hybrid, and Early hybrid varieties from another experiment.

These plants were started in the greenhouse in April and transplanted into the field on May 30. The proportion by weight and number of blotchy ripened fruit harvested from these experiments, which involved three to six thousand fruits, were recorded from several harvests.

Results

On the irrigated plots 30.4 percent, and on the non-irrigated plots, 22.9 percent of the fruit from six harvests showed blotchy ripening. The blotchy ripened fruit averaged 9 to 11 percent larger in size than non-blotchy fruit (Table 1). The amount of blotchy ripened fruit varied among harvest dates from 9.2 to 50.3 percent by number, and from 10.3 to 53.7 percent by weight.

In comparing the effect of variety on the incidence of blotchy ripening (Table 2), the Fireball shows the highest percentage at each harvest, averaging 33.0 percent; compared to 25.1 percent for Morton Hybrid and 26.9 percent for Early Hybrid. In these comparisons, the percent of blotchy ripened fruit by weight was also greater than the percent by number, since the blotchy fruit were larger than non-blotchy fruit, averaging 11 percent larger for Fireball, 2 percent for Morton Hybrid, and 5 percent for Early Hybrid. In the harvested fruit, blotchy ripening fluctuated over the season from a high value of 63.9 percent in the first harvest of Fireball to a low value of 7.3 percent for the third harvest of Morton Hybrid.

TABLE 1.--The Effect of Irrigation on the Incidence of Blotchy Ripening in Fireball Tomatoes.

	Blotchy Fruit				Relative Weight of Blotchy Fruit*	
	% by Number		% by Weight			
	Irrig.	Non-irrig.	Irrig.	Non-irrig.	Irrig.	Non-irrig.
July 30	34.5	32.2	37.3	36.6	108	114
August 15	30.9	20.9	33.7	22.4	109	107
August 19	24.9	10.4	28.0	12.2	112	117
August 22	17.7	9.2	19.8	10.3	112	112
August 29	33.0	34.1	37.7	39.2	114	115
September 5	50.3	40.0	53.7	45.3	106	113
Average	30.4	22.9	33.2	25.4	109	111

*As compared with non-blotchy fruit.

TABLE 2.--The Incidence of Blotchy Ripening on Three Varieties of Tomatoes.

	Blotchy Fruit						Relative Weight of Blotchy Fruit*		
	% by Number			% by Weight					
	F.B.	M.H.	E.H.	F.B.	M.H.	E.H.	F.B.	M.H.	E.H.
July 30	63.9	41.7	37.6	64.7	39.3	38.9	101	94	103
August 15	26.9	9.4	19.1	29.8	9.7	20.1	111	103	105
August 19	13.0	7.3	11.5	15.0	8.1	13.7	115	111	119
September 4	36.1	32.2	33.8	41.2	32.4	35.3	114	101	104
Average	33.0	25.1	26.9	36.5	25.6	28.3	111	102	105

*As compared with non-blotchy fruit.

F.B. - Fireball
M.H. - Morton Hybrid
E.H. - Early Hybrid

Discussion

On the basis of the above observations it appears that soil moisture was related to the development of blotchy ripening.

Seaton (39) concluded that excess transpiration was the cause of blotchy ripening and demonstrated the withdrawal of water from the fruit during rapid transpiration. He reasoned that blotchy ripening was caused by water being withdrawn from the fruit with the resulting collapse of the parenchyma cells adjacent to the vascular bundles.

In the light of subsequent observations concerning the blotchy ripening disorder, it is more plausible that the irrigated tomatoes experienced a greater incidence of blotchy ripening because they were lower in soluble solids. The fact that the larger fruit were more prone to blotchy ripening, and that the Fireball variety seemed to have a higher incidence than either the Morton Hybrid or Early Hybrid varieties, might also be related to low soluble solids. Moore (31) has shown that irrigation increases fruit size and lowers soluble solids, and a subsequent experiment in this study indicates that Fireball tomatoes have the lowest dry matter content in their walls of eleven varieties evaluated.

PART I. STUDIES OF SOME ENVIRONMENTAL INFLUENCES ON TOMATO GROWTH AND DEVELOPMENT WITH SPECIAL REFERENCE TO BLOTCHY RIPENING

An experiment by Seaton (39) demonstrating the withdrawal of water from the fruit, and his hypothesis that this phenomenon was related to blotchy ripening, prompted the following series of experiments, designed to induce blotchy ripening by procedures and techniques which would influence the transpiration rate of the tomato plant.

Greenhouse Experiments

An experiment was designed to test the influence of lampblack and white talc on the incidence of blotchy ripening. It was expected that the plants dusted with lampblack would absorb more heat during the day than the control plants, which would increase the vapor pressure of the water in the leaves and accelerate transpiration; and that during the night, they would radiate more heat and stimulate the build up of turgor pressure in the leaves. Under these circumstances, a diurnal fluctuation of water in the plants as well as in the fruits would result, and might be conducive to blotchy ripening. The talc treated plants were expected to remain cooler than the controls during the day, resulting in less water being transpired, and by radiating less heat at night, the fluctuations in turgor pressure were not expected to be as great. These treatments did not induce blotchy ripening.

A second experiment was conducted to determine the influence of continuous shading and shading up to green fruit maturity, interacted with talc, on the transpiration rate and the incidence of blotchy ripening.

It had been observed by Kidson and Stanton (22) that low light early in the season was associated with blotchy ripening, and the object of this experiment was to reproduce these conditions by reducing light with shade early in the season. Talc was used to determine its influence on the transpiration rate and on the incidence of blotchy ripening. No blotchy ripened fruit appeared in this experiment; however, a significant reduction of transpiration by complete shading of the plants was observed.

In conjunction with the previous experiment, the foliage of groups of Fireball plants were sprayed with various materials to determine their effects on the transpiration rate. The soil of the containers in which the plants were grown was covered with white plastic to retard surface evaporation and the transpiration losses were recorded. A hydrated lime slurry was the most effective treatment for accelerating transpiration, while a wax emulsion[1] was the most effective for retarding water loss. The deepest red color was observed with the fruit from plants treated with lime slurry, indicating that poor color was not associated with rapid transpiration. Blotchy ripening did not occur.

In still another experiment the effect of air temperature interacted with Wilt-Pruf[2] on blotchy ripening was determined. Although Wilt-Pruf has shown

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[1] Prepared by Dr. E. J. Miller of the Agricultural Chemistry Department of Michigan State University.

[2] An anti-transpirant for nursery stock, marketed by Nursery Specialty Products, Inc., Croton Falls, New York.

apparent beneficial results on fruit yield in a field experiment, it was ineffective in increasing yield or influencing blotchy ripening in this greenhouse experiment.

Field Investigation - 1959

The experiment was designed to determine the effects of fertilizer, hardening, planting date, and materials that influence transpiration, on the development of blotchy ripening of Fireball tomato fruit. Seed was sown in April and May and the tomatoes were transplanted into the field in May and June. Hardening was effected with cold temperature and the withholding of water. Two fertility levels were established, a high level of 800 pounds per acre of 12-12-12 and in a low fertility level of 150 pounds per acre of 12-12-12. The transpirational materials were applied to the foliage when the first fruit reached the mature green stage.

The tomato yields in this experiment were low, and less than one percent of the fruit developed blotchy ripening. Hardening depressed the early yields, while late planting and high fertility increased yields. The transpirant materials had no effect either on the yield or the incidence of blotchy ripening.

The later planting produced more fruit because of warmer weather and a better distribution of moisture. Hardening has been shown to have an adverse effect upon tomato plants and yield by Brasher (6) and Cassers (9). These plants were not vigorous and set only a light crop of fruit.

Another experiment using Fireball plants was designed to determine the influence of light and reduced air movement on the occurrence of blotchy ripening. On June 17, four wind barriers were constructed from a film of white plastic 18 inches wide, to fence in groups of nine plants in an 18 x 4 foot area. Single thicknesses of cheese cloth were also erected on wire forms over four groups of nine plants. After the first picking on July 20, two wind barriers and two cheese cloth coverings were removed to study the effect of sheltered plants suddenly being exposed to normal air movement and sunlight.

The continuously shaded and sheltered plants did not produce as well as the plants from which the shading and sheltering were removed (Table 3). Plants contained within the continuous wind barrier became hard and showed some marginal leaf burn, possibly from a high temperature, which was augmented by the reflective surface of the white plastic film. Dexter (12) found that potatoes which were protected from the wind became severely dessicated and unproductive. Light reduction more than wind reduction figured in the apparent reduction of the yield on the continuous shaded plants.

Eight materials were applied as foliar applications to Fireball tomato plants in a supplementary experiment. Plants sprayed with Johnson W5709[1] produced 2. 5 percent blotchy ripened fruit, while two Bordeaux sprays produced no blotchy fruit, but the differences were not significant.

The effect of pruning on the incidence of blotchy ripening was explored in an experiment using Fireball tomato plants. Four pruning treatments were

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[1] Experimental wax produced by the Johnson Wax Company.

TABLE 3.--The Influence of Wind Barrier and Shading on Fireball Tomatoes During 1959.

Treatment	Number* Normal	Number* Blotchy	Yield (Lbs. per Plant)
Shade			
Continuous	468	9	5.5
Part season	581	9	7.0
Wind break			
Continuous	392	6	5.3
Part season	448	10	5.6
Control	314	2	4.0
	Treatment: N. S.		

*from 18 plants.

TABLE 4.--The Influence of Pruning on Fireball Tomatoes During 1959.

Treatment	Number* Normal	Number* Blotchy	Yield (Lbs. per Plant)
Second cluster removed	536	3	7.1
First cluster removed	476	1	6.1
Roots pruned	444	1	5.6
Foliage removed	346	0	3.5
Control	436	0	5.3
	Treatment: N. S.		

*from 18 plants.

performed on two replications of nine plants each. These treatments consisted of removing either the first cluster, the second cluster, root pruning by cutting a circle around each plant four inches fromthe stem, or exposure of the fruit to the sun by removing the leaves from over the fruit. The number of fruit per plant increased by 23 percent by removing the second fruit cluster and decreased by 21 percent by removing the leaves shading the fruit. However, differences were not significant (Table 4); and the blotchy ripened fruits encountered were of no consequence.

In another experiment, green Fireball fruits were wrapped in aluminum foil and black plastic film while still attached to the plant, in an effort to induce blotchy ripening. The fruits wrapped with aluminum foil ripened normally, as did most of the fruits wrapped in black plastic; however, the fruits beneath the black plastic were often injured by the sun. Lorenz and Knott (25) have observed this phenomenon in fruit exposed to the sun and have shown that it is due to the distillation of water out of the cells of the exposed side.

Field Investigations - 1960

Morton Hybrid tomatoes sown on April 5, were transplanted into the field on May 28 from four-inch veneer bands. The treatments consisted of three plant spacings 6 x 7, 5 1/3 x 3, and 3 1/2 x 2, which allocated 42, 15.75, and 7 square feet per plant, respectively, with both a high and a low fertilizer level. Rotted manure at the rate of 80 tons per acre, and 10-20-20 at the rate of 600 pounds per acre at the high level, and 45 percent superphosphate at the rate of 300 pounds per acre at the low level were used. Within each plant spacing of both replicates, 12 plants were designated as a plot from which records were taken. The first six clusters on the record plants were tagged as they bloomed, and their fruit was harvested and graded at maturity. All of the 144 record plants were assayed with Nicotiana tobaccum, variety xanthi, for the presence of tobacco mosaic virus prior to the first harvest, but no appreciable mosaic infection was detected.

Results

As is indicated in Table 5A, neither fertility nor spacing had an influence on fruit size, although when total yields are considered, there was a tendency for larger fruit to be produced on plants at the wide spacings.

In Table 5B, plant spacing appeared to influence the yield of tomatoes, with close spacing producing the greatest weight per unit area for both early and total yields. Fertility did not influence the early yield, but its influence was quite apparent in the total yield, especially on the yields at the close spacing. From data relating to weight of fruit per plant, it is apparent that the widely spaced plants yielded more fruit, and that their yield was not curtailed by the low fertility, as was the yield of the more closely spaced plants.

Table 5C indicates that plants at the close spacing produced 80 percent more vine growth at the high than at the low level of fertility, while plants at the wide spacing produced only 20 percent more. The heaviest vine weight per unit area was produced at close spacing with high fertility. When the ratio of

TABLE 5. --The Effect of Plant Spacing and High and Low Soil Fertility on Tomato Growth and Fruit Development During 1960.

A. Effect on Fruit Size (expressed in grams per fruit)

Spacing	Early Fruit Size			Seasonal Fruit Size		
	High Fert.	Low Fert.	Avg.	High Fert.	Low Fert.	Avg.
42 sq. ft.	165	166	166	186	204	195
16 sq. ft.	173	159	166	172	171	172
7 sq. ft.	159	145	152	164	158	161
Average	166	157		174	178	

Treatment: N. S.

B. Effect on Fruit Weight (tons per acre)

Spacing	Early Yield			Total Yield			Total Lbs./Plant	
	High F.	Low F.	Avg.	High F.	Low F.	Avg.	High F.	Low F.
42 sq. ft.	1.94	1.35	1.65	32.0	28.2	30.1	61.7	54.1
16 sq. ft.	3.92	4.08	4.00	39.2	29.8	34.5	28.4	21.5
7 sq. ft.	5.64	6.62	6.13	48.8	26.8	37.8	15.6	8.6
Average	3.83	4.02		40.0	28.3			

L. S. D.	5%	1%
spacing	2.28	3.68
fertility	-	-

L. S. D.	5%
spacing	-
fertility	13.1

C. Effect on Vine Weight (tons per acre) and Fruit/Vine Ratios

Spacing	Total Vine Weight			Avg.	Fruit/Vine Ratio	
	High Fert.	Low Fert.	Avg.	(Lb/Plant)	High Fert.	Low Fert.
42 sq. ft.	5.38	4.47	4.93	10.35	5.95	6.31
16 sq. ft.	7.02	5.20	6.11	5.06	5.58	5.74
7 sq. ft.	9.15	5.16	7.16	2.94	5.33	5.19
Average	7.18	4.94				

Treatment: N. S.

D. Effect on Blotchy Ripened Fruit

Spacing	Total Yield (tons per acre)	
	High Fert.	Low Fert.
42 sq. ft.	.037	.024
16 sq. ft.	.035	.052
7 sq. ft.	.000	.317

fruit to vine is compared, it is observed that the plants at the close spacing produced the heaviest vine in relation to the fruit produced.

Table 5D indicated that no blotchy ripening was produced on closely spaced plants at the high fertility level, while the largest quantity was produced on plants at the low level of fertility.

In Table 6 the production from the first six clusters of plants at the three spacings and the two levels of fertility is indicated. It is apparent that the plant spacing of seven square feet resulted in the highest fruit production, on an area basis, from the first six clusters, and that there was a general yield decline in the first through the sixth cluster at all spacings. The lack of fertility seemed to stimulate production on the early clusters, since yield was higher at the low than at the high fertility level for all clusters except the fourth.

The fruit weight and number which were harvested from the first six clusters are recorded in Table 7. The values represent the average of two replications of 12 plants each. These data show that a reduction in area was attended by an approximate 30 percent reduction in yield. Using the first cluster as an example, 50 fruits weighing 18.6 pounds were produced at 42 square feet, 35 fruits weighing 13.1 pounds were produced at 16 square feet, and 28 fruits weighing 13.1 pounds were produced at 16 square feet, and 28 fruits weighing 9.5 pounds were produced at 7 square feet. However, since the reduction in yield was proportionally less than the reduction in area, the 7 square foot spacing produced the greatest yield on an area basis (Table 6).

TABLE 6. --The Effect of Plant Spacing at High and Low Fertility on the Production of Fruit from the First Six Clusters of Morton Hybrid Tomatoes - 1960 (Expressed in Tons per Acre).

Spacing	Cluster Location 1	2	3	4	5	6	Avg.	Total
				High Fertility				
42 sq. ft.	.81	.76	.63	.63	.59	.50	.65	3.92
16 sq. ft.	1.51	1.27	.97	1.24	.44	.42	.98	5.85
7 sq. ft.	2.46	3.05	1.53	2.05	1.22	1.27	1.93	11.58
Average	1.59	1.69	1.04	1.31	.75	.73	1.19	7.12
				Low Fertility				
42 sq. ft.	.81	.70	.50	.68	.50	.48	.61	3.67
16 sq. ft.	2.07	2.20	1.14	1.11	1.11	1.07	1.45	8.70
7 sq. ft.	2.99	2.64	1.66	1.48	1.61	1.24	1.94	11.62
Average	1.96	1.85	1.10	1.09	1.07	.93	1.33	8.00
				Average				
42 sq. ft.	.81	.73	.57	.66	.55	.49	.64	3.81
16 sq. ft.	1.79	1.74	1.06	1.18	.39	.75	1.22	7.28
7 sq. ft.	2.73	2.85	1.60	1.77	1.42	1.26	1.94	11.63
Average	1.78	1.77	1.08	1.18	.92	.83	1.27	7.56

L. S. D.	5%	1%
Spacing	.17	.25
Fertility	.13	-
Cluster	.41	.59
S x F	*	-
S x C	*	-

TABLE 7.--The Effect of Plant Spacing at High and Low Fertility on the Production of Fruit from the First Six Clusters of Morton Hybrid Tomatoes (Expressed in Number and Pounds of Fruit per 12 Plants)*.

Spacing		Cluster Location 1	2	3	4	5	6	Avg.	Total
					High Fertility				
42 sq. ft.	No.	50	50	32	32	24	21	35	209
6 x 7	Wt.	18.6	17.9	14.5	14.9	13.5	11.6	15.1	90.8
16 sq. ft.	No.	35	29	20	23	9	8	21	124
5 1/3 x 3	Wt.	13.1	10.9	8.3	10.8	3.9	3.5	8.4	50.4
7 sq. ft.	No.	28	34	19	22	10	4	16	117
3 x 2	Wt.	9.5	11.8	5.9	7.9	4.7	4.9	7.4	44.7
Average	No.	38	38	24	26	14	11	24	150
	Wt.	14.7	13.5	9.6	11.2	7.3	6.7	10.3	62.0
					Low Fertility				
42 sq. ft.	No.	53	41	25	32	22	19	32	192
6 x 7	Wt.	18.7	16.0	11.6	15.8	11.5	10.9	14.1	84.5
16 sq. ft.	No.	49	54	26	24	19	17	32	189
5 1/3 x 3	Wt.	18.0	19.0	9.8	9.7	9.7	9.2	12.6	75.9
7 sq. ft.	No.	36	42	18	15	15	4	22	130
3 x 2	Wt.	11.5	10.2	6.4	5.7	6.3	4.8	7.5	44.8
Average	No.	46	46	23	24	19	13	29	170
	Wt.	16.1	15.1	9.3	10.4	9.2	8.3	11.4	68.4
					Average Values				
42 sq. ft.	No.	51	46	29	32	23	20	34	201
6 x 7	Wt.	18.6	16.9	13.0	15.3	12.5	11.3	14.6	87.6
16 sq. ft.	No.	42	42	23	23	14	13	26	157
5 1/3 x 3	Wt.	15.5	15.0	9.0	10.3	6.8	6.4	10.5	62.9
7 sq. ft.	No.	32	38	18	18	13	14	21	123
3 x 2	Wt.	10.5	11.0	6.2	6.8	5.5	5.6	7.5	44.7
Average	No.	42	42	23	24	17	16	27	160
	Wt.	14.9	14.3	9.4	10.8	8.3	7.8	10.9	65.1

*Average of two replications.

Discussion

Other workers have shown that close spacing of tomatoes with proper fertilization and irrigation increases yield (31, 36, 38, 49), improves color (31), and decreases fruit size (36, 49). The purpose of this experiment, however, was to determine the effects of spacing on blotchy ripening. Since less than 0.5 percent of the fruit developed blotchy ripening, spacing in this experiment did not influence the disorder.

Fruit size, which appeared to be associated with blotchy ripening in the field experiment of 1958, did not stand out as a factor in this experiment, nor is there any apparent connection with yield, vine weight, or fruit/vine ratio. The only apparent influence on blotchy ripening is the spacing x fertility interaction (Table 5D). This could mean that the smaller, closely spaced plants were able to support the fruit which they bore with less stress on the plant than the larger, more widely spaced plants, when they were both well supplied with fertilizer. However, at the low fertility level, the competition became greater among the closer spaced plants, and the stress which resulted induced the disorder.

It should be noted that other research has indicated that neither high nor low levels of fertility cause the disorder (5, 46). However, in this experiment with close spacing the initial fertility was probably depleted rapidly during the season, thus making it difficult for the plants to mature the fruit which had set.

The Effect of Tobacco Mosaic Virus on the Incidence of Blotchy Ripening

Boyle and Wharton (5) reported that blotchy ripening was caused by tobacco mosaic virus. Although this belief was not generally held, at the close of the 1959 season and during 1960, leaf and fruit samples were collected from field plants, some of which had produced blotchy ripened fruit and others which had not. These samples were assayed for the presence of tobacco mosaic virus.

The blotchy ripened experiment in 1960 season included a *Nicotiana tobaccum xanthi* assay plant for each tomato plant. The plan was to assay each tomato plant prior to harvesting to determine if the pattern of blotchy ripening and tobacco mosaic virus infection coincided.

Results and Discussion

Table 8 summarizes the results of the assay work which was performed during 1959 and 1960. These data were not taken in conformity with any sampling procedure, instead, these assays were made to determine whether a particular fruit or leaf had tobacco mosaic virus. The totals, however, indicate that there was a higher incidence of tobacco mosaic virus among tomato plants which had produced blotchy ripened fruit than among tomato plants which had not.

If it may be assumed that blotchy ripening results from a shortage of soluble solids in the plant, it is reasonable to expect that the build-up of tobacco mosaic virus in these plants might further reduce the supply of carbohydrates available to the fruits. On this basis, it seems reasonable that plants affected with tobacco mosaic virus would produce more blotchy ripened fruit.

TABLE 8.--Summary of the Assays Conducted on *Nicotiana tobaccum xanthi* for the Presence of Tobacco Mosaic Virus in Tomato Plants and Fruits.

Source	Blotchy Tomatoes				Normal Tomatoes			
	In Leaf		In Fruit		In Leaf		In Fruit	
	+	-	+	-	+	-	+	-
1959								
B. R. Exp.	13	25	17	11	2	1	4	8
Others	22	1	67	5	-	-	-	-
1960								
B. R. Exp.	-	-	-	-	77	136	-	-
Others	-	-	37	25	-	-	2	5
Total	35	26	1 21	41	79	137	6	13

	Blotchy		Normal	
	+	-	+	-
Total	156	67	85	150

PART II. COMPOSITION VARIATIONS IN THE TOMATO WITH SPECIAL REFERENCE TO BLOTCHY RIPENING

In this study are reported some mineral and organic composition values from normal tomato foliage, and from fruit with and without blotchy ripening.

General Methods

The mineral composition was determined from tissue which had been oven-dried at 68° C and passed through a Wiley mill with a 20 mesh screen. Total nitrogen was determined by the Kjeldahl-Gunning method, and potassium on a Beckman model B flame spectrophotometer. Phosphosus, calcium, magnesium, iron, manganese, zinc, boron, copper and molybdenum were determined from a quarter gram of dried sample with a "Quantograph" which is a direct reading photoelectric spectrometer manufactured by the Applied Research Laboratories of Glendale, California (20).

Reducing sugar and total acidity were determined from the alcohol solution in which tomato plant and fruit parts had been preserved. Fifty grams of fresh material were placed in four-ounce bottles with 83 ml. of a mixture of 14 ml. of water and 69 ml. of 95 percent ethanol. The bottles were then brought to a boil and capped. The reducing sugar was determined from an aliquot of the alcohol preservative by the Lane-Eynon method (30). It was found that the same values were obtained from an analysis of this preservative as from aliquots of the filtrate after the sample had been pureed, filtered and cleared.

Total acidity was determined by titrating a 10 milliliter sample of the extract in duplicate against a 0.1 normal sodium hydroxide solution. The results were expressed in milliequivalents of hydrogen per 100 grams of fruit sample on both the fresh and dry weight basis. Soluble solids were measured from the juice of the tomato parts with a hand refractometer.

Seasonal Fluctuations in Mineral Nutrient Composition of Tomato Fruits and Leaves

Changes in mineral composition in tomato leaves and fruit were determined during the season using Morton Hybrid tomatoes which were field set on June 1, and yielded at the rate of 30 tons per acre. Beginning June 29, discs from the leaf above and below the first fruit cluster and an average sized fruit were sampled. This procedure resulted in composite samples of 200 leaf discs and 10 fruits from each of three replications of 10 plants. The last two leaf samples were taken from the leaves above and below the second cluster, and the last two fruit samples were also taken from the second cluster. Whole fruits were analyzed on the first two harvest dates, and wedges of fruit were analyzed at later dates.

Results

The fresh and dry weight values and the content of 11 elements found in leaf discs appear in Table 9. The fresh weight is low at both the beginning and end of the season, while the dry weight content is highest at the second harvest. The dry weight percentages do not fluctuate in the same manner as either the dry weight or fresh weight, indicating changes in either carbohydrate or water concentration in the leaves.

TABLE 9.--Fluctuations in Seasonal Leaf Mineral Composition of Morton Hybrid Tomato Leaves (Expressed in terms of content per 100 2 cm leaf discs from averages of three samples).

	Harvest Date							L.S.D.	
	June 29	July 8	July 19	July 29	Aug. 10	Aug. 23	Sept. 7	5%	1%
Fresh weight (grams)	12.1	14.1	15.8	15.0	15.1	13.7	12.1		
Dry weight (grams)	1.30	1.52	1.34	1.16	1.19	1.06	1.27		
H_2O (grams)	10.8	12.58	14.46	13.84	13.91	12.64	10.83		
Percent dry weight	10.7	10.8	8.5	7.7	7.9	7.7	10.5	.5	.8
Element	In Milligrams								
N	53.7	47.3	29.7	21.1	19.8	21.5	26.9	3.4	5.1
P	4.41	4.95	4.64	2.97	2.82	3.42	4.36	.49	.61
K	39.7	43.3	31.9	21.7	16.3	24.5	49.1	9.3	13.9
Ca	74	112	136	134	137	91	72	19	28
Mg	14.4	14.8	15.9	16.9	18.1	10.7	6.0	2.3	3.5
	In Micro-milligrams								
Mn	163	175	209	169	238	302	718	65	98
Fe	389	755	895	403	645	441	411	219	-
Cu	451	231	65	44	34	46	65	244	-
B	56	58	57	57	58	44	63	3	-
Zn	256	324	156	119	54	159	240	-	-
Mo	28	36	43	41	43	30	27	6	10

There is an increase in all elements except nitrogen and copper between the first and second sampling, as the leaves reach maturity. From the second to the fifth harvest, there is a decline in nitrogen, phosphorus, potassium, copper, and zinc, and an increase in calcium and magnesium. However, the last two samples show an increase in nitrogen, phosphorus, potassium, manganese, copper, boron, and zinc, and a decrease in calcium, magnesium, iron, and molybdenum.

The data on the dry weight basis is expressed in Table 10. In comparing the data in Table 10 with that in Table 9, it is noted that the values for the second harvest date are all relatively lower than those in Table 9. However, in general, the same trends are noted in both tables.

In Table 11, the increase in the fresh and dry weight and the variation in the mineral concentration of tomato fruits are indicated. All elements continued to move into the fruit up to the fifth harvest, even though the percentage of composition declines in some cases. However, the concentrations of nitrogen, phosphorus, copper, and zinc are lower after the fifth harvest. The fresh and dry weights reached their peak at the last harvest; however, the dry weight percentage reached its peak at the second harvest date.

While there are significant differences between harvest dates for six of the eleven elements, only two elements indicate a seasonal trend; nitrogen decreases throughout the season, and manganese increases.

TABLE 10.--Fluctuations in Leaf Composition of Morton Hybrid Tomato Plants During the Growing Season (Expressed in terms of dry weight from averages of three samples).

	Harvest Date						
	June 29	July 8	July 19	July 29	Aug. 10	Aug. 23	Sept. 7
Percent dry weight	10.7	10.8	8.5	7.7	7.9	7.7	10.5
	In Percent Dry Weight						
Element							
N	4.2	3.1	2.2	1.8	1.7	2.0	2.1
P	.34	.33	.28	.28	.24	.32	.35
K	3.1	2.9	2.3	1.9	1.4	2.3	3.9
Ca	5.7	7.4	9.9	11.5	11.2	8.5	6.4
Mg	1.12	.98	1.16	1.45	1.51	1.00	.48
	In ppm Dry Weight						
Mn	126	115	155	149	199	287	569
Fe	301	498	665	351	539	413	326
Cu	352	150	48	38	28	43	52
B	43	38	48	47	48	41	50
Zn	200	211	114	103	45	151	187
Mo	21	23	32	36	36	28	21

TABLE 11.--Fluctuations in Seasonal Fruit Mineral Composition of Morton Hybrid Tomatoes (Expressed in terms of average concentration in three 10-fruit samples).

	Harvest Date							L. S. D.	
	June 29	July 8	July 19	July 29	Aug. 10	Aug. 23	Sept. 7	5%	1%
Fresh wt. grams	7.7	27.5	91.5	139	173	189	278		
Dry wt. grams	.49	1.82	5.67	8.06	8.13	10.02	15.85		
Percent dry weight	6.4	6.6	6.2	5.8	4.7	5.3	5.7	.3	.5
	Expressed in Percent Dry Weight								
Element									
N	3.2	3.0	2.7	2.4	2.8	1.9	1.8	.3	.4
P	.64	.69	.79	.71	.75	.52	.42	.08	.12
K	5.0	4.5	4.9	4.5	5.0	4.6	4.2	.4	-
Ca	.26	.21	.20	.23	.27	.24	.19	-	-
Mg	.22	.21	.22	.17	.23	.19	.19	-	-
	Expressed in ppm Dry Weight								
Mn	20.7	24.0	25.3	25.3	26.7	26.7	29.3	-	-
Fe	60.7	85.3	69.3	86.0	77.3	65.0	66.0	-	-
Cu	12.3	11.7	8.5	9.2	8.7	3.3	2.7	3.3	5.0
B	22.7	20.3	23.0	20.7	22.0	17.3	16.7	2.5	3.7
Zn	12.0	32.0	27.3	23.3	26.7	21.3	16.0	6.0	9.0
Mo	1.97	1.53	2.06	1.47	2.23	2.20	1.63	-	-
	Fruit Color								
	green	green	green	green	pink	red	red		

Discussion

From the determinations made, it is apparent that the more mobile elements (nitrogen, potassium, phosphorus, coppēr and zinc) move into the leaf giving it a high mineral content at about the time when it is the most active, only to move out of the leaf after its metabolic rate decreases. Other elements continued to accumulate until senescence occurred (calcium and magnesium). Still other elements are unaffected by the decline of the leaf's metabolism and maintain a fairly constant concentration from the time of leaf maturity to senescence (manganese, iron, boron, and molybdenum).

In proportional differences between the values in Tables 9 and 10 for the second harvest, illustrate the differences which arise when nutritional results are presented on different bases. Results based on percent dry weight of the leaves are subject to variations resulting from the content of carbohydrates in the leaf. Carbohydrates have the effect of decreasing the percentage of mineral composition on the dry weight basis when they are present in large amounts, and increasing the percentage of mineral composition when they are lacking. Since the moisture content of leaves fluctuates more than carbohydrate content, results expressed on the fresh weight basis are also unsatisfactory. In Table 9 the mineral composition of the leaves are expressed on the basis of content per 100 two-centimeter leaf discs. These data probably reflect the mineral fluctuations of the leaf tissue with the greatest accuracy, although it should be noted that leaves become thicker as they mature so that a leaf disc from a mature leaf actually has more volume than a disc from an immature leaf.

A soil test taken at the close of the season indicated eight pounds of available nitrogen and 33 pounds of available phosphorus per acre. This may account for the failure of nitrogen and phosphorus to keep pace with the growth of the fruit (Table 11). It is possible that copper and zinc and also phosphorus may accumulate mainly in the seed, and after the seeds were formed, these elements ceased to enter the fruit. The fruit from the second cluster which was taken as the sixth and seventh samples, may never have been as high in those elements which sharply decreased after the fifth sample, as the fruit from the first cluster, which was used in the first five samples.

Composition of Wall Tissues of Tomato Fruit

Blotchy ripening most frequently appears on the shoulders and on the mid-section of ripe fruit, and on fruit from lower clusters of heavily bearing plants. It has rarely been detected on the blossom-end of the fruit and only infrequently appears on fruits from upper clusters.

To ascertain any differences in composition that might exist between different areas of a fruit, the walls of normal Morton Hybrid tomato fruits were sectioned into three areas: stem-end, mid-section, and blossom-end. Mineral composition was determined on dried tissue and reducing sugars and total acidity were determined from replicate 50 gram, ethanol preserved samples. The soluble solids of the same areas were taken at the time of sampling.

It was observed that the blotchy ripening disorder more frequently appeared on tomato wall areas between rather than over the septa. Reducing sugar and total acidity were determined on normal tomato wall areas between the septa and from the wall over the septa.

Determinations were also made of reducing sugars and total acidity between normal green and ripe fruit, and among five fruit parts (septa, placenta; and wall tissue from the stem-end, mid-section, and blossom-end).

Results

The mineral and organic composition values for the stem-end, mid-section, and blossom-end wall areas of the fruit of upper and lower clusters are recorded in Table 12. Statistically significant differences are observed for phosphorus, manganese, iron, boron, and zinc; and also for reducing sugar, total acidity and soluble solids.

Phosphorus accumulated to a greater extent in the walls of the lower fruit, especially in the mid-section and the blossom-end. Manganese, on the other hand, was quite uniformly distributed in the fruit walls, but accumulated to a greater extent in walls of fruit from the upper clusters. Nearly twice as much iron was found in the upper fruit as in the lower fruit walls, and within the individual fruits there was a gradation among the three areas with the blossom-end being highest. Boron and zinc were found quite uniformly in the walls of fruit from the lower and upper clusters.

Reducing sugars were lowest in fruit walls from the lower clusters especially in the blossom-end region, and total acidity was lowest in the stem-end wall region. The soluble solids of ripe fruit were highest in the walls of the blossom-end of fruits from the upper clusters, and generally higher than in green fruit.

Table 13 indicates that the reducing sugars were higher in ripe than in green fruits. The walls of the stem-end and blossom-end were equal in reducing sugar, whereas the soluble solids were considerably higher in the blossom-end (Table 12). The placenta was significantly lower in reducing sugars than any other part of the fruit.

Green fruits were higher in total acids than ripe fruits especially in the placenta. All the fruit parts vary in acidity with the placenta having by far the highest content and the stem-end wall area the lowest. The interactions between color and part were significant indicating a drop in placental acidity as the fruit ripened.

When the fruit wall areas between the septa are compared with the wall over the septa, Table 13, it is noted that there is a significant difference in reducing sugar between areas, with the mid-section being the lowest. While there was no statistical difference between the wall over the septa and the wall between the septa, the averages of 2. 17 percent for the septa walls and 1. 97 percent for the wall between the septa suggest that there is a tendency for the wall over the septa to be higher in reducing sugars. The blossom-end wall also appears higher in both reducing sugar and total acidity.

Discussion

As previously stated, blotchy ripening commonly occurs between the septa, on ripe fruit, and from lower clusters in the areas of the stem-end and

TABLE 12.--Composition of Wall Sections of Morton Hybrid Fruit, Produced on Upper and Lower Fruiting Clusters.

	Stem-end		Mid-section		Blossom-end		L.S.D.	
	Upper	Lower	Upper	Lower	Upper	Lower	5%	1%
			Expressed in % Dry Weight					
D.W.	5.4[a]	5.1	5.6	5.2	5.3	5.5	-	-
N	1.5	1.7	1.7	1.9	2.1	2.2	-	-
P	.22	.27	.31	.40	.35	.43	.03	.06
K	3.1	4.9	4.4	5.0	4.7	5.1	-	-
Ca	.29	.22	.23	.22	.16	.16	-	-
Mg	.20	.16	.21	.19	.20	.19	-	-
			Expressed in ppm Dry Weight					
Mn	26	22	26	18	26	18	5	-
Fe	100	62	97	48	155	87	30	50
Cu	12	12	14	13	13	13	-	-
B	17	17	19	20	21	22	2	-
Zn	28	29	42	38	40	40	8	-
Mo	2.8	1.0	.6	1.8	.9	1.2	-	-
			Expressed in % Fresh Weight					
Red. Sugar	4.0	3.5	4.0	3.1	3.1	2.4	.6	-
			Expressed in meq. of H per 100 grams fresh sample					
T. Acidity	3.2	3.4	4.2	3.7	4.0	4.7	0.8	-
			Expressed in % Fresh Weight					
Soluble solids							Avg.	
Ripe	4.7[b]	4.4	5.2	4.8	5.8	5.6	5.1	
Green	4.5	4.7	5.0	4.5	4.9	5.1	4.8	
Average	4.6	4.6	5.1	4.7	5.4	5.4		
	4.6		4.9		5.4			

L.S.D.	5%
Color	-
Area	.4

[a]Average of two samples.

[b]Average of nine samples.

TABLE 13.--Reducing Sugar and Total Acidity Content of Morton Hybrid Tomato Fruit Parts.

	Reducing Sugar[a]			Total Acidity[b]		
	Green	Ripe	Avg.	Green	Ripe	Avg.
S. E.[c]	3.7[d]	4.0	3.9	4.2	2.9	3.7
M. S.	3.3	3.6	3.5	4.7	3.4	4.2
B. E.	3.3	4.0	3.7	6.1	4.2	5.3
Septa	2.9	3.2	3.1	7.4	5.8	6.6
Placenta	2.1	2.4	2.3	16.8	10.3	13.7
Average	3.1	3.4		7.1	4.7	
L. S. D.		5%	1%	5%	1%	
Maturity		-	-	.8	-	
Part		.8	1.5	.5	1.1	
	Wall Area			Wall Area		
	Over Septa	Between Septa	Avg.	Over Septa	Between Septa	Avg.
S. E.	2.17	1.88	2.03	3.6	3.7	3.7
M. S.	1.96	1.76	1.86	3.6	3.7	3.7
B. E.	2.39	2.28	2.34	3.8	4.1	4.0
Average	2.17	1.97		3.7	3.8	
L. S. D.		5%	1%	5%	1%	
Septa		-	-	-	-	
Part		.21	-	-	-	

[a]Values based on percent fresh weight.

[b]Values based on meq. of hydrogen per 100 grams of fresh sample.

[c]Exterior fruit wall at: S. E. - stem-end; M. S. - mid-section; B. E. - blossom-end; and placenta - placenta.

[d]Average of two samples.

mid-section. In relating the data of Tables 12 and 13 to the occurrence of blotchy ripening in these locations, it is observed that these areas are lower in iron, reducing sugars, and soluble solids. It would appear that a low concentration in either iron, reducing sugar, or soluble solids may be related to the occurrence of blotchy ripening. However, this is the only experiment in which iron has been implicated, and reducing sugars are not consistently lowest in the stem-end and mid-section. It might, therefore, be postulated that the soluble solids are more closely related to the occurrence of blotchy ripening than either iron or reducing sugar concentrations.

Varietal Variation in the Mineral Composition of Tomato Fruit Walls

This experiment was designed to determine if the tomato varieties which may manifest a high incidence of blotchy ripening, such as Fireball, are inherently different in the dry matter and mineral composition of their fruit walls from varieties less susceptible to the disorder.

For this analysis, four replications of the fruit walls from eleven varieties of tomatoes were evaluated for dry weight and mineral element content during the month of September.

Results

The eleven varieties are listed in order of the percent dry weight, with Fireball the lowest at 3.8 percent and Red Cherry the highest at 7.3 percent, Table 14. On the dry weight basis, Fireball has the highest concentration of all elements except copper, boron, and molybdenum, while Red Cherry is only highest in copper, and relatively low or the lowest in all other elements.

TABLE 14.--Mineral Composition of the Walls of Eleven Varieties of Tomato Fruit.

	Percent of Dry Weight					
Variety	D. W.	N	K	P	Ca	Mg
Fireball	3.8	2.5	5.3	.38	.35	.27
Glamour	4.5	1.6	5.0	.38	.24	.21
Big Early Hybrid	4.7	1.8	4.7	.31	.25	.18
Roma	5.0	1.7	4.2	.40	.22	.20
Morton Hybrid	5.1	1.5	3.9	.35	.31	.18
Early Hybrid	5.5	1.3	3.8	.28	.23	.16
Indian River	5.6	1.4	4.2	.40	.23	.17
Yellow Pear	6.3	1.3	3.5	.38	.14	.16
Red Pear	6.3	1.4	3.7	.34	.23	.17
Penn-Orange	6.4	1.3	3.3	.30	.18	.19
Red Cherry	7.3	0.8	3.8	.23	.28	.12
L.S.D.						
5%	.5	.2	.4	.07	.06	.02
1%	.8	.3	.5	.10	.09	.03
	Parts per million, Dry Weight Basis					
	Mn	Fe	Cu	B	Zn	Mo
Fireball	30	112	16	19	37	2.3
Glamour	20	106	11	19	26	1.8
Big Early Hybrid	20	68	7	14	29	1.9
Roma	22	67	15	16	27	2.7
Morton Hybrid	25	78	11	20	26	3.3
Early Hybrid	23	67	12	16	27	1.7
Indian River	19	81	11	13	27	2.2
Yellow Pear	19	58	10	15	24	0.7
Red Pear	23	65	15	17	29	2.0
Penn-Orange	19	47	8	13	22	1.2
Red Cherry	27	88	20	19	26	1.7
L.S.D.						
5%	5	20	3	4	5	1.1
1%	7	28	5	6	7	-

On the basis of fresh weight, Table 15, mineral fruit wall contents are essentially reversed with Fireball having a lower concentration of many elements, and Red Cherry exhibiting the highest concentration of potassium, calcium, manganese, iron, copper, boron, and zinc. On the fresh weight basis, the concentration of phosphorus and molybdenum do not show significant variation among the varieties.

Discussion

There is an apparent relationship between the dry matter content of certain tomato varieties and their tendency toward developing blotchy ripened fruit. Yellow pear, Red pear, and Red Cherry tomatoes did not develop blotchy fruit. However, among the red, normal sized varieties (Fireball, Glamour, Big Early, Morton Hybrid, Early Hybrid, and Indian River) there is little doubt that under climatic conditions favorable to the induction of blotchy ripening, Fireball will develop the highest incidence, and fairly good agreement that Indian River will show the lowest incidence of the disorder.

A deficiency of potassium on the fresh weight basis may also favor the occurrence of blotchy ripening, since the varieties on which blotchy ripening is quite common (Fireball, Morton Hybrid, and Early Hybrid) all have significantly less potassium than Indian River, a variety which seldom displays blotchy ripening.

When comparing the mineral composition of tissues which differ widely in their percent of dry weight, it is advisable to make the comparisons on the

TABLE 15.--Mineral Composition of the Walls of Eleven Varieties of Tomato Fruit.

Variety	Percent of Fresh Weight					
	H_2O	N	K	P	Ca	Mg
Fireball	96.2	.093	.20	.015	.013	.010
Glamour	95.5	.070	.22	.017	.010	.010
Big Early Hybrid	95.3	.083	.22	.015	.011	.009
Roma	95.0	.085	.22	.021	.011	.010
Morton Hybrid	94.9	.070	.20	.020	.015	.009
Early Hybrid	94.5	.063	.21	.015	.014	.009
Indian River	94.4	.080	.24	.022	.013	.010
Yellow Pear	93.7	.083	.22	.021	.008	.010
Red Pear	93.7	.085	.23	.021	.015	.011
Penn-Orange	93.6	.083	.21	.019	.011	.012
Red Cherry	92.7	.058	.27	.017	.021	.009
L.S.D.						
5%	.5	.017	.02	-	.003	.001
1%	.8	-	.03	-	.005	-
	Parts per million, Fresh Weight Basis					
	Mn	Fe	Cu	B	Zn	Mo
Fireball	1.2	4.2	.63	.75	1.38	.09
Glamour	.9	4.7	.50	.83	1.13	.08
Big Early Hybrid	.9	3.2	.33	.70	1.33	.09
Roma	1.1	3.4	.75	.83	1.35	.14
Morton Hybrid	1.2	4.0	.50	1.03	1.30	.17
Early Hybrid	1.3	3.6	.58	.80	1.50	.09
Indian River	1.1	4.6	.55	.78	1.13	.12
Yellow Pear	1.2	3.6	.65	.95	1.50	.04
Red Pear	1.5	4.0	.95	1.05	1.85	.13
Penn-Orange	1.2	3.0	.53	.78	1.38	.08
Red Cherry	2.0	6.3	1.43	1.33	1.90	.12
L.S.D.						
5%	.5	1.0	.18	.15	.36	-
1%	.7	1.5	.26	.21	-	-

fresh weight as well as the dry weight basis. It is felt that the mineral composition expressed on the fresh weight basis has the varieties more nearly in the proper perspective to one another. Fireball has the lowest content of potassium on the fresh weight basis, which might be expected considering its susceptibility to blotchy ripening and the work of Bewely and White (4) which demonstrated the influence of potassium application on alleviating blotchy ripening. However, on the dry weight basis, Fireball has the highest content of potassium.

The low dry matter content in Fireball fruit may be related to the inability of the plant to supply carbohydrates to the fruit, and blotchy ripening might be related to a deficiency in the carbohydrate content of the fruit cells in the blotchy area. Because of the small size of its plant, Fireball probably produces a higher ratio of fruit weight to leaf area than most varieties.

Composition of Blotchy and Non-Blotchy Fruit

In this study the differences between blotchy and non-blotchy fruit was observed and evaluated.

Analyses were first made of fruits which exhibited blotchy ripening, with composition values for wall tissue with the disorder, compared with normal wall tissue from the same fruits.

In a subsequent experiment, tomato wall sections showing internal browning, yellow-orange, yellow-green, and ripe wall sections with vascular browning, were excised and their composition compared to normal sections from ripe tomato fruit walls, Table 17. The data derived from these four areas were then consolidated into Table 18, so that the "Blotchy" areas of Table 18 are the combined values of the "Brown" and "Yellow-Orange" areas, and the "Non-Blotchy" areas are the combined values of the "Ripe-with-Vascular-Browning" and the "Ripe Normal" fruit.

Wall sections of tomatoes from a commercial field which were mildly, moderately, and severely affected with the disorder, based on the size of the area affected, were analyzed, and these results appear in Table 19.

The stem-end, center-region, and blossom-end walls from non-blotchy and blotchy tomato fruits were analyzed. Their composition values are shown in Table 20.

The development of yellow shoulders, which sometimes occurs on tomato fruit exposed to the sun while ripening, might be related to blotchy ripening. Table 21 indicates the analytical results of yellow, normal, and blotchy wall areas from the stem-end region of tomato fruit.

Results

Among the fruits in which blotchy wall areas were compared to non-blotchy areas of the same fruit, Table 16, it is observed that the blotchy areas are the same or higher in all constituents except iron and dry matter, on both a fresh or a dry weight basis.

When different manifestations of blotchy ripening are compared in Table 17, "Ripe Normal" walls were higher than "Brown" or "Yellow-Orange" wall sections in dry matter and lower for all elements on the dry weight basis, and all elements except manganese and copper on the fresh weight basis. The greatest fluctuations on a dry weight basis are recorded for calcium, which is 59 percent higher in the "Brown" tissue, and iron which is 55 percent higher in the "Yellow-Orange" tissue than in the "Ripe Normal" tissue. The "Yellow-Green" tissue had the highest content of reducing sugars, and "Ripe Normal" and "Ripe-With-Vascular-Browning" were quite comparable in composition.

The data appearing in Table 18 under "Blotchy" and "Non-Blotchy" is a consolidation of the data in Table 17, combining the "Brown" with the "Yellow-Orange", and the "Ripe-With-Vascular-Browning" with the "Ripe Normal" values. The non-blotchy tissue is higher in dry matter and lower in all elements on a dry weight basis. Nitrogen, potassium, manganese, and copper are higher in the non-blotchy tissue on a fresh weight basis. The reducing sugars and total acidity are higher for the non-blotchy tissue on the

TABLE 16. --Mineral Composition of Blotchy and Non-blotchy Areas of Fireball Tomato Fruits.

Composition	Normal Wall		Blotchy Wall	
	%Dry Wt.	%Fresh Wt.	% Dry Wt.	%Fresh Wt.
Dry Wt.	5.0*		4.6	
P	.28	.01*	.29	.01
K	4.2	.20	5.2	.24
Ca	.25	.01	.31	.01
Mg	.25	.01	.25	.01
	Ppm Dry Wt.	Ppm Fresh Wt.	Ppm Dry Wt.	Ppm Fresh Wt.
Mn	25	1.3	29	1.4
Fe	131	6.7	124	6.5
Cu	10	.51	11	.54
B	20	1.0	20	1.0
Zn	18	.7	21	1.0
Mo	1.5	.07	1.8	.09

L. S. D.	5%	1%
Dry Wt.	.2	.3
Ca D. W.	.03	.05

*Averages of eight fruits.

TABLE 17.--Composition of Tomato Wall Areas (Variety: Fireball) Displaying Different Manifestations of Blotchy Ripening as Classified by the Pigmentation of Wall Area.

Values	Brown		Orange-Yellow		Yellow-Green		Ripe with Vascular Browning		Ripe Normal	
	D. W.	F. W.	D. W.	D. W.	D. W.	F. W.	D. W.	F. W.	D. W.	F. W.
%										
D. W.	3.5[a]		3.3		4.2		4.4		4.7	
N	3.7	.13	3.5	.12	2.5	.11	2.9	.13	2.6	.12
P	.56	.020	.62	.020	.39	.016	.42	.019	.38	.018
K	5.3	.19	5.7	.19	3.8	.15	4.8	.22	4.5	.21
Ca	.49	.017	.48	.016	.38	.016	.34	.015	.29	.014
Mg	.33	.011	.28	.009	.23	.010	.23	.010	.21	.010
Ppm										
Mn	30	.99	26	.85	24	.99	22	.98	22	1.03
Fe	114	4.0	162	5.3	123	5.1	88	3.9	89	4.2
Cu	20	.71	23	.74	18	.76	17	.71	19	.88
B	28	.96	28	.90	24	.96	21	.91	19	.88
Zn	52	1.8	48	.8	36	1.5	34	1.5	35	1.6
Mo	3.7	.045	3.5	.055	2.5	.070	2.9	.045	2.6	.025
%										
Red. Sugars	50.6	1.77	77.0	2.54	76.4	3.21	48.9	2.30	51.1	2.40
Total Acid.[b]	105	3.7	104	3.4	88	3.7	96	4.2	90	4.2

L.S.D.	N		Mg		K
	D. W.	F. W.	D. W.	F. W.	D. W.
5%	.7	.01	.06	.002	.03
1%	-	-	.10	.003	-

[a]Averages based on two samples.

[b]Meq. of H per 100 grams fresh weight.

TABLE 18.--Composition of Blotchy and Non-blotchy Wall Areas of Fireball Tomato Fruit.[a]

Composition	Blotchy		Non-blotchy		L. S. D.	
	D. W.	F. W.	D. W.	F. W.	D. W.	
					5%	1%
			Expressed in %			
Dry Wt.	3.36[b]		4.56		.46	.89
N	3.6	.12	2.8	.13	.3	.6
P	.59	.020	.40	.018	.09	
K	5.5	.19	4.6	.21		
Ca	.49	.016	.31	.014	.05	.10
Mg	.30	.010	.22	.010	.02	.05
			Expressed in Ppm			
Mn	28	.9	22	1.0		
Fe	138	4.6	89	4.0		
Cu	21	.72	18	.79		
B	28	.92	20	.89	8	
Zn	50	1.7	34	1.6	10	
Mo	1.4	.05	.7	.04		
Reducing Sugars (%)						
	64.0	2.15	51.6	2.35		
Total Acidity - Expressed as meq. of H per 100 grams of sample						
	104	3.5	99	4.5		

[a]Blotchy - combined brown and "orange-yellow" values; Normal - combined "Ripe-with-vascular-browning" and "Ripe normal" values from Table 17.

[b]Averages of four samples.

TABLE 19.--Mineral Composition of Tomato Wall Tissue from Mild, Moderate, and Severe Conditions of Blotchy Ripening (Variety: Fireball).

Composition	Mild		Moderate		Severe	
	D. W.	F. W.	D. W.	F. W.	D. W.	F. W.
			Expressed in %			
Dry Wt.	5.2[a]		4.0		3.8	
P	.23	.012	.41	.017	.42	.016
K	3.7	.19	5.6	.23	5.5	.21
Ca	.27	.014	.35	.014	.37	.015
Mg	.20	.011	.25	.010	.24	.009
			Expressed in Ppm			
Mn	18	.092	22	.088	28	.107
Fe	16	.82	28	1.12	85	3.34
Cu	7.9	.41	8.5	.35	6.8	.27
B	13	.65	18	.72	16	.62
Zn	7	.28	8	.31	7	.28
Mo	16	.80	2	.07	1	.06

[a]Averages of two samples.

fresh weight basis, but lower on the dry weight basis.

When walls from tomato fruit affected with mild, moderate and severe conditions of blotchy ripening are compared (Table 19) a decline in dry matter is noted from the mild to severe condition. Among the elements on a dry weight basis, the wall with mild blotchy ripening is highest only in molybdenum, while the wall with severe blotchy ripening is highest in all other elements except potassium, magnesium, copper, boron, and zinc, which are all highest in walls with moderate blotchy ripening. On the fresh weight basis, the fruit showing a mild condition of the disorder was highest in magnesium, copper and molybdenum, while fruit with the severe condition was highest in calcium, manganese, and iron, and fruit with moderate blotchy ripening was higher in the others. However, only phosphorus on the dry weight basis was significantly higher in affected fruits.

In Table 20, on the dry weight basis, blotchy tissue is consistently lower in dry matter and manganese, and consistently higher in all but potassium, calcium, boron, and molybdenum. On the fresh weight basis, blotchy tissue is consistently lower only in potassium and manganese.

Considering the three wall sections, the blossom-end is highest in dry matter, nitrogen, phosphorus, iron, and boron, and lowest in calcium, on both the dry and fresh weight bases. Neither the stem-end nor the center region are consistently highest in any element on either the fresh or dry weight basis, however, the stem-end is lowest in nitrogen, phosphorus, potassium, copper, boron, and zinc.

TABLE 20.--Composition of Wall Areas from Three Horizontal Regions of Blotchy and Non-blotchy Tomato Fruits (Variety: Morton Hybrid).

Wall Area	% Dry Wt.		% N D. W.	% N F. W.	% P D. W.	% P F. W.	% K D. W.	% K F. W.
From Blotchy Fruit								
S. E.[a]	4.6		2.0	.093	.38	.018	4.5	.20
C.	4.4		2.3	.105	.44	.019	4.9	.22
B. E.	4.9		2.4	.108	.48	.022	4.9	.23
From Non-blotchy Fruit								
S. E.	5.2		1.6	.083	.24	.013	4.0	.21
C.	5.0		1.8	.093	.35	.018	4.7	.24
B. E.	5.3		2.1	.115	.39	.021	4.9	.26
L. S. D.								
5%	.2		.3	.018	.05	-	-	-
1%	.3		.5	-	.08	-	-	-
	% Ca D. W.	% Ca F. W.	% Mg D. W.	% Mg F. W.	Mn (ppm) D. W.	Mn (ppm) F. W.	Fe (ppm) D. W.	Fe (ppm) F. W.
From Blotchy Fruit								
S. E.	.25	.011	.22	.010	18	.83	144	6.3
C.	.30	.013	.21	.009	20	.90	151	6.7
B. E.	.11	.007	.20	.009	18	.80	198	8.7
From Non-blotchy Fruit								
S. E.	.25	.013	.18	.010	24	1.28	84	4.3
C.	.22	.011	.20	.010	22	1.13	73	3.7
B. E.	.16	.008	.19	.011	21	1.20	121	6.5
L. S. D.								
5%	.05	.003	-	-	-	.23	56	2.6
1%	.08	.004	-	-	-	.34	-	-
	Cu (Ppm) D. W.	Cu (Ppm) F. W.	B (Ppm) D. W.	B (Ppm) F. W.	Zn (Ppm) D. W.	Zn (Ppm) F. W.	Mo (Ppm) D. W.	Mo (Ppm) F. W.
From Blotchy Fruit								
S. E.	19	.87	17	.76	38	1.8	.9	.04
C.	20	.88	21	.94	41	1.8	1.3	.06
B. E.	35	1.71	25	1.14	44	2.1	.7	.04
From Non-blotchy Fruit								
S. E.	7	.36	17	.88	29	1.5	1.9	.04
C.	14	.70	19	.97	40	2.0	1.2	.06
B. E.	13	.69	21	1.14	40	2.1	1.0	.06
L. S. D.								
5%	-	-	2	.11	-	-	-	-
1%	-	-	3	.16	-	-	-	-

[a]S. E. - Stem-end section; C - center section; and B. E. - blossom-end section.

[b]Average of two samples.

TABLE 21.--Composition of Three Types of Wall Tissue at the Stem-End of Tomato Fruits (Variety: Morton Hybrid).

Composition	Yellow[a]		Normal		Vas. Brown		L. S. D. 5%	
	D. W.	F. W.	D. W.	F. W.	D. W.	F. W.	D. W.	F. W.
				Expressed in %				
Dry Wt.	4.04[b]		3.57		3.45			
N	1.1	.06	1.3	.07	2.5	.13	.7	-
K	2.5	.15	4.4	.24	4.8	.25	.4	.03
P	.18	.011	.37	.020	.45	.023		
Ca	.23	.014	.19	.010	.43	.022	.04	.001
Mg	.14	.009	.16	.009	.25	.013	.05	-
				Expressed in Ppm				
Mn	22	1.4	18	1.0	20	1.1		
Fe	59	3.6	58	3.1	92	5.0		
Cu	4.0	.24	8.5	.45	13	.68	3.2	.12
B	14	.87	17	.92	20	1.01		
Zn	13	.79	23	1.22	30	1.55		
Mo	.20	.01	.90	.03	.50	.02		
Reducing Sugars (percent)								
	77	3.1	67	2.4	46	1.6		
Total acidity (meq. H per 100 grams sample)								
	55	2.2	114	4.1	107	3.7		.3
Soluble Solids (percent)								
	95+[c]	4.1	95+	4.0	84	2.9		.4

[a]Yellow, normally ripened and vascular browned shoulders.

[b]Average of two samples.

[c]Average of ten samples.

In Table 21 where "Yellow", "Normal", and "Vascular brown" shoulders are compared, the "Yellow" tissue is highest in dry matter, reducing sugar, soluble solids, and manganese in contrast with "Vascular brown" tissue which is lowest in dry matter, reducing sugar, and soluble solids, and highest in all elements except manganese and molybdenum on both the dry and fresh weight bases.

Discussion

On the basis of the composition values obtained, blotchy ripened tissue is characterized by low dry matter and soluble solids and usually by low reducing sugars. However, this disorder has not been associated with a reduced concentration of any element.

In Table 16, low iron content was associated with the occurrence of blotchy ripening. Molybdenum deficiency was suggested in Tables 19, 20, and 21, and manganese in Tables 20 and 21. However, since these differences in mineral contents were not consistent in all comparisons, they probably are not the important factor contributing to the disorder.

It is apparent from the composition values that "Yellow-green" tissue differs from the "Brown" and "Orange-yellow" tissues, in having a higher content of dry matter and reducing sugars. Therefore, it must be concluded that the "Yellow-green" tissue is either not a form of blotchy ripening, or else a very premature stage of the disorder. It is also apparent from these data that low dry matter and reducing sugars, and high content of iron, nitrogen, and zinc, which are common to the "Brown" and "Orange-yellow" tissue, do not persist in the "Ripe-with-vascular-browning" fruit, which had experienced blotchy ripening at an earlier stage of development.

A comparison of the composition of the yellow shoulder tissue with the blotchy and normal shoulder tissue indicates that yellow shoulder is not associated with blotchy ripening. Where blotchy tissue is characterized by low soluble solids, reducing sugar, and dry weight, the values of the yellow shoulders for these constituents exceed the values for both the blotchy and normal fruit.

The high composition values for the blossom-end area of tomato fruits, indicated in Table 20, especially for dry matter, may be related to the absence of blotchy ripening on the blossom-end, and the low calcium content may account for the high incidence of blossom-end rot in this area.

The results of soluble solids tests show significantly lower values for vascular browned tissue on the fresh weight basis. The values on a dry weight basis exceeded 100 percent indicating that the fruit sampled for soluble solids were higher than the samples which were dried. The refractometer should prove to be a practical device in field sampling to detect fruits that are predisposed to blotchy ripening, noting that the critical range is between 2.9 and 4 percent on the basis of this experimentation.

In this study it has been observed that blotchy tissue generally has the highest content of mineral nutrition on the dry weight basis, whereas on the fresh weight basis its mineral content is comparable with that found in non-blotchy tissue.

GENERAL DISCUSSION

The primary objective of the research work conducted in Part I was to induce blotchy ripening in tomato fruit. After reviewing the literature it was suspected that water relations might be responsible for blotchy ripening, and a series of experiments were devised to induce the disorder by manipulating the water relations of the plant.

Some experiments acted directly on the transpiration rate by increasing transpiration with such stimulants as Bordeaux mixture and decreasing transpiration with such inhibitors as waxes. Other experiments sought to indirectly influence transpiration by reducing air movement with wind barriers and closer spacing. The temperature of the fruit was influenced by wrapping with black plastic film and aluminum foil, and exposing others to direct sunlight by removing the shading foliage. Other experiments investigated the effects of hardening, time of planting, fertilizer level, variety, leaf and root pruning, and the removal of fruiting clusters.

On the basis of the results of the experiments conducted, no evidence was obtained that would indicate that blotchy ripening is related to transpiration rate, vapor pressure, or even water relations in general, since all treatments designed to influence these factors, including root pruning, failed to yield more than three percent blotchy ripened fruit.

There is an apparent relationship between the incidence of blotchy ripening and the ratio of the fruit weight to green plant weight, which suggests that the amount of blotchy ripened fruit and fruit of poor color increases as the ratio widens. On this basis, a heavy crop on a small plant might be expected to show a higher percentage of blotchy fruit than a light crop on a similar plant. Assuming this to be the case, blotchy ripening might be caused by insufficient photosynthate to adequately supply the fruit.

The possibility of attributing this disorder to lack of photosynthate may at first seem remote. However, if it is assumed that a plant functions at the maximum efficiency permitted by its environment, shading experimentally applied in the early stage of plant development might reduce the plant's efficiency and result in less fruit set. Permitting full sunlight to these plants at a later date probably would have facilitated the normal maturity of the light crop which had been set. However, if the sequence of shading was reversed so that plants which had been acclimated to full sunlight and were carrying the maximum fruit load permitted by these conditions, were suddenly partially shaded, their capacity to produce photosynthate would have been reduced below the metabolic demands of the plant and the developing fruits. Then the competition for photosynthate might result in blotchy ripened fruit.

In the case of the preliminary investigation where the harvest records revealed that irrigation increased the number of blotchy ripened fruit, it is also possible that a photosynthate deficiency was the underlying factor. While no analyses were conducted on these fruits, Moore (33) has observed that irrigation tends to increase the weight of fruit and lower the soluble solids content.

The research conducted in Part II was concerned with the mineral and organic composition of the tomato fruit, and was conducted in conjunction with the experiments in Part I, which were designed to induce blotchy ripening.

In general, these analyses have shown that blotchy ripening is associated with low reducing sugar, soluble solids, and dry weight. The results of this work further suggest that the reason blotchy ripening most frequently occurs on the walls of the fruit at the stem-end and mid-section, between the septa, and on fruit from lower clusters, is related to low dry weight, soluble solids, and reducing sugar in these areas. Other data also suggest that certain varieties, like Fireball, are more susceptible to blotchy ripening because their fruit walls are inherently low in dry matter, and their potassium contents are significantly less, on a fresh weight basis, than those of other varieties which are more resistant to the disorder.

Aside from contributing to the basic knowledge of the tomato fruit, the nutritional data show that the blossom-end of fruits borne on the lower clusters are lowest in calcium. Since low calcium content has been associated with blossom-end rot (13), this may account for the prevalence of this disorder on fruit of lower clusters.

Suggestions for Further Study

It is possible that spacing can materially alter the ratio of fruit weight to leaf area. Since it appears that blotchy ripening might be reduced by increasing the supply of carbohydrates to the fruit, an increase in the leaf area, relative to the weight of fruit produced, would increase the carbohydrates available per fruit.

Since diurnal variations in temperature have an effect on the accumulation of carbohydrates, it might be worth while to study the reaction of tomato plants brought to the bearing stage at a temperature of 75°F during the day and 60°F during the night, and then to reverse these temperatures. It might be expected that this temperature reversal would place a stress on the carbohydrate of the tomato plant, and possibly induce blotchy ripening.

The daily duration of sunlight influences carbohydrate accumulation by plants. Since blotchy ripening is possibly associated with a shortage of carbohydrates, it would be of interest to study the performance of tomato plants which had been brought to the bearing stage by conventional cultural practices and then were covered part of the day. It would also be of interest to observe how different planting distances and sucrose sprays applied to the foliage would interact with this curtailment of the photosynthetic period.

SUMMARY AND CONCLUSION

In a study which was concerned with blotchy ripening in the tomato, the cause of this disorder was sought by conducting experiments dealing chiefly with manipulations of the water relations of the plant. It was originally postulated that the breakdown of parenchyma cells in the vicinity of the vascular bundles, which characterize the advanced stage of blotchy ripening might be caused by water stress. Among the treatments used to influence water relations were lampblack dust, talc dust, lime dust, Bordeaux mixture, wax and oil emulsions, shading, foliage and cluster pruning, and wind barriers. Since none of these treatments were effective in inducing blotchy ripening in this investigation, it is concluded that water relations were probably not a major cause of the disorder. Tobacco mosaic virus is considered to be no more than a contributing factor since three-quarters of the infected fruit and one-third of the non-infected fruit gave a positive assay for the presence of the virus.

Laboratory analyses characterized blotchy ripened fruit as being lower in dry weight, soluble solids, and reducing sugars, especially in the wall areas displaying the disorder. The nutritional status of the blotchy wall area was generally higher than normal wall areas for all elements determined on a dry weight basis, but quite comparable on a fresh weight basis. The fact that blotchy ripened fruit tissue was lower in carbohydrates and dry matter accounts for their high mineral composition on the dry weight basis.

Future experiments have been suggested which would influence the carbohydrate contents of the tomato plant and indicate if carbohydrate deficiency is the cause of blotchy ripening. Cultural practices which might maintain a normal carbohydrate level during adverse temperature and light intensities have been discussed.

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