EFFECTS OF SOIL TEMPERATURE ON THE ROOT GROWTH OF MARSHALL STRAWBERRY PLANTS

by

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INTRODUCTION

In current investigations at the Oregon Experiment Station, dealing with the effects of sawdust used as a soil mulch or amendment on the growth and production of Marshall strawberries, it has been observed that surface soil under the mulch was consistently cooler and tended to have a higher moisture content than under conditions of clean cultivation or where sawdust was incorporated into the surface layer. Soil temperature measurements have shown, for example, that the sawdust mulch plots were on the average of 2° C. lower, at a depth of three inches, than the clean-cultivated plots. At the six-inch depth there was on the average less than one degree difference. The total yield of fruit was higher for the first season on the mulch plots and the plants were greener in color and more vigorous in growth. The berries also were brighter red in color and had a glossy, wax-like appearance, in contrast to the fruit from the clean-cultivated and soil-incorporated plots.

In endeavoring to account for these observations in the field, the following questions became apparent. (1) Does sawdust applied to the soil as a mulch tend to maintain a lower soil temperature? (2) Is the moisture content of the soil increased? (3) Is the soil aeration in the root zone of the plant improved? (4) Or is it a combination of factors, chemical and physical, that is responsible for the apparent increased plant and fruit qualities? The best method of arriving at an answer is to measure the plant's response to a given treatment.

While considerable information is available regarding the growth and yield of horticultural crops in relation to soil structure and fertility, less attention has been given to ecological factors, especially soil temperature. This factor would appear to be of special significance under Willamette valley conditions of prolonged cold spring conditions and often extremes of temperatures during the summer growing season. This investigation is concerned with the one aspect of the effect of soil temperature on the root growth of Marshall strawberry plants under controlled soil temperatures.

REVIEW OF LITERATURE

To date very little experimental work has been done on the effects of soil temperature on the amount of root growth of plants over a period of time. Of the work that has been done, sand cultures with nutrient solutions or agar mediums have been used as a growing medium. Cannon, (5, pp.320-333); Arndt, (1, pp.200-220); and Frasier, (9, pp.463-470) have made studies with mesquite, cotton, and corn seedlings, respectively, in determining the most rapid rate or grand period of growth over a period of two to eighteen hours.

Nightingale, (17, pp.588-594) in his work on the effects of soil temperatures with apples and peaches found at the end of 45 days the greatest root growth at soil temperatures of 65° F. for both genera. At a soil temperature of 85° F. there was only a very small amount of new root growth, while at soil temperatures of 95° no new growth was found. According to Nightingale, at soil temperatures of 65°, where the greatest amount of root growth was found, the greatest weight of roots was also noted. At 60° and 75° F. the roots weighed less and still less at either extreme. If the trees were allowed to establish themselves at a lower soil temperature and then were transferred to a soil temperature of 95° F., the new fibrous roots could survive only for a short time, then finally die. At 50° F. a very few new roots appeared while at 55° F. there were many short new roots on both the apple and the peach. This would tend to indicate that only a few degrees difference in the soil temperature can greatly modify the amount of root growth. Nightingale brings out the fact that the quality and character of the roots are equal in importance to the amount of root growth. Nightingale's data show further, that at soil temperatures above 75° F., the cortical tissue of the roots was dead or at least had turned dark brown.

Long, and Murneek, (15, pp.1-50) in studying the seasonal changes of nitrogen and carbohydrates in the strawberry plant, found a small amount of root growth during the dormant season until the ground became frozen. They observed an increase in the dry weight of the strawberry roots until December, and accounted for this increase by the storage of food reserves in the fall. Beginning in March, a sharp decrease in the dry weight of roots was noted, probably due to an increase in foliage growth. Ball and Mann, (2, pp.87-92) working in England with established strawberry plants, observed that only a limited amount of root growth occurs in the spring.

Weaver, (21, p.24) in his studies on the root development of field crops found, that for most cultivated plants, root growth ceases below a minimum of about 40° F. These soil temperatures affect not only the root and vegetative growth of the plant, but also the biological and chemical activities as well. Weaver, (21, p.25) states, "that in general, a soil temperature of 65° - 70° F. is favorable for the root growth of most plants, yet this will vary with species". Roots in deeper soils will grow at a much lower temperature. The effect of soil temperatures on the growth of plants can be shown by nurserymen who resort to bottom heat when propagating certain plants.

Kramer, (14, pp.152-154) found that the minimum or maximum soil temperatures for root growth varies with the species and that no certain soil temperature range applies to all plants. Agreeing with the results of Long and Murneek, Kramer found root elongation ceasing when the soil temperature was near freezing. Kramer also shows high soil temperatures may be as injurious to roots as low soil temperatures. With strawberries, Kramer found that high soil temperatures reduced the root surface to the point where water absorption is hindered to the extent that it causes a water deficit in the leaves.

Plate 1

General view of the constant temperature tanks in the greenhouse

METHODS AND MATERIALS

Construction of constant temperature tanks. In these experiments it was considered desirable to have a range of temperatures from 6° C. (42.8° F.) to 31° C. (87.8° F.) and to maintain these temperatures within a 1 - 2° C. variation. For this purpose six tanks were constructed as described.

Each temperature tank unit consisted of a 20 gauge sheet metal tank, three feet wide, five feet long, and two feet deep, which was riveted and soldered on all joints. The inner surface of each tank was painted with a red lead primer and then coated with an asbestos material, similar to that used as an under coating for auto bodies.

The sheet metal containers were placed in a reinforced marine plywood frame, the intervening side and bottom being insulated with two-inch thick bats of rock wool. The removable tops were constructed of three-fourths inch plywood and were made with eight evenly spaced holes sufficiently large to accommodate three-gallon earthenware crocks.

Steel frames with adjustable legs and a wooden rack to support the crocks were fitted inside the metal tank. All metal parts were painted with a red lead primer coat and then a coat of gray marine enamel to prevent corrosion.

For maintaining high soil temperatures (above room temperature) two 60-foot lead heating cables of 400 watt capacity were evenly spaced on the bottom surface of the tank. These cables were activated by a Fenwahl thermoswitch of suitable capacity. For maintaining low soil temperatures (below room temperature) a 2 x 5-foot refrigeration plate was mounted vertically near one side of the tank.

A one-quarter H. P. refrigeration unit supplied refrigeration for two tanks, and the temperature was controlled in each by individual thermostats and solenoid valves. The tanks intended for intermediate temperatures (near room temperature) were fitted with coils of three-eighth inch copper tubing through which cold water was circulated. It was found that the temperatures in these tanks could be controlled by the combination of heating elements and circulating water through the cooling coils.

To provide for uniform temperature conditions throughout the tanks, a circulating water pump was mounted at one corner. By this means a positive circulation of water was provided past or over the heating and cooling coils. Tests showed that the water temperature within the tanks could be controlled within 2° C.

Selection and preparation of plant material. The strawberry plants used were one-year old certified plants of the Marshall variety. This variety constitutes a large percentage of the commercial plantings in Oregon.

Approximately 500 plants were obtained and from these 200 specimens of a definite weight class were selected. After washing and removal of the old leaves, they were packed in the moist peat moss for about twelve hours to allow the moisture to equalize. The roots were then pruned to 4.5 inches before grouping them in weight classes. The first trial consisted of plants weighing 16$\pm$2 grams.

The potting soil was of a loam texture to which was added compost and sand. These soil components were first sterilized in a steam autoclave for four hours at fifteen pounds pressure. After cooling, the soil was put through a soil shredder and mixed thoroughly, then spread out on a greenhouse bench and turned twice daily for a period of ten days in order to allow any toxic gases if present to diffuse out and also to obtain a uniform soil moisture content.

The earthenware crocks to be used in the tanks had been glazed inside and out. Two coats of Tygon paint were applied on the unglazed bottom portion of each crock. Since the crocks were to be immersed in water baths for the maintainance of soil temperatures over a period of time, it was necessary to have the crocks waterproof. To test for this condition one crock after painting was immersed in water for one week. No gain in weight could be detected.

All crocks were tared to a constant weight by the addition of pea-sized gravel. Twenty-three pounds of soil were added to each crock, which brought the soil to within one inch of the top. The procedure for potting the plants was modified in the second experiment as later indicated.

Regulation of soil temperature and moisture. Six different soil temperatures were selected and the temperature of the tanks adjusted accordingly. The soil temperature of each treatment was as follows:

Treatment I, 6° C.; treatment II, 11° C.; treatment III, 16° C.; treatment IV, 21° C.; treatment V, 26° C.; and treatment VI, 31° C.

The crocks were randomized in each of the six treatments, giving each crock an equal chance of occurring in any one of the six treatments. The numbers were taken from a prepared list of randomized tables.

Maintaining a constant soil moisture content in the crocks, which were placed in water temperature tanks without any provision for soil drainage, presented a problem. At the time the plants were potted, the soil moisture content and field capacity were determined. Using the above percentages, it was possible to calculate the amount of water required to maintain the soil moisture content at 75 percent of the calculated field capacity. Frequent testing of the soil in the crocks with a soil tube showed that by watering to 75 percent of field capacity a water-logged condition in the bottom of the crocks could be prevented. A twelve-inch piece of 3/16-inch diameter aluminum tubing was inserted to the bottom of one crock in each tank to detect a water table if present. Once each week throughout the experiment a small suction pump was used, but at no time was any water found in the bottom of the crocks.

Two thermometers were used to record the soil temperature of one crock in each tank. One thermometer recorded the soil temperature at the three-inch depth, and the other at the eight-inch depth. Preliminary measurements showed that at the higher temperature treatments, 26° and 31° C., there was a soil temperature differential of four to five degrees between the top and bottom of the crocks. Various insulating materials were tried in order to overcome the wide soil temperature differential. Sawdust and spun glass wool were wet too easily with watering and proved to be unsatisfactory. Fine dry peat moss gave a good insulating effect if kept fluffed by frequent stirring. By the use of this material the soil temperature differential was reduced to 1.5° - 2° C.

<u>Preparation of plants for growth measurements</u>. Petiole and leaf measurements were taken before removing the plants from their respective treatments. The length between the ligule and the point where the leaflets branched constituted the petiole measurement, while the length of the center leaflet, measured along the mid-rib, was used as an indication of leaf size.

Two days before the plants were removed from the crocks they were well watered in order that the soil would separate readily from the roots. The contents were carefully removed from the crocks and placed on a medium-fine wire screen. By washing with a fine spray of water, the soil particles were easily separated from the plant roots. The plants were wrapped in damp cloths and stored in a refrigerated storage room at 38° F. until pictures could be taken, then divided into crowns and roots, and dried in a forced air oven at 70° C. to a constant weight. When dried, this plant material was weighed for analyzing on a dry weight basis.

The data were analyzed statistically by analysis of variance based on an unequal number of observations. Due to the wide variation in the number of observations of leaf sizes and petiole lengths, it was not practical to analyze these further even though significant differences were found at various soil temperatures.

EXPERIMENTAL RESULTS

EXPERIMENT I

On January 13, three strawberry plants were potted in each of the 48 crocks. The total weight of three plants for each crock was 48±4 grams. These plants were taken at random from the previously weighed samples. The remaining extra plants of the same weight class were potted in the same soil in washed number ten tin cans containing drainage holes.

The crocks were put in their respective temperature treatments on January 24. This lapse of time, ten days, between potting and placing the plants in the temperature treatments was considered sufficient for establishment of the plants, which was determined by removing three plants from the extra crocks every other day beginning one week after planting. The plant roots were washed free of soil and observed for signs of new root growth which was first noted on this date.

Watering of the plants was done by bringing each crock up to a calculated weight. The same weight was used for all crocks since a constant weight of soil had been added to each one, and the empty crocks had been previously tared to the weight of the heaviest one by the addition of pea-sized gravel.

The weather during the remaining part of January and the month of February was quite cloudy and the light intensity was very low. The greenhouse temperature was not easily controlled, and an attempt to regulate the controls to provide a mean night temperature of 50° F. and a mean day temperature of 65° F. proved unsatisfactory. Due to the wide range of temperatures between the low soil temperature of 6° C. and the high soil temperature treatment of 31° C., it was impossible to regulate or determine an optimum atmospheric greenhouse temperature for each soil treatment.

At high soil temperatures, the rate of root respiration would be above the compensation point if the greenhouse temperature was high and the light intensity low. In order to compensate for this a fairly low greenhouse temperature was maintained.

Occurrence of leaf scorch. At first the plants in all treatments appeared normal, with the plants in the high temperature treatments beginning to show new top growth. At the end of the second week a few plants began to show a scorching of the leaf margins. This marginal leaf scorching began with a wilting of the leaf tips and eventually the entire leaf margin turned brown. This proceeded inward until the whole leaflet had died. This behavior was apparent in all treatments regardless of temperatures, although it was more prevalent at high soil temperature treatments of 26° and 31° C. Leaves of these plants were examined under a microscope to determine if any disease organism was present, but none could be detected.

By the end of the third week only one plant remained alive in the 31 degree treatment. All others, apparently, had died from this leaf burn. Fifty percent of the plants in the 26 degree treatment had died and several others were showing severe wilt. Treatments at 26 and 31 degrees had to be eliminated during the fourth week since only four plants remained alive.

From the appearance of the plants in all treatments at this time it was apparent that the soil temperatures of 26° C. and 31° C., respectively, were too high for normal plant growth under these conditions. One extra three-gallon crock, prepared at the time of potting and having the same soil mixture and plants of the same weight class, was substituted in place of one in which the plants had died. The only difference between the plants in these two crocks was the substitution had a longer time to become established before being subjected to a high soil temperature. This plant was watched very closely for signs of wilting and leaf scorch. Four days later the plant was still in good condition and no visible signs of leaf scorch could be found. At this time, several one-gallon cans, which also had plants growing in the same soil mixture and were of the same weight class, were set in the three-gallon crocks with gravel and soil put around them so as to help conduct the heat into the soil in the can. All plants which were replacements in treatments of 26° and 31° C. were observed closely but throughout the remainder of the experiment the top growth was better than the plants in the other treatments. This behavior indicated that the plants can withstand soil temperatures of 26° and 31° C. provided they are established before subjecting them to high temperatures.

A few leaves on some plants in all other treatments showed leaf scorch by the end of the fifth week. It was however not evident on all plants nor did it follow any consistent pattern. One plant in a crock would show leaf scorch while the remaining two plants in the same crock were entirely free.

There was the possibility that the scorch may have been due to salt accumulations or poor soil aeration as a result of inadequate soil drainage. This may have been a factor except the plants in the one-gallon cans showed the same leaf symptoms. These cans had adequate drainage and were watered regularly so as to leach out any soluble salts and to provide oxygen through the water applied to them. The soil was equally loose and friable in the crocks as in the gallon cans.

In order to test for salt accumulations, a few Black Valiant wax bean seeds were planted in the soil from which the strawberries had been removed. This variety is very intolerant to a high concentration of soluble salts in the soil. These beans sprouted in four days in the high soil temperature treatments and grew very vigorously without showing any leaf tilting which is a characteristic symptom of high soluble salts on these beans. This further substantiates the fact that the leaf scorch which finally resulted in the death of the strawberry plants was not due to soluble salt accumulation.

The fact that the first signs of leaf scorch was a wilting of the margins that tended to work down the mid-rib, indicates that the plants were suffering from a water deficit. This was noticed sooner in the high temperature tanks where death of the plants soon followed.

This observation agrees with the work of Kramer, (13, pp.371-372) who found water absorption to be hindered by high soil temperatures. According to Kramer, most of the absorption takes place in the root hairs and the length of the root hairs is shortened by high soil temperatures.

Analysis of growth response. By statistical analysis, using analysis of variance based on unequal observations, a significant difference was found in the length of the petioles and leaf size. By the same method of analysis, no significant difference was found in the dry weight of roots or crowns as a result of soil temperatures used in this experiment.

Table 1 on the following page shows the average weights of the various plant parts. According to these data, a soil temperature of 16° C. results in the greatest crown weight, petiole length, and leaf size. A soil temperature of 6° produced the greatest root weight but is not significantly greater than that produced at 16° C.

From these results it is indicated clearly that a soil temperature of 16° C. is very close to an optimum for the growth of the Marshall strawberry plant under the growing conditions encountered during this experiment.

Plate 2 shows that as the soil temperature varies, the change in the dry weight of the roots and crowns are approximately parallel.

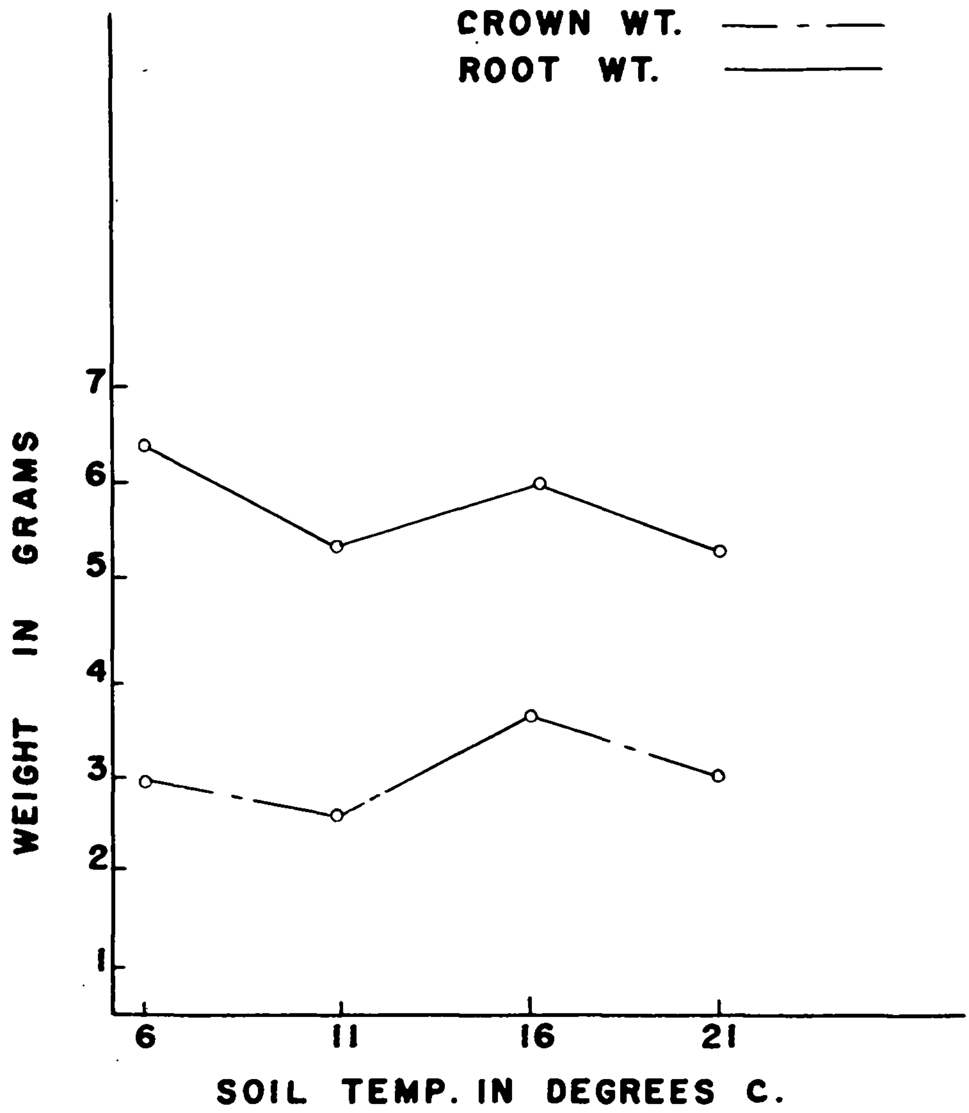


Plate 2 Weight of crowns and roots as effected by various soil temperatures in experiment I.

FIRST TRIAL

Table 1

Effects of various soil temperatures on the growth and development of roots, crowns and foliage of Marshall strawberry plants

Soil Temper-ature	Av. Root Wt. Grams	Av. Crown Wt. Grams	Av. Leaf Size m.m.	Av. Petiole Length m.m.	Number of Observations
6 C.	6.38	2.78	53.17	71.82	8
11 C.	5.24	2.56	49.16	69.24	8
16 C.	5.95	3.61	63.07	98.28	5
21 C.	5.27	2.99	61.14	93.89	6

EXPERIMENT II

Certified Marshall strawberry plants were also used in the second trial. In order for the young plants to become established before subjecting them to the soil temperature treatments, two plants were potted in each gallon can on March 21. This was before the plants in the previous trial were removed from the soil temperature treatments. The weight of the plants used per crock was 12 ± 3 grams in the second trial, which was approximately four grams lighter than those in the previous study. As other experiments being conducted in the same greenhouse required rather warm temperatures, the strawberry plants were set outside of the greenhouse until new roots formed. These plants remained outside until April 19 and then they were subjected to the various soil temperature treatments as in Experiment I. The one-gallon cans were set in the crocks which had pea-sized gravel in the bottom and around the sides with a two-inch layer of soil on top. This helped to keep the temperature of the soil closer to that of the water bath. Since the gallon cans had drainage holes in the bottom it was not necessary to remove the crocks from the tanks when watering. The plants were watered regularly, as needed, but not on a weight basis.

Prior to removing the plants from the temperature treatments, petiole and leaf measurements were taken. All foliage measurements were made by the same methods as in the previous trial.

The plants were removed from the treatments on June 19 and handled exactly as in the first trial in preparing the plant materials for analysis, with the exception that two plants constituted an observation rather than three as previously used.

Analysis of variance, based on an unequal number of observations, was used in analyzing the data.

Observations on growth. In the first two weeks, all treatments required equal amounts of water. During the third week, however, differences in the amount of new growth in the high soil temperature treatments were apparent, and daily watering of these plants was required.

With the light intensity improving and atmospheric temperatures becoming more favorable for plant growth, all treatments began to show good growth. By the middle of the fourth week the amount of leaf surface was almost equal regardless of soil temperature treatment. In general, at higher soil temperatures, the petioles were longer but in some cases, even at lower temperatures, there were petioles of equal length. At no time during the second trial were any signs of leaf scorch observed as in the first experiment.

Analysis of growth response. A significant difference was found in the root and foliage weights of the plants grown under the various soil temperatures, while no significant difference was found in the crown weights. Since the number of petiole and leaf measurements varied greatly within a treatment, they were not analyzed statistically and only the mean for each treatment was determined.

As shown in Table 2, it is evident that a soil temperature of

21° C. in the second trial showed the best plant growth of the Marshall strawberry. The root weight at a soil temperature of 21° was better than the weight produced at 26° by 4.92. A figure of only 3.71 was necessary for this to be significant. The root weights produced below 21° were not significant, but Plate 3 shows a general increase in these weights up to a soil temperature of 21° and then a sharp decrease at high temperatures.

In the foliage weights, the significant difference was found at soil temperatures below 21° C. The foliage weight produced at 21° was better than that produced at 11° by 4.6. Only 2.63 was necessary to be significant. Plate 3 shows a sharp increase in the foliage weights to 21° and above this it tapers off.

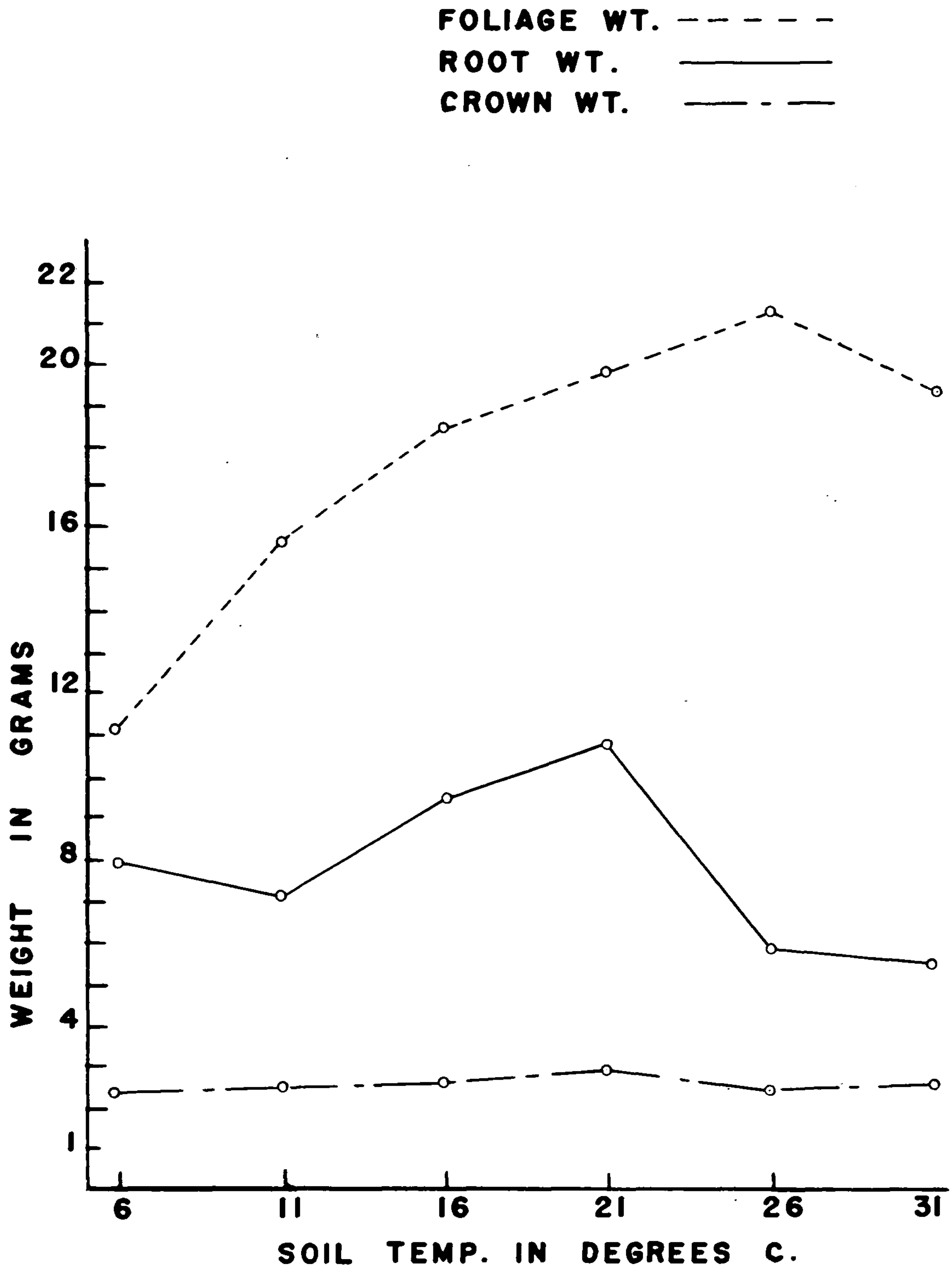


Plate 3 Weight of crowns,roots, and foliage as effected by various soil temperatures in experiment II.

SECOND TRIAL

Table 2 (A)

The effects of various soil temperatures on the growth and development of the roots, crowns and foliage of the Marshall strawberry

Soil Treatment	Av. Root Wt. in Grams	Av. Crown Wt. in Grams	Av. Foliage Wt. in Grams	Number of Observations
6° C.	7.98	2.35	11.18	7
11° C.	7.01	2.51	15.76	8
16° C.	9.50	2.63	18.44	8
21° C.	10.87	2.92	19.92	7
26° C.	5.95	2.47	21.27	7
31° C.	5.44	2.56	19.47	7

L.S.D. at 5 percent level.

8 vs. 8	3.47		2.54
8 vs. 7	3.59		2.63
7 vs. 7	3.71		2.71

SECOND TRIAL

Table 2 (B)

The effects of various soil temperatures on foliage size and runner production of the Marshall strawberry

Soil Treatment	Average No. of Runners	Average Leaf Size (in m.m.)	Petiole Length (inches)	Number of Observations
6° C.	1.29	72.68	4.70	7
11° C.	3.63	77.22	5.97	8
16° C.	6.0	77.95	6.26	8
21° C.	5.38	79.92	6.16	7
26° C.	6.63	77.64	5.88	7
31° C.	6.57	74.14	5.93	7

DISCUSSION OF RESULTS

While the data from Experiment I are inconclusive, it is evident from the results of the second experiment that the temperature of the soil was the determining factor in governing the amount of root growth of the Marshall strawberry. It was known that other ecological and climatic conditions were more favorable for plant growth but these were constant for all treatments, and the soil temperature was the only factor that varied.

Results show that the foliage weight is significantly decreased below a soil temperature of 16° C. even though other conditions are favorable for their growth. Above 16° C. the foliage weights increased slightly but were not significant.

It appears that foliage size is not closely correlated with the soil temperature, although the largest leaf size was obtained at a soil temperature of 21° C. and the longest petioles at 16° C. There appears to be little difference in foliage size between soil temperatures of 11° C. and 31° C. Probably the ecological factors of light intensity, day length, and atmospheric temperature are of greater importance than soil temperature in governing the foliage size.

In Experiment I, the author feels that climatic factors, rest period, maturity, and food reserves may have been equally as important,if not more so, than the soil temperature in governing the growth and development of the plants.

The light intensity, day length, and atmospheric temperature, although not recorded, were apparently not favorable for growth during the first trial. Strawberry plants in the field were found to be still dormant during the time Experiment I was conducted. Soil temperatures in the field at this time gave readings between 5° C. and 9° C. During the second experiment, when these plants in the field were observed to be growing, the light intensity, day length, and atmospheric temperature had increased.

The lack of a sufficient rest period may have been a factor in accounting for the poor plant growth in Experiment I. The strawberry plants in the first trial were obtained from a certified planting in Eastern Oregon and were removed from beneath the snow in order to conduct this study. The plants used in the second trial were plants removed from the field at the normal time of digging. The difference between the plants used in these experiments may have been one of rest period. The exact number of hours required to break the rest period of strawberries is not definitely known, but it has been shown there is a wide difference in the low temperature requirements between varieties.

The amount of food reserve in the plant may have been a reason, also, for some of the slow or negative response to the soil temperatures. By daily observation of all treatments in both experiments, there was found to be a wide variation in the rate of growth of the plants, regardless of treatment. This indicates that the growth of young strawberry plants is closely correlated with the amount of food reserves in the plant at the time of digging. This has been observed in the field and was evident in both greenhouse trials. Plants of the same weight and size used in these studies varied greatly in growth for a short time after planting. Plants only one foot apart in the field may also show striking differences, one having made no new growth while the other may be growing vigorously.

Plate 4

Root growth by the end of 70 days at a soil temperature of 6° C. in Experiment I

Root growth by the end of 70 days at a soil temperature of 11° C. in Experiment I

Plate 5

Root growth by the end of 70 days at a soil temperature of 6° C. in Experiment I

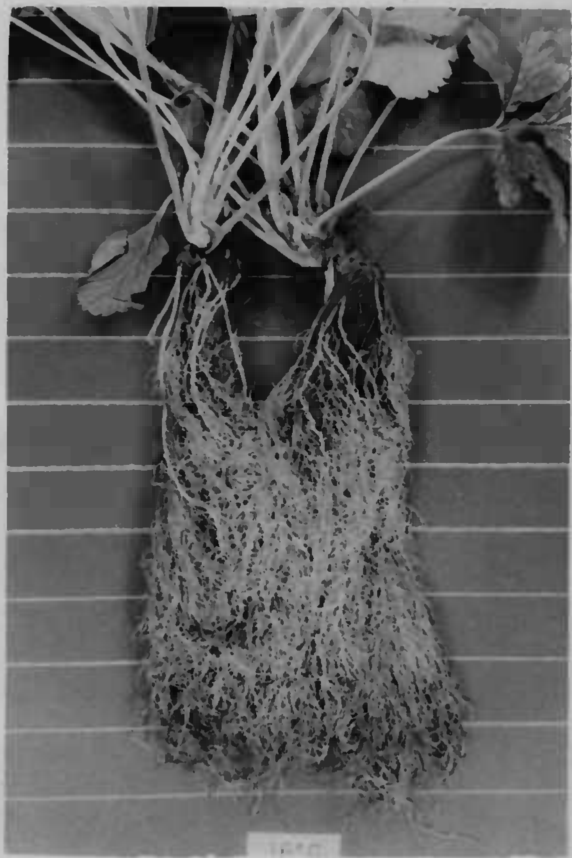
Root growth by the end of 70 days at a soil temperature of 21° C. in Experiment I

Plate 6

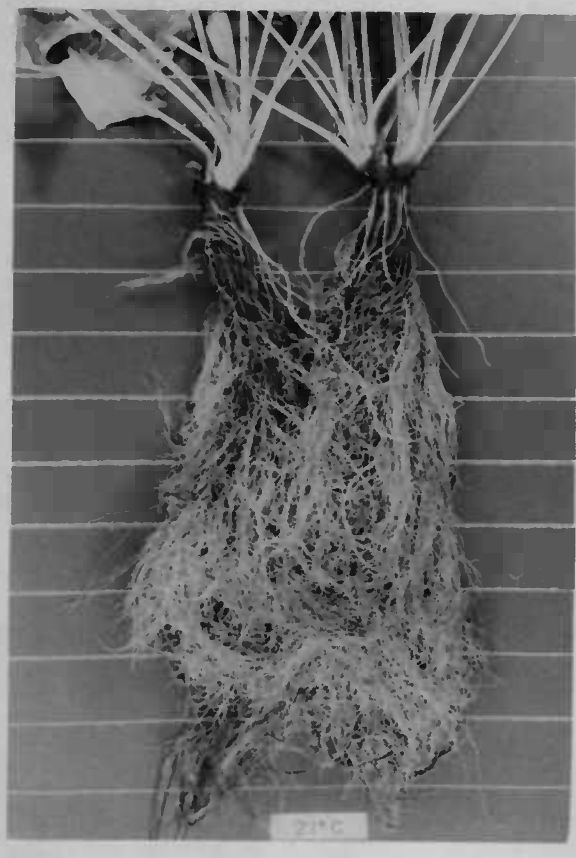
Root growth by the end of 60 days at a soil temperature of 6° C. in Experiment II

Root growth by the end of 60 days at a soil temperature of 11° C. in Experiment II

Plate 7

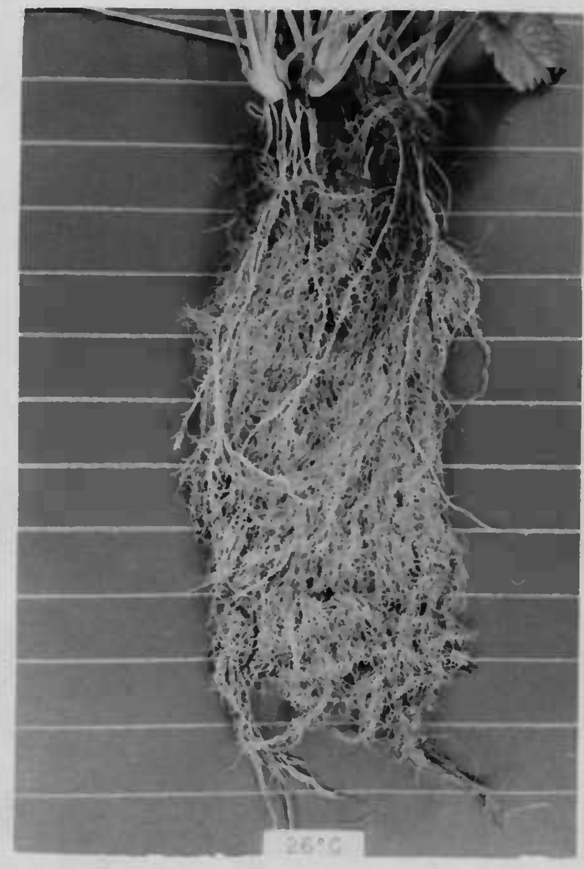


Root growth by the end of 60 days at a soil temperature of 16° C. in Experiment II



Root growth by the end of 60 days at a soil temperature of 21° C. in Experiment II

Plate 8



Root growth by the end of 60 days at a soil temperature of 26° C. in Experiment II

Root growth by the end of 60 days at a soil temperature of 31° C. in Experiment II

SUMMARY AND CONCLUSIONS

This investigation was carried out in an attempt to determine the influence of soil temperature on the development of the strawberry plant. In this study, young certified Marshall strawberry plants were grown in soil and subjected to soil temperatures ranging from 6° C. to 31° C. with five-degree intervals between soil temperature treatments. Two trials were made, the first during the late winter months, and the second during the spring. At the end of each investigation the plants were removed from their containers, and the roots washed free from all soil particles. Photographs were taken of the amount and type of new root growth that was made during each trial. The plants were then separated into roots, crown, and tops and dried in a forced air oven at 70° C. After a constant weight was reached, the plant parts were weighed separately and this weight recorded against the particular temperature treatment and the plant's location within the treatment. Analysis of variance was used to determine if any treatments were significantly different than others in the development of the roots, crowns, or tops. All calculations were based on a dry weight basis.

No specific soil temperature may be given as an optimum for the root growth of the Marshall strawberry plant, but from the results of this investigation several conclusions may be drawn.

Young Marshall strawberry plants may have a wide variation in their maturity and amount of stored food reserves even though they weigh the same on a fresh weight basis.

Light intensity and air temperatures may be below the point such that plants cannot grow even though the soil temperatures are favorable for plant growth.

At low soil temperatures of 6° C. and 11° C., new root growth consisted mainly of adventitious roots with only a limited amount of branched fibrous roots, while at higher temperatures the root system consisted of many branched fibrous roots and only a few adventitious roots.

A soil temperature of 16° C. in the first trial gave the largest increase in weight of both roots and crowns. Also, the longest petioles and the largest leaves were obtained at soil temperatures of 16° C.

In the second trial a soil temperature of 21° C. gave the highest weight of roots, crowns, and foliage. The foliage was not considered in the first trial as most leaves had been destroyed by the leaf scorching. With a soil temperature of above 21° C. there is a sharp decline in the dry weight of the roots. The crown and foliage weights tend to taper off and no significant decrease in their respective dry weights was found.

This study serves only as a preliminary investigation along this field. The effect of soil temperatures on the amount of root growth is a starting point, but its effect on the plant during its fruiting life and what is the composition of these roots at various soil temperatures must be answered in order that we may begin to learn some of the ecological effects on the physiological behavior of the strawberry plant.

BIBLIOGRAPHY

1. Arndt, C. H. Temperature-growth relation of the roots and hypocotyl of cotton seedlings. Plant physiology 20:200-220. 1945.

2. Ball, E. and C. E. T. Mann. The influence of the time of planting on the development of the strawberry. Journal of pomology and horticultural science VI:87-103. 1927.

3. Brown, E. M. Some effects of temperature on growth and chemical composition of certain pasture grasses. Missouri agricultural experiment research bulletin 299. 1939.

4. Brenchley, W. A. Effect of high root temperature and excessive insulation on growth. Annals of applied biology 9:197-209. 1922.

5. Cannon, W. A. Relation of the rate of root growth in seedlings of mesquite to the temperature of the soil. Plant world 20: 320-333. 1917.

6. Clements, F. E. and E. V. Martin. Effect of soil temperature on transpiration in *Helianthus annus*. Plant physiology 9: 619-630. 1934.

7. Darrow, George M. Experimental studies on the growth and development of the strawberry. Journal of agricultural research 41:307-325. 1930.

8. ______. Measurement of strawberry leaves. Plant physiology 7: 745-757. 1932.

9. Frazier, J. C. Nature and rate of development of the root system of *Apocynum cannabium*. Botanical gazette 105:463-470. 1944.

10. Gray, G. F. Transpiration in strawberries as affected by root temperatures. Proceedings of the American society for horticultural science 39:269-273. 1941.

11. Gourley, J. H. Production of a mulch material. American fruit grower p.18. March 1946.

12. Kramer, Paul J. The intake of water through dead root systems and its relation to the problem of absorption by transpiring plants. American journal of botany 20:481-492. 1937.

13. ______. Effects of soil temperature on the absorption of water by plant. Science 79:371-372. 1934.

14. ______. Plant and soil water relationships. New York, McGraw-Hill, 1948. 347p.

15. Long, J. H. and A. E. Murneek. Nitrogen and carbohydrate content of the strawberry plant. (Seasonal changes and the effects of fertilizers.) Missouri agricultural experiment station, research bulletin 252. 1937.

16. Mann, C. E. T. and E. Ball. Studies on the root and shoot growth of the strawberry. Journal of pomology and horticultural science 5:149-169. 1926.

17. Nightingale, G. T. Effects of temperature on growth, anatomy, and metabolism of apple and peach roots. Botanical gazette XCVI, no.4:581-639. 1935.

18. Schroeder, R. A. The effects of root temperature upon the absorption of water by the cucumber. Missouri agricultural experiment station bulletin 309. 1939.

19. Turk, Lloyd M. and N. L. Partridge. Effects of various mulching materials on orchard soils. Soil science 64:111-125. 1947.

20. Van Horn, C. W. and A. L. Schrader and I. C. Hart. Root and crown development of strawberries. Proceedings of the American society for horticultural science 36:461-465. 1938.

21. Weaver, J. E. Root development of field crops. New York, McGraw-Hill, 1926. 291p.