A PHYSIOLOGICAL STUDY OF GROWTH AND FRUITING OF THE TOMATO (LYCOPERSICUM ESCULENTUM) - WITH REFERENCE TO THE EFFECT OF CERTAIN CLIMATIC AND EDAPHIC CONDITIONS

by

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INTRODUCTION

The tomato has been cultivated in America, for culinary purposes only, a little more than one hundred years, but today it is the most important canning crop in the United States, its total annual acreage and value exceeding that of any other vegetable crop with the exception of the potato crops. More than 640,000 acres were planted in tomatoes in 1937 and the total value of the crop exceeded $51,000,000. In that year more than 1,750,000 tons of tomatoes were used for canning alone. In addition to its use both in the raw and canned state, the tomato has many by-products which constitute an industry of increasing importance.

A thorough knowledge of the cultural, climatic, and edaphic requirements to produce a crop of tomatoes is necessary in order to secure the highest quality product and obtain the maximum financial return per acre. This knowledge is essential owing to the continued increase in production and low prices obtained during recent years, and is especially important to the grower of tomatoes for canning, because the fruit must be left on the vines until fully mature in order to obtain the desired color and other qualities essential for a canned product of high-quality.

Studies by several investigators have shown the value of knowing the relationship between certain environmental factors and the resulting growth and fruitfulness in such vegetable crops as peas and sweet corn. Using the tomato, a similar study to determine the growth and fruiting response of the crop to certain temperature, moisture, and soil conditions would be valuable. Previous investigations have emphasized certain phases of this problem but, so far as the author has been able to ascertain, a comprehensive investigation involving all phases of the problem has not been made in the United States.

The importance of the tomato as a canning crop in Maryland alone, fully justifies the expenditure of considerable effort to solve some of the many problems of the grower and canner. The experiments reported herein were planned: (1) to determine the effect of certain climatic conditions, mainly temperature and rainfall, on (a) rate of plant growth, (b) rate of fruit development and ripening, and (c) yield of mature fruit; (2) to determine the relationship between growth and fruiting of tomato plants and the nutrient level in the soil; and (3) to obtain a more accurate knowledge of the growth characteristics of the tomato plant under field conditions.

REVIEW OF LITERATURE

Methods of Expressing Growth Rate

A number of methods and formulae have been devised for the mathematical expression of the rate of growth. All formulae, however, do not hold exactly over the entire period of growth, nor do they agree equally well with the growth rate of all plants. This condition exists, of course, because the formulae fail to adequately express the effect of all the factors which affect the growth of plants at any particular time. Very good agreement, nevertheless, has been obtained by the use of the various formulae on certain plants and for certain well defined stages in their growth. Blackman (9) has shown that for many annual plants the rate of growth, at least in its early stages, follows approximately the "compound interest law". He points out that Wilhelmy's law is merely a restatement of the "compound interest law".

Another formula that has been frequently used in expressing the rate of growth of plants and other organisms is one for an autocatylytic reaction given by Robertson (87) and others.

Briggs, Kidd, and West (23) developed a formula to express assimilation rate of plants by using the relationship between leaf area and increase in dry weight to express the "compound interest law".

Luckwill (60) using the formula of Briggs, Kidd, and West (23) found that the mean assimilation rate of tomato plants, regardless of species or type, increased up to fifteen weeks after sowing and after that time showed a steady decline. When the logarithm of the dry weight of the stems was plotted against the logarithm of the dry weight of the leaves a straight line was obtained, and k was found to be a constant for each of the three types of plants used. Ashby (4) found, that, during the preflowering period of the life cycle of the tomato, leaf number increased in a linear manner with time. This relationship of leaf number with time was found by Luckwill (60) to be an exponential function during the period of flowering, and a linear relationship during the preflowering period. This difference is explained on the basis of the occurrence of branching at the time the first cluster is formed, and hence from that time onward the increase in leaf number becomes an exponential function because of the increase in the number of branches with time. Ashby (4) found that the efficiency index of the tomato remained practically constant for the period from germination to the onset of flowering, while Luckwill (60) found that during the flowering period the efficiency indices for all three plant types fell continuously.

Pearsall (85), using the formula for Huxley (53), calculated k between stem and root weight of a number of plants and found that in every case k remained a constant.

Factors Affecting Plant Growth

Climatic. Many factors influence the growth and development of plants, but one or two factors of climate may be the most important and exert an indirect influence upon other factors and consequently show a rather high correlation with the growth rate. Such have actually been the findings of Smith (90) and Hildebrandt (47).

McLean (69) states that the quantitative aspect of the relation between plant activities and climate, presents an exceedingly complex problem, the solution of which cannot be expected in the near future. He further points out that most investigations in this field have been attempts to correlate plant growth with one, or at the most two, climatic factors, generally with temperature and rainfall.

Various methods have been devised for evaluating the influence of climatic conditions upon plant growth. The factors most frequently considered are temperature and rainfall. Using the Van't Hoff-Arrhenius principle, Livingston and Livingston (59) prepared a table of "efficiency indices" for temperatures between 40 and 90 degrees F. The results obtained using the direct "summation" methods agreed within a plus or minus variation no greater than 5 per cent. Later, Livingston (58) supported by the findings of Lehenbauer (57) on the growth rate of maize seedlings at different temperatures, developed socalled "physiological indices" which recognized a maximum and a minimum temperature for plant growth and also an optimum temperature beyond which growth rate was retarded until the maximum was reached. Such indices, however, do not apply to those changes taking place in the grains of sweet corn upon ripening where the processes mainly involved are of a chemical nature. Brenchley (21) found that under greenhouse conditions the percentage rate of increase in the total dry matter was correlated only with temperature during the foreperiod of growth, but was correlated with both temperature and sunshine thereafter. Appleman and Eaton (2) in a study of the effect of temperature on the ripening processes in sweet corn found that the Van't Hoff-Arrhenius principle was operative. Calculation involving use of 40 degrees F. as a base temperature gave very good agreement with the observed rate of ripening in the sweet corn grains. These authors found that the physiological indices did not provide even an approximate measure of the rate of these processes. Magoon and Culpepper (66) found that the common base of 40 degrees F. was too low for use with sweet corn in predicting the effect of temperature on the physiological development of the plant during the growing season and recommended base lines falling within 50 to 60 degrees F., depending upon the variety or the strain.

Boswell (20) using heat summation above the base line of 40 degrees F. found that in a given season blossoming of peas occurs after receiving a fairly constant amount of heat, regardless of time.

Baker and Brown (5) studied the effect of sunshine and shape of the tomato fruit on the rate of ripening and found a significant positive correlation between the number of hours of sunshine and the number of days to ripen the fruit after it had started to color. They obtained a non-significant correlation between fruit shape and rate of ripening. Watts (94) found that, under greenhouse conditions, increases in either intensity of light or duration of photoperiod were followed by increases in dry weight of tomato plants. An increase in temperature produced an effect similar to that of an increase in light. He concluded that for the greenhouse crop the temperature should be somewhat higher than 60 degrees F.

Bewley (7) found a positive correlation between hours of bright sunshine and crop yield for the greenhouse crop of tomatoes.

Orchard and Bewley (81) obtained increased yields of greenhouse tomatoes by heating the soil to eighty or eighty-five degrees F.

Orchard (80) concluded that the optimum air temperature for the greenhouse tomato crop in England is from 63 to 65 degrees F.

Bolas and Melville (13) studied the metabolism of tomato seedlings in the greenhouse to show (1) the influence of light and temperature on the assimilation rate and (2) the influence of temperature on rate of respiration and translocation. They found that the relation between the assimilation rate, light, and temperature is very complex.

Investigations to determine the optimum temperature for maximum rate of photosynthesis in plants of the temperate regions have indicated that 25 degrees C. is the optimum. Dastur (28) working with various tropical plants, including Helianthus annus, found that the maximum rate of carbon dioxide assimilation was between 34 and 36 degrees C. In an earlier publication Dastur and Buhariwalla (27) stated that the influence of water content of leaves on the rate of assimilation is greater than that of the chlorophyll content and he draws the same conclusion from his work with tropical plants.

Melville (71) in a study of the influence of environment on the growth and metabolism of tomato found that (1) the gain in dry weight increases to a maximum as water content of the leaves increases up to 91.5 percent, (2) further increase in water content above 91.5 percent resulted in a rapid decline in the rate of gain of dry weight, (3) the optimal percentage water content was dependent on light.

Bolas (10) found that as the light intensity became greater the optimum temperature became higher. At a mean light intensity of 100 foot candles the maximum rate of assimilation was attained at a temperature of 62 degrees F. and any increase above this intensity resulted in a rapid decrease in assimilation rate. The optimum temperature (as far as assimilation rate is concerned) for 200 foot candles was found to be about 75 degrees F. and at 1,000 foot candles 90 degrees F. was found not to be excessive. Bolas and Selman (15) later state that under the conditions normally obtained in the greenhouses there is no evidence of any increase in assimilation rate during a single day with increases in light above a total of 6,500 foot candle hours. When they plotted the dry weight of seedling tomato plants at the seven leaf stage against time of the year they found that the dry weight curve gradually rose as light intensity increased and reached a maximum in July when the light intensity was highest after which there was another fall in the dry weight as the light intensity again decreased.

MacGillivray (62) studied the effect of temperature on the development of color in the tomato and found that temperatures of 90 degrees F. or above were very detrimental to color development in vine ripened fruits. When day temperatures were high he concluded that the development of lycopin was permitted by the lower temperatures at night.

Nightingale and Mitchell (79) grew tomatoes in sand cultures with complete nutrients at 47 percent moisture saturation, at a constant temperature of seventy degrees F. and at 35 percent and 95 percent relative humidities. The plants grown at 35 percent humidity when compared to those grown at 95 percent humidity grew slower, had relatively thicker leaves, stiffer stems, leaves were lighter green and contained less chlorphyll. On the other hand Mitchell (73) working with the tomato and several other vegetables found that the rate of carbon fixation of the leaves was not affected by a rapid decrease in the humidity of the air surrounding them or by exposure of the leaves for 15 or 20 hours to the low humidity. Freeland (36) found that with a number of plants a greater amount of ash and dry weight was accumulated under high transpiration than with the same plants under conditions of low transpiration.

Although it is recognized that the greater part of the carbon dioxide fixed by the plant is converted to carbohydrate by the green leaf, the influence of environmental factors on the translocation of photosynthetic products from the leaf into the stem and root is still not well known. Selman (89) has attempted to analyse some of the more obvious factors involved. The wide seasonal differences were ascribed to the difference in length of the night, during which the

the plant is losing weight by respiration and the leaf also by translocation. Under summer conditions the rate of translocation was directly proportional to rate of assimilation, while in the winter months no correlation was found to exist between assimilation and translocation. Translocation appeared to fall with a rise in light intensity, reaching a minimum at about 1,000 foot candles and then rising again.

Porter (86) in a study of the effect of light intensity found that the percentages of dry matter, ash,water, fresh weight and elaborated food material showed a close positive correlation with light intensity. He states that humidity becomes a critical factor in photosynthesis when the light intensity is reduced. The correlations showed that 32.4 percent of photosynthate variation was due to light intensity alone, and that temperature and humidity are negligible factors only when correlated with light intensity. Tiedjens (93) states that cool temperatures tend to promote more vigorous roots and a larger top growth. He points out that plants set on lighter soils on successive days may vary as much as two weeks in maturity if one lot is set when all conditions are favorable and the second lot when the weather suddenly becomes hot and dry. He suggests that plants set early in the season are not so drastically affected because moisture and temperature are more uniform.

Smith (91) has made a comprehensive study of the effect of seasonal condition on the quality of canned tomatoes. She states that during the producing period the fruit develops best when the day temperature is 80 to 90 degrees F., and the night temperature not less than 60 degrees F. She used 55 degrees F. as a base for calculating degree-hours, apparently assuming that below this temperature there was very little or no ripening taking place in the tomato fruit. It is shown that low rainfall caused high total solids in the fruit.

Foster and Tatman (35) in a recent publication state that starch congestion in the stems of tomato plants appears more correlated with nitrogen deficiency than with wide variations in potassium supply. Lower temperatures caused an increase in starch congestion and there was some tendency for congestion to be greatest at the 47 percent moisture level.

In a study of the effect of environmental conditions on the modification of flower structure in tomato varieties, Howlett (51) found that the maximum pistil length in relation to stamens occurred when the plants were growing during a period of relatively short day lengths and under low light intensity with an abundance of readily available nitrogen. The short pistil was produced when the days were long, the light of high intensity, and the supply of readily available nitrogen only moderate.

Edaphic and Nutritional. At the present time considerable importance is attached to the effect of these factors on the growth and fruiting of the tomato because of the large acreage that is now annually planted on the light soils of the Atlantic Coastal Plain, and because these soils contain, in many regions, subminimal quantities of some of the minor elements (46) and rapid leaching of the major fertilizer elements occurs in them under the humid conditions of the eastern part of the United States.

Brooks and MacGillivray (24) found that the percentage of dry matter of tomato fruits varies inversely in certain limits with the percentage of soil moisture. Soil moisture at the level of 70 percent to 50 percent of the field capacity produced the largest quantity and largest sized fruit. Dry matter varied from 9.04 percent at 70 percent soil moisture, to 6.60 percent at 34 percent soil moisture.

In experiments on the effect of various fertilizers and fertilizer constituents on tomato production, Mack (65) found that the largest average yields were produced by the plots receiving barnyard manure. He concluded that phosphorous was the outstanding limiting element, and that nitrogen in combination with other elements produced no significant gains in total yields although a lack of nitrogen in the fertilizer decreased the yield during the first two weeks. From the results of rapid chemical tests of tomato plants in the field made over a period of several seasons, MacGillivray (61) found that nitrate content of the plants varied more than that of any other element in the plant - giving the highest test at the beginning of the season and the lowest at the end. He points out that the survey emphasized; (1) the great variation in fertility in fields of the same region and even in different regions of the same field and (2) the apparent low nutrient level of tomato plants during August and September for one or two of the nutrient elements (usually nitrogen or nitrogen and phosphorous).

Emmert (31) found that an acid reaction increased the early yield of tomatoes but decreased the total yield below that of the checks. The effect of the lower pH. values (4.0 - 5.5) was explained by the statement that acidity made phosphorous available but checked nitrification. When an alkaline reaction of pH. 7.5 to 8.5 was produced in the soil by $NaCO_3$ a very marked increase in yield was obtained - due, he thinks, to the stimulation of nitrification. He concludes that soil in the pH. range from 4.0 to 8.5 does not seem to influence the growth and yield of tomatoes directly, but does determine the nutrient relationship and toxicity of soil elements that control growth. In a later publication Emmert (32) confirmed the effect of the low pH. on tomato yields and states further that nitrate nitrogen was the limiting factor, in many cases, in depressing the yield of tomatoes.

Kraybill (56) states that when phosphate is limiting, nitrate accumulates in the tomato plant along with carbohydrates while the general appearance is that of a low nitrogen plant. Eckerson (29) corroborated Kraybill's findings and further noted that reductase activity decreases with phosphate content. After the fifth week of phosphorous starvation she found that complex phosphorous compounds broke down, starch decreased rapidly and phosphatides and proteins begin to break down and the plant did not survive very long after this.

Gerdel (39) working with corn found that a continuous abundance of nitrogen, phosphorous and potassium throughout the season caused a marked differentiation of the vegetative and reproductive cycles associated with a narrow silking range, earliness of silking and high yield. Growth curves of the plant were bimodal, each consisting of two S curves where the autostatic portion of one overlapped the autokinetic portion of the other.

Moinat (74) working with seedlings of Phaseolus vulgaris found that a greater amount of mechanical tissue per unit leaf area was formed in the plants grown at the lower soil moisture levels.

Hoffman (49) studying the influence of nitrate and ammonium nitrogen on the growth of greenhouse tomatoes found no significant differences in yield, grade or average fruit size at soil pH. from 5.5 to 8.0.

Parker (84) determined the green weight of vines grown at various pH. ranges and found the highest weight of vines at maturity was produced on soil of the pH. ranges between 5.5 and 6.4 between which there was not a significant difference. However, above and below these limits there was a decrease in green weight which decreased as the acidity or the alkalinity increased. He points out that the injurious effect of low pH. was aggravated in soils of low organic matter content (less than 2 percent).

Emmert (34) studied the effect of soil moisture on the nutrient levels in tomato plants and found that on dry soils the level of phosphate decreased and potassium increased while there was very little change in the potassium level in the plant on moist or on very dry soils. Huelson (52) shows that in seasons of deficient rainfall maturity of the tomato is markedly delayed. He states that manure and phosphorous are the most important fertilizer amendments for highest tomato yields under Illinois conditions.

Tiedjens (93) states that where calcium is maintained at a good level for tomatoes there should be at least 100 pounds of potassium available per acre.

The efficiency of "rapid soil tests" to determine the fertilizer needs of crops grown on various soils has been a matter of conjecture but they are being more commonly used as time passes. Anderson (1) found that on some soils the various tests for phosphorous and potassium were in fairly good agreement and agreed with crop response whereas on other soils some of the tests were not in agreement.

Hester (45) found that, on a Sassafras sandy loam soil in New Jersey, tomato plants made 2 percent of their total growth and absorbed 3 percent of the total nutrients during the first month after transplanting, 26 percent of their growth and 30 percent of the total nutrients were absorbed during the second month and 72 percent of total growth, and about 67 percent of the total nutrients the third month after field transplanting. The total nutrients in pounds absorbed during the 3 months was: nitrogen 98.7; phosphorous 28.8; potassium 173.9; calcium 106.8 and Magnesium 20.5. Hester (46) later states that soluble aluminum in mere traces is harmful to the tomato plant. In a greenhouse test using Sassafras sandy loam soil he obtained very little growth and no fruit at pH. of 4.8; at pH. of 5.0 he obtained 0.04 pounds of fruit per plant and at pH. between 6.0 and 7.0 about 4 pounds of fruit per plant. He points out that phosphates in soils low in organic matter are only between 10 to 20 percent effective, and that soils of the Sassafras type have a greater fixing power for phosphorous than soils of the Portsmouth or Elkton type.

Defoliation. Hoffman (48) studied the effect of defoliation upon the yield of greenhouse tomatoes and found that leaf pruning caused a decrease in the total number and weight of fruit matured in proportion to the severity of pruning. The loss was most severe when leaf pruning was done while the fruits were quite small. Weinberger (95) found that peaches produced on trees having fewer leaves, had a lower sugar content and a lower percentage of dry matter than fruits from trees having a larger number of leaves per fruit. Most of the work that has been done on the factors affecting defoliation of tomato plants has been carried out by MacGillivray (63) (64). He planted tomatoes in the field at various dates and found that the later the date of planting the less the defoliation at the end of the season. He also studied the effect of different levels of fertility on the rate and degree of defoliation and states that the lower the fertility or nutrient level in the soil the greater the defoliation after a given period of time, usually at or near the end of the growing season. The entire absence of nitrogen was found to have less effect upon defoliation than the lack of phosphorous or potassium. The absence of potassium seemed to cause the greatest loss of foliage.

Gustafson and Stoldt (42) working with tomatoes found that the efficiency of the plants, as far as fruit production is concerned, is greatest when the leaf area per fruit is small. They found that by increasing the leaf area the size of the fruit could be increased after the time of setting. They intimate that three fruits per leaf is the maximum production efficiency possible.

Muncie and KenKnight (75) state that defoliation of tomato plants causes the fruit to be watery and have a lower pH.

Other Factors. Briggs (22) and Gregory (40) have shown that the effect of external conditions on the growth of the plant is caused by the effect of these external factors on the acceleration or retardation of the manner in which the internal factors express themselves. Thus it can be said that the growth of the plant is the function of the internal factors and their response to the external environment. Egorov (30) and Taranovsky (92) studied the effect of removal of flowers on growth and absorbtion of soil nutrients by various field crops. They observed the following major changes upon flower removal: (1) the higher osmotic pressure of the cell sap; (2) a marked increase in development of all vegetative organs including roots; (3) a greater assimilation of carbon dioxide, increased absorbtion of soil nutrients and higher total production of dry matter. Mason (67) reports a marked retardation in growth of both central stem and lateral branches of the cotton plant during flowering and fruiting. The rate of elongation of the main stem was found to decrease in exact proportion to the amount of flowers formed and fruits set. Murneek (76) reports that with tomatoes under all types and extremes of nutrition the presence of a relatively large crop of fruits resulted in retarded vegetative development and that some of the lower leaves may be lost in the drain on the food supply by the organs of reproduction Korschelt (55) states that under ~~under~~ conditions of comparatively limited absorbtion of soil nutrients or restricted organic synthesis, the vegetative organs of a plant may become totally exhausted due to the excessive drain by the embryos, leading eventually to death of the whole organism. Bakhuyzen (6) thinks the primary cause of the death of an annual that has flowered is the considerable loss of water at the time of flowering, which results in a decrease in assimilating capacity of the leaves and their gradual dying. In tomato plants Murneek (77) found that the tomato plant absorbed the greatest amount of soil nutrients and synthesized the largest quantities of organic substance when fertilization was permitted but fruit was not allowed to develop too far.

Dastur (26) has found that the correlation between water content of the leaves and the rate of assimilation, is practically linear. He suggests that the decrease in assimilation is the result of a decrease in water supply caused by the inability of the vascular system to supply the needs of the plant and that the inefficiency of the water conducting system of the plant may be one of the internal limiting factors which terminate the duration of the length of life of leaves and ultimately of plants.

Heath (43) has more recently shown that in the cotton plant both the efficiency index and the relative leaf growth-rate have a slight downward trend as the plant becomes older. The percentage of the total dry weight which consists of leaves also falls with time. He explains the fall by assuming that as time proceeds an increasing proportion of the products of photosynthesis is used for stem, flower buds, and other plant parts.

Correlation and General Growth Studies

Gustafson (41), in his studies on growth of tomato fruits, observed that the later developed fruits in a cluster were always smaller than the first ones set. He further states that there seemed to be a relation between size, or perhaps age of the plant at the time of fruit setting and the final size of the fruit. Size of fruit and number per cluster increased until the third or fourth cluster when the maximum was reached. Later developing fruits were distinctly smaller. He assumed these differences in size of fruit were due to the relative food supply of the plant. Hepler (44) states that early varieties produce mature fruit earlier because they grow more rapidly during the early part of the season and produce their clusters earlier than later varieties.

Jozefowics and Corbett (54) found that the time between anthesis of the blossom and maturity of the fruit was not constant for every fruit on the plant. It was observed that all the fruits on the first cluster and the first fruits on the following clusters ripened in approximately the same length of time while the later fruits on the clusters above the first required a definitely longer time to ripen. However, it was found that in the case of an abnormally robust and healthy plant the "number of days to maturity" approached a constant.

Houghtaling (50) states that the ovary of the tomato at the time of blossoming has the same number of cells which the fruit will have. This indicates that the increase in size of the tomato fruit is merely an increase in the size of the individual cells and not the result of cell division.

In an attempt to determine the cause of "blotchiness" in tomato fruit, Owen (82) found that the yellow portions of the fruit contained less potassium than the red portions. Chemical analyses the following season also showed the same relationship. Seaton (89) in a histological study of "blotchy ripening" found that the blotchy areas on the tomato fruit were caused by the collapse of the parenchyma cells in the fleshy layer of the ovary wall near and adjacent to the vascular bundles. The breakdown of these cells was thought to sever the connection to the outlying cells for a transfer of the food materials and water and thus inhibit normal ripening. This author thought the fundamental cause of the breakdown was withdrawal of water from the tissue of the fruit during periods of excessive transpiration occurring two to five days before the ripening of the fruit.

Bolas and Melville (13) obtained data to indicate a marked seasonal change in the percentage water content of seedling tomatoes. Later Melville (70) showed that both daily and seasonal fluctuations were greatest in the leaves and smaller in the stems. The water content was highest in the stems and lowest in the leaves of the seedlings. Melville (71) in a study of the relationship of water content to assimilation rate in tomato seedlings found that the water content of the seedlings of the same age and history varied little from plant to plant.

Bolas and Selman (16) from a study of translocation of assimilate concluded that in seedling tomato plants the greater part of the movement of assimilate out of the leaf system into the stem and root occurs during the assimilation period and not, as frequently thought, during the night. Bolas and Goodal (12) found that there is a flow of a assimilate from the older to the younger leaves during the whole of the twenty-four hours and that very little of the gain in the dry weight in the youngest leaves is due to their own assimilation. These workers found that the respiration rate of the youngest leaves was exceedingly high.

Goodall (38) found that diurnal changes in water content of tomato leaves are small with the exception of the young leaves in summer. These reached a minimum in the evening and attained a maximum in the early morning. Goodall (39) found that in summer the position of the cluster on the main stem of a tomato plant is dependent upon the previous growth of the plant and that length of day apparently affected it. Clusters on lateral branches from the higher nodes of the main stem formed earlier than branches which arose from the lower nodes.

MATERIALS AND METHODS

Plants of the Master Marglobe variety were planted in the field on five different planting dates in the year 1937, and on six different planting dates in the year 1938. Between each planting date there was approximately a two weeks interval, with the exception of the fifth planting in the year 1937, which was planted about one month after the fourth planting.

At the time of transplanting to the field the plants of each planting were as near the same size and in the same stage of development as conditions permitted. The dates of seeding, "pricking off" and field transplanting are given in Table I.

Table I. Dates of Seeding and Transplanting and the Number of Days from Seeding to Transplanting for each Planting.

Planting	Seed Planted		Transplanted to Flats		Transplanted to Field	
	1937	1938	1937	1938	1937	1938
1	March 31	March 15	April 9 9 days	March 28 13 days	May 8 38 days	May 3 49 days
2	April 12	March 29	April 20 8 days	April 8 10 days	May 21 39 days	May 17 49 days
3	May 3	April 12	May 11 8 days	April 25 13 days	June 7 35 days	May 31 49 days
4	May 24	April 26	June 1 8 days	May 14 18 days	June 21 28 days	June 14 49 days
5	June 9	May 10	June 18 9 days	May 24 14 days	July 15 36 days	June 28 49 days
6		May 24		June 8 15 days		July 12 49 days

In the year 1937 six single row plots, of nineteen plants each, were provided for each planting date with the plots (rows) arranged at random in each of six blocks. In the year 1938 four row plots were used with six plants in each row or twenty-four plants per plot (replicate). The plots were distributed over the field area in a 6 x 6 Latin square. Plant spacing for both years was six feet between rows and four feet between plants in the row.

The records of flowering and fruit maturity dates and other individual fruit records were secured from four plants in each of the six replicates for each planting date. In the year 1937 the first four plants in each row were used, and in the 1938 planting the first plant in each of the four rows in each plot replicate was used. For dry weight determinations two plants were taken from each replicate; the last two plants in each row were used in the planting of 1937, and the last plant in each of the two outside rows of each plot in 1938. The yield record of ripe fruit was obtained from the remaining plants in each row in the year 1937 and from the two inner rows of each plot in the year 1938.

In 1937 the plants were harvested for dry weight determinations on July 22, August 25, and October 2, and in 1938 on July 12, August 15, and October 6. The number and fresh weight of the leaves, clusters and fruits and the fresh weight of the stems were all determined in the field for each plant as soon as it was harvested. Dry weight of the various plant parts was obtained after preliminary drying in a large capacity, forced draft, steam dryer and final drying in an electric oven at 85 degrees C. for at least 36 hours.

In both years about one week before the date of the first planting a 6-6-5 fertilizer was applied broadcast to the plots at the rate of about one thousand pounds per acre. Sodium nitrate was applied to the plots as a side dressing at the rate of 350 pounds per acre in July, 1937 and in July and August 5, 1938.

Soil samples from the top six inches were taken for moisture and soil nutrient level determinations at weekly intervals during the growing season in 1937 and every three weeks in 1938. All soil samples were taken within 3 to 6 inches of the stems of the plants. In 1937 three samples were taken from each replicate row, with a one and three-fourth inch soil sampling tube. In 1938 each of the four rows in a replicate plot was sampled. In both years the dry weight of the sample from each replicate was at least 600 grams. Moist weight of the samples was determined immediately after sampling, and the soil dried in an electric, forced draft oven at 100 degrees C. for at least 48 hours to determine the moisture content. The soil samples for the rapid chemical tests were obtained at the same time as the moisture samples and from the same positions in the plots. Rapid chemical tests for ammonia and nitrate nitrogen, phosphorous, potassium, soluble aluminum and manganese, ferric iron, magnesium, calcium and organic matter were made. pH. was determined by the Beckman pH. meter. All rapid chemical tests were made by the Soils Laboratory, Department of Agronomy, University of Maryland. The method used for estimation of each of the elements is given by Thomas and Williams (92a).

The field plots in the 1937 series were of two soil types; a Sassafras fine sandy loam and an Ochlockonee silt loam, while the soil in the 1938 plots was a Sassafras fine sandy loam in the greatest proportion with some streaks of a gravelly loam running through the area.

Temperature and humidity records for the growing season of both years were obtained by means of a hygrothermograph in a standard weather instrument box at the edge of the plots about four feet above the surface of the soil. Rainfall for 1937 was obtained from the official weather record of the College Park station. In 1938 the rainfall record was obtained from a four inch rain guage placed at the edge of the plots beside the weather instrument box.

The various data obtained were analyzed by the analysis of variance whenever it seemed feasible. The differences presented in the tables as necessary for significance are twice the standard error of a difference for odds of 19:1 and three times the standard error of a difference for odds of 99:1.

RESULTS

I. Climatological Data

Temperature and rainfall, in relation to the various planting dates are shown in Figure 1 for the growing season of 1937 and in Figure 2 for the 1938 season. The temperature data were calculated and graphed as the mean day and the mean night temperature because the relationship between day and night temperature is important in plant responses to temperature. The temperatures presented were calculated from thermograph records with the aid of a planimeter. The mean day temperatures were calculated from the thermograph sheet for the 12 hour period from 6:00 A. M. to 6:00 P. M. each day, and the mean night temperatures for the period from 6:00 P. M. to 6:00 A. M.

The average mean temperatures for day and night were, in general, higher during May and June in 1937 than during the same months in 1938. On the other hand, during the months of July and September the average mean day temperature was slightly lower in 1937 than during the same months in 1938.

During the months of May, June, July and August of the year 1937, the rainfall was well distributed and considerably above normal for this four month period. The rainfall during September of that year was, however, 1.62 inches below normal. The total rainfall during September 1938 was 2.25 inches above normal but 1.45 inches below normal for June. The total rainfall for the period from May 1 to

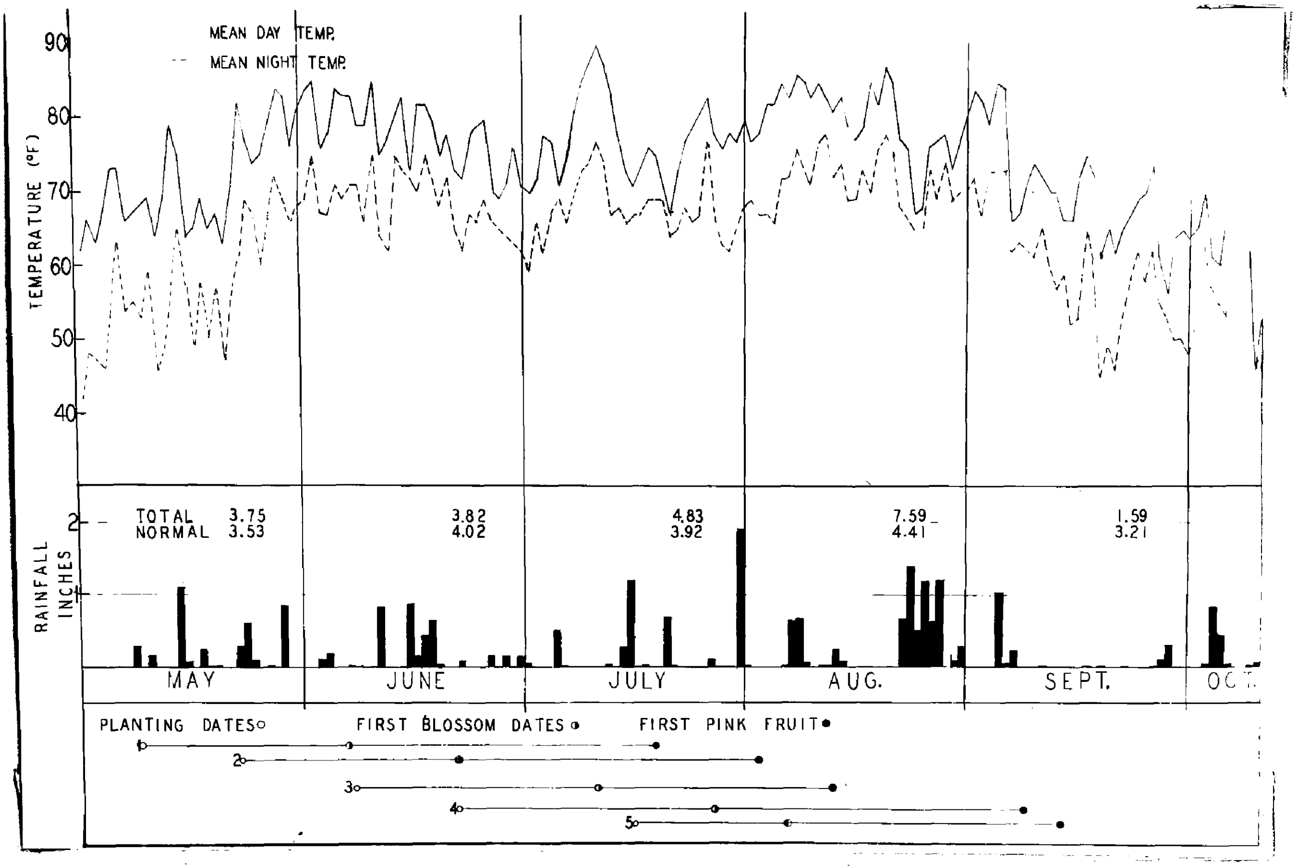


Figure 1. Climatological data for the growing season of 1937 at the University of Maryland, Horticulture Farm, Beltsville, Maryland, with respect to dates of (1) planting, (2) anthesis of first blossom and (3) maturity of first fruit

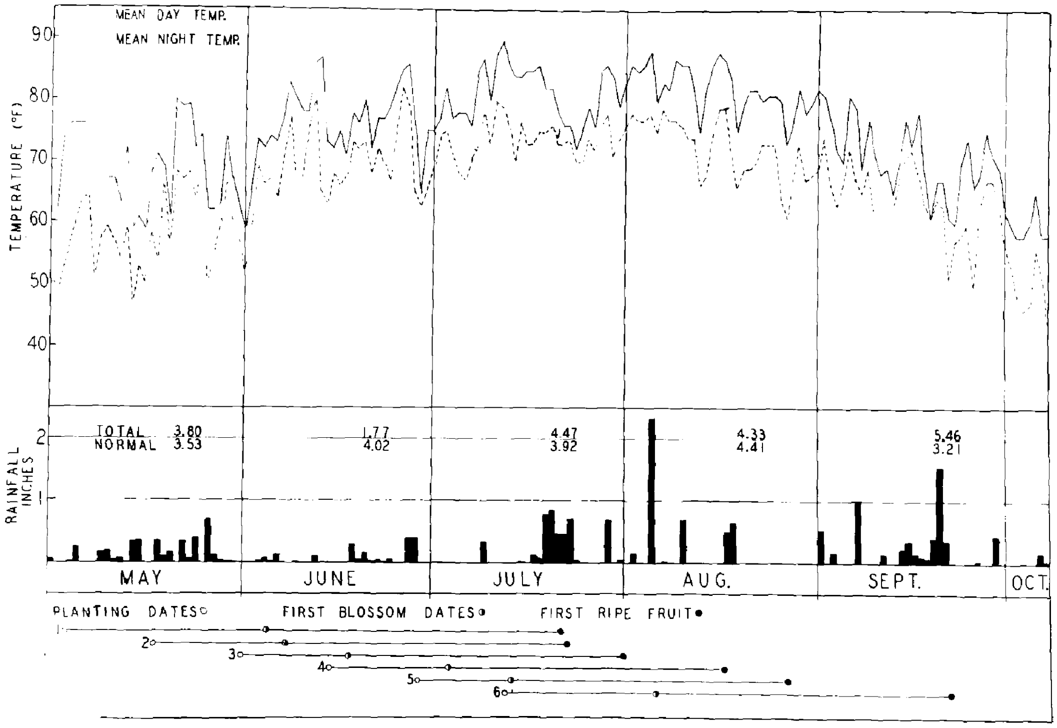


Figure 2. Climatological data for the growing season of 1938 at College Park, Maryland, with respect to dates of (1) planting, (2) anthesis of first blossom and (3) maturity of first fruit .

October 1, 1938 was 0.74 inches above normal. From the standpoint of distribution, the rainfall during the growing season of 1937 was more satisfactory for uniform plant growth than that during the 1938 growing season.

To study the temperature requirements of the tomato for vegetative growth and fruit development it first became necessary to establish the minimum temperature base line from which to calculate temperature values. Hour-degree temperature summations were calculated above base temperatures of 40, 45, 50, 55 and 60 degrees F. The standard deviations of the summations were calculated for each of these base temperatures for the following three periods of plant development: (1) period from transplanting to anthesis of the first flower, (2) transplanting to maturity of fruits and (3) blossom anthesis to fruit maturity. The hour-degree summations above the various base temperatures for each planting date and for the various growth periods together with their standard deviations and the coefficients of variability are presented in Tables II, III, and IV. For the period from transplanting to anthesis of the first blossom 55 degrees F. was found to give the lowest standard deviation while 40 degrees F. which is commonly used for such temperature value calculations, gave the highest standard deviation of any temperature used. The standard deviation for the base temperature of 60 degrees F. was only slightly higher than that for 55 degrees F. but the coefficient of variability was 40.1 percent as compared to 26.4 percent

Table II. Hour-Degree Heat Summations from Date of Field Transplanting to Anthesis of First Blossom.

Date of Field Trans-planting	Date Anthesis First Blossom	Hour degrees above Indicated Base Temperature.				
		40°F.	45°F.	50°F.	55°F.	60°F.
May 8.	June 6	18,254	14,774	11,294	7,814	3,494
May 21.	June 21	22,944	19,224	15,504	11,784	8,064
June 7.	July 10	27,432	23,472	19,512	15,552	11,592
June 20.	July 26	30,686	26,366	22,046	17,726	13,406
July 15	Aug. 2	15,624	13,464	11,304	9,139	6,984
1st Four Planting	Mean	24,829	20,959	17,089	13,469	9,139
	Standard Deviation	4,686	4,382	4,078	2,754	3,783
All Plantings	Mean	22,988	19,460	15,932	12,603	8,708
	Standard Deviation	5,579	4,934	4,320	3,326	3,490
	Coeffi-cient of Variability	24.3%	25.4%	27.1%	26.4%	40.1%

Table III. Degree Hour Heat Summations Above Different Base Temperatures for the Period from Transplanting to Fruit Maturity -- 1937.

Date of Transplanting to Field	Date First Blossom Anthesis	Date Fruit Maturity	Hour degree temperature summation above indicated base temperature.			
			45°F.	50°F.	55°F.	60°F.
May 8.	June 6	July 18	44,914	36,393	27,873	18,513
May 21.	June 21	Aug. 2	50,844	41,964	33,080	24,204
June 7.	July 10	Aug. 12	48,276	40,356	32,436	24,516
June 20.	July 26	Sept. 8	57,446	47,846	38,246	28,646
July 15.	Aug. 2	Sept. 13	41,642	34,442	27,237	20,042
		Mean	48,624	40,202	31,774	23,184
		S. D.	5,395	4,659	3,998	3,588
		C. V.	11.1	11.6	12.6	15.5

Table IV. Heat Summation in Hour-Degrees from Blossom Anthesis to Fruit Maturity Above Various Base Temperatures -- 1937.

Date of Trans-planting	Date of Blossom Anthesis	Date of Fruit Maturity	Hour-degrees summation above indicated base temperature.			
			45°F.	50°F.	55°F.	60°F.
May 8.	June 6	July 18	30,139	25,099	20,059	15,019
May 21.	June 21	Aug. 2	31,620	26,460	21,300	16,140
June 7.	July 10	Aug. 12	24,804	20,844	16,884	12,924
June 20	July 26	Sept. 8	31,080	25,800	20,520	15,240
July 15	Aug. 2	Sept. 13	28,178	23,138	18,098	13,058
Mean ---------------------			29,164	24,268	19,372	14,476
Standard Deviation ---------			2,475	1,895	1,632	1,266
Coefficient of Variability -			9.2	7.8	8.4	8.7

at 55 degrees F. Calculation of the hour-degree heat summations above the various base temperatures for the period from transplanting to maturity of first fruit showed that 60 degrees F. was the base which showed on the average the least deviation in all the plantings. These data are presented in Table III.

In Table IV are presented the temperature summations above the bases of 45, 50, 55 and 60 degrees F. for the period of fruit development (from blossom anthesis to fruit maturity). As was found to be the case with the period from transplanting to fruit maturity, 60 degrees F. was also the base which gave the lowest standard deviation for the period of fruit development. Comparison of the coefficients of variability for the fruit development period shows that the lowest was obtained by use of the base of 50 degrees F. and the highest at 45 degrees F.

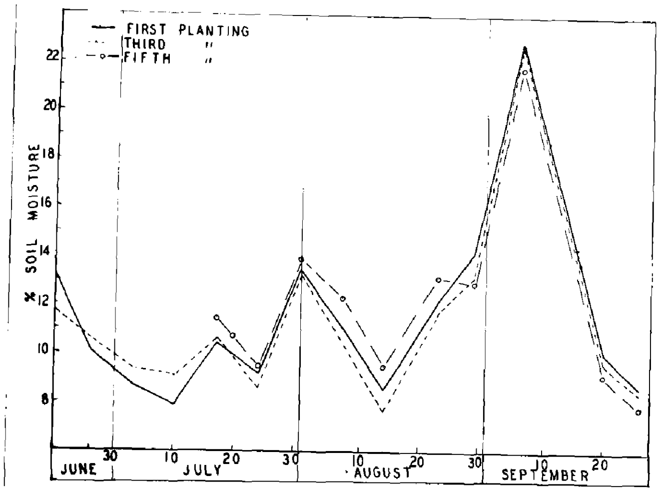
II. <u>Soil Moisture and Nutrient Levels</u>

The percentage water content of the soil at weekly intervals throughout the season of 1937 is shown in Table V for each planting and presented graphically for three planting dates in Figure 3. From June 26 until July 10 the soil moisture in the top six inches of soil from the first planting was lower than in any other planting. On July 17, there was less moisture in the soil around the roots of the plants in the second planting than in any of the other plantings.

Table V. Percentage Moisture Content of Top Six Inches of Soil from Each Planting At Weekly Intervals During the Season of 1937.

Date of Trans-planting to Field	Average Percentage Water Content of Soil on Indicated Date														Relative Water Removing Power 7/17 to 9/26	Average Water Deficiency in Pounds per Acre As Compared to Check
	June		July					August				September				
	20	26	3	10	17	24	31	7	14	22	29	6	19	26		
1. May 8	13.1	10.1	8.7	7.9	10.4	8.2	13.5	11.1	8.6	12.2	14.2	22.9	10.1	8.7	112	1270
2. May 21	11.8	10.3	9.1	8.6	9.8	7.7	13.6	10.9	8.3	12.1	13.7	22.7	10.0	8.6	135	1530
3. Jume 7	11.7	10.6	9.4	9.1	10.6	8.6	13.3	11.1	7.7	11.7	13.2	22.9	9.7	8.5	138	1560
4. June 20	-	-	9.5	9.4	11.7	9.2	14.3	12.5	9.4	12.5	12.2	23.2	9.6	8.0	100	1130
5. July 15	-	-	-	-	11.5	9.1	13.9	12.3	9.5	13.2	12.9	22.1	9.2	7.8	109	1230
*Check	-	-	-	-	12.6	9.9	14.8	-	10.4	14.2	14.1	23.5	10.3	10.4	-	-

*Soil sample taken at least 15 feet from plants. Samples from each planting date were taken within 3 to 4 inches of plants.



Fifure 3. Average water content of soil from the first, third, and fifth plantings at weekly intervals during the growing season of 1937.

With the exception of July 31, this relationship was maintained until August 14, at which time the soil from the third planting contained the least water per unit dry weight of soil. From September 19 until October 2 the soil from the fourth and fifth plantings was lowest in water content when compared to the first three plantings. In general, there was a negative correlation between the water content of the soil around the roots and the age of the plants, up to a certain stage of development beyond which there was a decrease in their capacity to take water from the soil. An interesting fact shown in Figure 3 is that the plants in both the third and fifth planting reached their maximum water absorbing power at exactly 58 days after transplanting to the field. The same general soil moisture results were obtained in 1938 but only six moisture samples were taken during the season. In the 1938 season the soil of later plantings contained less water than the first plantings at an earlier date than the corresponding plantings in 1937.

The amounts of nitrogen, phosphorous and potassium in the soil from each planting for weekly intervals during the season of 1937 are shown in Table VI. Phosphorous content fluctuated considerably from plot to plot and from week to week during the season so that no definite trends are evident. However, when the values for each planting for the entire season are averaged, the soil from the plots of the first three plantings contained, on the average, less phosphorous than did the soil from the fourth

[redacted]

om that area in the field

Nitrate nitrogen content of

Table VI. Weekly Level of Phosphorous, Nitrate Nitrogen, and Postassium in the Soil Fròm Plots of Each Planting Date - 1937. Each Number Represents Pounds Per Acre.

Date of Field Transplanting	June	July				August				September			Weekly Mean
	26	3	17	24	31	7	14	21	28	6	19	26	
	Phosphorous (Available)												
1. May 8	8	2	3	0	13	0	3	4	5	26	13	26	8.6
2. May 21	9	3	9	2	4	1	8	3	4	22	18	22	8.8
3. June 7	3	2	8	1	3	0	2	3	5	33	4	18	6.8
4. June 20	-	2	8	1	7	0	3	2	3	33	18	53	11.8
5. July 15	-	-	8	0	26	1	3	3	4	21	9	26	10.1
6. Check*	-	-	17	3	3	-	3	5	-	30	17	40	11.8
	Nitrate Nitrogen												
1. May 8	45	44	48	56	28	36	31	17	5	10	7	8	22.9
2. May 21	39	50	60	64	48	36	44	17	8	5	20	9	33.3
3. June 7	45	56	64	72	72	64	57	49	5	14	8	11	43.1
4. June 20	-	56	70	73	67	72	64	73	8	24	13	20	49.1
5. July 15	-	-	64	70	79	85	56	73	5	20	24	15	49.2
6. Check*	-	-	60	60	47	-	47	60	15	9	15	15	36.4
	Potassium (Available)												
1. May 8	313	350	242	300	242	250	150	250	167	240	58	75	220
2. May 21	254	330	225	300	325	208	200	275	200	242	75	66	225
3. June 7	304	333	292	350	383	208	225	250	167	233	117	5	239
4. June 20	-	337	300	350	375	308	283	383	250	333	133	156	292
5. July 15	-	-	275	350	350	300	242	392	242	325	150	83	271
6. Check*	-	-	400	350	350	-	350	350	250	350	150	200	306

* Soil sample taken at least 15 feet from plants. Samples from each planting date were taken within 3 to 4 inches of the plants.

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and fifth planting, and also from that area in the field where no plants were growing. Nitrate nitrogen content of the soil showed a much closer relationship to planting dates and time of sampling than did phosphorous. This is clearly shown in Table VI. The nitrate nitrogen content of the soil in each of the first three plantings was not significantly different on June 26, but on the next sampling date (July 3) the first planting showed less than any of the others and the second planting less than the third or fourth. The first planting continued with few exceptions, to show less nitrate nitrogen in the soil than any other planting during the period from July 3 to September 26. The average weekly level of nitrate nitrogen was greatest in the soil from the later plantings and least in the earlier plantings. The ammonia nitrogen content of the soil fluctuated considerably from week to week during the season but the soil in all plantings always contained approximately the same quantity. Potassium content of the soil from the plots of the different plantings showed very little differences among plantings until July 31. The sampling on this date showed that the potassium content of the soil from the first planting was lower than that of the soil from any other planting. From August 7 until the end of the season the soil from the first three plantings consistently contained less potassium than the soil from any of the later plantings or the check samples. Mean weekly potassium determinations in each planting show that the later the planting the greater the potassium content of the soil.

In Table VII are given the average amounts of the various elements not previously considered together with the average organic matter content of the soil and the average pH for the soils used in the two years. The soluble aluminum content of the soil used in 1937 was 104 pounds per acre greater than that of the soil used in 1938. The calcium content, on the other hand, was almost 100 pounds greater in the 1938 soil. The magnesium content of the 1938 soil was 3 pounds per acre higher at the end of the season than the magnesium content of the 1937 soil at the beginning of the season. Organic matter content was low in both soils but was extremely low in the 1938 soil. In agreement with the higher calcium content of the 1938 soil, the reaction was approximately 0.5 pH higher than in the 1937 soil. The quantity of manganese was practically the same in the two soils.

III. Growth and Correlation

Leaves. The data in Table VIII show that the dry weight of leaves per plant was much higher during July and August 1938 than for the corresponding plantings during the same period in 1937. In 1938 the dry weight of leaves from each plant in earlier plantings was more than twice that, at the time of the second harvest in August, for the same plantings in 1937. The greatest dry weight of leaves per plant was attained in both years during mid-season, after which the dry weight of the leaves per plant actually

Table VII. The Mean Number of Pounds Per Acre of Aluminum, Manganese, Calcium and Magnesium, and the Soil Reaction and Organic Matter In the Soils Used in Each of the Two Years, 1937 and 1938.

Year	Average Number of Pounds Per Acre of Indicated Element				Average Percentage Organic Matter	Average pH. of Soil
	Soluble Aluminum	Soluble Manganese	Available Calcium	Available Magnesium*		
1937	113	12.0	107	10 to 6	1.1	4.6
1938	9	11.7	206	52 to 13	0.2	5.05

* The first number is the amount of magnesium in the soil in June and the second figure is the amount in September.

decreased. Such a decrease in dry weight of the leaves, as the season progresses, is a partial measure of the rate of defoliation of the plants. In 1938 the dry weight of the leaves per plant decreased in all plantings during the period from August to October, and in all plantings except the fifth for same period in 1937. The percentage decrease in dry weight of the leaves from August to October was most rapid in the earlier plantings. The first two plantings in 1937 and the first four plantings in 1938 showed the most rapid decrease in leaf dry weights during the later part of the season. The average number of leaves per plant also decreased during the latter part of the season but not as rapidly as the dry weight. In 1937 the number of leaves per plant on August 25 was approximately the same for each of the first three plantings. However, in 1938 the plants in the first and second plantings averaged about 200 more leaves per plant than did the plants of the third planting. The average dry weight per 100 leaves is an indication of their relative sizes. In 1937 the greatest dry weight per leaf, for the entire season, occurred on plants in the first and second plantings on July 22. At the end of the 1937 season,the average dry weight per leaf was lowest in the first planting while for each of the other plantings it was about the same. In the 1938 season, the maximum leaf size (as measured by dry weight) attained, during the season, was approximately the same for all the plantings. The values shown in the fourth section of Table VIII show that

Table VIII. Average Dry Weight and Number of Leaves Per Plant, Their Average Dry Weight Per Hundred, Percentage Water Content and Percent of Dead Leaves Attached to Plants at End of Season, for Each Planting Date in 1937 and 1938.

Date of Transplanting to Field	Average Dry Weight per Plant (grams) On Indicated Date.			Average Number of L Leaves per Plant On Indicated Date.			Average Dry Weight per 100 on Indicated Date.			Average Percent Water Content on Indicated Date.			Percent Dead Leaves Attached to Plant, Oct.2
1937	July 22	Aug. 25	Oct.2	July 22	Aug.25	Oct. 2	July 22	Aug.25	Oct.2	July 22	Aug. 25	Oct. 2	
May 8	131.2	86.0	40.0	129	197	195	102.1	43.5	20.4	80.1	74.8	75.1	45.2
May 21	148.9	122.0	74.2	133	203	168	112.0	60.3	44.0	80.3	78.1	77.6	49.9
June 7	36.7	67.0	61.0	65	182	174	56.7	36.7	34.9	79.8	80.9	78.5	45.4
June 20	6.1	94.3	79.6	18	154	193	34.0	61.2	41.3	83.9	82.0	80.5	26.5
July 15	1.3	43.5	84.9	8	77	186	16.3	56.2	45.8	85.9	78.9	83.9	13.5
1938	July 12	Aug 15	Oct.6	July 12	Aug15	Oct.6	July12	Aug 15	Oct.6	July12	Aug 15	Oct.6	
May 3	189.4	362.2	58.5	175	475	178	110.9	76.3	32.8	84.5	80.2	59.1	70.9
May 17	169.0	347.0	100.4	149	457	222	113.5	76.0	45.3	84.3	82.8	47.2	65.0
May 31	82.9	267.8	56.6	89	266	180	106.2	98.7	31.5	84.5	79.0	64.0	64.1
June 14	29.4	245.9	38.6	34	240	142	87.9	102.4	34.2	85.1	84.5	63.6	60.6
June 28	3.9	153.5	57.1	10	159	139	39.7	96.6	41.0	85.7	84.4	54.8	63.0
July 12	-	96.6	81.5	-	91	128	-	105.7	63.7	-	86.6	74.0	49.7

the maximum leaf dry weight attained in both seasons was about 110 grams per 100 leaves. Approximately this weight was attained in 1938 by plants in the first, second, and third plantings on July 12 and in the fourth, fifth and sixth plantings by August 25. Apparently the leaves in the first and second plantings were the only ones to attain this size during the season of 1937. It is interesting to note that the average dry weight of the leaves on the plants at the end of the season is very nearly the same in both seasons for all plantings with the single exception of the sixth planting in 1938.

The mean seasonal percentage of water in the leaves was for the two years very nearly the same. However, at the time of the July harvest the water content was <u>higher</u> in the leaves from plants grown in 1938 than those grown in 1937, but at the time of the last harvest in October the water content was <u>lower</u> in the leaves from the plants grown during the 1938 season. In 1937 some of the values for water content of the leaves are actually higher in October than they were for the same planting in August. The percentage water in the leaves from the plants grown in 1938 showed for each planting a gradual but consistent decrease as the season progressed, being lower on each successive sampling date.

The percentage of dead or yellow leaves attached to the plants on October 2 in 1937 was higher for plants in each of the first three plantings than for the plants in any other planting and lowest for plants of the fifth or last planting. In 1938 the first five plantings had practically the same percentage of dead leaves attached to the plants on October 6. Only the plants in the sixth planting (July 12) had a lower percentage of dead leaves still attached to the plants at the end of the season, in 1938, than any other planting.

Stems. The dry weight of the stems is a fairly good measure of the vegetativeness of the plants. On October 2, 1937 the dry weight of the stems of the plants from the second planting was significantly greater than that for any other planting, not including the first planting. This is clearly shown in Table IX. In 1937 the dry weight of the stems of plants in the fifth planting was less than that of any other planting. Comparison of the stem dry weights of the plants grown in 1938 with the plants in corresponding plantings and of the same chronological age grown in 1937 shows that stem dry weight for 1938 was much greater, especially from mid-August to the end of the growing season. There was not a significant difference between the dry weight of the stems in the first and the second plantings in 1938 although the actual dry weight was slightly greater for the plants in the first planting. Comparison of the stem dry weights at the end of the 1938 season for the last four plantings shows that plants in the third planting were significantly lower in dry weights of stems than either the first or the second planting but higher than the last three plantings; the stem

Table IX. Dry Weight and Water Content of Stems and Average Number of Clusters Per Plant at Three Different Times During the Growing Season for Each Planting Date.

Date of Trans-planting to Field	Dry Weight (grams) of Stems Average per Plant on Indicated Date.			Percentage Water Content of Stems on Indicated Date.			Number of Clusters per Plant on Indicated Date		
	July 22	August 25	October 2	July 22	August 25	October 2	July 22	August 25	October 2
1937									
1. May 8	53.5	72.8	90.0	83.7	84.6	81.3	25	37	44
2. May 21	55.6	87.5	110.4	85.8	84.7	82.4	27	43	49
3. June 7	12.5	47.9	88.0	87.6	85.9	84.1	9	27	39
4. June 20	1.8	41.3	84.8	89.2	88.4	84.8	2	26	43
5. July 15	.7	13.2	52.6	89.4	89.3	85.3	-	22	24
	July 12	August 15	October 6	July 12	August 15	October 6	July 12	August 15	October 6
1938									
1. May 3	79.1	204.8	260.6	86.8	85.6	75.5	32	71	87
2. May 17	69.6	186.4	244.8	87.3	85.8	79.9	27	59	72
3. May 31	28.1	104.2	182.1	88.1	87.0	84.1	10	46	57
4. June 14	7.7	87.7	103.1	88.3	87.6	84.3	3	34	37
5. June 28	1.4	46.3	106.2	88.2	89.3	85.0	1	19	37
6. July 12	-	26.6	88.9	-	89.9	88.4	-	9	30

dry weight of the plants in the fourth and fifth plantings did not differ from each other and that of the sixth was lower than any other.

The water content of the stem showed, during both years, a very close correlation with both the age of the plant (time of planting) and the time in the season at which the determination was made. The later the date of planting the higher was the water content of the stem, when compared to that of earlier plantings, at a given time during the growing season. Also, for any given planting date the water content of the stems was progressively lower on each of the three successive dates of sampling (July, August and October). There were no marked differences in water content of the stems for each of the two years except at the end of the season. For October the stem water content for the plants grown in 1938 was lower for the first and second plantings when compared to the water content of the stems of the plants in the same plantings grown in 1937.

Clusters. The number of clusters per plant is given in Table IX. At the end of the growing season in 1937, the average number of clusters per plant was greater for plants in the second planting than in plants of any other planting, although the difference is not significant. However, in 1938 the plants in the first planting had, at the end of the season, a significantly greater number of clusters per plant than did those in the second or any other planting. Comparison of a given planting for the two years showed that the greatest difference existed in the number of clusters for plants of that planting date at the end of the season. The number of clusters per plant for plants in the first three plantings, consistently and significantly greater, both in August and in October of 1938, than for the corresponding plantings and dates in 1937. This is in agreement with the generally greater growth attained by the plants in 1938 as compared to that of the plants grown in 1937.

Fruit. The ratio of the dry weight of the fruit to the dry weight of the stems gives an estimate of the efficiency of the plants as producers of fruit. Stem dry weight was selected because it is subject to less fluctuation than either the leaf dry weight or the total dry weight both of which vary as the result of late season defoliation. The fruit/stem ratios together with the total yield of fresh ripe fruit for the season and other data concerning fruit development are all presented in Table X. The fruit/stem ratios increase from the beginning to the end of the season and, in general, are highest for the first and the second planting. In 1937 there was no difference between the fruit/stem ratios of the first and the second plantings but at the end of the season in 1938 that of the first planting was significantly larger than that for the second planting. The ratio for the second planting in 1938 was the same for both August and October while the ratio for the third planting was actually higher in August than it was in October. This was the only instance in both years where the ratio

Table X. Ratio of Dry Weight of Fruits to Dry Weight of Stems in July, August, and October, Total Yield of Ripe Fruit, Days from Blossom Anthesis, to Fruit Maturity, Percentage of Blossoms Setting Fruit and the Average Number of Fruit Per Cluster.

Date of Transplanting to Field	Fruit/Stem Ratio on Indicated Date			Total Yield in Tons per Acre*	Days from Blossom Anthesis to Fruit Maturity	Percentage Blossoms Setting Fruit	Average Number of Fruit Set Per Cluster
1937	July 22	August 25	October 2				
1. May 8	1.5	1.9	1.9	5.7	42	49	2.3
2. May 21	0.6	1.4	1.9	6.4	41	45	2.4
3. June 7	0.2	1.8	1.6	3.4	35	42	2.0
4. June 21	-	0.7	1.1	2.0	42	40	2.0
5. July 15	-	0.5	1.5	1.0	-	35	-
1938	July 12	August 15	October 6				
1. May 3	1.9	2.5	2.9	16.2	47	54	3.7
2. May 17	1.6	2.3	2.3	16.4	45	64	3.6
3. May 31	0.8	2.4	2.1	8.7	44	60	3.2
4. June 14	0.6	1.4	2.4	9.7	44	47	2.2
5. June 28	-	0.8	2.2	6.5	44	45	2.1
6. July 12	-	0.2	2.2	6.1	47**	43	1.9

* Significant difference between yields in 1937 = 1.3 tons, and in 1938 ± 4.8 tons.

** Days to Pink stage, not to Harvest date.

actually was lower at the end of the season than during the mid-part of the same season.

Comparison of the total yields of ripe fruit for the season shows that in both years the first and second plantings are significantly higher in yield than any of the other plantings but are not different from each other. In 1937 the third planting is significantly lower than the first and second but significantly higher than the fourth or fifth planting. The third, fourth, fifth, and sixth plantings did not significantly differ from each other in total yield in the 1938 season.

The number of days from blossom anthesis to maturity of the fruit was, in 1937, either 41 or 42 days for all the plantings with the exception of the third in which the time required was only 35 days. For the 1938 season 44 to 45 days were required in the second, third, fourth and fifth plantings to ripen the fruit after blossom anthesis. In the same year 47 days were required between blossom anthesis and full maturity of the fruit in the first planting and 47 days were required in the fifth planting to bring the fruits only to the "pink stage" of maturity.

The average percentage of blossoms which developed into mature fruit was higher in 1938 than in 1937. The percentage set for the second and third plantings was considerably higher in 1938 than for the same plantings in 1937, being respectively 19 percent and 18 percent higher in 1938.

The percentage set on the other plantings was also higher in 1938 but by only 5 to 8 percent. In both years the percentage of blossoms setting fruit showed, in general, a decrease with late planting. In 1937 the highest percentage set was obtained in the first planting and each successive planting showed a progressively decreasing blossom set. However, in the 1938 season the second planting gave the highest percentage set with the other plantings falling in the order named; third, first, fourth, fifth, and sixth. On the basis of number of fruit per cluster the plantings fall into two similar groups in both years. In 1937 the greatest number of fruits per cluster was produced by plants in the first and second plantings and in 1938 by the plants in the first, second and third plantings. The difference is especially marked in 1938. This is clearly shown in the last section of Table X.

The water content of the fruit was determined at the time of the plant harvests for dry weight determination but the data are not presented since they showed no significant variations during the season. The average water content of the fruit throughout the season of both years was consistently near 94.4 percent. Likewise, the average weight of the fruits from the various plantings did not differ significantly.

Total Dry Weight. The total dry weight of the plants (above ground portion) in each planting is shown in

Table XI on the following page. From an analysis of variance of the 1937 data it was found that the total dry weight of the plants in the first and second plantings was not significantly different either at the time of the July harvest or at the time of the August sampling date. However, a comparison of the total dry weight of the plants harvested on October 2, shows that the dry weight per plant in the second planting was significantly higher than that for the plants in the first planting. The dry weight of the plants in the third, fourth and fifth plantings was the same for equal periods after field transplanting. Plants in the first and second planting did not significantly differ from each other in total dry weight until approximately 100 days after the second planting after which time the total dry weightof the plants in the second planting increased more rapidly than the dry weight of those in the first planting. On the basis of total dry weight at the end of the 1937 season (October 2) statistical analyses showed that: (1) plants of the second planting were highest; (2) there was no difference between plants of the first, third and fourth plantings; and (3) total dry weight of the plants in the fifth planting was significantly lower than that of the plants in the first and second plantings. As can be seen from Table XI, the same general relationships also held at the 1938 season.

[redacted]

Table XI. Dry Weight (grams) of Fruit, Leaves, Stems, and Clusters, and the Total Dry Weight Per Plant in July, August, and October, for Each Planting for the Years 1937 and 1938.

Date of Trans-planting to Field	Dry Weight in Grams on Indicated Date														
	Fruit			Leaves			Stems			Clusters			Entire Plant		
1937	July22	Aug 25	Oct 2	July22	Aug 25	Oct 2	July22	Aug 25	Oct 2	July22	Aug 25	Oct 2	July 22	Aug 25	Oct 2
May 8	80.7	134.9	171.3	131.3	86.0	39.7	53.5	72.8	90.0	3.6	6.8	10.4	269.1	330.5	312.0
May 21	34.0	124.3	212.3	148.8	122.0	74.2	55.6	87.5	110.4	4.5	8.8	7.9	242.9	342.6	P 404.8
June 7	2.3	85.3	145.1	36.7	66.9	61.0	12.5	47.9	88.0	1.4	5.0	7.5	52.9	205.1	301.6
June 21	-	27.7	92.1	7.7	94.3	79.6	1.8	41.3	84.8	0.2	4.3	5.7	9.7	167.6	262.2
July 15	-	6.6	78.5	1.4	43.8	84.8	0.7	13.2	52.6	-	0.7	3.2	2.1	64.3	219.1
1938	July 12	Aug 15	Oct 6	July 12	Aug 15	Oct 6	July12	Aug 15	Oct 6	July 12	Aug 15	Oct 6	July12	Aug 15	Oct 6
May 3	152.4	503.0	688.1	189.3	362.2	P 62.5	79.1	204.7	329.9	7.5	17.5	19.8	428.4	1087.4	1010.4
May 17	111.5	433.2	567.4	169.1	347.0	100.4	69.5	186.4	244.8	6.6	18.1	18.7	356.7	984.7	931.2
May 31	22.9	254.3	381.6	82.9	262.8	56.6	28.1	104.2	182.1	1.4	10.0	12.1	135.3	631.2	632.3
June14	4.8	138.2	248.4	29.4	245.9	48.6	7.7	98.4	103.1	0.4	6.3	8.5	42.2	488.9	408.6
June 28	-	39.3	236.5	3.9	153.5	57.1	1.4	46.3	106.2	.06	3.9	10.4	5.4	243.0	410.1
July 12	-	4.2	194.7	-	96.6	81.5	-	26.7	88.9	-	1.0	7.0	-	128.4	372.2

[redacted]

Growth Rate. In Table XII are presented the "efficiency indices" of growth for each planting with respect to the increase in dry weight of the fruit and of the stem tissue during the two periods from mid-July to mid-August and from mid-August to the first week in October for each year. The formula used for calculation of these values was that given by Blackman (9), as follows:

$$W_1 = W_0 e^{rt}, \text{ or } \ln \frac{W_1}{W_0} = rt$$

where W_1 = the final weight, W_0 = the weight at the beginning of the period, r = the rate of interest, and t = time, and e is the base of natural logarithms. Comparison of the values in Table XII show that for the first period (July-August) the most rapid growth was made by the plants in the later plantings, both with respect to fruit dry weight and stem dry weight increases. The values for the second period show that this more rapid rate of growth was maintained by these plantings for the remainder of the season. Comparison of the values for the first and the second plantings throughout the season of both years shows that in 1937 the plants in the second planting maintained a more rapid rate of increase in dry matter of fruit and stem tissue for the entire season. In 1938, however, the values for these two plantings are strikingly similar for the entire season in both increase in dry matter of fruit and stem tissue.

Table XII. Rate of Increase in Dry Weight of Stem and Fruit Tissue for the Plants in Each Planting for Two Periods During the Growing Seasons of 1937 and 1938.

Planting	Efficiency Index of Growth During Indicated Period							
	1937				1938			
	FRUIT		STEMS		FRUIT		STEMS	
	7/22 to 8/25	8/25 to 10/2	7/22 to 8/25	8/25 to 10/2	7/12 to 8/15	8/15 to 10/6	7/12 to 8/15	8/15 to 10/6
1.	1.5	.61	.92	.53	3.56	.58	2.79	.30
2.	3.8	1.38	1.33	.59	3.98	.51	2.90	.51
3.	10.6	1.36	1.00	1.56	7.05	.76	3.84	1.06
4.		3.10	.91	1.84	9.85	1.10	7.31	.09
5.		6.37	.86	3.54		3.38	10.28	1.56
6.								2.27

The increase in number of leaves per plant when plotted against the number of days after transplanting gave an extremely symmetrical growth curve for the 1938 season. The 1937 curve shows a much slower rate of rise during the first 30 days after transplanting but after this the slope of the curve is almost identical to that for the 1938 curve. The growth curves for increase in leaf number with time are shown in Figure 5. The older plants in 1937 showed evidence of defoliation even as early in the season as 65 days after transplanting to the field. This is clearly shown in the upper portion of the 1937 curve in Figure 5 where the number of leaves on plants 75 days after transplanting is actually less than that for plants only 60 days after transplanting. The K value for the 1937 curve was considerably higher than that for 1938.

Figure 6 shows the rate of increase in formation of clusters as the plant grows older. In both years there was a very rapid rate of increase during the period from 20 to 50 days after field transplanting. The rate of rise of the two curves for this period is almost identical, although the k value is slightly higher for 1937. After 45 or 50 days from field transplanting there was a definite retardation in the rate of cluster formation as shown by the decrease in rate of rise of the curves at this point.

The rate of increase in dry weight of leaves up to the 55 day point was practically identical with rate of increase in leaf number. Beyond this point, the dry weight curve falls much more rapidly than the leaf number curve. This is clearly shown for both years in Figure 7. The k values for the curves of the two years are similar.

Figure 8 shows the rate of increase in dry weight of the stem tissue of the tomato plants. These curves are almost identical with those for dry weight of the leaves except they do not drop as rapidly as the latter at the upper portion of the curve. Here, again the k values for the two years are very similar.

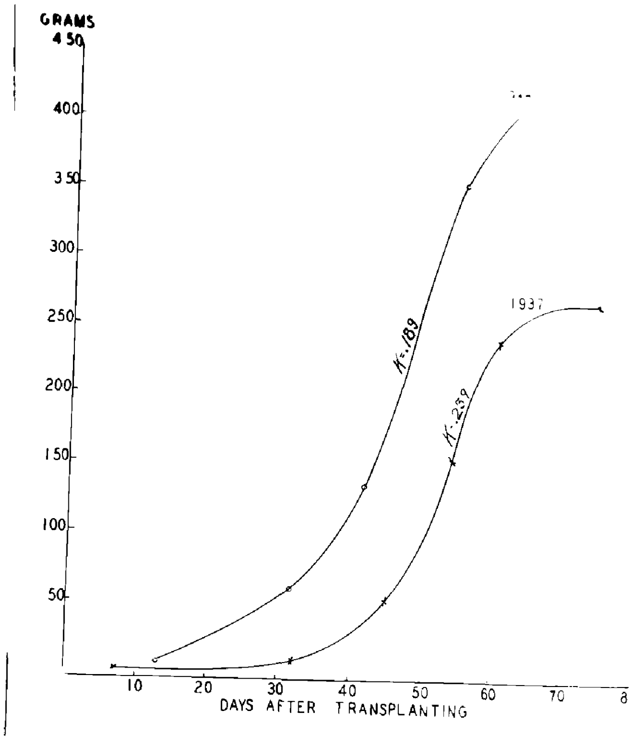

Figure 4. Total dry weight per plant for the period from seven to seventy-five days after transplanting to the field.

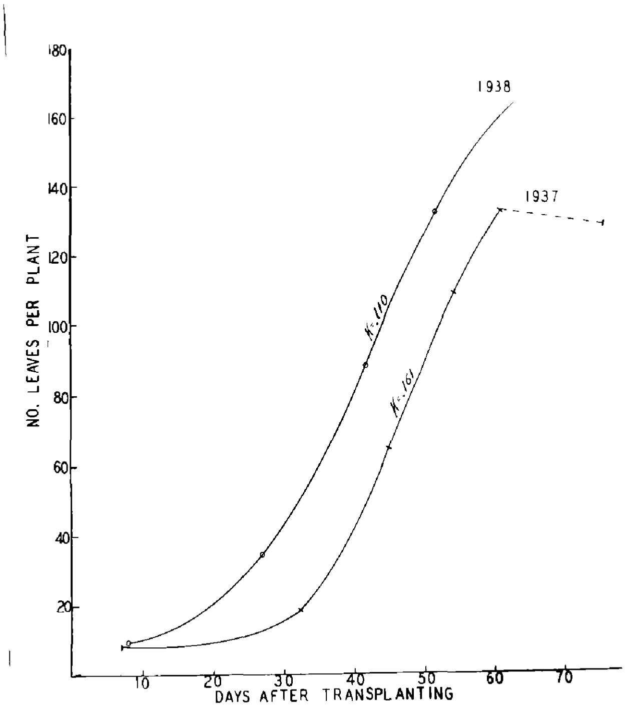

Figure 5. Number of leaves per plant for the period from seven to seventy-five days after transplanting to the field.

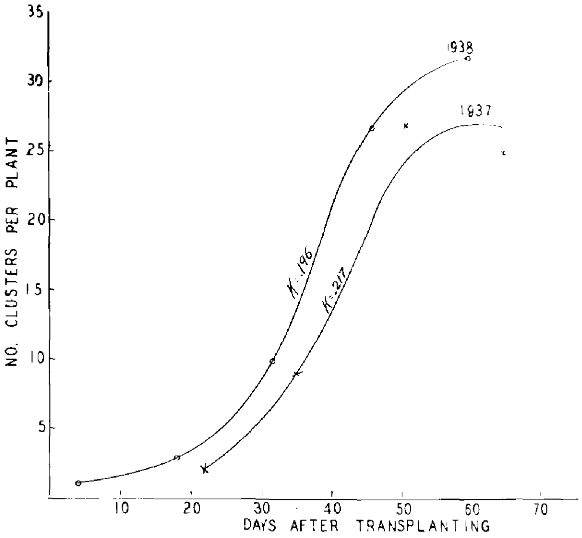

Figure 6. Number of clusters per plant for the period from seven to seventy-five days after transplanting to the field.

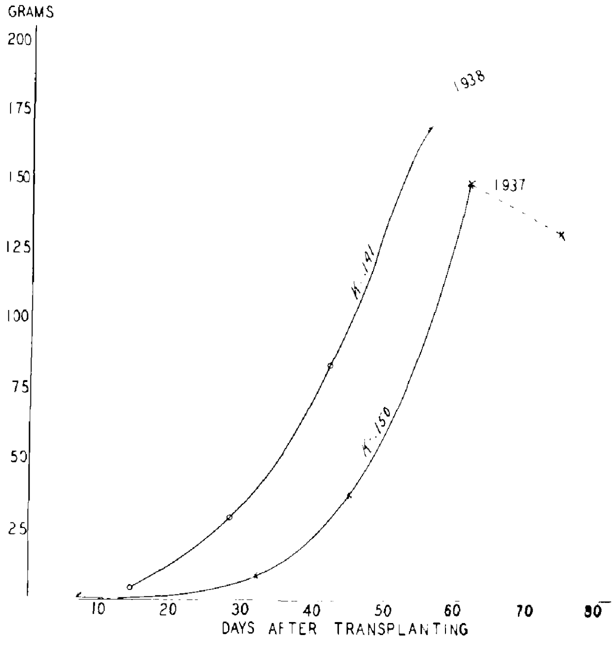

Figure 7. Dry weight of leaves per plant for the period from seven to seventy-five days after transplanting to the field.

The curves in Figure 9, which show the rate of increase in dry weight of fruit, exhibit the greatest difference between the two years of any of the growth curves presented. The rate of dry matter accumulation in fruits during the year 1938 was much more rapid than during 1937. In both years one-half of the total yield was attained in about 73 days after transplanting but the total dry weight of fruit formed per plant at the end of one hundred days in 1938 was more than three times that accumulated in 1937.

The rate of increase for total plant dry weight was more rapid during the first 35 days in 1938 but the two curves are closely parallel from this time until about 60 days after transplanting. Then the 1937 curve rapidly levels off, whereas the rate of dry matter accumulation in 1938 was only slightly decreased at this time.

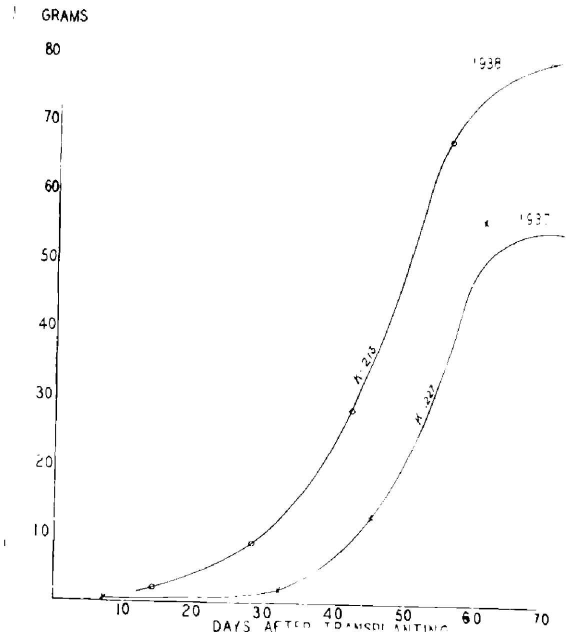

Figure 8. Dry weight of stem tissue per plant for the period from seven to seventy-five days after transplanting to the field.

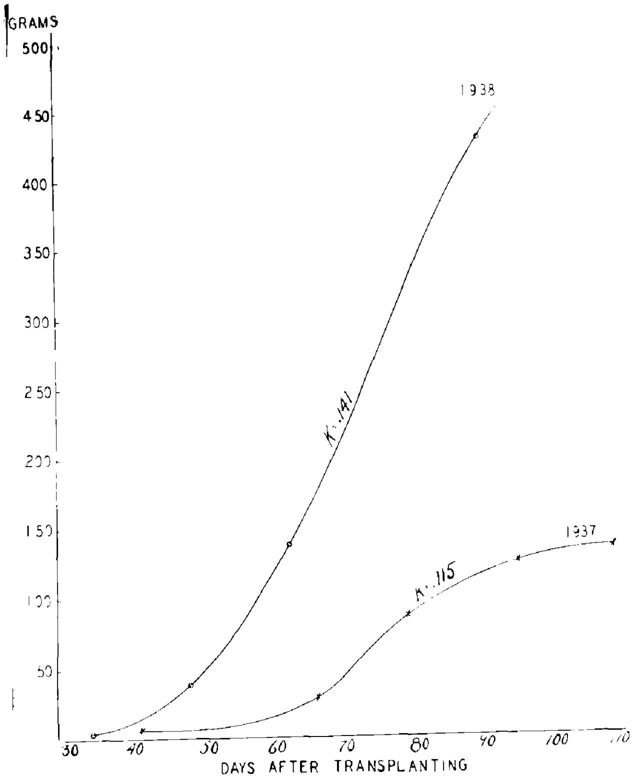

Figure 9. Dry weight of fruit produced per plant during the period from thirty to one hundred ten days after transplanting to the field.

DISCUSSION

One of the most interesting phases of this investigation has been the apparent association of certain of the phases of growth with the rate of growth of the plant as a whole. Careful examination of the growth curves presented on the preceding pages shows invariably that the most rapid rate of growth of the plant began at the time of anthesis of the first flowers on the plants. Likewise, the highest "efficiency indices" of plant growth occurred immediately following initial flowering. In 1937 the average time of anthesis of the first blossom was between 30 and 35 days after transplanting to the field and in 1938 it was somewhat sooner after transplanting to the field -- about 20 days. This relationship may be clearly seen for the two years by reference to Figures 1 and 2, where the planting dates and the dates of anthesis of the first blossom and the time of maturity of the first fruit are all shown in relationship to each other at the base of the figures. The growth curves for 1937 show that rapid acceleration in the rate of growth did not begin until 30 or 35 days after transplanting,whereas this rapid acceleration in 1938 clearly began near the 20th day. The decline in growth rate came at the time, in both years, when the first fruit were beginning to mature, or in the period between 60 and 70 days after transplanting to the field, The rate at which the decline in growth rate set in (inflection of the curve) appears to have been more rapid in all cases in 1937 than in 1938. The cause for this difference appears to be readily traced to certain limiting soil conditions. However, this can be considered later.

The causal mechanism involved in the differences in growth rate associated with certain reproductive functions in the life cycle of the tomato is not clear. The rapid increase at the time of anthesis of the first flowers and hence of gametic union may be caused by the establishment of certain metabolic gradients in the plant with the point of greatest concentration or activity lying in the flower where fertilization has been effected. Such an explanation has been suggested by Murneek (77), who also questioned the possibility of the presence of some simple physiological mass relation such as that found in Bryophyllum by the classical work of Loeb. Another possibility in the association of flower fertilization with the most rapid rate of growth of the plant lies in the possible formation of some hormone or hormone-like substance in the flower at the time of anthesis and fertilization which greatly accelerates the growth rate of the plant as a whole when it is transported to various parts of the plant.

On the other hand, it may be true that initiation of flowering is not a causal factor in accelerating the growth of tomato plants but simply an associated factor. Anthesis of the first flower indicates the time of formation of the first inflorescence of the tomato plant and it is at about this time, or very soon thereafter, that the plant sends out numerous lateral, auxiliary branches. The presence of these branches connotes the presence of numerous growing points other than the original apical one of the main stem and hence growth would proceed as an exponential or logarithmic function of time rather than as a more or less linear function up to the time of branching (flowering). Hence, this may explain the rapid increase in rate of growth at the time of the formation of the lateral branches. If such an explanation entirely accounted for the rate of growth at this period then the advent of flowering would be merely an associated condition which indicated the time of the branching. Ashby (4) and Luckwill (60) have shown that the rapid increase in number of clusters formed per plant after a certain period is actually the result of the extensive branching of the tomato plant. Why cannot the period of rapid rate of growth of the entire plant be accounted for on a similar basis?

The association of the time that the "self-inhibiting" phase of the growth curve begins with the time of maturation of the first fruit on the plant is equally as interesting. From the standpoint of practical application it is even more important. The most plausible explanation for the association of decrease in growth rate with maturation of the fruit appears, in the light of evidence presented by Murneek (77) for tomato and Mason (67) for cotton, to be that the developing fruit are able in some manner to monopolize the food which the plant absorbs and thus the remainder is not sufficient to carry on normal vegetative growth. It is felt that sufficient application has not been made of the findings of Murneek (77) with respect to the nitrogen requirements of tomato plants during the fruiting stage. He found that the plant does not store large quantities of nitrogen and he pointed out that in the absence of an abundant supply of soil nitrates the developing fruit will soon exhaust the entire plant as the result of movement of the existing nitrates and other nutrients into the fruit. The fact that the fruit contains relatively large quantities of nitrogenous constituents indicates the need for an ample and readily available nitrate supply in the soil at the time of fruit set and development. The effect of such an increased nitrogen supply at the time of fruit development may be seen in the rate at which the rate of growth decreased in the two years of this investigation. In 1938 the fall in rate of growth during the 60 to 70 day period was much less than that during the same period for 1937 as the result of more favorable soil nutrient levels. In the latter year sodium nitrate was added to the soil twice during the period of fruit development and only once during the 1937 season. The relationship between fruit development and nutrient level in the soil and the time and rate of defoliation of the tomato plant are shown in the growth curves for dry weight of leaves and for the number of leaves. It seems significant that defoliation first began in 1937 at the time the first fruit were maturing. In 1938 the first appearance of defoliation was not until later, during the growing season. All of this seems to point to the fact that at the time of fruit development the tomato plant should be supplied with a readily available source of all nutrients in order to meet the demands of the fruit and at the same time maintain a good rate of vegetative growth. The greater yields during the 1938 season can be explained on the basis of higher soil nitrates, magnesium, and phosphorous and a lower content of toxic aluminum. In 1937 the first fruits that developed apparently depleted the supply of available nutrients in the soil and at the same time exhausted the supply in the plant to the extent that normal vegetative growth was soon impossible and the older, lower leaves, when their mineral content became so low as to make impossible normal growth processes, abscissed. Why the fruit can monopolize the available food supply and even take nutrients from other portions of the plant to supply its needs is still open to conjecture. Perhaps the development of certain hormones by the growing fruit may so shift the metabolism of the plant and so divert the path of nutrients that any and all needs of the fruit are supplied first, and only in the presence of an excess quantity of the nutrients over the needs of the fruit do the other portions of the plant obtain such materials. Such a system where an organ liberates a hormone which influences the metabolism in other parts of the plant is similar to the endrocrine system of the animal body. Murneek (77) suggests the possibility of a controlling glandular organism or a system of secretions in the plant that might explain the action of the developing fruit on the other portions of the tomato plant.

Correlation of plant growth with one or two factors of climate is frequently difficult because of the many other factors involved which produce an interacting effect on the development of the plants. In the case of the tomato which has a rather complex growth cycle the correlation of a single climatic factor would be expected to be doubly difficult. In this investigation the attempt to correlate temperature, expressed as degree-hour summations above a certain base temperature, with the growth attained by the plants at a given physiological stage of development did not meet with consistent results. It is questionable whether the temperature during the first six or eight weeks of growth in seedling stage can be overlooked and a close correlation still obtained between the temperature during the period from the time of transplanting to the field and the time of anthesis of the first blossom. This was attempted in this investigation. The temperatures prevailing and the fertility level at which the seedlings are grown probably have a profound and definite effect upon the later development of the plant. Certainly the temperatures during this period would influence the time period to the attainment of a certain stage of development later, in the field.

The effect of temperature upon the growth and development of plants is varied. It is generally recognized that the rate of photosynthesis increases according to the Van't Hoff law with increase in temperatures between approximately 40 to 80 degrees F. Above 80 degrees F., there is a decrease in the rate of photosynthesis of most plants in the temperate zone. Respiration rate also increases with temperature so that the greatest net gain in assimilatory material by the plant is effected during those days where the temperature in general approaches 80 degrees F. during the day but drops sufficiently low at night so that the rate of respiration is slowed to the point where most of the photosynthate formed during the day will be translocated and assimilated by the plant rather than lost via respiratory processes. This may explain the reason why the efficiency indices (Table XII) for the period between August 22 and October 2 in 1937 were higher than for the similar period in 1938, despite the fact that the plants made such greater total growth in 1938. Reference to Figures 1 and 2 will show that the temperatures prevailing during the periods mentioned above were lower for 1937 than for 1938. This is especially true of the night temperatures. In 1938 the higher night temperatures during this late portion of the season may have speeded up the process of senescence because of the "faster living" of the plants at this stage in their life cycle, as the result of a more rapid respiration rate.

Dastur (26) and Dastur and Desai (28) found that water content of the leaves is more important in determining their rate of photosynthesis than is their chlorophyll content. The average water content of the leaves was higher at the time of the July and August harvest periods in 1938 than in 1937 and this may in part also, account for the greater efficiency of the plants as builders of dry matter in 1938 as compared to the plants grown in 1937. However, as previously pointed out there are too many other causal factors involved to be able to state definitely that any one or two are the principal ones. How the increase in water content of the leaves brings about greater photosynthetic efficiency is not known. The effect may be one of a direct nature by indicating a greater and more readily available supply of water by which photosynthetic processes are carried on or the increase in water may be merely a condition associated with some other factor. On the other hand, the water content of the leaf tissue may be an accurate indication of the physiological age of the leaf tissue, thus as the leaf becomes older the water content falls and with senescence come other changes in the leaf which decrease its efficiency as a builder of dry matter. Bakhuyzen (6) has shown that senescence of plant tissues is accompanied by a decrease in water content and he believes that the lack of water to carry on vital processes may eventually cause death of the plant.

The quantity of the various elements in the soil as determined by the rapid soil tests is not necessarily an indication of the quantity that is available to the plant. The latter may be higher or lower than that indicated by the rapid tests. The degree of correlation is mainly dependent upon the ability of the reagent used for extracting the soil sample to duplicate the power of the plants to remove a given nutrient from the soil. Plant tests for the various elements in conjunction with the soil tests would seem to be of most value. The simultaneous use of both the plant and the soil tests would aid in determining the relationship existing between the content of the various elements in the soil and the actual quantities absorbed and utilized or stored by the plant. It is important to know the relative soil content of the various elements in order to study the concentrations at which the antagonistic effect of various elements on the absorption of others is important and also because in light soils considerable loss of certain salts may result from leaching.

A number of soil factors could have been involved in either a major or minor role in causing the decreased yield of ripe fruit and total plant growth in 1937. In view of the findings of other workers with the tomato and with other crops, it seems safe to conclude that the edaphic conditions which contributed most to the decreased growth in 1937 were; (1) low pH. of the soil with the resultant high concentration of soluble aluminum, (2) low available magnesium, and (3) low available phosphorous in the soil.

SUMMARY AND CONCLUSIONS

The purpose of the investigation here reported was to obtain a detailed knowledge of the growth and fruiting of tomato plants under field conditions and to correlate, if possible, certain climatic and edaphic conditions with the growth and fruiting responses of the plants. To this end plants were planted in the field in 1937 on the following dates: (1) May 8, (2) May 21, (3) June 7, (4) June 21 and (5) July 15 and in 1938 on; (1) May 3, (2) May 17, (3) May 31, (4) June 14, (5) June 28 and (6) July 12.

The above ground portions of the plants were harvested at three different times during the growing season each year in order to obtain a record of plant growth and development in the different plantings. The dates of plant harvest were as follows: 1937; July 22, August 25 and October 2 and for 1938; July 12, August 15 and October 6. The data obtained for each planting at each plant harvest included: (1) dry weight of stem tissue per plant, (2) number and dry weight of leaves per plant, (3) number and dry weight of fruits per plant, (4) number and dry weight of clusters per plant, and (5) the total dry weight per plant. The yield of ripe fruit throughout the growing season was determined for each planting date from six replicate plots of at least 12 plants per replicate.

Temperature and humidity records were obtained in both years by a hygrothermograph in the field. Soil moisture and soil nutrient level determinations were made at weekly intervals during the growing season in 1937 and at three week intervals during the 1938 season. Blossoms were tagged the day of anthesis and detailed record obtained throughout the season of the rate of fruit development, percent blossoms developing into fruit, number of blossoms per cluster, and other pertinent information, from plants in each date of planting.

Calculation of degree-hours temperature summation above base temperatures of 40, 45, 50, 55 and 60 degrees F. showed that for the year 1937 the base temperature of 55 degrees F. gave the smallest standard deviation when applied to all plantings and taking the period between time of field transplanting and time of anthesis of the first blossom. The base temperature of 60 degrees F. gave the lowest standard deviation when the hour-degree temperature summation was calculated for the period from anthesis of blossom to fruit maturity.

The maximum power of the plants to absorb water from the soil appeared to be reached in from 45 to 55 days after transplanting to the field when the plants were 80 to 90 days old.

The low total yield secured in 1937 as well as the lower total dry weight of the plants appeared to be associated with; (1) soil reaction below 5.0, (2) 100 pounds of soluble aluminum per acre in the soil, (3) only 10 pounds of available magnesium per acre, (4) very low phosphorous level throughtout the first and mid part of the growing season.

Under normal conditions fo~~u~~rty-five days are required to ripen the fruit after anthesis of the blossoms. This period became longer when the fruit ripened in September and shorter when the fruit ripened in the hot days of August and July.

The highest total yields of ripe fruit were obtained from plants planted in the first two plantings in both years (May 8 and 21 in 1937 and May 3 and 17 in 1938). There was no significant difference between these two plantings in total yield but both were significantly higher in yield than any other planting as well as in total dry weight of plants. No consistent increase in earliness of fruit production was evident in the first planting as compared to the second. All plantings after June 1 yielded approximately the same amount of ripe fruit by the end of the season.

Growth rate of the entire tomato plant or of any part as measured by increase in dry weight during the first 80 days after field transplanting followed the course of a typical sigmoid curve. Calculated k values for curves representing growth rates of various parts of the plant ranged from .110 for number of leaves per plant in 1938 to .239 for total dry weight per plant in 1937. Although the total amount of growth was very different for the two years yet the k value for the growth curve of a given part of the plant or for the whole plant was remarkably close for the two years.

The "efficiency index" of plants calculated according to the formula of Blackman, was found to be highest, in general, between 30 to 70 days after time of transplanting to the field. For both years the highest "efficiency index" obtained was slightly higher than 10.

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