INVESTIGATIONS ON " BLOTCHY RIPENING " OF GREENHOUSE TOMATOES

THESIS FOR THE DEGREE OF M. S.

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INVESTIGATIONS ON "BLOTCHY RIPENING"
OF GREENHOUSE TOMATOES

Thesis

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by

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THESIS

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Introduction

Greenhouse vegetable production in Michigan centers around Grand Rapids with smaller producing areas near other cities. For years the Grand Rapids area produced a large portion of the greenhouse leaf lettuce grown in the middle western states. However, the severe competition of the western grown head lettuce with the leaf lettuce during the past decade has forced the growers to change to a more profitable crop and in most cases this has been greenhouse tomatoes. According to the Fifteenth Census of the United States 1,299,545 square feet were devoted to greenhouse tomatoes in Michigan in 1930 with a gross return of approximately $259,909.00.

The change from leaf lettuce to tomatoes, however, has been accompanied by a number of serious problems. In the first place, greenhouse tomatoes are sold on the markets in competition with field grown tomatoes from Florida, California, Mexico, Cuba and other southern sections, where the fruit is harvested green and ripened artificially. The vine-ripened greenhouse tomatoes command a higher market price due to their better quality. Secondly, the greenhouses were constructed primarily for the production of lettuce, a cool season crop, and in many cases were not equipped to maintain the higher temperatures required for tomatoes, nor were they equipped for

adequate ventilation. Lettuce will produce satisfactory crops under the poor sunlight conditions prevailing during Michigan winters, but this is not usually true with tomatoes. The tomato plant requires a different soil fertilization system than that required by lettuce and is therefore not a satisfactory companion or succession crop for the latter. Leaf mold (Cladosporium fulvum, Cke.), mosaic, fusarium wilt (Fusarium lycopersici, Sacc.), blossom-end rot and other diseases as well as injury caused by nematodes (Heterodera-radicola), white fly (Trileurodes vaporariorum), red spider (Tetranychus bimaculatus), and other insects, the controls of which have been formulated, all result in reduced yields where they are not adequately controlled. But, during the past decade, one of the most baffling problems of Michigan greenhouse tomato growers has been the "blotchy ripening" or "green spot" of the fruits, which often greatly reduced the quality of the finished product. It is the purpose of this thesis to present experimental data bearing upon this problem.

Review of Literature

Blotchy ripening has not been reported, to the writer's knowledge, as a disorder of greenhouse tomatoes in the United States. Bewley and White (4) consider blotchy ripening a rather serious disorder of glasshouse tomatoes in England and from their descriptions and color plates it is to all appearances the same condition that prevails in this section. They report that in many cases the percentage of blotchy fruits is as low as 0.5 or 1 per cent., but under unfavorable conditions it may rise as high as 50 per cent. Under conditions in England they found the disorder was most prevalent during late May, June, and July and less prevalent or completely absent during the remaining months of the year. Their results over a five year period (1921-1925) indicate that blotchy ripening is connected with an insufficient supply of available potassium and nitrogenous nutrients, particularly the former, whereas phosphate deficiency appeared to be unimportant. The feeding of affected plants with potassium and nitrogen fertilizers resulted in a corresponding reduction in the quantity of affected fruits. Applications of sulphate of potash at the rate of 500 pounds per acre were sufficient to correct blotchy ripening on average soils. However, they report cases where it was necessary to apply three tons of sulphate of potash in order to reduce blotchy ripening to negligible proportions. Under the most favorable manurial conditions, however, they found small quantities of blotchy fruits were invariably produced, and they state that "apparently other factors, probably climatic in nature, are operative." Root invading fungi, such as Colletotrichum tabificum, interfere with the feeding of the plant and indirectly result in blotchiness of the fruit, according to these writers. In several cases, they also traced blotchy ripening to the dryness of the soil below the surface six inches. They further report that exposure of fruits to excessive sunlight when the potash and nitrogen supply is inadequate causes a type of uneven ripening known as "green back" or "hard back."

Hoffman (7) states that nitrogen deficiency affects the size and number of fruits more than it does their shape. He found that fruits on nitrogen-deficient plants usually were smooth, solid, and well colored, if adequate amounts of the other nutrients are present, but they were much smaller and fewer than when adequate amounts of nitrogen were available. His results also indicate that the ripening of the fruits was delayed on nitrogen-deficient plants after the first two or three clusters were matured. Fruits in the upper clusters were greatly retarded in growth and slow in ripening. He recommends the use of ammonium sulphate as a side dressing at the rate of 250 pounds per acre each week after the third cluster has set fruit for eight applications,in order to overcome any nitrogen deficiency.

Bewley and Corbett (3) have shown that the period between the opening of the flower and the picking of the fruit varies considerably and that this maturation period lengthens as the plant ages and the truss lengthens.

According to Duggar (6) the characteristic color of ripe tomato fruits is due to the presence of two carotinoid substances, lycopersicin, the red pigment, and carotin. These carotinoids develop in the fruits as they approach maturity whether on or off the plant. Smith and Smith (21) bagged small fruits of several varieties grown under both outside and greenhouse conditions with manilla bags lined with heavy black paper. They found that "during the ripening of tomato fruits in total darkness no chlorophyll developed. The fruits were pure white and gradually shaded into the yellow or red as they approached maturity. When mature, the bagged and unbagged fruits of red varieties were the same color." Duggar (6) found that green tomatoes stored at 35°C. were ripe in 6 days but yellowish in color, due to the failure of lycoperiscin to develop at that high temperature; at 20 to 25°C. and 12 to 26°C. normal red developed. He suggests that failure of lycopersicin to develop at high temperatures is probably due to a lack of oxygen, the limited supply being used in respiratory activities. That oxygen is essential for lycopersicin development was also shown by Duggar, as tomatoes stored in hydrogen and nitrogen did not redden.

Sando (19), using fruit of known age, determined, by tagging the blossoms and chemical analyses, that in general throughout the ripening period there was an increase in moisture, acids and sugars, and a decrease in solids, total nitrogen, starch, pentosans, crude fiber, and ash.

Miller (14) grew tomato plants in sealed containers at Manhattan, Kansas, and kept the soil in good moisture tilth by the daily addition to it of the water that had been removed by the plants during that time. A single plant, of the Louisiana Pink variety pruned to a single stem, transpired 34 gallons of water during the growing season from May 19 to September 2, 1924. He also presents stomatal count data secured over a three-year period on several varieties of tomatoes. He found that there was an average of 131,000 stomata per square inch on the lower surface of tomato leaves and 62,000 per square inch on the upper surface, giving a total of 193,000 stomata per square inch.

Mac Dougal (12) by the use of an auxograph studied the daily accretion in size of tomato fruits in connection with temperature and water relations. As the temperature of the fruit, attached to the plant, rose from 12° to 14°C. to 26° to

28°C. the volume increased to a point where the increased temperature caused an excessive water loss by transpiration which overbalanced the gain by hydration. The mid-day shrinkage could not be prevented by watering the plants abundantly. His data show that a water deficit may exist in the fruits because of excessive transpiration regardless of the moisture content of the soil.

Newhall and Wilson (15) in their studies of Cladosporium leaf mold state that "transpiration is found to be the greatest factor responsible for high humidities in greenhouses. As many as 400 gallons of water an hour have been computed to be given off by an acre of greenhouse tomatoes under normal conditions in June."

Ripening Disorders of Greenhouse Tomatoes.

Several ripening disorders have been confused with blotchy ripening and in order to distinguish between them two are described.

Streak or stripe.

Streak has been known as a greenhouse trouble for many years. All parts of the plant may show symptoms of streak. On the fruits, according to Ramsey and Link (18) "the disease is characterized by more or less extensive brown discolorations of the surface, which may result in a great diversity of pattern, such as circular spots, blotches, loops, and streaks. These areas are somewhat sunken, and on green fruit the brown color may be absent, in which case the disease manifests itself as variations in the intensity of the green color. Immature fruits do not ripen. The brownish surface discolorations of the ripening fruits sometimes penetrate the inner tissues and entirely destroy the marketability of the fruits." During recent years it has been shown that certain viruses alone and some virus mixtures will produce streak when introduced into tomato plants.

"Green Back" or "Hard Back."

Another condition which is often confused with blotchy ripening is "green back" or "hard back." Hard green areas are apparent around the cavity, while the rest of the fruit softens and turns red. As the ripening processes continue, the affected areas may either remain green or become orange in color, but invariably they remain hard, even though the remainder of the fruit becomes over-ripe. The flesh immediately below the hard green area is opaque, hard and green, whereas other tissues are clear, soft and red. The vascular bundles within the hard flesh are usually green in color and necrosis of the bundles has not been observed. Frequently the wall of the fruit is thinner than in the riper areas. The cause of this disorder is unknown but it seems to be more prevalent when the sunlight is intense and appears to be more serious on certain varieties than others. The Blair and Lloyd varieties were found to be highly susceptible to this condition. Bewley and White (4) express the opinion that the injury may be reduced by applying sufficient potash and nitrogen.

True Blotchy Ripening.

Blotchy ripening is referred to locally as green spot, green spotting, green back, and Grand Rapids disease. The two latter terms are confusing, since green back as described above

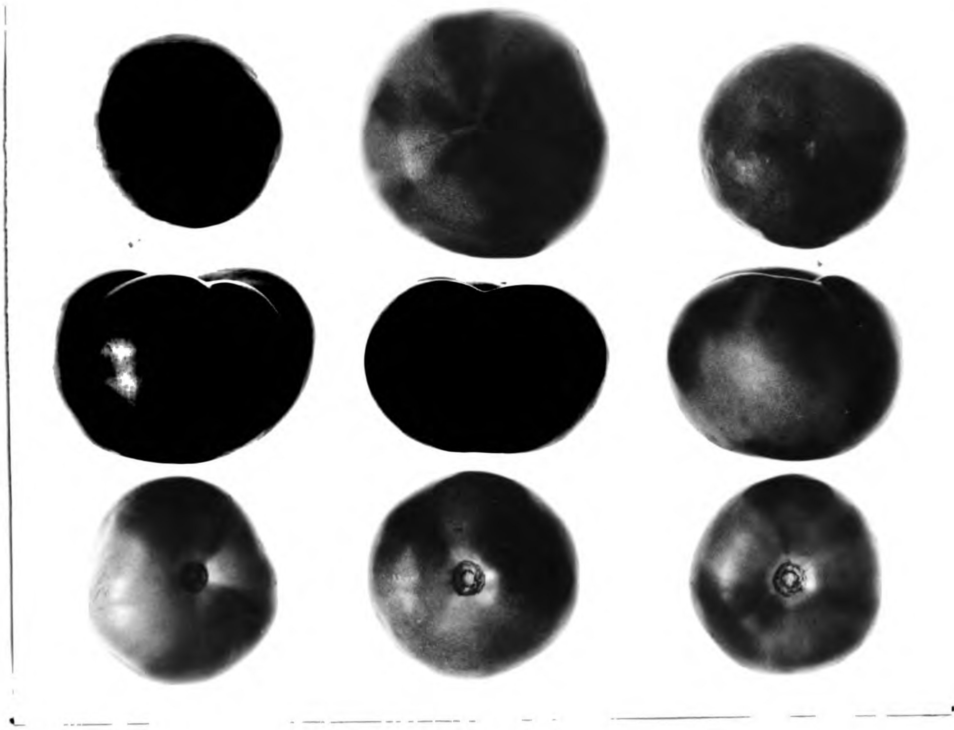


Figure 1. Greenhouse tomatoes affected with blotchy ripening showing the location and extent of the blotchy areas. These fruits are typical of the condition found during June and July.

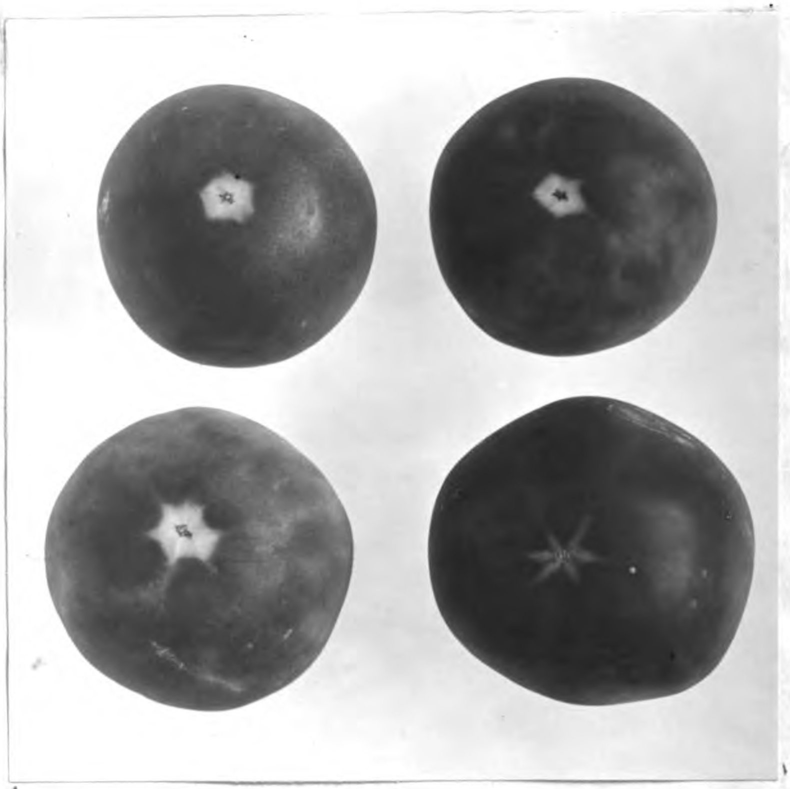


Figure 2. A type of blotchy ripening occasionally observed in the Blair variety. Small colorless areas appear at the stylar scar region.

is considered to be a condition distinct from true blotchy ripening and bacterial canker (Aplanobacter Michiganense Smith) has been referred to as the Grand Rapids disease by various investigators. The writer's opinion is that the terms "blotchy ripening" and "green spot" are the more descriptive of the various names offered and since the condition was first described under the former by Bewley and White there seems to be no need of changing it. Throughout this paper blotchy ripening and green spot will be used to refer to the same condition.

In fruits affected by blotchy ripening, areas of the outer wall, or pericarp, fail to develop and color normally. These areas are not confined to the cavity region and may appear in any portion of the outer wall of the fruit, but are usually more numerous near and radiating from the cavity. Figure 1 shows blotchy fruits in which all portions of the fruits are affected. Figure 2 illustrates an unusual condition of the stylar region, occasionally observed only in the Blair variety. There is no sharp line of demarcation between the green or white and the normal red areas; the colors merge gradually. As the fruit approaches maturity these areas remain hard and green and as ripening proceeds further they assume a waxy or glassy appearance. The vascular bundles lying beneath these clear, glassy areas are almost invariably brown and necrotic, as may be observed from the outside. The area may be confined along one of the furrows formed above the inner walls of the fruit which separate it into carpels and have been found occasionally immediately above the main bundle of the carpel. Figures 3 and 4 show cross and longitudinal sections through

Figure 3. Cross sections of blotchy fruits. Note the necrotic vascular tissues in the blotchy areas of the pericarp which are not present in the unaffected areas.

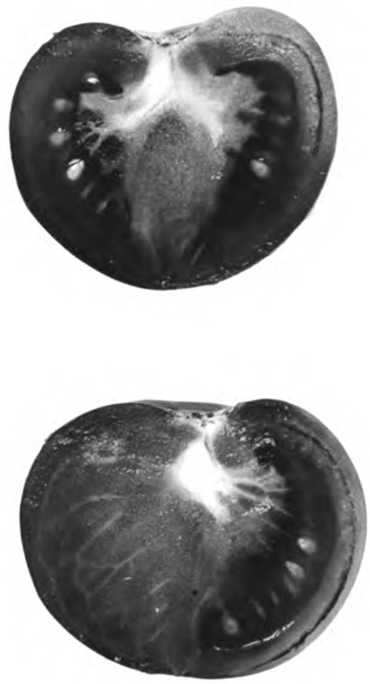


Figure 4. Longitudinal sections through blotchy areas. The necrotic bundles extend throughout the affected areas and are not apparent in the healthy portions.

affected areas which show the relative positions of the necrotic vascular bundles. When viewed under low power these sections almost invariably show the presence of gaps or canals in the parenchyma tissues adjacent to the bundles. The walls of the parenchyma cells of these canals are usually brown and necrotic. Bewley and White (4) adopted a clearing method consisting of carefully removing the epidermis and clearing in xylol following alcohol. Observing bundles by this method they found that the veins radiate from the point of peduncle attachment, and that in the upper half of the fruit there are few cross connections, while in the lower half the veins anastomose to form an intricate net work. Their examinations of healthy and blotchy fruits by this method show that there were differences between the bundles. The bundles in blotchy areas were somewhat thicker than those in the healthy fruits, owing to the spongy nature of the cells surrounding them. Necrosis of the bundles were frequently observed and the necrotic bundles they found were directly beneath the blotchy areas. They further observed that groups of corky cells adjacent to the affected bundles frequently occurred.

The disorder is apparently entirely confined to practically mature fruits. Several hundred fruits of all stages of development were dissected and examined for evidences of blotchiness. Not one of the immature fruits were found to show indications of developing into a blotchy fruit. The first evidences of blotchiness were observed only after the fruit had begun to develop a light pink color which was usually from three to five days before the fruit was ripe enough to harvest.

Blotchy ripening is distinctly a disorder of the fruit;

no other parts of the plant are apparently affected. The blotchy fruits occur on plants that appear normal in every respect. An occasional blotchy fruit has been observed on plants with symptoms of fusarium wilt, mosaic, and nematode injury, but even under these conditions other fruits on the plant ripened normally.

Methods

The plants from which the data reported in the following experiments were secured were, except where noted, all grown from seed of a pure line of the Grand Rapids Forcing variety. The greenhouse used has been devoted almost exclusively to tomatoes for the past eight years, two crops being grown annually; a fall crop bedded in August or early September and removed in January or early February, and a spring crop bedded in February or early March and removed in August. The house is divided into two ground beds by an eighteen inch concrete walk which extends around the ends and sides of the beds. The soil of the ground beds was originally a sandy loam to which approximately thirty tons of well rotted manure per acre has been applied annually and is in a high state of fertility. A permanent hollow tile system of steam sterilization underlies each bed and it has been necessary to give the soil an annual sterilization in August. The soil management system followed has been a manure application after sterilization supplemented with from 1000 to 1500 pounds of commercial fertilizer high in phosphorus and potassium. Before the fall crop of 1931 an application of 1500 pounds per acre of an 0-20-20 analysis fertilizer was given and an additional 1000 pounds of the same material was applied before the spring crop in 1932. After the third cluster had set fruit, applications of 200 pounds per acre of sulphate of ammonia were made every ten days until three weeks before the last picking. At present the soil has a reaction of pH. 7.8.

The planting system followed consisted of six rows in each of the beds. The distance between the rows was 28 inches and the plants were set 20 inches apart in the rows. The plants were trained to the single stem system and the usual methods of insect and disease control were followed. Watering during the cloudy weather of late winter and early spring was done with the hose at the base of the plants and after May 15 the overhead sprinkler system of irrigation was used. A night temperature of 58°F. was maintained early in the season and increased as the outside temperatures increased during late May, June and July. A day temperature of 60° to 65°F. on cloudy days and from 70° to 75° F. on sunny days was maintained early in the season. During late May, June and July efforts were made to keep the temperature as near 75° to 80° as was possible by ventilation. Early in the growing period only the ridge ventilators were opened but later both ridge and side ventilators were opened. Continuous temperature and humidity records were kept throughout the season. The hygrothermograph was housed in a standard type of shelter centrally located in the greenhouse.

Records were kept on each plant under test and on the individual fruits of each of the plants. These records included the date the fruit set; the date it was harvested; the weight of the fruit in grams; the location as to cluster and position on the cluster; the number of fruits per cluster; and the estimated per cent. of the surface of each fruit that was affected by blotchy ripening. Records of this type were kept on approximately 30,000 fruits or between two and one-half and three tons of fruit in 1932. Only a part of which are given under the following headings, as several of the varieties used produced a high percentage of "hard back" fruits which were recorded with the blotchy fruits. The amount of green spot or blotchy fruits given in the following tables and graphs is expressed as the per cent. of the total number of fruits harvested of which more than one per cent. of their surfaces were blotchy.

Seasonal Occurrence

Observations of blotchy ripening, made in the Experiment Station greenhouses at East Lansing and in a number of commercial greenhouses at Grand Rapids during the 1930, 1931 and 1932 seasons, have shown that blotchiness is a serious disorder of the spring crop ripening during late May, June, July and August and is not a trouble of noticeable consequence on the fall crop ripening from October to January. Cases have been observed in commercial ranges where as high as fifty per cent. of the fruits harvested during June and July were so severely affected that they could be sold only as culls, while in the same ranges less than one per cent. or a complete absence of the disorder was found on the fruits ripening from October 1 to February 1.

In the Experiment Station greenhouses blotchiness has been observed only occasionally on fruits ripening from October 1 to February 1 and the past three years less than 0.5 per cent. of the fruits ripening during this period have been affected. The fruits affected in these cases were invariably from plants located in the outer rows of the beds nearest to the heating pipes, where the temperature is approximately $5^{\circ}F.$ higher than other parts of the house and where the soil is exposed to greater fluctuations in its moisture content. However, on the spring crop both the percentage of fruits affected with green spot and the area of the individual fruits that is affected increases materially as the season advances and the outside temperatures become higher, as is shown by data from the 1932 spring crop given in Table I.

Table I - Seasonal occurrence of green spot, 205 plants of the Grand Rapids variety, spring crop 1932.

Harvesting period	Total yield		Blotchy fruits		
	Number fruits	Weight in kilograms	Number of fruits	Per cent of total number	Average per cent of surface blotchy
May 1-31	203	21.77	14	6.89	7.71
June 1-30	2296	244.77	264	11.50	13.31
July 1-31	4677	456.20	1314	28.11	15.05
Aug. 1-8	144	12.13	38	26.38	21.05

Blotchy ripening was observed to be more serious in commercial ranges during the harvesting periods of the spring crop in 1930 and 1931 than in 1932. Meterological records show that in 1930 and 1931 temperatures above normal, accompanied by long periods with little or no precipitation, prevailed during June and July. The 1932 season more nearly approaches the normal prevailing climatic conditions for this section.

Varietal and Strain Susceptibility

A certain amount of varietal and strain susceptibility to the conditions resulting in blotchy ripening undoubtedly exists. No variety or strain has been observed to remain consistently free from the disorder. A variety test at this Station in the spring of 1931 (20) in which most of the varieties grown commercially were included, showed that some varieties are more susceptible to the disorder than others. Based on observations on the varieties in this test and on those grown in commercial houses, the varieties may be arranged in order of their decreasing susceptibility as follows: Blair Forcing, Lloyd Forcing, Bonny Best, John Baer, Grand Rapids Forcing, Best of All, Alsia Craig, Ideal Forcing, Comet Forcing, Lorillard Forcing, Marglobe, and Globe. Seed from various American and European sources were used with several of the varieties. The Blair and Lloyd Forcing, though highly productive, had such a high percentage of blotchy fruits, that they have been discarded by the better growers.

In the spring of 1931 individual plant selections were made in the Grand Rapids Forcing variety from plants which at that time were little affected by blotchy ripening and were producing a heavy crop of desirable fruits on the basis of size, shape, and quality. These selections were planted in 1932 and records kept on twelve plants from each selection. The results are given in Table II along with similar data for the Blair Forcing and Alsia Craig varieties.

Table II - Comparison of the susceptibility of varieties and strains grown in spring, 1932, to blotchy ripening.

Strain or Variety	Avg. yield per plant		Per cent of total fruits blotchy
	Number fruits	Weight in pounds	
Grand Rapids Sel. 123-31	43	9.38	42.91
" " " 18-31	46	8.79	42.74
" " " 12-31	36	8.81	38.61
" " " 17-31	47	8.61	31.57
" " " 128-31	31	7.79	24.80
" " " 209-31	34	7.18	18.33
" " " 225-31	32	6.72	13.88
" " commercial seed	34	7.84	28.32
Blair Forcing	46	11.72	79.06*
Alsia Craig	45	6.56	24.19

* Includes blotchy and "green back" fruits.

As is indicated in Table II, no selection was found which produced a reasonably low per centage of blotchy fruits and at the same time maintained a high production per plant. The selections varied considerably but even these variations were around the mean of the variety, as is indicated by the plants grown from commercial seed.

In another test seeds were saved from blotchy fruits of several varieties. From 75 to 90 per cent. of the surfaces of these fruits were involved in the blotchy areas. Plants grown from these fruit selections did not produce any significant variations either higher or lower than the average percentage of blotchy fruits for the respective varieties.

Area of Fruit Involved in the Blotchy Spots

In order to determine the average extent of the injury, as the blotchy fruits were harvested, the affected areas were estimated and recorded separately for each fruit. Data were secured on 1515 blotchy fruits of the Grand Rapids variety in 1932. The classified data are given in Table III and shown graphically in Figure 5.

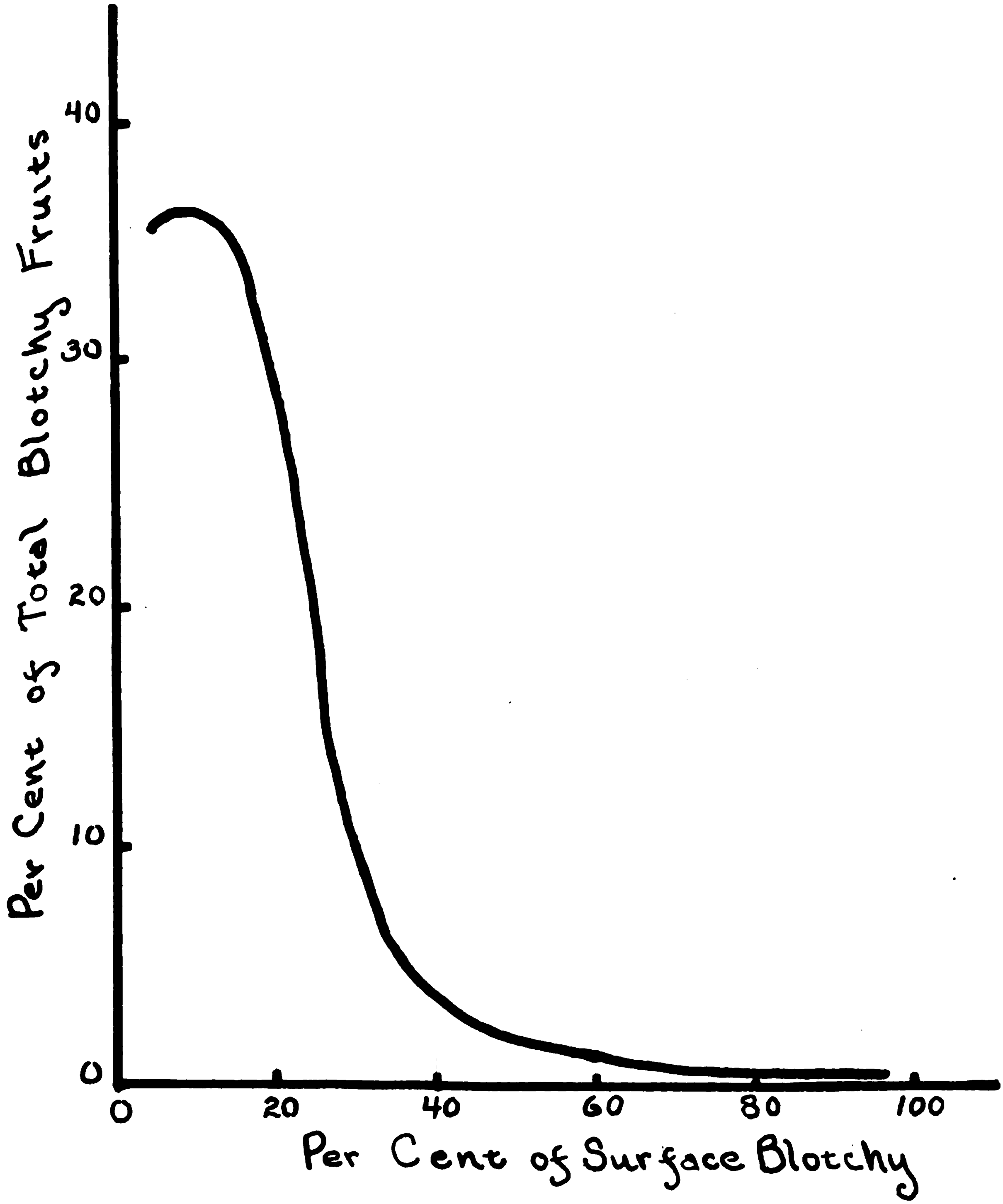
Approximately 70 per cent. of the fruits affected with green spot fall within the range from 0.1 to 20 per cent; 87 per cent. less than 30; 91 per cent. less than 40; and 93 per cent. less than 50 per cent. Under commercial conditions fruits with less than 10 per cent of the surface affected are usually packed with the fancy or choice grades and those with more than 10 per cent with the second and cull grades.

Table III - Area of fruit involved in the blotchy spots of 1515 blotchy fruits of the Grand Rapids variety in spring of 1932.

Per cent of surface blotchy	number of blotchy fruits	Per cent. of total number blotchy
0.1 - 9	546	36.04
10 - 19	535	35.31
20 - 29	267	17.62
30 - 39	73	4.81
40 - 49	35	2.31
50 - 59	15	.99
60 - 69	15	.99
70 - 79	16	1.05
80 - 89	8	.52
90 - 99	5	.33

Figure 5

Area of Fruit Showing Blotchiness



Fruit Size and Blotchy Ripening

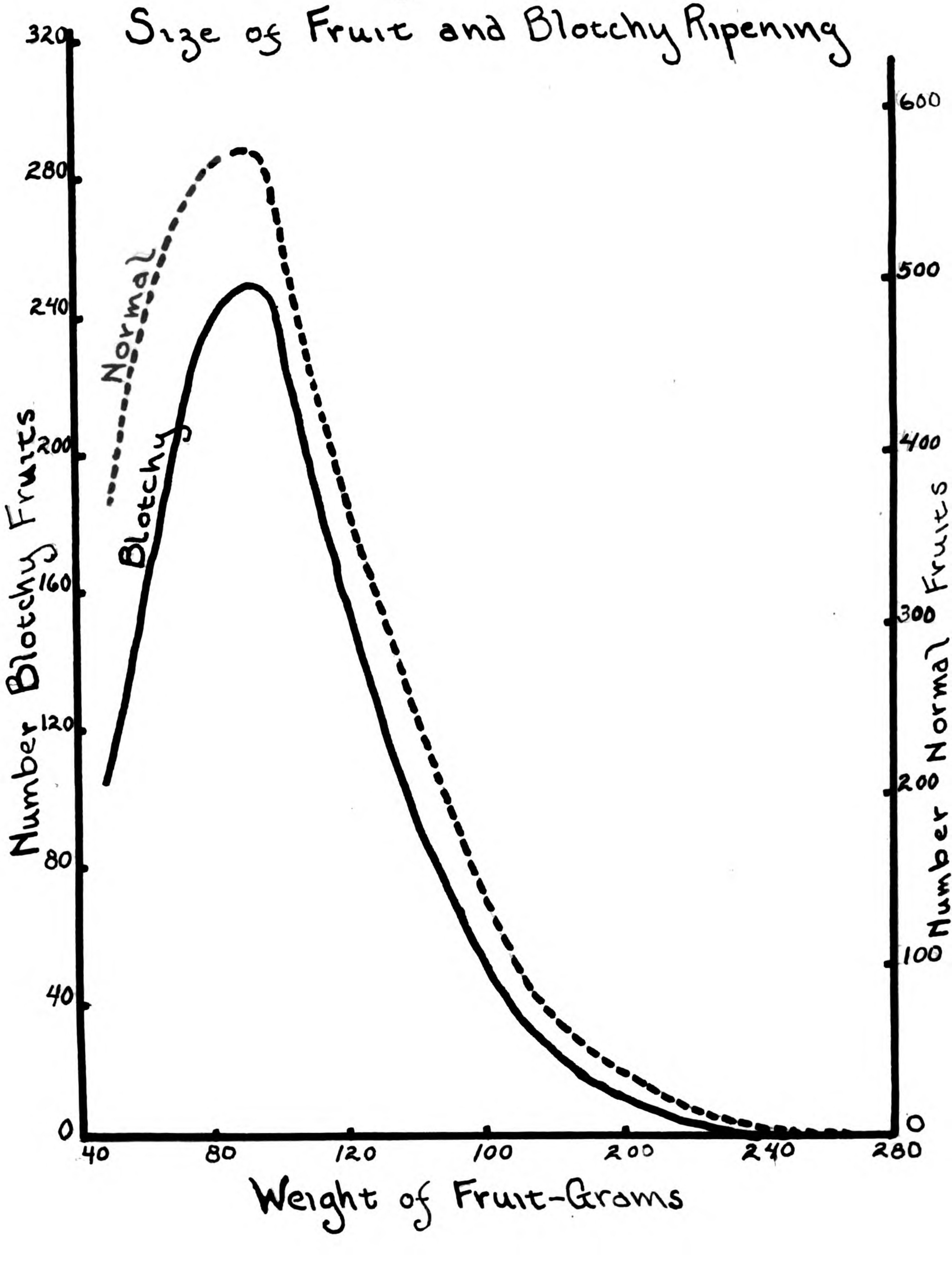
It was thought that some relation may exist between the size of the fruit and the conditions which underlie blotchy ripening. In order to determine any relation of this nature, each fruit was weighed separately on a small gram scales when it was harvested. The data from 3621 fruits of the Grand Rapids variety, of which 2633 fruits ripened normally and 1003 were blotchy are given in Table IV and the distribution curves for both the normal ripening and the affected fruits are shown in Figure 6.

It is evident that no relation between fruit size and green spot existed during the 1932 season as the distribution curve of the affected fruits shows little, if any, variation from that of the normally ripened fruits.

Table IV - Showing the relation of size of fruits and blotchy ripening for 3621 fruits of the Grand Rapids variety in the spring of 1932

Weight of fruits in grams	Number of normal fruits	Number of blotchy fruits
40 - 59	370	103 28%
60 - 79	539	199 37%
80 - 99	595	249 42%
100 - 119	442	187 42
120 - 139	296	120 44%
140 - 159	196	64 32
160 - 179	90	33 37
180 - 199	54	21 49
200 - 219	25	6
220 - 239	15	0
240 - 259	6	5
260 - 279	4	1
280 - 299	1	0

Figure 6


Size of Fruit and Blotchy Ripening
Normal
Blotchy
Number Blotchy Fruits
Number Normal Fruits
Weight of Fruit-Grams
0
40
80
120
160
200
240
280
320
0
100
200
300
400
500
600
40
80
120
100
200
240
280

Length of Maturation Period and Green Spot

It has been observed by the writer that if fruits were delayed in their normal ripening processes they are more likely to be affected by blotchy ripening than are fruits that ripen in a normal length of time. In the spring of 1932, the period from the time the flower was pollinated and the ripening of the resulting fruit was determined by tagging the blossoms. All blossoms which were previously pollinated and the corollas of which were losing their normal deep yellow color were tagged daily late in the afternoon. When the fruits were harvested the date of setting was recorded along with the picking date and the number of days intervening was considered as the maturation period.

The maturation period was found to vary considerably. The period of normal fruits setting in March and ripening in May was approximately 60 days and as the season advanced, fruit set in early June and ripening in July required from 40 to 47 days. The mean of the Grand Rapids variety for the entire spring crop of 1932 was 53 days. Fruits affected with green spot were found in most cases to have a longer maturation period than normal fruits and as this period lengthened the percentage of blotchy or spotted fruits increased materially, as is shown in Table V and Figure 7.

Figure 7

Length of Maturation Period and Blotchy Ripening

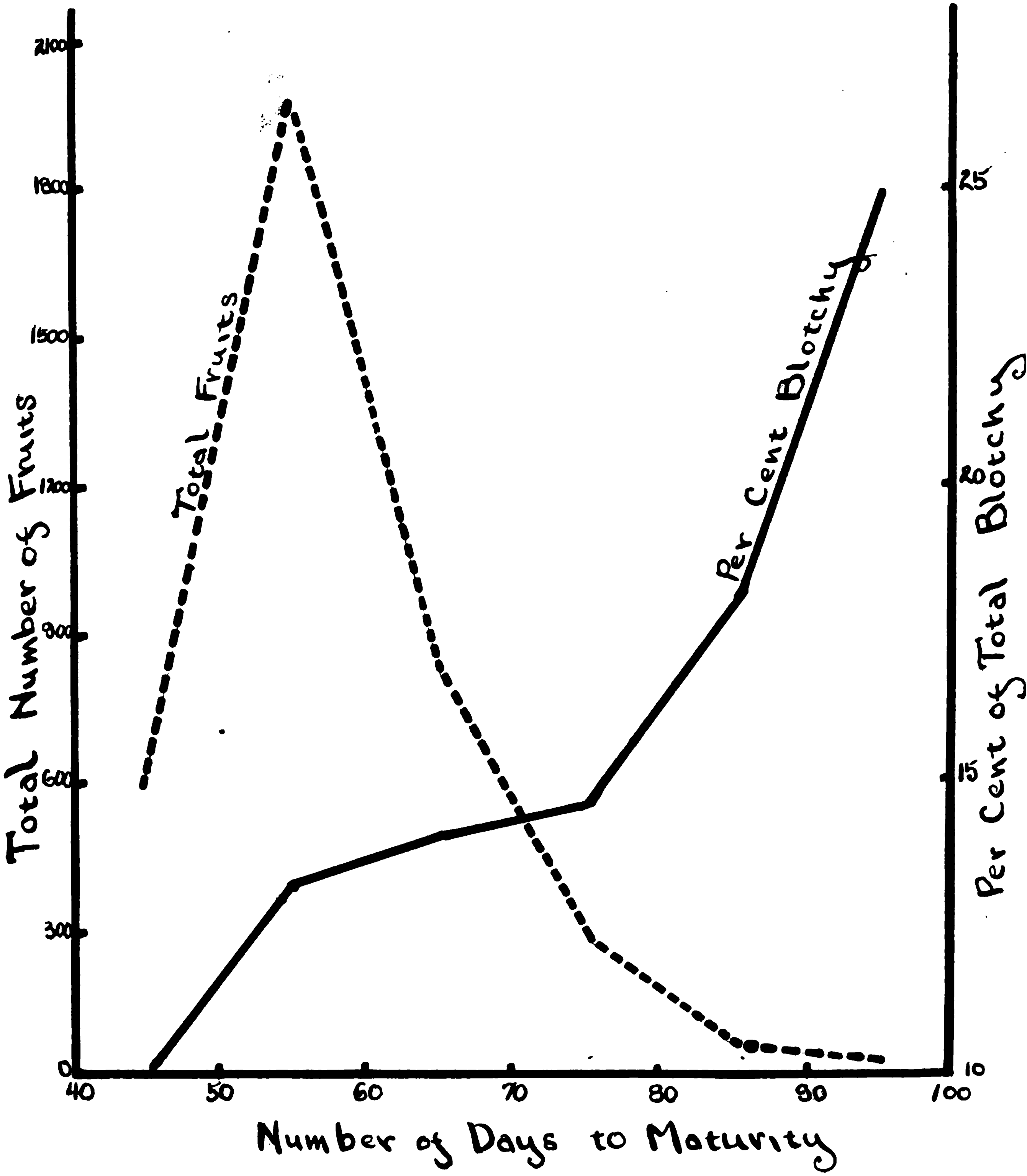


Table V - The effect of the Maturation period and the percentage of green spot produced for 3793 fruits in spring of 1932.

Number of days to maturity	Total number of fruits	Number of spotted fruits	Per cent of total spotted
40 - 49	585	59	10.08
50 - 59	2003	267	13.33
60 - 69	812	115	14.16
70 - 79	281	41	14.59
80 - 89	61	11	18.03
90 - 99	32	8	25.00

Location of Fruit and Green Spot

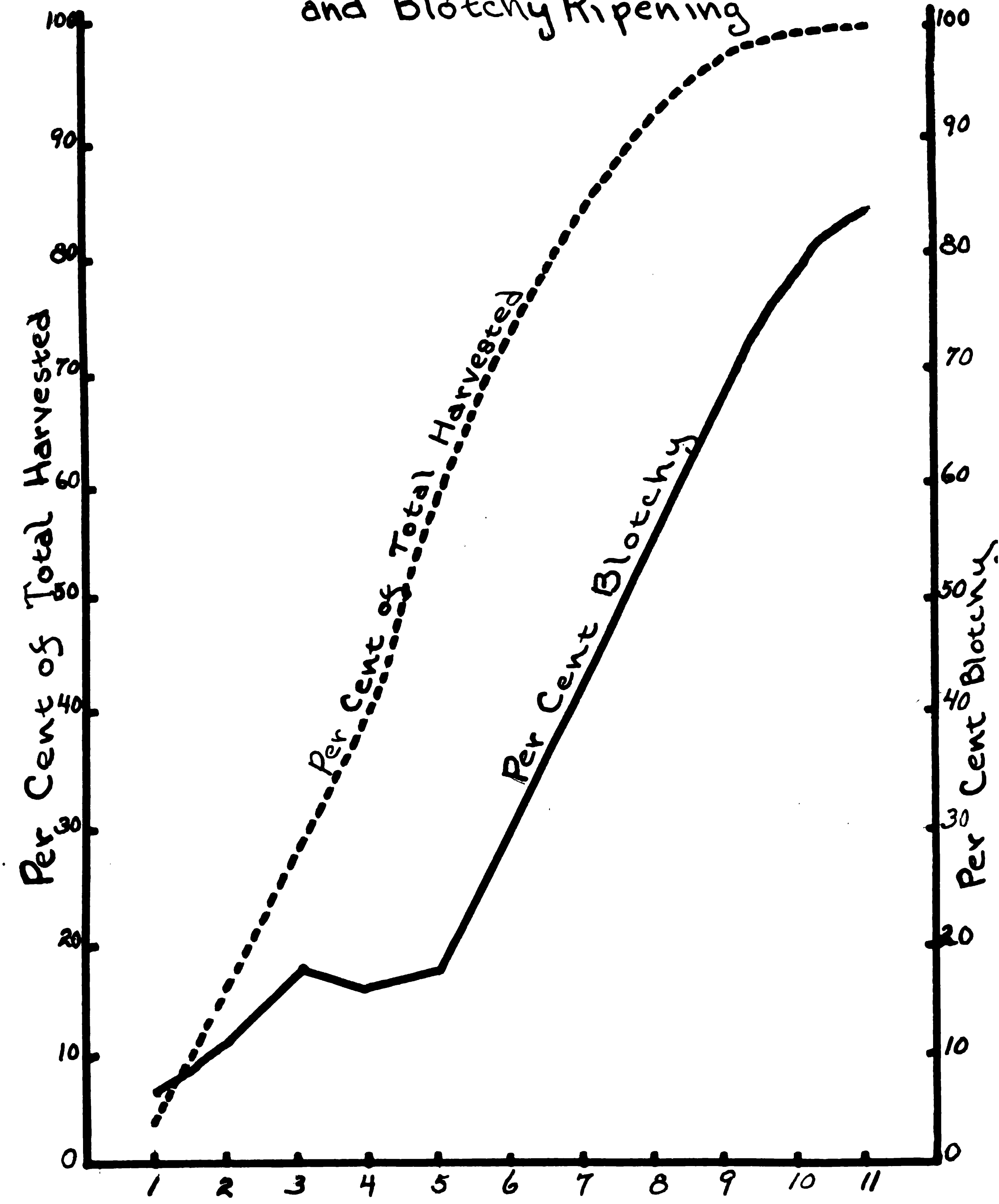
Blotchy ripening may or may not appear on any of the fruits of a plant. Numerous observations have revealed that an entire cluster of fruits may be affected by the disorder or a single fruit on a cluster may show large blotchy areas while the other fruits ripen normally. The first two clusters may ripen normally while a high percentage of the fruits on the third and fourth clusters may be affected and the fruits in the remaining clusters may show varying amounts or complete absence of the disorder.

During the harvesting season of 1932 when the fruits were picked records were taken as to the location of each of the fruits as to cluster and position of the fruit on the cluster. The cluster nearest the base of the plant was considered as the first cluster and the other clusters on the plant were numbered in ascending order. The fruit nearest the main stem was considered as the first fruit on each of the clusters and the others were numbered consectively to the end of the cluster. Where a compound inflorescence occurred the fruits on the two branches were considered from their nearness to the main stem and not in consective order on each of the branches. When the harvesting was completed it was possible to locate each fruit on a given plant. Such data were secured from approximately 500 plants and those for 100 plants of the Grand Rapids variety showing the location of the fruit as to clusters and the corresponding percentages of blotchy fruits are presented in Table VI and the plotted data in Figure 8.

Table VI - Position of fruit as to cluster and percentage of green spot produced on 100 plants of Grand Rapids variety in the spring of 1932.

Cluster number	Total number fruits	Number spotted fruits	Per cent. of total spotted
1	174	12	6.89
2	416	42	11.22
3	442	77	17.42
4	475	74	15.58
5	691	119	17.22
6	503	146	29.02
7	411	175	42.57
8	297	166	55.89
9	190	128	67.36
10	76	60	78.94
11	25	21	84.00

Figure 8
Position of Fruit on Plant
and Blotchy Ripening

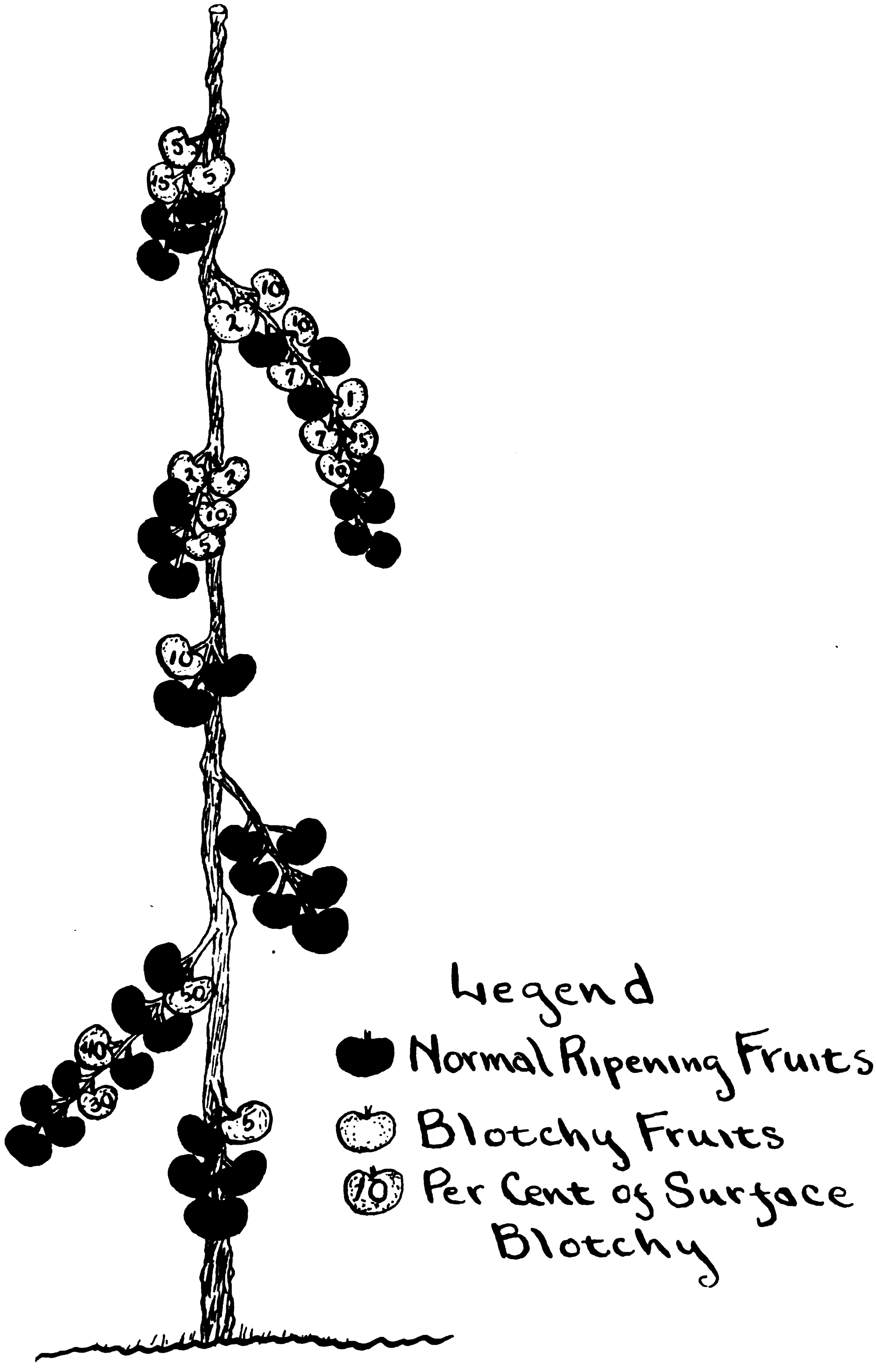


As is shown in Table VI, approximately two-thirds of the fruits were located on the lower five clusters and after the fifth cluster the number of fruits decreased materially with only a small number of fruits setting on the upper clusters. This condition was undoubtedly brought about by high temperature and excessive transpiration during June when these clusters were blossoming. The per cent of blotchy fruits increased materially after the fifth cluster and from this cluster to the eleventh cluster the increase is practically a straight line function. These data would further indicate that as the fruits on the lower clusters are removed from the plant the conditions which underlie blotchiness are greatly intensified.

Figure 9 illustrates the location of both the blotchy and normally ripening fruits of one of the plants. This illustration is based on actual data for a single plant of the Grand Rapids variety and may be considered as typical of the condition as it has been observed for three seasons. The variations in the locations of blotchy fruits as found on a single plant should be sufficient evidence that the disorder is not the result of any invasion by fungi, bacteria or virus and that it is purely physiological in nature.

If green spot increases as the plant ages and the fruits are harvested from it, it is logical to expect the percentage of blotchy fruits to increase as the inflorescence lengthens. However, when fruits in the same position on all clusters were considered collectively, no significant differences were noted, as is shown by the data given in Table VII.

Figure 9



Location of Blotchy Fruits

Table VII - Position of fruit on the cluster and amounts of green spot produced on 100 plants of the Grand Rapids variety in spring of 1932.

Position on cluster	Total number of fruits	Number of spotted fruits	Per cent of total spotted
1	566	151	26.67
2	539	163	30.24
3	481	138	28.69
4	472	134	28.38
5	411	113	27.49
6	327	67	20.48
7	263	73	27.75
8	207	62	29.95
9	132	36	27.27
10 and over	302	83	27.48

Many commercial greenhouse tomato growers express the opinion that green spot is more prevalent where the fruits are exposed to direct solar insolation. It was difficult to secure accurate data regarding this question but numerous observations did not reveal that this was true with blotchy ripening but may have a definite relation with "green back." As many blotchy fruits were found under completely shaded conditions as were found where the fruits were exposed to direct solar insolation.

Location of Plants and Green Spot

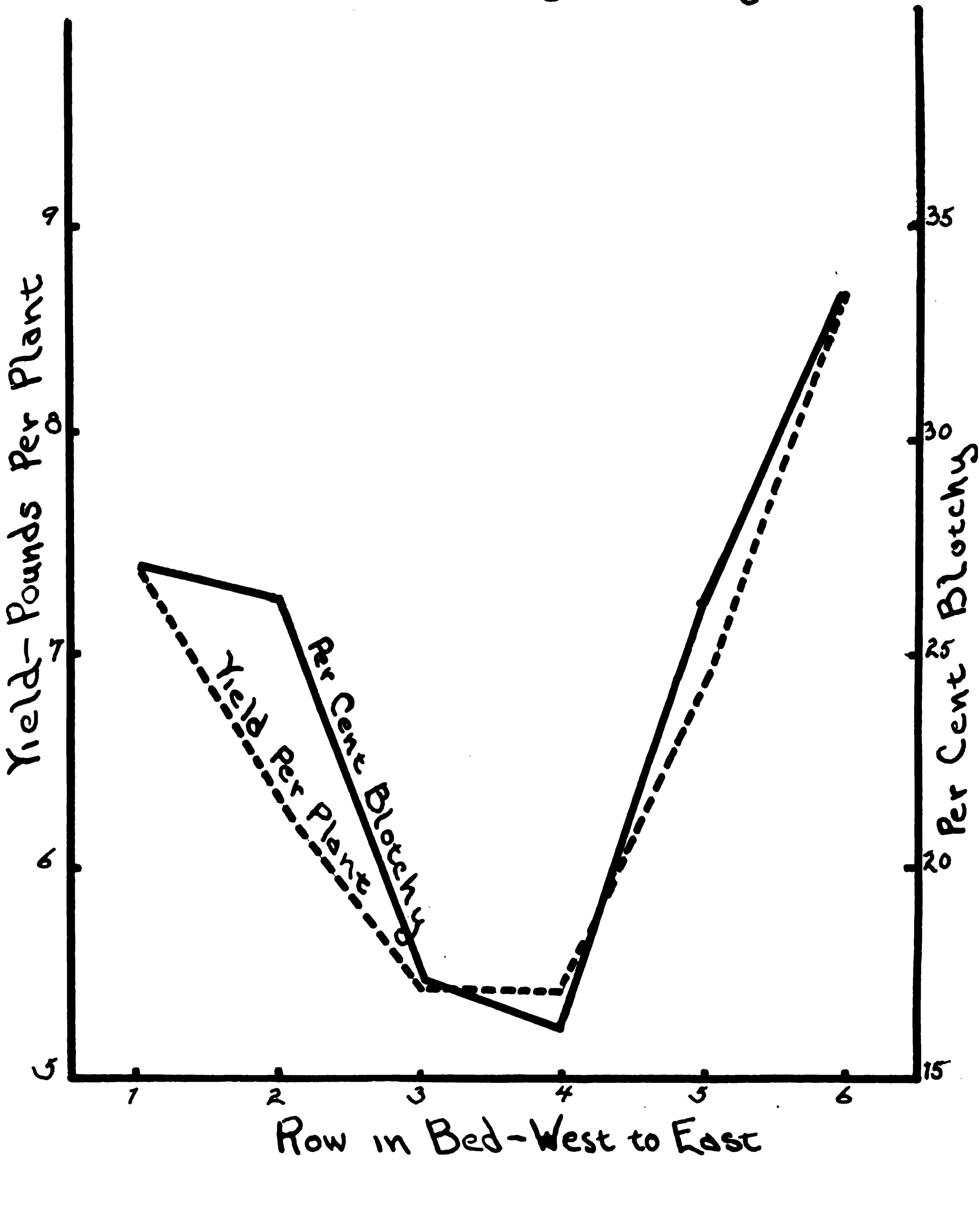
Plants located in the rows to the outside and ends of the beds have been observed invariably to produce larger yields than similar plants in the inner rows and it has been further observed that the former are usually more severely affected with green spot. As mentioned under the discussion of methods, the experimental house is divided into two ground beds by an 18 inch concrete walk which extends around the ends and sides of the beds. Six rows 28 inches apart and the plants set 20 inches apart in these rows is the planting system followed. In the spring of 1932 data were recorded on plants in 20 rows across the east bed of the house, that is, 20 plants in each of the six rows constituted the individual units. The row nearest the center walk was considered as row 1 and the others were numbered in consecutive order across the bed, so that row 6 was the outside row nearest to the heating pipes which are suspended on the outer wall of the house and also nearest to the side ventilators. The average yield per plant along with the percentages of blotchy fruits produced in each of the rows are given in Table VIII and are presented graphically in Figure 10.

Table VIII - Amounts of green spot produced on plants in different locations in the bed in spring of 1932.

Row number	Yield per plant in pounds	Total number of fruits	Number of spotted fruits	Per cent of total spotted
1	7.40	763	207	27.12
2	6.30	601	158	26.28
3	5.44	637	110	17.26
4	5.38	615	100	16.26
5	6.85	671	175	26.08
6	8.67	764	256	33.50

Figure 10

Location of Plants in Bed and Blotchy Ripening



Date of Planting and Green Spot

Various investigators in this and neighboring states, as well as observations in commercial ranges, have shown that a direct relation exists between the date of planting of the spring crop and the resulting yields. In general the later the seed is sown after December 15, the smaller are the yields from the respective plantings. Three plantings approximately one month apart were made in 1932 in order that any effects of size and age of plant as well as climatic conditions prevailing during ripening could be studied in their relation to blotchy ripening. The seedling was made in each case from six to seven weeks before the plants were bedded. The seed was sown in flats and the young seedlings were grown in three-inch clay pots until they were set in the permanent beds. No effort was made in any case to harden the plants and as a whole they were in excellent condition when bedded on February 12, March 10, and April 15. Thirty-five plants constituted a plot and all plantings were grown as nearly as possible under the same conditions.

The first ripe fruit were picked from the plants bedded February 12 on May 5 and the peak of the first fruiting cycle was reached between June 6 and 12 with a second peak nearly equal to the first between July 11 and 17. Those bedded March 10 ripened their first fruit May 20 with the first peak between June 6 and 12 and the second peak from July 25 to 31. The first ripe fruits were picked from the last planted plot on June 9. The first peak from this plot was from June 20 to 26 and the second between July 25 and 31. At the end of the harvesting season the plants of the first two plantings were practically the same size while those of the April 15 planting were considerably smaller. The yield per plant in pounds, the total number of fruits and the number and percentages of spotted fruits from the different plots are given in Table IX.

Table IX - Yield per plant, number of fruits, number and percentage of blotchy fruits from plants bedded at different intervals.

Date set in bed	Average yield per plant in pounds	Total number of fruits per plot	Number of blotchy fruits per plot	Per cent of total fruits blotchy
Feb. 12	10.72	1683	363	21.56
Mar. 10	9.38	1616	186	11.51
Apr. 15	9.02	1215	107	8.80

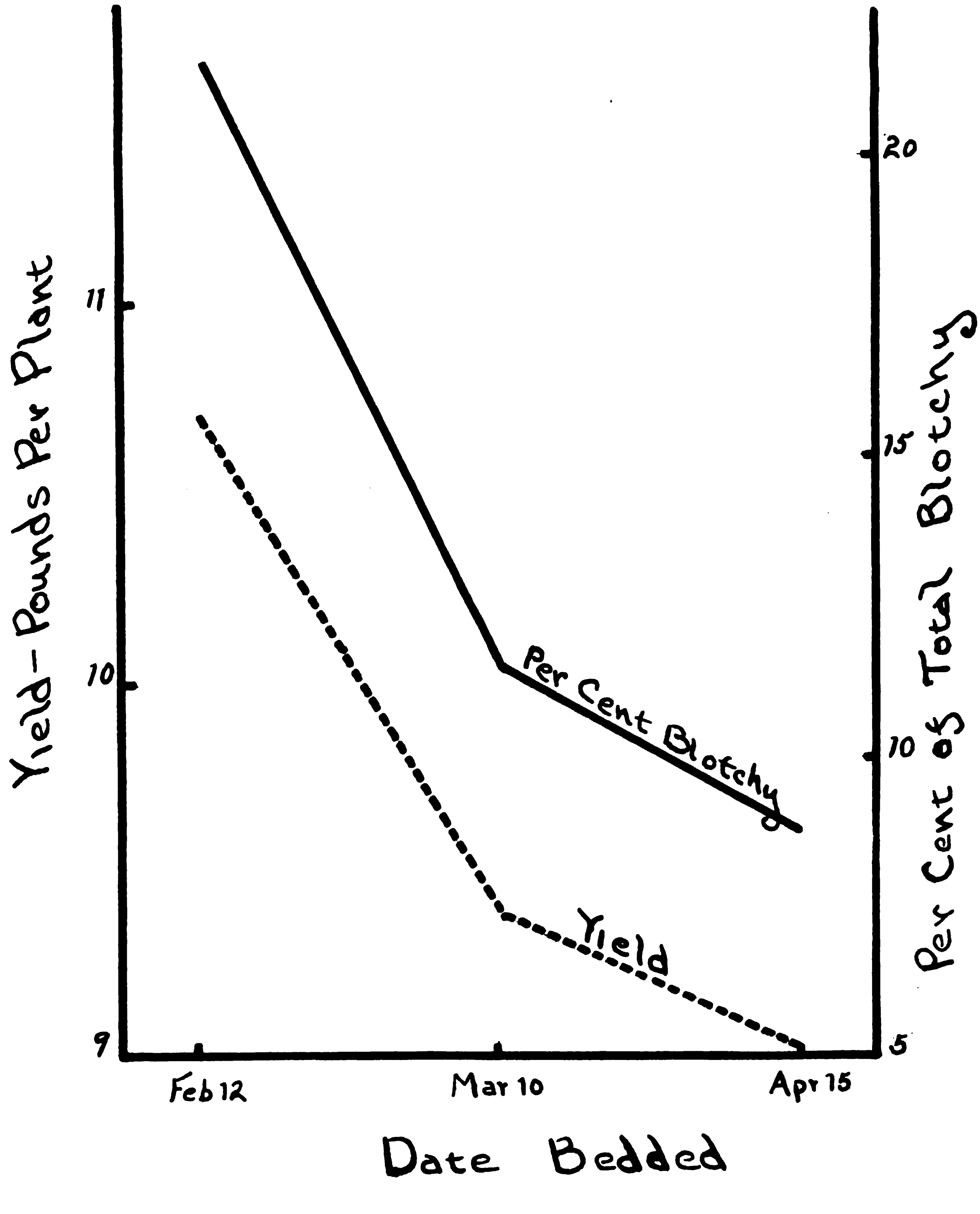
The data given in Table IX and the plotted data in Figure XI show that the earlier planting made February 12 gave the largest yield per plant and the April 15 planting the lowest while the planting made March 10 was intermediate. The same relationship was found between the different plantings when the per cent of blotchy fruits were considered. The weekly variations in the per cent of spotted fruits along with the prevailing temperature conditions are given for the various plantings in Table XI and in Figures 12, 13 and 14.

Effects of Fertilizers

Before the fall crop was bedded in 1931 a series of fertilizer plots were established for the purpose of studying any effects of applications of nitrogen, phosphorus and potassium alone and in combination on the amounts of blotchy fruits produced. One of the ground beds was divided into six plots each, 14.5 ft. by 8.33 ft. in size by inserting boards two inches

Figure 11

Date of Planting and Blotchy Ripening



thick across the bed from one concrete walk to the other, to a depth of 18 inches. The boards extended approximately two inches above the surface of the soil to prevent any washing of soil or nutrients between the plots. As previously stated, the soil was a fertile sandy loam which had been used for the preceding seven years for the production of tomatoes and had been manured annually with supplementary applications of chemical fertilizers high in phosphorus and potassium. Before the fall crop was planted in 1931 the soil was sterilized and all plots received an application of approximately 25 tons per acre of well rotted horse manure. The manure and fertilizers were applied to the surface and mixed well with the upper ten inches of soil before the plants were set. The following treatments were given:

Plot 1.- Nitrogen only - 800 lbs. ammonium sulfate at planting plus 250 lbs. every 10 days after third cluster had set until 3 weeks before final harvest.

Plot 2.- Phosphorus only - 2000 lbs. 0-20-0 at planting. No additional fertilizer given.

Plot 3.- Potassium only. - 2000 lbs. 0-0-20 as KCl at planting plus 200 lbs. KCl every 10 days after third cluster had set until 3 weeks before final harvest.

Plot 4.- Check - no fertilizers applied except manure at time fall crop was bedded.

Plot 5.- Phosphorus and Potassium - 2000 lbs. 0-20-20 at planting plus 200 lbs. KCl every 10 days after third cluster had set until 3 weeks before final harvest.

Plot 6.- Phosphorus, Potassium and Nitrogen - 2000 lbs. 0-20-20 at planting time plus applications of 250 lbs. Ammonium sulphate every 10 days after third cluster had set until 3 weeks before final harvest.

Thirty plants of the Grand Rapids variety were bedded in each plot the first week in September 1931. Because of the delayed planting and poor light conditions these plants gave only a fair yield. Less than 0.5 per cent of the fruits were blotchy and these were uniformly distributed on the various plots. Practically all of these fruits developed in the outside row nearest to the heating pipes where the temperature averaged 4 to 5 degrees higher and conditions were favorable to more rapid transpiration. This crop was removed in January and before the spring crop was bedded the following treatments were given:

Plot 1	400 lbs. Ammonium sulfate
Plot 2	1000 lbs. 0-20-0
Plot 3	1000 lbs. 0-0-20
Plot 4	Nothing
Plot 5	1000 lbs. 0-20-20
Plot 6	1000 lbs. 0-20-20

The plants for the spring crop were set the last week in February. One half of the plants in each plot were from a pure line of the Grand Rapids variety and the other from a pure line of the Blair Forcing variety. The varieties were so planted that alternate plants were of the same variety. Additional applications of ammonium sulfate and potassium chloride at intervals of 10 days were given, as outlined for the fall crop. The harvesting period extended from the last week of May to August 1. The Blair Forcing variety on all plots produced a high percentage of "hard back" fruits and as these were included in the records as blotchy fruits the data for this variety are not given. A negligible quantity of "hard back" fruits appeared on the plants of the Grand Rapids variety and the percentages of spotted fruits for the different fertilizer plots are given in Table X.

Table X - Effects of fertilizers on the percentage of blotchy ripening in spring of 1932

Fertilizer treatment		Per cent of blotchy fruits
Check	(4)*	18.55
P - alone	(2)	17.96
N - alone	(1)	16.92
K - alone	(3)	14.22
P plus K	(5)	15.93
PK plus N	(6)	8.28

* Indicates the number of the plot

The data presented in Table X, though for a single season and from a limited number of plants, would indicate that on this particular soil heavy applications of nitrogen, phosphorus and potassium alone and phosphorus and potassium in combination had little, if any, effect on the percentage of blotchy fruits produced. However, where a combination of phosphorus and potassium in equal quantities applied before planting and supplemented with top dressings of ammonium sulfate during the development of the fruits, the system how followed by the better growers, reduced the injury by approximately one-half. The data would further indicate that factors other than those of a nutritional nature are operative in bringing about the conditions resulting in blotchiness.

No data are available as to what results may be expected in this section on a less fertile soil or a soil deficient in one or all of these nutrients. Observations in commercial ranges where the soil types and fertilizer treatments vary widely have not given any indications that applications of fertilizers are

the solution to this particular problem.

Temperature and Green Spot

The seasonal variations in the severity of green spot indicate that temperature may be one of the important seasonal factors involved. Greenhouse temperatures on bright sunshiny days are from 15° to 25°F. higher than outside temperatures, even when the ventilators are open and no artificial heat is used and, as the mean daily outside temperatures, as well as the length of day and the number of clear days, increase materially during the maturation and ripening of the spring crop, a relationship between temperature and severity of green spot undoubtedly exists. It is not an uncommon occurrence during June, July and August for greenhouse temperatures from 10 A.M. to 5 P.M. to be above 100°F. while the corresponding night temperatures may fall to between 60° and 70°F. Hybro-thermographic records from February 1 to August 1, 1932, as well as records of weekly variations in the per cent of green spot, were available for studying this phase of the problem.

In order to reduce the temperature data to a workable basis for comparison, 70°F. was chosen as an optimum temperature for the plants during the daylight hours. Weekly variations in temperature were calculated from this basis; that is, the temperature in excess of 70° was multiplied by the number of hours the excess existed. As an example, if an average temperature of 80°F. prevailed for two hours, the excess would be 10 x 2 or 20; if an average of 85° for the next two hours, the excess would be 30 or the total for the four hours would be 50. Thus the sum of the hourly excesses for the daylight hours was taken as the weekly accumulated excess and compared with the weekly variations in the percentages of blotchy fruits from the three plantings of 35 plants each in the date of planting test and also from 100 plants grown in another test. These data are given in Table XI and the plotted data are shown in figures 12, 13, 14 and 15.

That temperature exerts an influence on the quantity of blotchy fruits is well shown in figures 12, 13, 14 and 15 where the per cent of green spotted fruits follows rather closely the variations in the weekly excess temperatures. It is interesting to note that in most cases there is a lag of approximately one week between the influence of temperature and the amount of blotchy fruits, except in the case in figure 15 for the twelfth week where a large picking was made on Saturday of that week.

Table XI - The relation of temperatures and green spot for the Grand Rapids variety - Spring, 1932.

Weeks of harvesting season		Accumulative temperature excess 70°F.	Per Cent Blotchy Fruits			
			First planting	Second planting	Third planting	100 plants in last bed
1	4/25-5/1	88				
2	5/2-5/8	332	0			
3	5/9-5/15	268	0			
4	5/16-5/22	136	7.69	0		
5	5/23-5/29	282	14.03	0		
6	5/30-6/5	572	12.98	0		
7	6/6-6/12	660	12.98	1.97	4.35	0
8	6/13-6/19	1232	19.01	2.98	2.27	11.00
9	6/20-6/26	1084	16.40	6.29	17.87	15.82
10	6/27-7/3	836	14.90	0	-----	11.51
11	7/4-7/10	1328	-----	----	7.60	14.91
12	7/11-7/17	1892	10.04	2.36	6.66	15.23
13	7/18-7/24	1498	38.88	18.91	15.27	11.27
14	7/25-7/31	1246	45.52	36.53	5.79	19.12
15	8/1-8/7	----	-----	9.09	5.00	-----

Transpiration Studies

Since blotchy ripening is apparently closely associated with the vascular tissues of the fruit and as conditions favoring excessive transpiration have been observed to increase the amount of blotchy fruits, the writer endeavored to study the transpiration of tomato plants under greenhouse conditions during June and July, 1932. The method used was essentially the same as that described by Marshall (12). The plants used were grown under conditions as previously described and at the time of the tests were approximately two meters tall and had been topped so

Figure 12

Temperature and Blotchy Ripening

First Planting

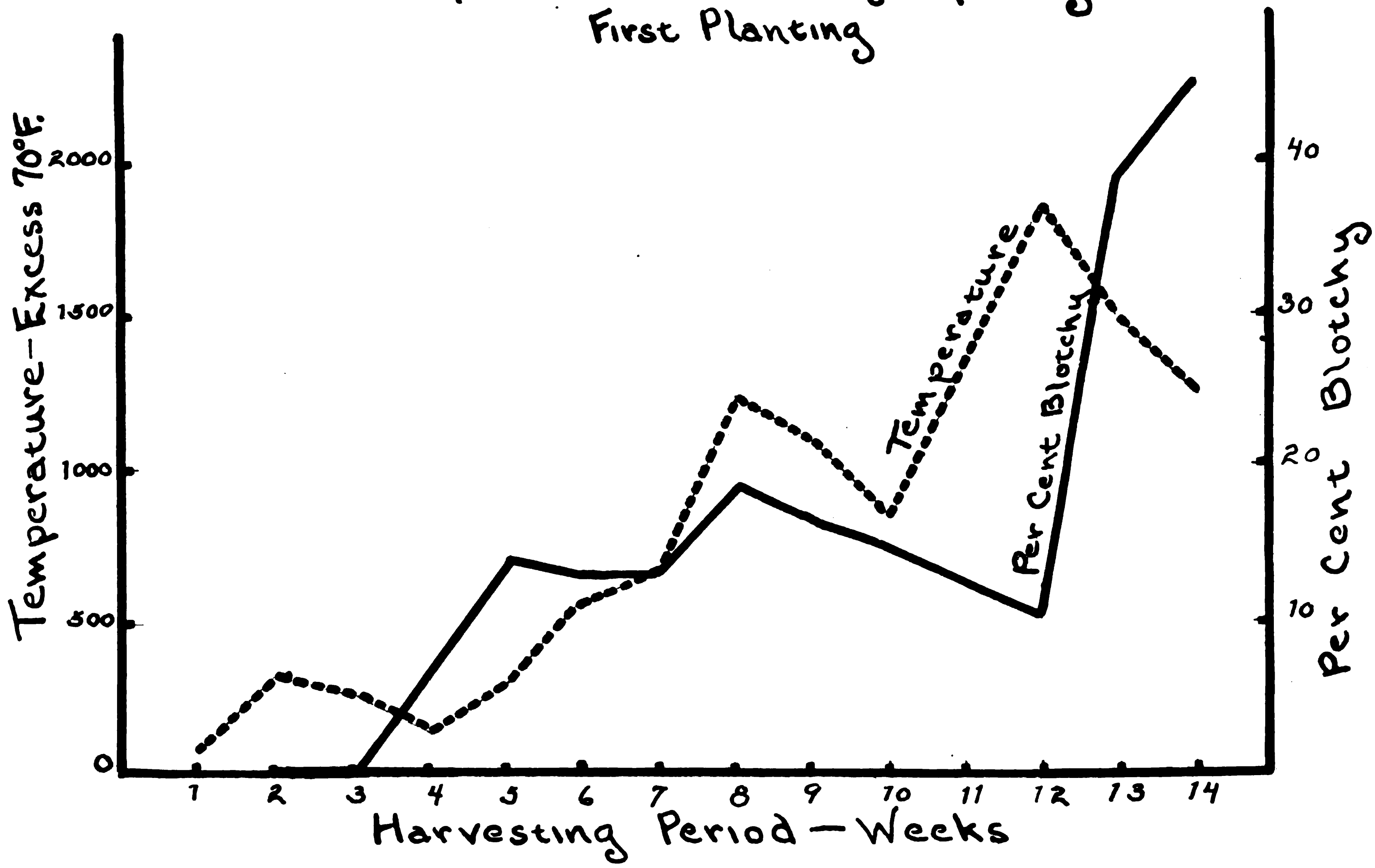


Figure 13
Temperature and Blotchy Ripening
Second Planting

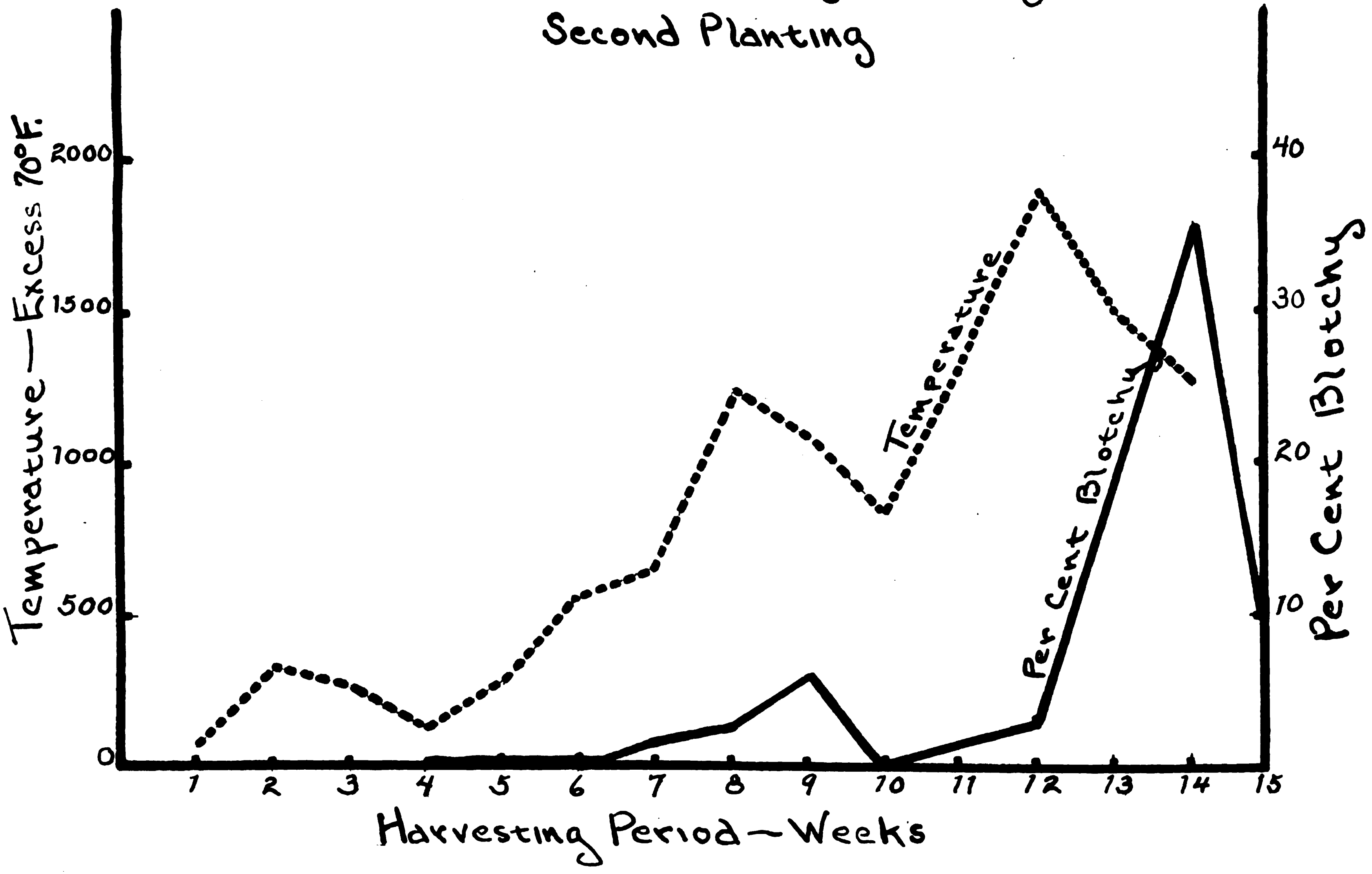


Figure 14
Temperature and Blotchy Ripening
Last Planting

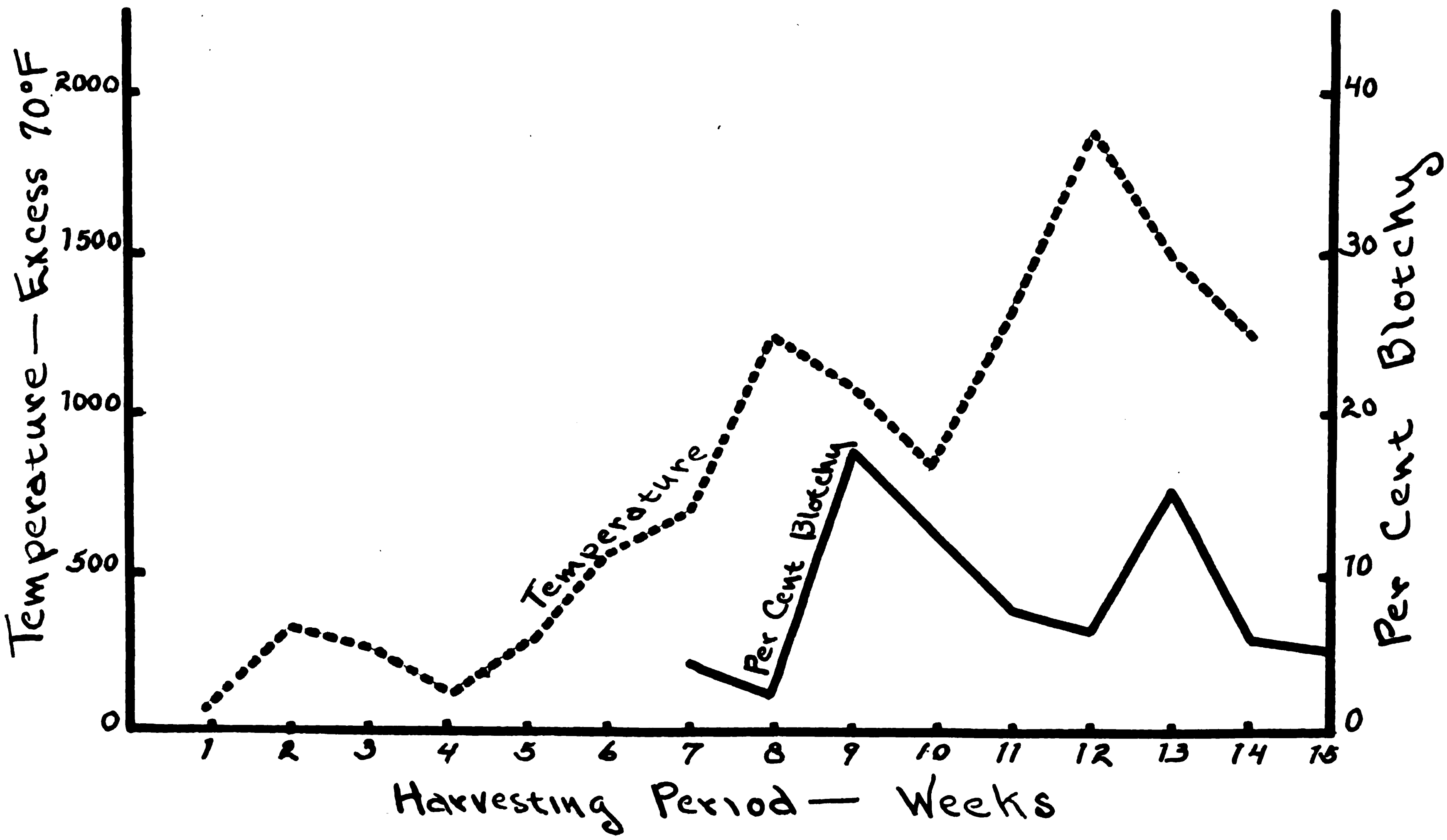
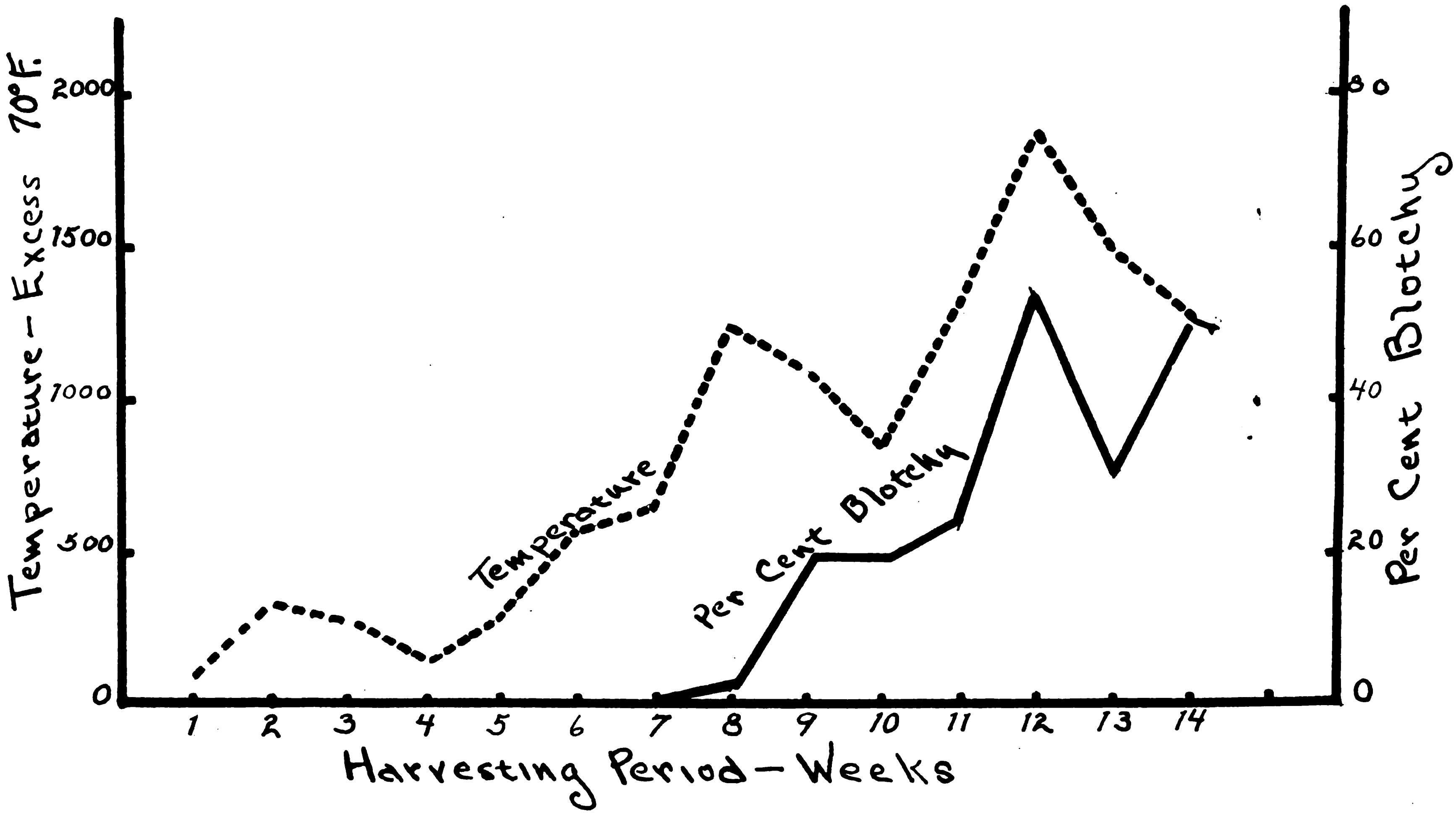


Figure 15

Temperature and Blotchy Ripening

100 Plants — East Bed



that practically all of the leaves were fully mature. There were approximately twenty-five leaves to a plant with a total leaf area of about 10,000 square centimeters. The fruits on the plants had a total weight of between two and three kilograms per plant. Practically all of the above ground portions of the plants were used except a small portion of the main axis which was immediately recut under water when the potometers were connected. All connections were made under water in order to exclude any air pockets. The apparatus consisted of a 100 c.c. burette connected to the plant by heavy rubber tubing. All rubber connections were made air-tight by wrapping and twisting florists' wire around them. Because of the angular and ribbed nature of the stems considerable difficulty was experienced in securing air-tight connections. This was overcome by moulding a plastic, water-proof wax preparation around the stem before it was cut and submerged in water. The connection was then made by slipping the rubber tubing over the stem and up over the waxed area where it was wired. Care was exercised to prevent any of the wax from coming in contact with the cut surface. The water was supplied from the burettes located at approximately the same level as the base of the excised plants which were suspended in their normal position from overhead wires. The burettes were filled from another burette so that any error during the filling was eliminated. Burette readings were made every ten minutes and temperature readings were made at the same interval. Immediately after the tests the leaf areas of the plants were determined by measuring their lengths and reading the areas from a curve previously determined by Porter (15).

Some 30 tests at various hours of the day and under different weather conditions were made. Only the record secured on July 9 is given since it is the most complete of the diurnal trend. This was, however, checked with data secured at various times during the day on similar days and under similar conditions. The plants used on July 9 were set up between 3 A.M. and 4 A.M. and the readings were begun shortly before sunrise and continued throughout the day until 11 P.M. Three plants, each connected to a separate potometer, were used and the data, given in Table XII and shown graphically in Figure 16, are the means for these plants after corrections for differences in leaf areas were made.

Excised clusters of fruit, which were representative of the quantity of fruits found on the plants at the time of the tests, were set up by connecting the potometers to the main axis of the inflorescence as described for the excised plants. The areas of the fruits were subsequently determined by quartering the fruits, tracing around the flattened quarters on heavy wrapping paper and measuring the tracings with a planimeter. The area of the fruits used on July 9 was 1333 square centimeters and their weight was 1389 grams. The amount of water used by the fruits per hour was calculated on the basis of 10,000 square centimeters in order that it may be comparable to that transpired by the same leaf areas. These data are also given in Table XII and Figure 16.

Figure 16
Diurnal March of Transpiration
July 9, 1932

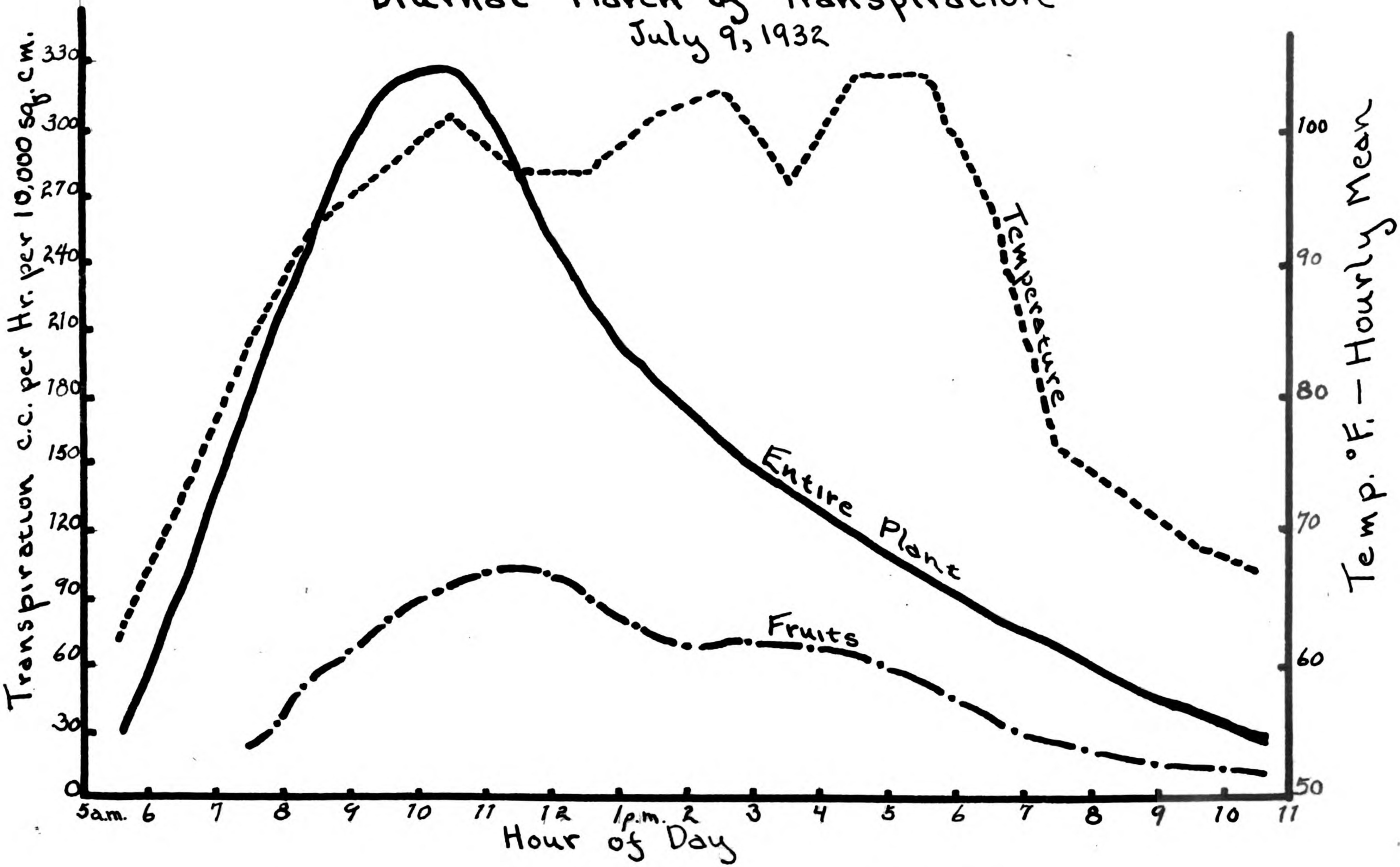


Table XII - The diurnal trend of hourly transpiration rates on July 9, 1932.

Hour	Mean hourly temp. °F.	Transpiration c.c. per 10,000 sq. cm. per hr.	
		Entire plant	Fruit only
5-6 A.M.	62	30.21	-----
6-7	73	81.53	-----
7-8	85	179.44	25.25
8-9	93	259.97	49.63
9-10	97	315.28	83.45
10-11	101	327.92	98.56
11-12 M.	97	286.70	105.75
12-1 P.M.	97	213.93	87.77
1-2	101	182.65	73.38
2-3	103	159.21	72.66
3-4	96	135.84	69.06
4-5	104	122.65	65.46
5-6	104	97.09	48.92
6-7	94	97.55	36.04
7-8	76	83.45	27.34
8-9	73	56.51	20.14
9-10	69	37.73	17.26
10-11	67	24.45	12.95

An increase in the transpiration rate from sunrise follows rather closely the increase in temperature until the maximum transpiration rate is reached about 11 A.M., after which it falls rather rapidly. This fall was probably due to the closing of the stomata and not to a plugging of the vascular tissues, as other tests begun at other hours showed a similarity to this curve. No stomatal studies were made, however, to determine this point. The amount of water transpired by the clusters of fruits is relatively small and insignificant when compared to that transpired by the plant and probably a considerable part of this was transpired by the sepals, peduncles and other cluster parts included. A part was probably used for increase in size and weight of the fruits and not actually lost from them. The transpiration curve for the fruit clusters more nearly follows the temperature changes than does that of the plants after 11 A.M.

Although potometer determinations are open to a number of serious criticisms, if the data secured by this method may be used as an estimate of the rate of transpiration, an average sized plant,if supplied with an unlimited supply, would transpire in one day between three and four quarts of water. At this rate an acre of greenhouse tomatoes planted in rows three feet apart and sixteen inches apart in the row would transpire between 8,000 and 10,000 gallons of water per day.

Effects of Shade

Eight practically full grown plants of the Grand Rapids Forcing variety were enclosed in an unbleached muslin cage on June 13, 1932. Macbeth illuminator reading showed that practically 75 per cent of the available sunlight was excluded by the muslin. The temperature within the cage was practically the same at all times as that of the surrounding air while the relative humidity ranged from 15 to 25 per cent higher in the cage. Data secured from these plants, along with data from eight unshaded plants, are given in Table XIII.

Table XIII - Effects of Shade on Blotchy Ripening - 1932

Treatment	Total Number Fruits	Spotted Fruits	Per cent of Total Spotted
Check	285	100	35.08
Shaded	219	33	15.06

That the percentage of blotchy fruits may be reduced materially by shading is shown by the data in Table XIII. A large part of the blotchy fruits from the shaded plants were harvested soon after the plants were enclosed. Whether the reduction in blotchy fruits by shading was a result of the decreased solar insolation or the increased humidity was not determined.

Study of Water Movements

In order to study the movement of water from the fruits to the leaves during periods of excessive transpiration, a one per cent solution of water-soluble eosine was used. The lower one-fourth of attached fruits were cut away and the fruits immediately submerged in a beaker containing the dye solution. The beakers were suspended with small wires and the level of the solution was at all times kept above the cut surfaces of the fruits. Several fruits of different ages and in different locations were treated in this manner. The movements of the dye were traced from the fruit to the leaves by removing the bark of the main axis of the inflorescense and the main axis of the plant. The exposed central woody portion of these organs formed a nearly white background so that the appearance of dye in the vascular tissues could be detected readily. In the leaves the dye could be seen in the veins easily from the surface.

When this trial was made between 9 and 10 A.M. on bright sunny days in July, the dye was observed in the main stem in twenty to thirty minutes after the fruits were submerged in the solution. In most cases it was observed in the veins of the upper leaves one to one and one-half hours after it entered the fruit. The movement appeared to be most active in the upper and younger portions of the plant and less active near the base. When this method was used on cloudy or rainy days from 4 to 8 hours passed before any trace of the dye appeared in the main stem and from 8 to 24 hours before it could be detected in the leaves.

This method thus gave results indicating that during periods of excessive transpiration the leaves are capable of drawing water from the fruits.

Discussion

The data presented indicate that numerous factors underlie the conditions resulting in blotchy ripening of greenhouse tomatoes. The disorder is one of the vascular and closely associated tissues of the outer wall of the fruit and has none of the symptoms characteristic of injuries produced by invasions of fungus, bacterial, or virus organisms. It is apparently the result of certain physiological disturbances within the plant.

Although Bewley and White (4) in England were able to reduce the amount of blotchy fruits from 40 to 50 to less than one per cent by applications of potassium and nitrogenous fertilizers, particularly the former, under the conditions of our experiments these fertilizers, when applied alone, had little, if any, affect on the amounts of blotchy fruits produced. On one plot where 4800 pounds of potassium chloride per acre was applied during one year, that is, 800 pounds before the fall crop was planted, eight applications of 200 pounds each during the development of this crop, 400 pounds before the spring crop was bedded, and ten surface applications of 200 pounds each during the maturation of the spring crop, no significant reduction in the number of blotchy fruits was produced. Similarly, no significant reductions were secured from nitrogen and phosphate fertilizers applied in excess of the amounts actually needed by the plant or where phosphate and potassium in combination were used. A significant reduction was obtained, however, where a basic application of 0-20-20 supplemented with surface feedings of 200 pounds of sulfate of ammonia was given, but even under this treatment the percentage of spotted fruits was not reduced to insignificant quantities. Soil samples at the end of the season from the beds in which other experiments were carried on, when tested by the Spurway method (23), gave high tests for available potassium, phosphorus, nitrates, calcium, magnesium and blank tests for iron, aluminum, manganese, sulfates, chlorides, nitrites, ammonia and sodium. The percentage of blotchy fruits appearing on these beds varied from 10 to 45.

Although nutrient deficienty at times may be an important factor underlying the conditions developing into blotchy ripening, several characteristics of the disorder are unexplainable on this basis and the following questions arise. If the deficiency of a nutrient or of nutrients results in blotchy ripening, why is the disorder not equally severe on the fall and spring crops? Why does the disorder not become evident until the fruit is nearly mature? Why should any differences exist between fruits of practically the same size and age on a plant and between plants located in different positions in the greenhouse? Undoubtedly more evidence than that secured in these investigations is necessary to show that fertilizers plan an unimportant role in the conditions which bring about blotchy ripening. However, the writer is unable to accept this theory of the conditions antecedent to blotchy ripening until data dealing with the above questions are presented.

The data presented on the seasonal occurrence of blotchy ripening, the effects of shading, the relationship with temperature variations, the position and amount of fruit on the plants, as well as the appearance of the disorder only as the fruit approaches maturity, all indicate that meteorological conditions are casually related to blotchy ripening. The weather conditions prevailing when the severity of the disorder is intensified, such as the increased daily illumination, the greater solar insolation, the increased temperatures, and lower relative humidity or increased evaporating power of the air, would each individually and all collectively increase the transpiration rate of the plants.

Data obtained by various methods and by different investigators (1, 8, 9, 25) have shown that during the midday hours a more or less considerable water deficit occurs in the leaves of plants, even under conditions of an abundant supply of moisture in the soil. This has led to the conclusion that during periods of maximal transpiration, the rate at which water is absorbed and translocated through the plant is insufficient to counteract that lost by transpiration. The daily water balance was represented by Maximov (13) as follows: As a result of the progressive loss of water and the deficienty of the supply, the palisade cells of the leaf lose their turgor and a pressure arises in the cells. This tension is transmitted to the contents of the vessels which give up a portion of their water to the leaf. In doing so a pressure is produced in the vessels and by way of the vessels the tension is transmitted to all other tissues of the plant. Thus the mesophyll of the leaf may draw water from all parts of the plant, including the absorbing layer of the root, the meristematic tissues, as well as developing or opening flowers, and from setting or ripening fruits. Under these conditions the transpiring leaves draw upon such reserves of water as the organs may contain. This transference of water from one part of the plant to another has been demonstrated by Bartholomew (2), MacDougal (11), Krasnoselsky - Maximov (8) and Marshall (12). In consequence of this change in the direction of the water stream various physiological disturbances are produced.

This hypothesis has been offered as an explanation of blossom end rot of tomatoes (5, 24, 26), the internal decline in lemons (2), bitter pit or stippen of apples (10), the dropping of blossoms in the tomato (17, 22), the shedding of unopened balls in cotton (9), and the poorly and sparsely filled grain of cereal crops. Therefore, the hypothesis, that the withdrawal of water from the tissues of tomato fruits by excessive transpiration, in a period three to five days before the fruit ripens, results in necrosis of the bundles and surrounding tissues associated with blotchy ripening, is advanced as a logical explanation of the conditions resulting in the disorder.

The data which have been presented on the various phases of the problem are explicable on the basis of this theory. Increases in temperature are largely dependent upon the intensity of solar radiation and as there is an increase in the intensity of solar radiation during the development of the spring crop the greenhouse temperatures increase considerably. The higher temperatures require more ventilation and consequently the relative humidity of the air is lowered and its evaporating power increased. The increased solar radiation, the higher temperatures and the increased evaporating power of the air would all have an accelerative effect on the transpiration rate and the suggested theory affords an explanation for the rather close agreement between excessive temperatures and blotchy ripening. The inhibition of lycopersicin development by high temperatures reported by Duggar ( ) is reversible; that is, when fruit are transferred to optimum temperatures the red pigment develops. However, it has not been possible to alter the color of blotchy fruits by any similar treatment as the tissues are apparently permanently injured.

The greater number of blotchy fruits produced in locations favoring excessive transpiration, such as, in the outer rows near the heating pipes and ventilators further substantiates the hypothesis. Likewise, shading would reduce leaf temperatures, lower the evaporating power of the air, reduce the effects of solar insolation, and result in decreased transpiration and consequently fewer blotchy fruits would be produced. The size of the fruit apparently does not have any effect on whether or not it developed blotchiness.

If the fruits are thought of as a water reserve for the plant, after the greater portion of them ripen and are removed, the rate of water withdrawal from the remaining fruits would be increased during periods of stress. This reduction in moisture reserve, as well as the accompanying increase in leaf area and accelerated transpiration, would result in conditions favorable to the development of large numbers of blotchy fruits in the upper clusters of the plants, which is in agreement with data given in Table VI.

The with drawal of water from the fruits by the leaves would interfere with the translocation of elaborated foods into the fruits and would consequently delay their normal development and ripening. Thus, it follows, that if the normal development and maturation of the fruit is delayed, it is more likely to be affected by blotchy ripening than had not the normal maturation been interrupted.

Plantings made in April, as compared with those made in February, develop under conditions which induce a type of growth susceptible to unfavorable meteorological conditions during ripening. The later-set plants usually develop more extensive root systems and their foliage is less likely to be the soft, succulent type produced under the poor sunlight conditions prevailing during the development of the earlier-set plants. The size of the plants from the two plantings would make considerable differences in their leaf areas, as well as differences in their transpiration rates per plant, and theoretically corresponding differences in the number of blotchy fruits produced would be expected.

Suggestions for the practical prevention of the disorder cannot be formulated from the limited data now available but modification of the conditions which favor excessive transpiration would no doubt be of value. The complicated nature of the conditions antecedent to blotchy ripening require that the whole problem be further investigated before the theory of nutrient deficiency is discarded and before the hypothesis advanced by the writer is accepted.

Summary

Blotchy ripening, a physiological disorder of greenhouse tomatoes ripening during May, June, and July is reported. The characteristic symptoms are the failure of areas of the outer wall of the fruit to develop and color normally, which is accompanied by necrosis of the vascular and surrounding tissues in these areas.

Considerable differences exist between varieties and between strains within a variety in their susceptibility, but none have been found to be free of the disorder.

Apparently no relation between size of fruit and blotchiness exists. Distribution curves of different sizes of normally ripening and blotchy ripening fruits are practically identical.

Conditions resulting in delayed maturity of the fruits tend to increase their susceptibility to the development of blotchiness.

Results secured with nitrogenous, phosphate, and potassium fertilizers applied alone and in combination have not indicated that the disorder is nutritional. Where potassium chloride was applied at the rate of 4800 pounds per acre in one year the per-

centage of blotchy fruits was not reduced significantly. Slight reductions were secured where a complete fertilizer was applied. High tests for available nitrates, phosphorus and potash were secured at the end of the season on soils where the amounts of blotchy ripening varied from 10 to 45 per cent.

Higher percentages of blotchy fruits were secured from the upper clusters of the plants and after a large part of the fruit ripens and is removed from the plants the conditions favoring the disorder are intensified. No relation between the different fruits on a cluster and their susceptibility to blotchiness was found to exist.

Plants bedded in April produced fewer fruits and a lower percentage of blotchy fruits than those set in February or March.

A rather close agreement between excessive temperatures and blotchy ripening has been shown to exist regardless of the age of the plant.

Plants in positions favoring excessive transpiration produced more blotchy fruits than plants not so situated. Similarly, shading resulted in fewer blotchy fruits.

The withdrawal of water from the fruits by the leaves during periods of excessive transpiration has been shown by the use of an analine dye.

A hypothesis, that the withdrawal of water from the fruits during periods of excessive transpiration three to five days before the fruit ripens results in the necrosis of the bundles and associated tissues of the blotchy areas, is advanced.

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