SOME RESPONSES OF THE HOWARD 17 STRAWBERRY PLANT TO APPLICATIONS OF NITROGEN AND MOISTURE IN THE NON-FRUITING AND FRUITING YEAR.

BY

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INTRODUCTION

From the standpoint of yield the application of nitrogen fertilizers to strawberry plants has given contradictory results as evidenced by numerous field experiments in various sections of the United States and Canada. In some cases significant increases in yield have resulted, while in others equally significant decreases have been obtained. The fertilizer applications have been made at various times. In some instances they were applied at the time the plants were set in the field, or soon after; in other cases split applications were made in which part of the fertilizer was applied at the time of setting in the field and the remainder applied either in the fall or following spring. In still other cases, the applications were made in the spring of the fruiting year.

In the Northern states fruit-bud differentiation occurs during September and October of the year previous to fruiting and any treatment that might affect the differentiation of the buds would need to be applied previous to this time. In the extreme Southern states, however, the length of day and temperature of the late winter and early spring months are favorable for fruit-bud differentiation. Consequently it is possible that differentiation of buds and yield could be affected by treatments applied at this time. This condition may possibly occur as far north as North Carolina in certain seasons. In the Northern states when temperatures become favorable for growth of the strawberry plant in the spring, the length of day seems to be too long for differentiation of fruit-buds to occur.

In some of the experimental work with strawberries it has been found that the application of nitrogen fertilizers resulted in increased leaf area. Under conditions of low soil moisture, larger leaf area and consequent greater transpiration surface might deplete the soil moisture to such an extent as to result in drought injury to the nitrogen fertilized plants sooner than would occur in plants not fertilized with nitrogen. Nitrogen fertilization has been reported to stimulate weed growth in strawberry beds and in periods of drought the weeds would serve to aggrevate the harmful effects of low soil moisture. These factors might possibly affect fruit-bud differentiation if they occurred during the summer previous to fruiting. In the fruiting year nitrogen fertilization or an abundant soil moisture supply might cause excessive vegetative development of the plants. A larger number of leaves and leaves of larger leaf area, as well might be produced by the plants. These growth conditions might result in a poor set of fruit, poor color of the fruit, and large soft berries which under the excessive shade of the large leaves would be subject to field rots. It is conceivable that prior to and during fruit-bud differentiation such conditions of growth might also affect fruit-bud differentiation to a considerable degree by affecting the carbohydrate-nitrogen balance, as has been shown by the well known work of Kraus and Kraybill with the tomato fruit.

Such factors undoubtedly have considerable importance in the interpretation of the discrepancies between the results of nitrogen fertilization as has been reported by numerous investigators.

The strawberry plant, because of its habit of forming fruit-buds the year previous to fruiting, its shallow root system, and sensitivity to soil and climatic conditions presents unusual problems to the commercial grower. It was with the purpose of studying in some detail the responses to be expected from varying the moisture and nitrogen available to the plant during its vegetative and reproductive periods that this investigation was undertaken.

REVIEW OF LITERATURE

In a consideration of the effects of nitrogen fertilizers and soil moisture on the responses of the strawberry plant it is important to know whether such treatments were applied before or after the time of fruit-bud differentiation. Some rather extensive investigations concerning the time of fruit-bud differentiation in strawberries in Maryland have been made by Waldo (40) at the United States Plant Field Station. In general it was found that our commonly cultivated varieties showed differentiation of fruit-buds during September and early October. Other investigations concerning the time of fruit-bud differentiation have been conducted by Schilletter (32) in Iowa and by Hill and Davis (15) in Canada. In Iowa differentiation first occurred between the tenth and twentieth of September and in Canada it occurred around the middle of September. In these regions the fall is the only time of the year in which differentiation occurs under normal conditions. Hence, any fertilizer or soil moisture treatment must be applied some time previous to the time of differentiation if any effect on number of fruit buds is to be expected. Treatments applied the spring of the fruiting year can only affect the buds already differentiated.

In actual practice fertilizer treatments have been applied both the year previous to fruiting and in the fruiting year. Among the experiments which have shown increased yields resulting from the spring applications are those of Brown (3) in Oregon, and White (43), (44) in New Jersey, and Schrader (31) in Maryland. Shoemaker (33) in Ohio and Macoun and Davis (24) in Canada applied nitrogen fertilizers in split applications and obtained higher yields than where it was applied in one application. In the case of split applications part was applied at the time of setting the plants in the field or soon after, and the remainder either in the fall or the following spring. In North Carolina, Darrow and Waldo (6) applied organic and inorganic nitrogen fertilizers in split applications, part being applied in the fall and part the following spring, and as single applications in January. Except in one case where fertilizer injury occurred, all applications resulted in increased yields. Except in the case of the North Carolina experiments and those where the split applications were made, the above applications were made after fruit-bud differentiation so that the treatments could not have had any effect on the number of buds differentiated.

In latitudes further south there may be a considerable period of fruit-bud differentiation in the spring. Darrow and Waldo (7) state that from Virginia northward there is no period of spring fruit-bud differentiation. In Alabama, Taylor (37), found that an application of nitrogen fertilizer in January of the fruiting year resulted in an increased yield. This response to the fertilizer may have been due to the effect on differentiation in the season previous or to the effect on differentiation during the spring of the fruiting year. At Hammond, Louisiana, Syzmoniak (36) applied nitrogen in the form of a complete fertilizer the year previous to fruiting and obtained marked increases in yield. The soils in that section of the state, however, were very poor and may account for the marked response to fertilizers. In the Philippines, Rodrigo (30) found that fertilized plots receiving a 5-10-5 fertilizer yielded more than the unfertilized. One-half of the fertilizer was applied before planting and the other half in the latter part of September. Harvesting began the latter part of November and continued until June.

Some of the more carefully controlled experiments relative to the effect of nitrogen fertilizer on the strawberry are those of Loree (24) in Michigan and Davis and Hill (10) in Canada. Loree grew strawberry plants in six inch pots filled with a light sandy soil and applied nitrogen fertilizers at various times. The application of nitrogen fertilizer, whether alone or in combination with phosphorus and potassium, increased the yields in every case. The largest yields were obtained from plants fertilized during the spring and summer periods of the non-fruiting year and again in the spring of the fruiting year. By use of sand cultures Hill and Davis showed that there must be sufficient amounts of phosphorus and potassium in the soil if increased yields are to be expected from the use of nitrogen fertilizers. These results would tend to substantiate those of Loree. The lack of potassium or phosphorus in the soil might account for the failure to obtain increased yields when nitrogen fertilizers are applied.

Other investigators under similar conditions of latitude have found that the application of nitrogen fertilizer resulted in a decreased yield. Chandler (4) in Missouri found that nitrogen fertilizer, applied a year before the crop is harvested and also in the spring of the fruiting year, resulted in decreased yields. The berries on the nitrogen fertilized plants were observed to wilt much more than those grown on the unfertilized plants. Other experiments at the Western Kentucky Sub-Station (17), in New Hampshire (20), (39), (42), and in Ohio (34) have shown decreases in yield when nitrogen fertilizers were applied to strawberries. In the New Hampshire experiments the fertilizer applications were made at various times; in the spring of the fruiting year, in split applications, and the year previous to fruiting. In Ohio the nitrogen fertilizer was applied in the spring of the fruiting year. In New Hampshire it was found that the nitrogen fertilizer increased the leaf area about twenty per cent and that the leaves had a greater tendency to wilt than did those on the check plots. It was thought that this may have been due to greater transpiration and consequently a more rapid depletion of the soil moisture under the nitrogen fertilized plants. This supposition was further strengthened by the fact that in 1924 when the rainfall during the fruiting season was but 1.22 inches as compared with 2.26 inches for 1923, the crop was reduced more on the nitrogen fertilized plots than on the check plots. It was concluded that soil moisture might be the limiting factor in regard to the effect of nitrogen fertilizer on yield. In the New Hampshire experiments the soil seemed to be in a fairly high state of fertility before any nitrogen was applied, and increases in yield might not be expected, especially if soil moisture were limiting.

MATERIALS AND METHODS

Plant Materials

The Howard 17 variety of strawberry was used in all the investigations reported in this paper. This variety was selected because it is one of the four commercial varieties grown in Maryland. In some sections of the country it is the leading variety of strawberry.

In the preparation of the plants for chemical analyses, a transverse cut was made just above the highest roots. The upper portion was called tops and the lower portion called roots. Consequently, part of the crown remained with the top portion and part with the root portion.

In the case of the plants used for the photoperiod studies, the samples were taken in the morning at the time the plants were brought into the light. Six plants were used for each individual sample. In the field studies, two plants of each age were selected from each of the six blocks receiving the same treatment. Thus, there were twelve plants of each age in each treatment; a composite sample was made of these twelve plants. Sampling was begun around ten o'clock in the morning and completed as soon as possible. Fresh and dry weights of the plants were obtained.

In the case of the fruit, a 50-gram fresh weight sample was taken for the moisture and total nitrogen determination and a 100-gram fresh weight sample for the determination of carbohydrates. The fruit was cut into thin slices for these samples. The carbohydrate sample was preserved in eighty per cent alcohol to which precipitated chalk had been added.

All of the plant material and the fruit for the moisture and nitrogen determinations was dried in a ventilated oven at 65°C. for thirty-six yours. After obtaining the dry weights the plant material was ground in a Wiley mill and preserved in glass bottles until used for the analyses. The dried fruit samples were preserved in small paper bags until ready for analysis.

Chemical Methods

Soil.

Standard methods were used for the determination of the readily available phosphorus and the replaceable potassium of the soil. Soil nitrates were determined according to Harper's modification of the colorimetric phenoldisulphonic acid method (14).

Plant and Fruit Materials.

Total Nitrogen. Total nitrogen was determined by the official Kjeldahl-Gunning method (1) modified to include nitrate nitrogen. A one gram sample of the dried plant material was used for this determination and with the fruit the dried residue from the 50 gram fresh weight sample.

Soluble Nitrogen. An aliquot of the alcoholic extract prepared for the soluble carbohydrate determinations was removed to a Kjeldahl flask and the alcohol and water evaporated off until only a gummy mass remained in the flask. An attempt was made to remove all moisture from the sample. A measured amount of salicylic-sulphuric acid mixture was added to the material in the flask and the flasks stoppered and allowed to stand over night. From this point on, the determination was the same as that for total nitrogen.

Insoluble Nitrogen. The difference between the soluble and total nitrogen was considered as the insoluble fraction.

Reducing Substances. In the case of the fruit samples, which had been preserved in eighty per cent alcohol, the alcohol was poured off and the residue transferred to a large porcelain evaporating dish and dried in a ventilated oven at 65°C. The residue was then transferred to small tared beakers and dried to constant weight. After grinding the residue to pass a 100 mesh sieve, an aliquot was taken and extracted for six hours with eighty per cent alcohol in a Soxhlet extraction apparatus. This extract was then added to a similar aliquot of the alcohol in which the sample had been preserved. The residue was saved for acid hydrolyzable polysaccharides.

With the roots and tops a two gram sample of the dried and ground sample was weighed out and extracted with eighty per cent alcohol in a Soxhlet extraction apparatus for a period of twelve hours. The residue was saved for the determination of acid hydrolyzable polysaccharides. From this point on the methods used for the fruit and plant samples were the same.

An aliquot of the alcoholic extract was evaporated until the odor of alcohol was no longer noticeable. Water was added if necessary to prevent the sample from caramelizing before all traces of alcohol were removed. When all the alcohol had been evaporated, approximately 100 cc of water were added and the mixture heated to 80°C. After cooling, enough neutral lead acetate solution was added to clear the solution which was then filtered into a beaker containing an excess of sodium oxalate crystals in order to precipitate the lead. The lead oxalate was then filtered off and the solution made to volume. A 50 cc. aliquot was removed from the determination of free reducing substances. The determinations were made in duplicate.

Total Sugars. An aliquot of the above solution was used for the determination of the total sugars after inversion with hydrochloric acid at room temperature for twenty-four hours. This solution was then neutralized with thirty-five per cent sodium hydroxide solution, and made to volume. From this solution 50 cc. aliquots were removed for reduction.

Sucrose. The difference in reducing power of the solution before and after inversion with hydrochloric acid times the factor .95 was taken as the amount of sucrose present.

Starch. The residue from the alcoholic extraction was digested with Taka-diastase according to the method described by Denny (11). A negligible amount of copper was reduced by the mixture after this digestion. Microscopical examination failed to disclose the presence of starch. Consequently, after the first lot of samples no further digestions with Taka-diastase were made, but the sugar-free residue was hydrolyzed with acid.

Acid Hydrolyzable Polysaccharides. The residue from the alcoholic extraction was ground to pass a 100 mesh sieve, transferred to a 500 cc. Florence flask, and 100 cc. of water added. Ten cc. of twenty-five per cent hydrochloric acid were added and the mixture hydrolyzed under a reflux condenser for a period of two and one-half hours. After cooling, the material was neutralized with sodium hyrdoxide solution, filtered, and the filtrate made up to volume. Fifty cc. aliquots were used for reduction.

All reductions for the carbohydrate determinations were made with Fehling's solution according to the Munson and Walker method. The reduced copper was determined according to the Bertrand method, using .05 normal potassium permanganate solution which had been standardized with a pure glucose solution.

Histological Methods

After the buds were removed from the crown of the plants they were placed in an alcohol-acetic acid-formalin killing and fixing solution. The air was exhausted from the buds by placing them in partial vacuum for ten minutes. They were then stored until ready for embedding. The killing solution was poured off, the buds washed in running water, dehydrated in alcohol, and the alcohol removed by n-butyl alcohol. From the butyl alcohol they were embedded in paraffin. The sections were cut from sixteen to twenty-four microns in thickness and stained in Delafield's haematoxylin.

Statistical Methods.

The field plots, greenhouse plots, and the data secured were planned so that Fisher's (12) Analysis of Variance method could be used for the interpretation of the results. This method of analyzing experimental data has been used and discussed by Immer, Hayes, and Powers (16) in barley variety adaptation investigations, and by Latimer and Wentworth (20) in strawberry fertilizer investigations. Consequently, no explanation of the use of this method will be presented except as it applies to the data at hand.

EXPERIMENTAL RESULTS.

Growth Responses of the Strawberry Plant Before Fruit-Bud Differentiation When Grown Under Conditions of Low and High Soil Moisture and Nitrogen.

Description of Plot Layout and Methods. On April 21, 1934 plants of the Howard 17 variety were set in the field. The soil was quite uniform and in a good state of fertility, having been cropped with vegetables previously. The plots were fifteen by forty-eight feet in size and contained two rows of five plants each, spaced eight feet apart in the row with rows five feet apart. Guard rows marked the boundaries of the plots. There were five replications of each treatment, making six plots per treatment and a total of twenty-four plots in all. This large planting distance was used so that the runner plants could be trained in the row as desired.

The roots of the plants, before setting in the field, were shortened to about three and one-half inches in length and all but one or two of the leaves removed. All the blossoms were picked off as they appeared. Incidentally, not one of the 240 plants set for experimental records, nor any of the 235 guard plants died.

The runner plants were trained along the row in four unbranched series, two on either side of the mother plant. The parallel series were spaced about one foot apart. At weekly intervals, all runner plants showing indications of rooting were marked by a six inch garden stake placed in the soil beside them. The date of rooting was marked on the stake and a record was also kept in a note-book.

The plants were grown under four different treatments which were as follows:

Nitrogen fertilizer and irrigation.
Nitrogen fertilizer without irrigation.
No nitrogen fertilizer and irrigation.
No nitrogen fertilizer and without irrigation.

A top dressing of nitrate of soda was applied to the nitrogen plots at the rate of 150 pounds per acre on June 5, July 12, and August 20. The nitrate of soda was cultivated into the soil after application. No nitrogen was applied to the other plots. Furrow irrigation was applied to the irrigated plots beginning July 16 and at nearly weekly intervals thereafter. The soil was kept well cultivated throughout the growing season.

Samples of soil were taken at intervals throughout the growing season for soil moisture and nitrate determinations. A composite sample of all the plots of a treatment was made. The soil samples were taken to a depth of six inches since Ball and Mann (2) have shown that ninety per cent of the strawberry root system is in the upper six inches of soil. Samples were obtained at four places in each plot and adjacent to the plants with a sampling tube two or three days after irrigation.

<u>Effect of Treatment on Soil Moisture and Soil Nitrates.</u>

Soil samples were taken throughout the duration of the experiment so that the plant responses could be checked with the soil conditions which were maintained experimentally. The season was extremely dry during July and August and temperatures were very high. Vegetable crops growing in the same locality suffered from the drought conditions. During the first part of September an excessively heavy rainfall occurred, in fact all rainfall records for the month were exceeded.

In Table 1 the results of the soil moisture determinations are shown. Marked effects of irrigation on soil moisture were apparent throughout the season except for the two sampling dates -- August 18, and September 27. On August 18 the samples were taken soon after a rather light rainfall and caused the soil to show a high moisture content. The samples on September 27 were taken after the very heavy rainfall occurring the first part of the month, and the soil still showed a decided effect of this excess moisture. On these two dates the natural rainfall had obliterated all effects of irrigation. However, on August 25 and September 1, the moisture determinations showed the characteristic difference due to the irrigation treatments. Particular emphasis should be put on the heavy rainfall the first part of September. In the first two weeks 11.37 inches of rain fell, which broke a 58 year record of 10.81 inches. The seasonal average soil moisture for the four treatments showed that

Table 1 -- Percentage Moisture Content of Upper 6" of Soil as Affected by Irrigation and Rainfall. (Expressed as Percentage of Oven-Dry Weight).

Treatment	Date Sampled								Average
	July 18	July 28	Aug. 4	Aug. 11	Aug. 18	Aug. 25	Sept. 1	Sept. 27	
	%	%	%	%	%	%	%	%	%
Nitrogen fertilizer irrigated	11.78	10.17	12.93	9.72	15.13	11.37	9.75	12.33	11.65
Nitrogen fertilizer not irrigated	9.44	8.34	11.25	7.20	15.09	9.99	7.68	12.60	10.20
No nitrogen fertilizer irrigated	12.63	13.14	13.58	9.92	15.59	11.89	9.96	12.77	12.43
No nitrogen fertilizer not irrigated	8.59	8.15	12.16	7.35	15.44	9.40	7.74	12.44	10.16

the irrigated plots averaged 11.65 per cent and 12.43 per cent, and the unirrigated plots averaged 10.20 and 10.16 per cent, or an average difference of 1.86 per cent. Unfortunately the wilting coefficient of the soil was not determined, so it is not known how high the unirrigated plots were above this. Since the soil was a sandy loam, it is probable that the wilting coefficient was around 6 to 7 per cent.

At all times soil nitrates were considerably higher in the nitrate plots as is shown in Table 2. The seasonal averages showed that the nitrate plots contained approximately four times as many nitrates as did the plots not receiving nitrogen fertilizer. On the average, the irrigated plots, whether receiving nitrate or not, were considerably lower in nitrates than the unirrigated plots. This was undoubtedly due to the leaching of the nitrates from the upper few inches of soil by the irrigation water. Since the soil samples were only taken to a depth of six inches, it is not known just what the nitrate content of the soil below this depth might have been. On August 11 and September 27 the nitrates were lower in all plots, whether irrigated and fertilized or not. On August 11 this was probably due both to the use of the nitrates by the plants and a slight amount of leaching from the soil by light showers. On September 27 the low nitrate content was undoubtedly due to the heavy rains occurring the first part of the month. The nitrates on this latter date were

Table 2 -- Nitrates in Parts per Million of Air-Dry Soil as Affected by Applications of Nitrate of Soda and by Irrigation, 1934.

Treatment	Date Sampled									Average
	June 16	July 18	July 28	Aug. 4	Aug. 11	Aug. 18	Aug. 25	Sept. 1	Sept. 27	
Nitrogen fertilizer irrigated	60.9	50.5	47.1	68.3	18.8	33.7	30.4	32.9	10.8	39.3
Nitrogen fertilizer not irrigated	62.5	68.0	56.5	50.1	33.4	19.2	72.3	77.3	10.6	50.0
No nitrogen fertilizer irrigated	8.2	8.4	6.7	16.8	7.6	7.5	14.3	8.8	8.5	9.6
No nitrogen fertilizer not irrigated	10.0	10.5	7.6	24.7	11.7	14.7	19.0	16.3	7.5	13.6

practically the same in all treatments. As a season average, the plots fertilized with nitrate of soda had a nitrate content of 33 parts per million more than the non-fertilized plots. Thus, there was a considerable difference in the nitrate content of the soil due to the treatments applied.

Effect of Moisture and Nitrogen Treatment on Plant Growth.

Number of Runner Plants.

The effects of the soil treatments on plant growth prior to and during the time of fruit-bud differentiation were determined in various ways. Perhaps one of the most striking characteristics of the strawberry plant is its ability to propagate itself by runner plants. In commercial plantings the mother plants set out in the spring of the year produce runner plants, the first of which are usually produced sometime during May or June, depending on seasonal conditions, and these runner plants in turn produce other runner plants. The development of runners and runner plants in the strawberry has been fully described by Darrow (5). In the present investigation all runner plants formed by the mother plant beyond the first four were broken off as soon as they could be detected. Each of the runner plants produced during the season was limited to the formation of one other runner plant. In this manner the number of runners which could root from any one plant was limited. Each clon then could produce plants in but four places; namely, at the end of each of the four runner series.

In Tables 3 and 3(a) the effects of the treatments on the number of runner plants formed at weekly intervals during the growing season is given. In order to conserve space, the figures given represent the total number of plants formed for the six blocks of a treatment. The data for the Analysis of Variance, however, is based on the single plot and period. From Table 3(a) it will be seen that treatment and period made significant contributions to the total variance. The Z-value given is that necessary for odds of 19:1 that the effects observed are not due to random sampling. The standard error of the difference, which was derived from the mean variance for error, is given and two times the standard error of the difference, which in this case is 24.66, may be used as a minimum difference required between any two treatments to show significance. From an examination of Table 3 it will be seen that all treatments are significantly different from one another. In other words, the differences in the number of runner plants produced by each of the various treatments varies by more than twice the standard error of the differences from any other treatment. The most plants were produced in the plots re-

Table 3 — Effect of Nitrogen and Soil Moisture Treatments on Number of Runner Plants Formed During 1934. (Expressed as Total Number Produced by 60 Mother Plants per Treatment).

Period	Treatment: Nitrogen fertilizer irrigated	Treatment: Nitrogen fertilizer not irrigated	Treatment: No nitrogen fertilizer irrigated	Treatment: No nitrogen fertilizer not irrigated	Total
Up to and including June 28	97	81	103	108	389
June 28-July 6	125	128	137	138	528
July 6-July 13	102	111	110	125	448
July 13-July 20	74	90	91	85	340
July 20-July 27	100	91	98	96	385
July 27-Aug. 3	74	87	99	100	360
Aug. 3-Aug. 10	76	82	76	87	321
Aug. 10-Aug. 17	59	86	100	92	337
Aug. 17-Aug. 24	77	85	90	106	358
Aug. 24 - Aug. 31	59	81	97	91	328
Aug. 31-Sept. 7	76	84	90	108	358
Sept. 7-Sept. 14	62	82	103	110	357
Sept. 14-Sept. 21	68	69	74	84	295
After Sept. 21	43	30	120	26	219
Total	1,092	1,187	1,388	1,356	5,023

Standard error of the difference: 12.33

Table 3a -- Analysis of Variance for Number of Runner Plants Formed on Plots Receiving Nitrogen and Moisture Treatments.

Variance due to	Degrees of freedom	Variance	Mean Variance	$\frac{1}{2}$ $\log_e$	Z value	
					Found	Necessary
Blocks	5	499.12	99.82	2.3011		
Treatment	3	703.34	234.45	2.7286	1.4585	0.4787
Periods	13	2708.77	208.37	2.6696	1.3995	0.2804
Periods X Treatment	39	1258.20	3.23	0.5862		
Error	275	3502.71	12. 69	1.2701		
Total	335	8672.14				

ceiving irrigation and no fertilizer. The next highest was on the unfertilized and unirrigated plots. The nitrate plots produced the fewest runner plants; the irrigated plots producing fewer runner plants than the unirrigated plots.

As compared with nitrogen fertilizer, irrigation was found to have a negligable affect on the production of runner plants. The seasonal average differences in soil moisture were possibly not great enough to produce striking effects, although irrigation did materially affect the nitrate content of the soil. Nitrogen fertilizer had the opposite affect on runner plant production than was anticipated. This may have been due to the time and rate of application. That nitrogen fertilizer had an adverse affect on the plants is not borne out by the soil and plant data since the plots receiving nitrogen and no irrigation produced more plants than the plots receiving both nitrogen and irrigation, although the former plots had a greater seasonal nitrate content of the soil than did the latter plots.

In Table 3 the total number of runner plants for the six plots of each treatment is given by weekly intervals. The peak for runner plant production for the season was reached during the week of June 28 to July 6. This was true of all treatments. Ordinarily the Howard 17 variety does not form many runners after the first part of September in Maryland. The fact that so many were produced in this experiment after September 1 was probably due to the excessive rainfall the first part of the month. In general, runners were produced quite uniformly throughout the season, both on the irrigated and non-irrigated plots. From the period of July 27 to August 3 the production of runner plants on the nitrogen plots was uniformly lower than in the plots not receiving nitrogen. The irrigated nitrogen-fertilized plots produced the fewest number of runner plants.

Effect of Treatment on Number of Leaves on Different Age Plants.

The number of leaves on each runner plant and the mother plants was determined toward the latter part of the growing season, in October. Since the plants differed in age according to their position in the runner series and date of rooting, the number of leaves was determined for each position. The analysis of variance for these data is presented in Table 4(a). The Z-value for treatment was not significant and it may be concluded that the nitrogen and irrigation treatments did not significantly affect the number of leaves per plant at the different positions on the runner series. For plants at the different positions in the runner series, significant differences were found.

In Table 4 are presented data for the average number of leaves for each age of plant in the six blocks of a treatment. The standard error of the difference

Table 4 — Average Number of Leaves per Plant at Different Positions in the Runner Series as Affected by Moisture and Nitrogen Treatments. Data Secured October 13-20, 1934.

Treatment	Number of leaves at position indicated									Average
	M.P.	#1	#2	#3	#4	#5	#6	#7	#8	
Nitrogen fertilizer irrigated	18.2	8.7	7.5	6.4	5.5	4.8	4.0	3.7	3.4	6.9
Nitrogen fertilizer not irrigated	16.9	8.8	7.4	6.45	5.6	4.8	4.0	3.6	3.2	6.75
No nitrogen fertilizer irrigated	17.5	9.7	8.2	7.2	6.1	5.1	4.4	3.8	3.4	7.3
No nitrogen fertilizer not irrigated	17.0	10.1	8.5	7.1	6.3	5.6	4.7	3.9	3.3	7.4

Table 4a — Analysis of Variance for Number of Leaves per Plant at Different Positions in the Runner Series as Affected by Moisture and Nitrogen Treatments.

Variance due to	Degrees of freedom	Variance	Mean Variance	$\frac{1}{2}\log_e$	Z Value Found	Z Value Necessary
Blocks	5	99.84	19.97	1.4971		
Treatment	3	14.10	4.70	0.7737	.3444	.4787
Position	8	3,606. 57	450.82	3.0555	2.6262	.3309
Treatment X Position	24	14.92	0.62	-0.7610		
Error	170	400.74	2.36	0.4293		
Total	210*	4,136.17				

* - 5 degrees of freedom dropped for substituted averages.

Figure 1 is a graphical reproduction of the number of runner plants formed during the season, and perhaps, brings out more clearly the differences between the low and high nitrogen treatments.

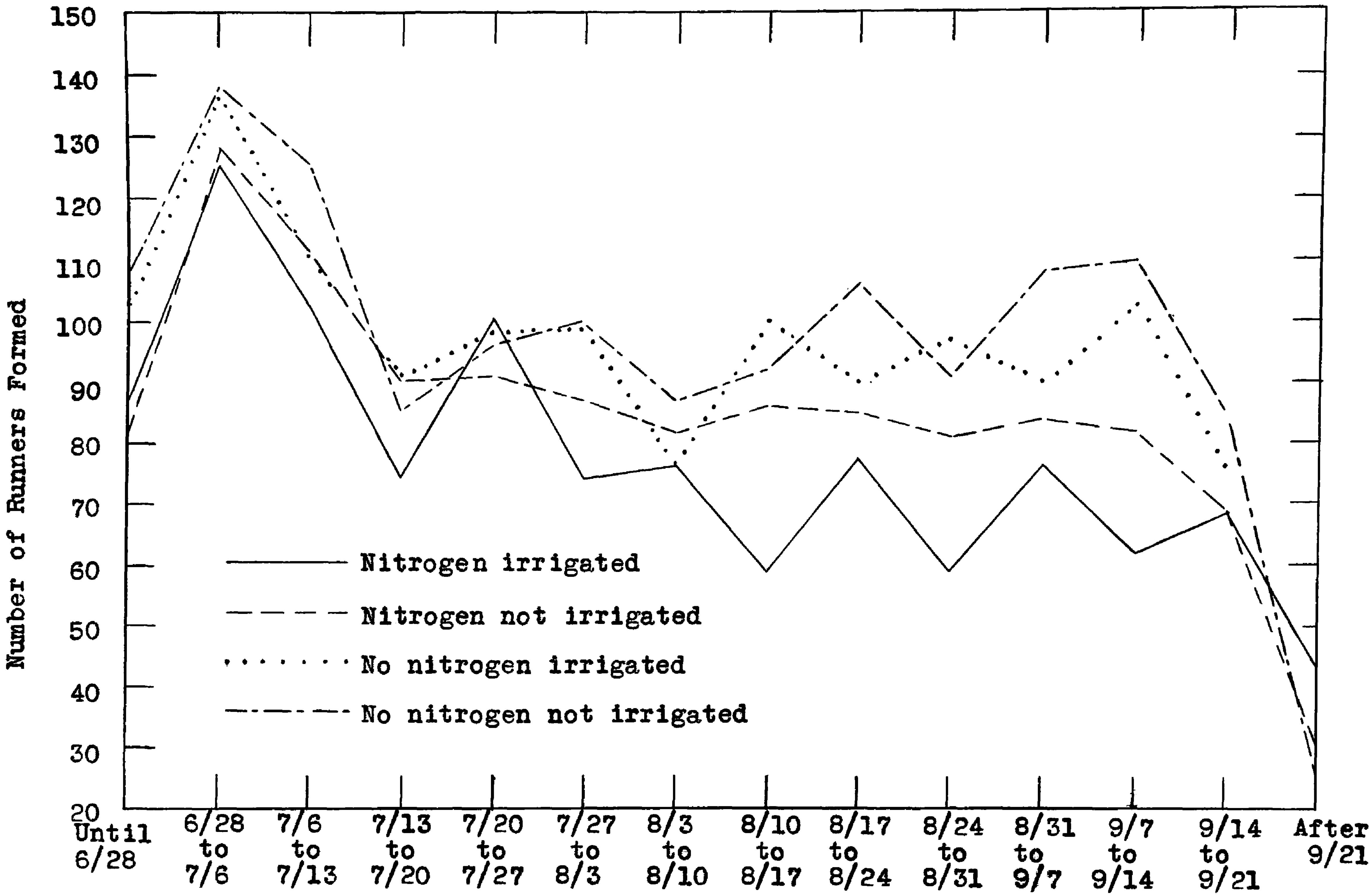

Fig. 1

Effect of Moisture and Nitrogen Treatments on Runner Plant Formation Throughout the Season.

between means, based on the mean variance for error, is also given. Two times this value provides a convenient estimate of a minimum difference necessary for significance.

In all cases the number one plants, those between the mother plants and number two plants, had a significantly greater number of leaves than the number three plants, as judged by twice the standard error of the difference between means. The number two plants had a significantly larger number of leaves than the number four plants, but not significantly more than the number three plants. Other differences were also apparent. Unquestionably, there was a decided downward trend in number of leaves on the plants produced the latter part of the season. The low interaction of position and treatment indicates that treatment had no affect on the number of leaves per plant in the different positions.

If the number of leaves and the resultant leaf area are of importance from the standpoint of fruit-bud differentiation and subsequent yielding ability, then the older runner plants will produce the greater number of blossoms and fruit the following season. That the nitrogen treatment which resulted in a high nitrate content of the soil affected the number of leaves, adversely, if at all, is somewhat surprising, although in line with the results obtained for the number of runner plants formed. It is usually expected that more as well as larger leaves will result from the application of nitrogen fertilizers under field conditions.

Length of Runner Between Plants.

The length of the runner between runner plants might possibly be a measure of the vegetative vigor of the plants and consequently would provide another indication of the effects of treatment on plant vigor. For this reason a measurement of the length of the runner between the plants in the runner series was made in October. Since the plants had been trained in straight runner series, the length of the distance of the runner between plants could be quite accurately determined. The averages for the length of the runner between the plants at the various positions on the runner series are given in Table 5 and the analysis of variance for the data in Table 5(a).

The interaction of treatment and position was not significant, indicating that the length of runner between positions is independent of treatment. Both treatment and position made a significant contribution to the total variance. In Table 5 the means for the several treatments and positions are shown. Comparing first the average length of runner between plants of a treatment, it will be seen that the average length of runner between plants of the unfertilized and non-irrigated plots is significantly greater than on those receiving nitrate of soda. The no nitrogen-irrigated plots were intermediate. These data are correlated with the data for the number of leaves and number of runner plants produced. The position of

Table 5 -- Effect of Nitrogen and Soil Moisture Treatments on Average Length of Runner Between Plants in the Runner Series. (Each Figure Represents the Average Length in Inches per Plot).

Treatment	Length of runner between							Mean for treatment
	Mother plant & #1	#1 & #2	#2 & #3	#3 & #4	#4 & #5	#5 & #6	#6 & #7	
Nitrogen fertilizer. Irrigated.	6.49	6.13	6.16	6.33	6.83	6.84	6.74	6.50
Nitrogen fertilizer. Not irrigated.	6.47	6.26	6.20	6.37	6.81	6.99	6.87	6.56
No nitrogen fertilizer. Irrigated.	6.67	6.26	6.38	6.48	7.07	7.41	7.59	6.84
No nitrogen fertilizer. Not irrigated.	6.75	6.40	6.51	6.91	7.41	7.74	7.84	7.08
Mean for position.	6.59	6.26	6.31	6.52	7.03	7.24	7.26	

Standard error of the difference between means for treatment: .09
Standard error of the difference between means for position: .11

Table 5(a)-- Analysis of Variance for Length of Runner Data.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	5	3.34	0.67	0.9510		
Treatment	3	8.87	2.96	1.6938	1.4588	.4787
Position	6	26..12	4.35	1.8863	1.6513	.3706
Treatment x Position	18	3.08	0.17	0.2653		
Error	135	22.28	0.16	0.2350		
Total	167	63.69				

the plants on the runner series largely determined the length of runner between plants. As successive runner plants are formed after the first one, the increase in length of runner between plants is very uniform and consistent. (See INSERT on next page).

Number of Blossoms per Plant.

During the winter a random sample of runner plants from positions two, four, and six on the runner series was taken from the plots in the field and transplanted into greenhouse benches. This was done to determine the number of blossoms that had been formed by the plants grown under the various treatments and at the different positions on the runner series. These plants were grown under uniform conditions of soil moisture and fertility in the greenhouse. The data for the results obtained are recorded in Table 6 and the analysis of variance in Table 6 (a). From the latter table it will be seen that the effect of both treatment and position was very significant. The Z-value given is that required to give odds of 99:1. In both cases this value was considerably exceeded.

The plants on the no nitrogen-nonirrigated plots produced considerably more blossoms per plant than those receiving other treatments. These were blossoms which had been differentiated the previous fall. The production of blossoms in these plants is correlated with the number of leaves, the number of runner plants formed, and the length

In Figure 2 the consistent differences in length of the runner between runner plants of the high and low nitrogen treatments are shown in a striking manner. The increase in length of runner between plants as they occur further and further out on the runner series may also be observed.

Fig. 2 - Effect of Treatment on Average Length of Runner Between Plants.

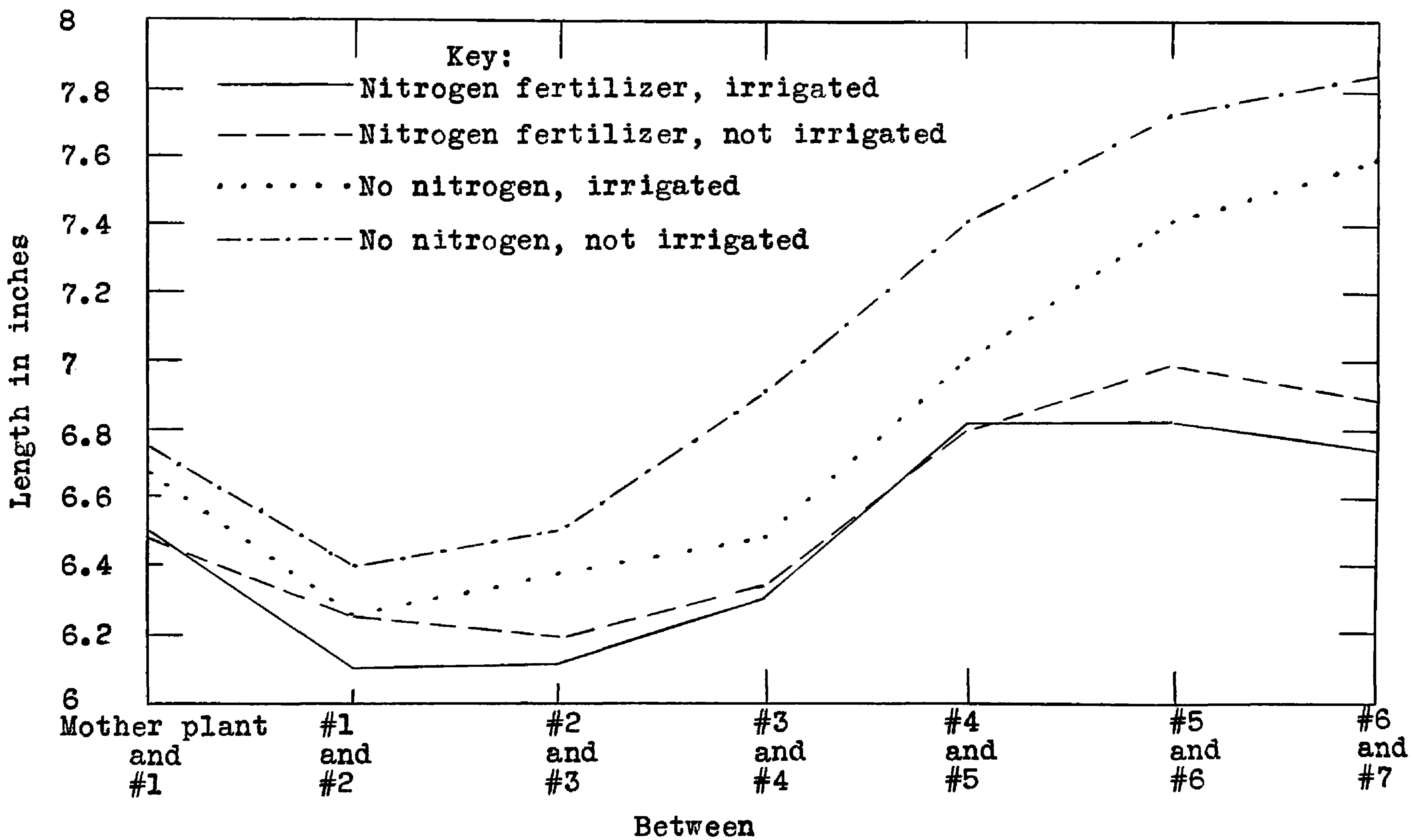

Table 6 -- Effect of Treatment and Age of Plant on the Production of Blossoms.

(Expressed as Total Number of Blossoms for 27 Plants per Treatment and Position).

Treatment	Position of plant and date of rooting.			Total for treatments
	#2 July 13	#4 Aug. 3	#6 Sept. 14	
Nitrogen fertilizer. Irrigated.	443	339	263	1,045
Nitrogen fertilizer. Not irrigated.	409	343	236	988
No nitrogen fertilizer. Irrigated.	390	310	232	932
No nitrogen fertilizer. Not irrigated.	471	355	345	1,171
Total for positions.	1,713	1,347	1,076	4,136

Standard Error of Difference for totals between treatments: 60.95

Standard Error of Difference for totals between positions: 70.38

Table 6a -- Analysis of Variance for Blossom Data.

Variance Due to:	Degrees of Freedom	Variance	Mean Variance	$\frac{1}{2}\log_e$	Z value Found	Z value Necessary
Blocks	2	122.89	61.44	2.0590		
Treatment	3	3,490.00	1,163.33	3.5295	.8642	.7806
Position	2	17,032.39	8,516.19	4.5248	1.8595	.8670
Position x Treatment	6	923.83	153.97	2.5183		
Error	22	4,544.45	206.57	2.6653		
Total	35	26,113.56				

of the runner between plants. It will be recalled that these plots were low in soil moisture and moderately high in nitrates, though not as high as the nitrogen plots, during the growing season. On the other hand, the no nitrogen irrigated plots produced the fewest blossoms. These plants had produced as many leaves as those in the above treatment, but the soil moisture was the highest and the nitrates were the lowest in these plots of all those considered. Perhaps this treatment delayed the differentiation of fruit buds somewhat and as a result not as many were formed before freezing weather set in as in the other treatments. The nitrogen plots were intermediate in flower production, lowest in number of leaves, number of runner plants and length of runner between plants. The soil of these plots was highest in nitrates. The nitrates may have been in such concentration as to be somewhat toxic to the plant, though not sufficiently so to inhibit fruit-bud formation.

It seems, therefore, that the one outstanding treatment in these studies, in so far as growth and fruit-bud differentiation are concerned is that of no nitrogen and no irrigation. These results are at variance with some of the published experiments with strawberries in which increases in yield have been obtained by the use of nitrogen fertilizers the year previous to fruiting. In some of the fertilizer experiments with strawberries, the nitrogen has been applied in split applications, some before and some about the time of or after differentiation, and this further complicates the problem of interpreting the results.

The difference in the number of blossoms produced by the plants in the different positions in the runner series is striking and significant. These results are in accord with those obtained by Morrow and Beaumont (27), Shoemaker (33), and others who have found that the earlier the runners were rooted, the greater their production would be. From the data in Table 4 relative to the number of leaves per plant, it will be recalled that the oldest plants had the largest number of leaves and that there was a gradual decrease in number of leaves to the youngest plants. The production of blossoms per plant decreases in a similar manner. Apparently the leaf area and age of plant are important if maximum production is to be obtained.

Fruit-Bud Differentiation and Chemical Composition of Plants Grown Under Various Treatments.

Fruit-Bud Differentiation

Effect of Nitrogen Fertilizer and Soil Moisture on Time of Differentiation.

Considerable work has been done relative to the effects of plant nutrition and photoperiodism on the initiation of the reproductive processes in plants. The investigations of Kraus and Kraybill (19) concerning the effects of nutrition on the reproductive and vegetative responses of the tomato plant and those of Garner and Allard (13) relative to the effect of length of day on the vegetative and reproductive responses of various plants are too well known to need extended discussion in this paper.

The problems of nutrition and photoperiodism and their effects on the differentiation of fruit-buds in the strawberry plant is of importance to every strawberry grower, who, whether he realizes it or not, has the crop he is to harvest during the following summer very largely determined by the time freezing weather begins in the fall. His fertilization, cultivation, and other cultural practices undoubtedly have affected the size of the crop. The growth conditions prior to and during the time of fruit-bud differentiation are of the utmost importance, as they may hasten or retard this process. In the North, the time during which fruit-buds may be formed, after initiation of the process is once begun, is limited by the temperature. Once temperatures become too low for growth, there is undoubtedly no further differentiation of buds. These conditions might not be of so great importance in the South where conditions are more favorable for growth throughout the winter. Soil moisture and nitrogen treatments might affect the time that the process of fruit-bud differentiation was begun and in this way very materially influence the subsequent crop of fruit. For this reason, samples were taken from the various treatments for chemical analyses and a histological examination in order to gain some insight into the possible effects they might have on fruit-bud differentiation.

In samples taken September 6 no fruit-bud differentiation could be distinguished. The growing point of the crowns was broadening, but there was no postive differentiation at this time. On October 4, fruit-bud differentiation was evident. In plants rooted on July 6 many of the buds showed three primordia present. In plants rooted July 27 the crown had broadened and showed a slight elongation of the flower stalk. These were the the least advanced of all plants collected. Plants rooted August 24 were somewhat more advanced than were the above plants, but not as far advanced as were the plants rooted July 6. Evidently in 1934 fruit-bud differentiation was initiated in the Howard 17 strawberry sometime between September 6 and October 4. Probably the relatively late differentiation in 1934 was due to the unusually wet weather in early September. No difference in degree of differentiation among the various treatments could be observed, but this also may have been due to the unusual weather conditions.

Effect of Photoperiodism on Fruit-Bud Differentiation.

In order to compare the effects of nitrogen fertilizer and soil moisture treatments in their effects on fruit-bud differentiation with plants which did not receive the normal day length of light, some plants were subjected to an 11-hour day, beginning the first part of July. The plants for this study were runner plants which had been rooted in three inch pots plunged in the soil beside the mother plants. After these plants had rooted, they were severed from the mother plant and subjected to an 11 hour day of light by placing them in total darkness for the remaining 13 hours. They were brought into the light at seven o'clock in the morning and returned to the darkened chamber at six o'clock at night. Water was applied to the pots as necessary. Samples were taken of these plants at frequent intervals for chemical analysis and for the examination of the buds to determine when differentiation of fruit-buds occurred. Similar plants were grown in pots and subjected to the normal length of day so that comparisons could be made.

A careful and critical examination of paraffin sections prepared from this material was made. It was found that definite fruit-bud differentiation occurred in a lot of plants rooted in the pots on June 22 and subjected to a 11 hour day from July 9 to the time of sampling, on August 13. The plants at this time were 52 days of age and had received the short day treatment for a period of 35 days. On August 7 this same lot of plants showed no differentiation. Another lot of plants rooted on June 29 and subjected to the short day treatment from July 24 showed the first differentiation of fruit-buds on August 20. The plants were 52 days of age and had been subjected to the 11 hour daily light period for 27 days. In still another lot of plants, rooted on July 12 and short day treatment begun on August 1, the first definite fruit-bud differentiation occurred on August 27. These plants were 46 days of age and had been growing under the shortened photoperiod for 27 days. On September 11 all the plants which had been growing with a daily light period of 11 hours showed tertiary and in some cases quarternary flowers. On the primary flowers the sepals and petals had formed and the anthers were fairly well developed. Even the secondary flowers were beginning to show the development of the anthers. In plants growing under the normal length of day, no definite fruit-bud differentiation had occurred on September 11, at the time that this experiment was discontinued. As reported elsewhere, the field grown plants showed no differentiation on September 6 and on October 4 differentiation had not progressed very far.

A summary of the effect of photoperiodism on the Howard 17 strawberry variety shows that fruit-bud differentiation may be greatly hastened by subjecting the plants to an 11 hour daylight period. It would appear that the process of fruit-bud differentiation in this variety of strawberry is inaugurated as the days become shorter in the fall, but that by subjecting the

the plants to an 11 hour photoperiod during July and August fruit-bud differentiation may be induced. Approximately a month of this short day treatment is sufficient at this period to cause differentiation. These results do not exactly corroborate those reported by Darrow (9) who placed Howard 17 strawberry plants under 10 and 12 hour light periods from May to October. He found that under the 10 hour day the plants produced some blossoms by the end of July. Under the normal and 12 hour day no flowers were produced. Also, under the 10 hour day no flowers were produced after July 28. In another year, plants of the Howard 17 variety were subjected to 8, 10 and 12 hour daily light periods from July 16 to September 4, yet no evidence of fruit-bud formation was found. On the other hand, Sudds (35) reported that flower bud initiation was hastened by subjecting the plants to an 8 hour day, presumably during the summer months. The data reported herein would tend to substantiate those reported by Sudds. According to Darrow, the temperature is an important consideration in photoperiod studies with the strawberry and it may be that variations in this factor would explain the discrepancies in the results obtained in different seasons.

Chemical Composition of Plants.

Plants From Photoperiod Studies.

In Table 7 the data for the dry weights, as well

Table 7 — Chemical Composition of Plants Grown Under Conditions of Normal Length of Day. (Expressed as Percentage of the Dry Weight).

	Number of Days Comparable Plants were Under Photoperiod Treatment									
	15		20		29		34		40	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
Average by Weight per Plant(grams)	1.92	0.53	1.59	0.45	2.51	0.80	2.18	0.89	2.18	0.92
Soluble Nitrogen	0.1907	0.6427	0.3461	0.4026	0.3461	0.5650	0.2755	0.6004	0.2401	0.3178
Insoluble Nitrogen	2.2648	1.2038	2.1775	1.4850	1.9381	1.0861	1.9895	0.9237	2.1025	1.0440
Total nitrogen	2.4555	1.8465	2.5236	1.8876	2.2842	1.6511	2.2650	1.5241	2.3426	1.3618
Reducing Substances	3.25	2.81	3.56	3.94	4.44	5.50	4.97	5.31	5.31	4.75
Sucrose	1.26	1.25	1.57	0.71	2.01	0.31	1.67	0.49	1.88	0.83
Total Sugars	4.58	4.13	5.21	4.69	6.56	5.83	6.73	5.83	7.29	5.62
Acid Hydrolyzable Polysaccharides	13.60	12.60	13.20	13.50	14.30	12.80	15.70	14.80	15.90	16.70
Total Carbohydrates	18.18	16.73	18.41	18.19	20.86	18.63	22.43	20.63	23.19	22.32

as that for carbohydrate and nitrogen content of the plants grown under the normal day are shown. In Table 8 similar data for the plants subjected to the 11 hour day are presented. In the computation of these tables the plants were grouped according to the number of days they had been growing under the photoperiod treatments when sampled. In some cases the data represent the averages for four different lots of plants and in others they represent the averages for two or three lots of plants. The figures for the number of days given in the table for the normal day plants were reckoned from the time that similar lots of plants had been placed under the photoperiod treatments.

Tables 7 and 8 show that the total nitrogen content of the plants growing under the normal length of day was at all times higher than that of the short day plants. In general the soluble nitrogen content was lower in the short day plants than in those growing under the normal length of day. In every instance the insoluble nitrogen was lower in the short day plants. The content of reducing substances was generally higher in the short day plants. In most cases, on the other hand, sucrose was higher in the plants growing under the normal day lengths. Values for total sugars were not consistent, in some cases they

Table 8 — Chemical Composition of Plants Grown Under Conditions of an 11-hour Photoperiod. (Expressed as Percentage of the Dry Weight).

	Number of Days Grown Under 11-hour Day									
	15		20		29		34		40	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
Average dry weight per plant (grams)	1.99	0.89	2.12	0.87	2.54	1.08	2.40	1.26	2.61	1.43
Soluble Nitrogen	0.1730	0.3990	0.2648	0.4450	0.2242	0.3267	0.2048	0.2543	0.2331	0.3178
Insoluble Nitrogen	2.0574	1.0098	1.7592	0.9396	1.6701	0.9616	1.4851	0.7594	1.2663	0.7335
Total nitrogen	2.2304	1.4088	2.0230	1.3846	1.8943	1.2883	1.6899	1.0137	1.4994	1.0513
Reducing substances	3.46	3.47	4.55	4.53	5.33	5.03	5.21	5.08	5.62	4.78
Sucrose	0.76	0.58	1.14	0.66	1.22	1.17	1.02	0.98	1.13	1.24
Total sugars	4.27	4.08	5.76	5.23	6.64	6.27	6.28	6.11	6.82	6.09
Acid Hydrolyzable Polysaccharides	14.60	11.35	14.73	13.30	15.22	16.42	17.00	23.40	18.75	23.70
Total Carbohydrates	18.87	15.43	20.49	18.53	21.86	22.69	23.28	29.51	25.57	29.79

were higher in the normal day plants. Except for two instances, the acid hydrolyzable polysaccharides were higher in the short day plants. In every case, except that of the roots for the plants which had been grown under the 11 hour day for 15 days, the total carbohydrate content was higher in the short day plants. This difference tended to become greater the longer the plants were grown under the short day treatment, this being especially so with the roots.

Briefly summarized, then, these data show that the total nitrogen, the soluble nitrogen, and the insoluble nitrogen was higher in the plants growing under the normal length of day. On the other hand, the free reducing substances, acid hydrolyzable polysaccharides, and total carbohydrates were higher in the short day plants. Sucrose tended to be higher in the normal day plants and total sugars showed no definite trend. In every instance the dry weights of both the tops and roots were higher in the short day plants.

Figure 3 is a graph of the total carbohydrate/total nitrogen ratios for the roots and tops for both the normal and short day plants and probably gives a clearer conception of the data than do the figures. It will be observed that the ratio of total carbohydrates to total nitrogen is much higher in the short day plants than in those grown under the normal length of day. This

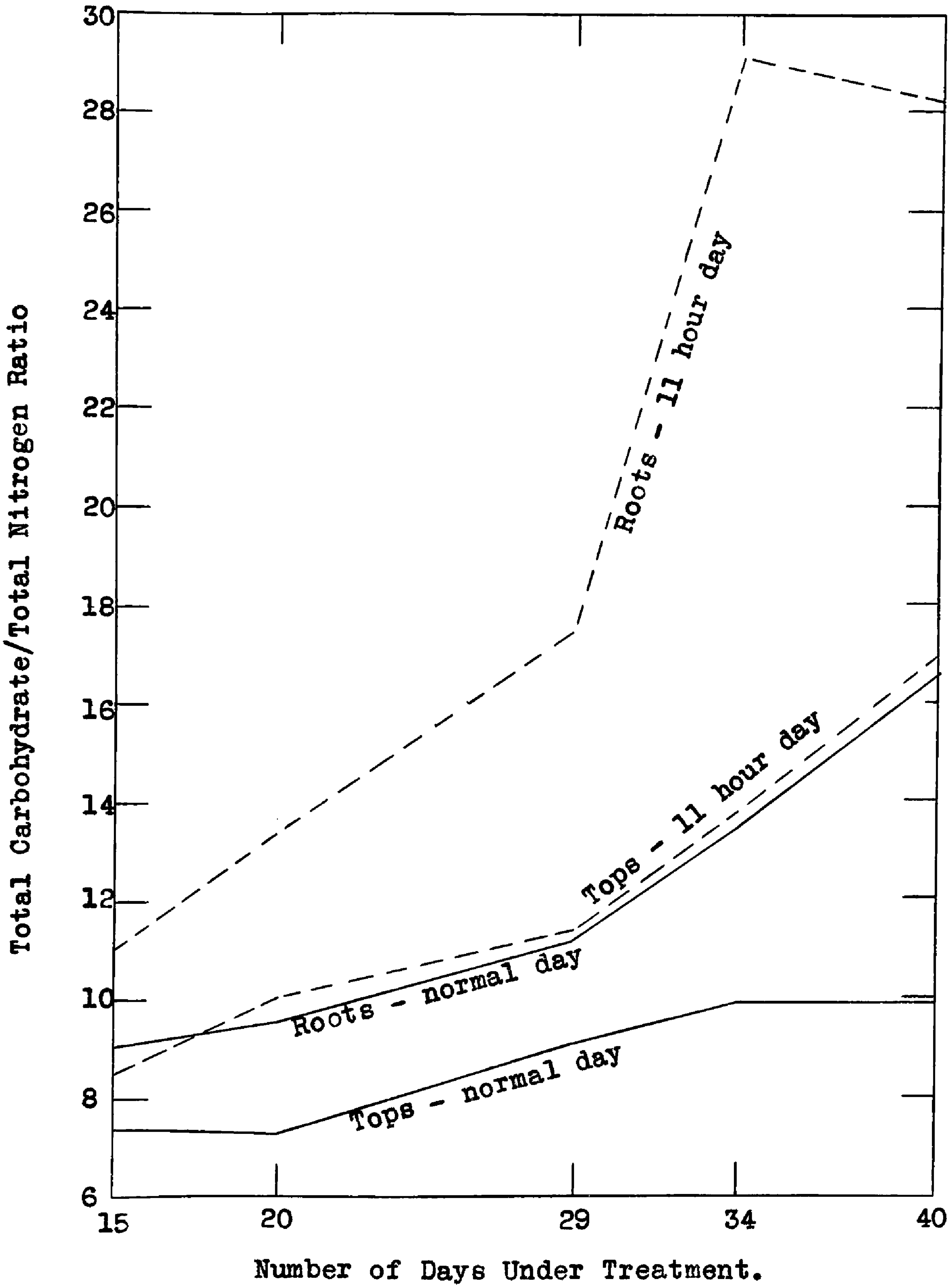

Fig. 3

Effect of an 11-hour Day on the Carbohydrate/Nitrogen Ratio of Strawberry Plants.

This difference becomes all the more marked the longer the plants were subjected to the 11 hour photoperiod. Another striking difference is that the ratio in the roots was considerably higher than that in the tops; this was especially true of the short day plants.

At the time fruit-bud differentiation was first observed in the short day plants the total carbohydrate/total nitrogen ratio in the roots was approximately 11 in the tops and 18 in the roots. At no time during the duration of these photoperiod experiments, which were discontinued September 11, was a ratio as high as this reached in the plants growing under the normal length of day. Neither had these plants differentiated fruit buds by September 11.

Although other factors undoubtedly are associated with the phenomena, it would seem that fruit-bud differentiation in the strawberry is at least associated with a balance between the carbohydrate and nitrogen constituents. In some nutritional studies with the strawberry conducted by Whitehouse (45) it was found that the time of fruit-bud formation was correlated with a balance between the nitrogenous and carbohydrate materials in the plant.

At this point it might well be mentioned that after digestion of the residue from the sugar extraction with Taka-diastase for starch, no reduction of Fehling's solution was obtained from the resulting mixture. Microscopical examination of the plant material, both with the iodine test and examination for starch grains in polarized light, showed that starch was absent or else present in very minute quantities. Loree (22) found in plants sampled on October 26 a starch content in the tops of from 0.72 to 1.32 per cent of the oven dry material, while in the roots he found as high as 4 per cent. On this date, total carbohydrates varied from 17.4 per cent to 28.9 per cent, according to the treatments applied. On the other hand, Whitehouse (45) reported a starch content of from 6.81 to 20.02 per cent for the tops and 3.26 to 25.98 per cent for the roots of plants sampled for chemical analyses during August and September in two different years and grown under various nutritional conditions. Under these same conditions the total carbohydrates varied from 21.14 to 36.97 per cent for the tops and from 17.38 to 36.49 for the roots. In Tables 7 and 8 of the present investigations, it will be seen that the total carbohydrate content of the tops varied from 18.18 to 25.57 per cent for the tops and from 15.43 to 29.79 per cent for the tops. These results are more in accord with those of Loree than those of Whitehouse. The latter obtained some very high values for the total carbohydrate content of the plants, and inasmuch as he found some high values for the starch content, it would seem plausible that he might have obtained reduction of Fehling's solution from some substance other than by hydrolyzed starch. This may have been caused by acid hydrolysis of the materials after the digestion of the starch.

Plants From Nitrogen and Soil Moisture Treatments.

Random samples of plants for chemical analyses were taken from the plots in the nitrogen and soil moisture treatments. Two and three ages of plants were taken, i.e. plants rooted July 6, July 27, and August 24. At the date of the first sampling the runner plants rooted on August 24 were not large enough for the preparation of a sample without using more plants than could be sacrificed from the plots. Each sample was analyzed separately for the nitrogen and carbohydrate constituents. In this manner it was hoped to find any relationship that might exist between the chemical composition of the plants, the soil treatments, and the production of blossoms and fruit by the plant. As was shown by the histological examination of the buds, fruit-bud differentiation had not occurred at the time the first chemical samples were taken, September 6. Differentiation had occurred when the last samples were taken, October 4.

Dry Weight.

The data for the dry weight of the plants is presented in Table 9. An examination of the table

Table 9 -- Effect of Nitrogen Fertilizer and Irrigation on the Dry Weight of Plants.

(Average Dry Weight per Plant Expressed in Grams).

Treatment	Tops					Roots				
	Date Sampled					Date Sampled				
	September 6		October 4			September 6		October 4		
	Date rooted		Date rooted			Date rooted		Date rooted		
	July 6	July 27	July 6	July 27	Aug. 24	July 6	July 27	July 6	July 27	Aug. 24
	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)	(gms.)
Nitrogen fertilizer. Irrigated.	2.86	1.68	4.28	3.64	1.77	0.76	0.61	0.98	0.70	0.38
Nitrogen fertilizer. Not irrigated.	2.79	1.97	4.87	3.64	1.42	0.80	0.59	1.10	0.75	0.44
No nitrogen fertilizer. Irrigated.	2.87	1.95	4.78	3.99	2.15	0.59	0.57	1.08	0.74	0.53
No nitrogen fertilizer. Not irrigated.	3.06	2.02	5.08	4.87	2.23	0.64	0.48	1.07	0.82	0.56

Note: The runners rooted July 6 occupied position #1, those rooted July 27 position #3, and those rooted August 24 position #5 on the runner series.

shows that the dry weight of the tops of all ages of plants was highest in the unfertilized and unirrigated plots. The data for the roots are not so consistent, except with the youngest plants at the last date of sampling. In both tops and roots it will be noted that as the plants increase in age the difference between treatments becomes less. The early accumulation of dry weight in the young plants of the no nitrogen series may be of some significance. These data are in accord with the growth data presented earlier.

Nitrogen Content.

In Tables 10 and 11 the data for the nitrogen fractions of the plants are presented. With but three minor exceptions it will be seen that in the plants sampled September 6 the nitrogen fertilized plants were higher in soluble nitrogen, insoluble nitrogen, and total nitrogen than were the plants to which nitrogen fertilizer had not been applied. While the greatest concentration of soluble nitrogen was found in the roots, the reverse was true of the insoluble nitrogen. This was true in all cases, regardless of treatment. The total nitrogen content showed the same relationship as the insoluble nitrogen. Although all of the nitrogen fertilized plants were higher in the various nitrogen fractions, the differences do not seem to be as great as might be expected from the differences in the nitrate content of the soil.

Table 10 -- Nitrogen Content of Howard 17 Strawberry Plants Sampled September 6, 1934.

(Percentage Dry Weight)

Treatment.	Soluble nitrogen		Insoluble nitrogen		Total nitrogen	
	Date rooted		Date rooted		Date rooted	
	July 6	July 27	July 6	July 27	July 6	July 27
			Tops			
Nitrogen fertilizer. Irrigated.	.4308	.3743	2.2432	2.9221	2.6740	3.2964
Nitrogen fertilizer. Not irrigated.	.3037	.4873	2.7944	3.0485	3.0981	3.5358
No nitrogen fertilizer. Irrigated.	.3532	.4450	2.2222	2.2645	2.5754	2.7095
No nitrogen fertilizer. Not irrigated.	.3037	.3320	2.2267	2.5951	2.5304	2.9271
			Roots			
Nitrogen fertilizer. Irrigated.	.8546	.7134	1.2108	1.2973	2.0654	2.0107
Nitrogen fertilizer. Not irrigated.	.8667	.7769	1.0551	1.2201	1.9218	1.9970
No nitrogen fertilizer. Irrigated.	.6427	.6851	1.0329	1.2435	1.6756	1.9286
No nitrogen fertilizer. Not irrigated.	.6992	.6922	1.0215	1.0654	1.7207	1.7576

Table 11 -- Nitrogen Content of Howard 17 Strawberry Plants Sampled October 4, 1934.

(Percentage Dry Weight).

Treatment	Soluble nitrogen			Insoluble nitrogen			Total nitrogen		
	Date rooted			Date rooted			Date rooted		
	July 6	July 27	Aug. 24	July 6	July 27	Aug. 24	July 6	July 27	Aug. 24
Tops									
Nitrogen fertilizer. Irrigated.	.3108	.4097	.3814	2.6648	2.7726	3.2624	2.9756	3.1823	3.6438
Nitrogen fertilizer. Not irrigated.	.3249	.3744	.2755	2.0414	2.9938	3.1478	2.3663	3.3682	3.4233
No nitrogen fertilizer. Irrigated.	.2543	.4732	.3249	2.4182	2.5782	2.0997	2.6725	3.0514	2.4246
No nitrogen fertilizer. Not irrigated.	.4308	.3320	.3178	1.8124	2.3956	2.4650	2.2432	2.7276	2.7828
Roots									
Nitrogen fertilizer. Irrigated.	.5721	.5156	.4379	1.2813	1.4267	1.2787	1.8534	1.9423	1.7166
Nitrogen fertilizer. Not irrigated.	.4591	.6074	.5015	1.2233	1.2049	0.9552	1.6824	1.8123	1.4567
No nitrogen fertilizer. Irrigated.	.5439	.5721	.2896	1.0427	1.3155	1.1808	1.5866	1.8876	1.4704
No nitrogen fertilizer. Not irrigated.	.5933	.4732	.5156	1.0139	1.2160	0.9616	1.6072	1.6892	1.4772

An examination of the data for the samples taken October 4 (Table 11) shows that at this date the plants have apparently become more uniform, regardless of treatment. The earlier differences are not so marked, but some tended to persist. The percentages of all nitrogen fractions tended to be higher in the plants from the nitrogen plots. The soluble nitrogen in the roots had decreased, but still was higher than that in the tops. This was true of plants of all ages. The insoluble nitrogen remained fairly constant and the smaller quantities found in the roots from the non-irrigated plots still persisted. The converse condition found previously in the tops, that of the non-irrigated plants showing the highest insoluble nitrogen, had disappeared.

Carbohydrate Content.

In Table 12 and Table 13 are shown the results of the carbohydrate analyses for the samples taken September 6 and October 4, respectively. A critical examination of these tables indicates that the differences in the various carbohydrate fractions are small and inconsistent, and no distinct correlations with the previous measurements of the plants are indicated. The most consistent results were those of the roots in the sampling of October 4. The values for reducing substances, total sugars, and acid hydrolyzable polysaccharides tended to be higher in the plants grown without nitrogen fertilizer and there was a slight indication

Table 12 -- Carbohydrate Content of Plants Sampled September 6, 1934.

(Percentage Dry Weight).

TOPS

Date Rooted	Fraction	Treatment: Nitrogen fertilizer irrigated	Nitrogen fertilizer not irrigated	No nitrogen fertilizer irrigated	No nitrogen fertilizer not irrigated
July 6	Reducing Substances	3.31	3.31	2.81	2.56
	Sucrose	1.86	2.05	2.14	2.37
	Total Sugar	5.27	5.47	5.06	5.06
	Acid Hydrolyzable Polysaccharides	16.50	16.00	14.80	14.30
	Total Carbohydrates	21.77	21.47	19.86	19.36
July 27	Reducing Substances	2.62	3.56	2.26	2.87
	Sucrose	1.53	0.34	2.37	1.59
	Total Sugar	4.23	3.92	4.75	4.54
	Acid Hydrolyzable Polysaccharides	15.50	19.60	15.70	15.20
	Total Carbohydrates	19.73	23.52	20.45	19.74

Table 12 -- (Continued).

ROOTS

Date Rooted	Fraction	Treatment: Nitrogen fertilizer irrigated	Nitrogen fertilizer not irrigated	No nitrogen fertilizer irrigated	No nitrogen fertilizer not irrigated
July 6	Reducing Substances	2.56	2.75	3.00	2.87
	Sucrose	0.41	0.23	0.68	0.61
	Total Sugar	2.99	2.99	3.72	3.51
	Acid Hydrolyzable Polysaccharides	14.20	15.90	14.10	14.40
	Total Carbohydrates	17.19	18.89	17.82	17.91
July 27	Reducing Substances	2.44	2.69	2.75	3.37
	Sucrose	1.61	0.19	0.52	1.22
	Total Sugar	4.13	2.89	3.30	4.65
	Acid Hydrolyzable Polysaccharides	15.50	14.30	14.00	13.50
	Total Carbohydrates	19.63	17.19	17.30	18.15

Table 13 -- Carbohydrate Content of Plants Sampled October 4, 1934.

(Percentage Dry Weight).

TOPS

Date Rooted	Fraction	Treatment: Nitrogen fertilizer irrigated	Nitrogen fertilizer not irrigated	No nitrogen fertilizer irrigated	No nitrogen fertilizer not irrigated
July 6	Reducing Substances	12.25	17.00	13.50	15.62
	Sucrose	1.42	2.25	2.61	2.57
	Total Sugar	13.75	19.37	16.25	18.33
	Acid Hydrolyzable Polysaccharides	15.20	14.50	15.00	14.70
	Total Carbohydrates	28.95	33.87	31.25	33.03
July 27	Reducing Substances	9.75	8.00	9.50	6.37
	Sucrose	0.83	3.29	1.46	1.86
	Total Sugar	10.62	11.46	11.04	8.33
	Acid Hydrolyzable Polysaccharides	14.60	15.80	14.80	15.20
	Total Carbohydrates	25.22	27.26	25.84	23.53
Aug. 24	Reducing Substances	9.62	7.75	9.75	8.50
	Sucrose	1.35	2.73	0.64	3.40
	Total Sugar	11.04	10.62	10.42	12.08
	Acid Hydrolyzable Polysaccharides	14.60	14.00	14.50	14.10
	Total Carbohydrates	25.64	24.62	24.92	26.18

Table 13 -- (Continued).

ROOTS

Date Rooted	Fraction	Treatment: Nitrogen fertilizer irrigated	Nitrogen fertilizer not irrigated	No nitrogen fertilizer irrigated	No nitrogen fertilizer not irrigated
July 6	Reducing Substances	3.50	3.62	4.37	4.00
	Sucrose	0.44	1.31	0.80	1.35
	Total Sugar	3.96	5.00	5.21	5.42
	Acid Hydrolyzable Polysaccharides	19.10	17.40	18.90	21.30
	Total Carbohydrates	23.06	22.40	24.11	26.72
July 27	Reducing Substances	3.50	3.62	3.37	4.37
	Sucrose	0.24	0.32	0.76	0.40
	Total Sugar	3.75	3.96	4.17	4.79
	Acid Hydrolyzable Polysaccharides	18.00	19.40	20.30	20.00
	Total Carbohydrates	21.75	23.36	24.47	24.79
Aug. 24	Reducing Substances	3.25	3.62	3.87	4.37
	Sucrose	0.08	0.32	0.09	0.21
	Total Sugar	3.33	3.96	3.96	4.58
	Acid Hydrolyzable Polysaccharides	17.40	18.50	18.90	18.70
	Total Carbohydrates	20.73	22.46	22.86	23.28

that irrigation may depress carbohydrate storage. The more obvious differences are that the sucrose content of the roots is lower than that of the tops in nearly every case. The total carbohydrate content of the roots was lower than that of the tops also, and this may largely be accounted for by the larger amounts of total sugars in the tops.

Carbohydrate/Nitrogen Ratios.

The data for the total carbohydrate/total nitrogen ratios are presented in Tables 14 and 15 for plants sampled on September 6 and October 4, respectively. By trial the ratio of reducing substances, total sugars, and acid hydrolyzable polysaccharides to the total nitrogen was found to be the most consistent as a basis for comparison. For the sake of brevity only the ratio between the total carbohydrate/total nitrogen content is presented in the tables. Referring to Table 15 it will be seen that the ratios in the tops were lower in the later formed plants than in the earlier formed plants. This also was true for the roots, with one exception. The ratios were higher in the roots than in the tops. With but two exceptions, the ratios were higher in the plants not receiving nitrogen than in those to which it has been applied.

In Table 15, which shows the ratios occurring in the plants at the time during which they were forming fruit-buds, the same trends as were noted in the previous table may still be noted. In this case the differences

Table 14 -- Total Carbohydrate/Total Nitrogen Ratios of Plants Sampled on September 6, 1934.

Treatment.	Tops.		Roots.	
	Date rooted		Date rooted	
	July 6	July 27	July 6	July 27
Nitrogen fertilizer. Irrigated.	8.14	5.98	8.32	9.76
Nitrogen fertilizer. Not irrigated.	6.93	6.65	9.83	8.11
No nitrogen fertilizer. Irrigated.	7.71	7.55	10.63	8.97
No nitrogen fertilizer. Not irrigated.	7.65	6.74	10.41	10.33

Table 15 -- Total Carbohydrate/Total Nitrogen Ratios of Plants Sampled on October 4, 1934.

Treatment.	Tops.			Roots.		
	Date plant rooted.			Date plant rooted.		
	July 6	July 27	Aug. 24	July 6	July 27	Aug. 24
Nitrogen Fertilizer. Irrigated.	11.38	8.57	6.76	12.09	12.03	13.08
Nitrogen fertilizer. Not irrigated.	12.23	7.49	7.49	13.71	12.00	14.23
No nitrogen fertilizer. Irrigated.	12.36	7.71	10.80	16.84	16.86	15.83
No nitrogen fertilizer. Not irrigated.	13.93	9.47	8.96	15.00	16.57	15.47

in the ratios between the tops and the roots are even more striking than they were earlier in the season. The roots of the plants which were rooted at the various dates had a uniformly higher ratio than the tops and no difference existed in the ratio due to the age of the plant. With the tops it may be noted that the oldest plants had the highest ratio and with one exception the youngest plants had the lowest ratio. In the roots the ratios were considerably higher in the unfertilized plants of all ages than in the nitrogen-fertilized plants.

The carbohydrate/nitrogen ratios were higher at the later date of sampling. Since the nitrogen content of the tops on the two sampling dates was quite similar, the increase in the ratios at the later date was due to an increase in carbohydrates. In the roots, however, there was an actual decrease in the nitrogen content during the interval between the sampling dates. The high ratios indicate, therefore, a considerable storage of carbohydrates in the roots.

The moisture and nitrogen treatments have had little effect on the carbohydrate/nitrogen ratio and moreover the ratios were not correlated with the actual blossoming record of the plants as shown in Table 6. Probably the most striking feature of the ratios is their correlation with the number of blossoms formed per plant at the different positions on the runner series. This relationship held for the ratios found in both the roots and tops at the first date of sampling and for the tops at the last date of sampling. It is difficult, however, to determine the true significance of the carbohydrate/nitrogen ratio, since the effects of treatment, which were fairly definite, showed no correlation with the blossoming data.

Effect of Treatments Applied the Fruiting Year on Plant Growth, Yield, and Chemical Composition of the Fruit.

Description of Soil and Plot Layout. The effects of moisture and nitrogen fertilizer on the strawberry plant during the fruiting season, especially during the period of ripening, may be of profound importance in affecting the size and quality of the crop. Doubtless these effects are largely independent of the previous treatments applied to the plant, although of course residual effects of previous treatment would be expected. In order to observe and measure some of the effects of moisture and nitrogen applications in the spring of the fruiting year a random sample of field-grown plants was selected for size and uniformity and set in greenhouse benches. Nitrogen and soil moisture treatments were established for the purpose of studying the effects of these treatments on the strawberry plant during the fruiting cycle. Four treatments, comparable to those later established in the field, were used. These were as follows:

High nitrogen - high moisture
High nitrogen - low moisture
Low nitrogen-high moisture
Low nitrogen-low moisture

Nitrate of soda was applied in solution to the high nitrogen plots at intervals to maintain a high nitrate nitrogen content of the soil. The soil in the high moisture plots was kept near the field capacity, while that in the low moisture plots was kept near the wilting percentage. No fertilizer was applied to the low nitrogen plots. Two samples of soil, taken as the benches were being filled, showed that it contained 0.186% total nitrogen; 1 part per million of nitrate nitrogen, 53 parts per million of replaceable potassium, and 2 parts per million of readily available phosphorus. The nitrate and phosphorus content of the soil was, therefore very low, while the potassium content was high. The soil reaction showed a pH of 5.8, which according to the findings of Morris and Crist (26) and Waltman (41), should have been about optimum for strawberries.

Each treatment occurred once in each bench. The plots were approximately one one-thousandth of an acre in area. Twenty-two plants were set per plot at a distance of approximately a foot in each direction and with guard plants surrounding each plot. Individual plant records for the various responses and yield were kept.

On the plots in the high moisture series no wilting of the plants was noticed at any time. On the dry plots, however, the plants wilted around noon on very warm days. Table 16 shows the changes in the soil moisture during the course of the experiment. The moisture content of the soil was maintained at a considerably higher level (4 to 5 per cent) in the high moisture plots than in the low moisture plots. No great variation in moisture occurred. Moreover, the moisture content of the two blocks of each treatment were, in general quite uniform.

The nitrate nitrogen content of the soil during the course of the experiment is shown in Table 17. A considerable variation in the nitrate content of the plots receiving the same treatment will be noted. The greatest variation occurred in the high moisture plots and may have been due to unequal leaching of the nitrates in the plots receiving this treatment. However the nitrates were considerably higher in the plots to which nitrate of soda was applied. In both the low nitrogen and high nitrogen series, the nitrates were lowest in the high moisture plots, probably because of leaching due to the abundance of water applied.

Effects of Nitrogen and Moisture Treatments

Number of Leaves.

A count was made of the number of leaves per plant about the time that the first fruit was ripening. These data are presented in Table 18 and the analysis of variance for the data in Table 18 (a). The Z-value

Table 16 -- Soil Moisture. Greenhouse, Winter, 1934.

(Expressed as Percentage of the Dry Weight).

Treatment	Block	Date of sampling					Average
		Feb. 23	Mar. 3	Mar. 10	Mar. 24	April 14	
		%	%	%	%	%	%
High nitrogen. High moisture.	I	10.43	9.45	10.84	6.79	10.76	9.65
	II	10.43	9.63	11.71	8.35	10.49	10.12
High nitrogen. Low moisture.	I	8.03	7.01	6.58	4.49	7.05	6.63
	II	4.72	4.54	5.86	4.54	5.86	5.10
Low nitrogen. High moisture.	I	14.98	13.41	15.09	12.09	12.12	13.54
	II	9.21	8.18	10.71	10.71	10.74	9.20
Low nitrogen. Low moisture.	I	7.80	6.50	6.23	4.54	6.29	6.27
	II	5.02	5.04	5.56	4.59	5.69	5.18

Table 17 -- Soil Nitrates. Greenhouse, Winter, 1934.

(Expressed as Parts per Million of Air-dry Soil).

Treatment	Block	Date of sampling					Average
		Feb. 23	March 3	March 10	March 24	April 14	
High nitrogen High moisture	I	26	31	29	31	33	30
	II	72	69	59	71	43	63
High nitrogen Low moisture	I	46	52	47	53	41	48
	II	33	34	32	35	34	34
Low nitrogen High moisture	I	4	4	5	5	5	5
	II	12	11	11	12	8	11
Low nitrogen Low moisture	I	12	11	13	14	10	12
	II	8	9	9	9	8	9

Table 18 -- Effect of Nitrogen Fertilizers and Moisture on Number of Leaves Produced. (Total of 22 Plants Per Plot).

Block	Treatment			
	High Nitrogen High Moisture	High Nitrogen Low Moisture	Low Nitrogen High Moisture	Low Nitrogen Low Moisture
I	251	190	258	199
II	226	162	234	169
Total	477	352	492	368

Standard error of the difference: 3.72

Table 18 (a) — Analysis of Variance

Variance Due to:	Degrees of Freedom	Variance	Mean Variance	1/2 Loge	Z-Value	
					Found	Necessary
Blocks	1	1,431.13	1,431.13	3.6331		
Treatment	3	7,870.38	2,623.46	3.9361	3.3155	1.6915
Error.	3	10.37	3.46	0.6206		
Total	7	9,311.28				

given is that necessary for odds of 99:1 that treatment was significant. As shown in Table 18 more leaves were produced by the plants growing on the high moisture plots, and of these plots the most leaves were produced on those not receiving nitrogen fertilizer. The plants on the low moisture plots produced more leaves when nitrogen was withheld than when it was applied. Using two times the standard error of the difference as an estimate of a minimum difference necessary for significance, it will be seen that all treatments are significantly different from each other. Nitrogen fertilizer and soil moisture, then, may have a pronounced influence on the development of the plant after fruit-buds are formed. The number of leaves produced was clearly more closely associated with the moisture content of the soil than with the nitrogen content.

The difference in response between the two plots in the same treatment was possibly due to the position of the benches in the greenhouse. In every case the plants grown on one bench had a greater number of leaves than those grown under the same treatment in the other bench.

Length of Leaf Petiole.

An analysis of the length of the leaf petioles, as affected by nitrogen and soil moisture treatments, was also made. These data are shown in Table 19 and the analysis of variance in Table 19 (a). The Z-value for

Table 19 — Effect of Nitrogen Fertilizer and Soil Moisture on the Leaf Petiole Length. Greenhouse, Winter, 1934. (Expressed as Average Petiole Length per Plant in Inches).

Block	Treatment			
	High Nitrogen High Moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
I	1.93	1.62	2.23	1.56
II	1.91	1.43	1.94	1.37
Average	1.92	1.52	2.08	1.46

Standard error of the difference: .1

Table 19 (a). Analysis of Variance.

Variance Due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-Value	
					Found	Necessary
Blocks	1	.05	.05	0.8047		
Treatment	3	.54	.18	1.4451	1.4451	1.1137
Error	3	.03	.01	0.0000		
Total	7	.62				

treatment exceeded that necessary for odds of 19:1 that treatment had had a significant effect on the length of the leaf petiole. Since a difference in logarithms only is desired, the decimal point in this case was moved two places to the right so that whole numbers could be used in the calculations.

Since treatment was found to have a significant effect on petiole length, the various treatments may be compared on the basis of the standard error of the difference. An examination of Table 19 shows that the plants receiving the high moisture treatments produced leaf petioles which were significantly longer than the plants receiving the low moisture treatments. Nitrogen fertilizer had no significant effect. These results show that under conditions of high soil moisture in the fruiting season the plants will produce leaves with longer petioles than those grown under low soil moisture conditions. Nitrogen under the conditions of this experiment had no effect on leaf petiole length.

Number of Blossoms.

A count was made of the number of flowers produced under the different treatments. In a consideration of these data, it should be remembered that the treatments were applied after the winter rest period. If under normal conditions the strawberry plant does not form fruit-buds in the spring of the fruiting year in the northern part of the United States and Canada, it would not be expected that the treatment applied in the spring of the fruiting year would have any affect on the number of blossoms developed. The plants in the greenhouse produce some secondary bloom, as is typical of the strawberry plant in the south, but these blossoms were produced later and were not considered in the present investigation. In Tables 20 and 20 (a) the results of this study are presented.

Since the variance for treatment is much less than that due to error, no further consideration of these tables is necessary. Obviously, treatment did not affect the number of blossoms produced and this is the effect that was anticipated.

Weight of Berry.

At the time of harvest the number of berries produced per plant and the weight of the berries in grams was recorded. From these data the effect of treatment on the average weight of berry was calculated. These data are shown in Tables 21 and 21 (a). In Table 21 (a) the decimal point of the mean variance was removed one place to the right before determining the values for 1/2 $\log_e$. The Z-value found showed that treatment made a significant contribution to the total variance. Twice the standard error of the difference may be used as a basis for the comparison of the various treatments. This comparison shows that the high moisture treatments produced

Table 20 -- Effect of Nitrogen Fertilizer and Soil Moisture on Number of Blossoms Produced. Greenhouse, Winter, 1934.

(Expressed as total number of flowers per plot, 22 plants).

Block	Treatment			
	High nitrogen High moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
I	203	235	254	225
II	246	177	197	195
Total	449	412	451	420

Table 20 (a) -- Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	1	1,300.5	1,300.5	3.5852		
Treatment	3	595.0	198.33	2.6449		1.1137
Error	3	3,381.5	1,126.83	3.5135		
Total	7	5,276.0				

Table 21 -- Effect of Nitrogen Fertilizer and Soil Moisture on Weight of Berry. (Expressed as Average Weight for Season in Grams).

Block	Treatment			
	High nitrogen High moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
I	4.61	3.69	6.38	3.46
II	5.06	2.22	5.31	3.33
Average	4.83	2.95	5.84	3.39

Standard error of the difference between means: .61

Table 21 (a) -- Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	1	0.61	0.61	0.9041		
Treatment	3	10.59	3.53	1.7821	1.1146	1.1137
Error	3	1.15	0.38	0.6675		
Total	7	12.35				

berries which weighed significantly more than those produced by the low moisture plots. There was no difference in weight of berry due to the nitrogen treatment. These results would emphasize the effects often observed under field conditions of even a very light rainfall during the harvest season increasing the size of the fruit. Under the conditions of this experiment then, increasing the soil moisture during the fruiting season had a profound affect on the weight of berries, while nitrogen showed no effect.

Total Yield of Fruit.

The yield data presented in Tables 22 and 22 (a) are those of the total yield for the entire picking season. The first berries were picked on April 11 and the last ones on May 11. Although the variance due to blocks was quite large, treatment contributed a significant amount to the total variance. The variation among blocks was in a large measure due to the exceedingly low yield of one of the eight plots.

The Z-value found showed that the odds were greater than 99:1 that the differences observed were due to treatment and not to chance. When twice the standard error of the difference is used for comparing treatments it will be seen that the difference between the yields of the high moisture plots and the low moisture plots was highly significant. The effect of nitrogen in decreasing the yields in the high moisture plots was

Table 22 — Effect of Nitrogen Fertilizer and Soil Moisture on Yield. (Expressed in grams for Total Yield of 22 Plants per Plot).

Block	Treatment			
	High mitrogen High moisture (grams)	High nitrogen Low moisture (grams)	Low nitrogen High moisture (grams)	Low nitrogen Low moisture (grams)
I	833.7	814.5	1,045.8	732.8
II	833.1	315.6	881.7	576.3
Total	1,666.8	1,130.1	1,927.5	1,309.1

Standard error of difference: 28.6

Table 22 (a) — Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	1	3,821.38	3,821.38	1.8211	1.4647	.9462
Treatment	3	8,717.43	2,905.81	1.6838	1.3274	.6651
Error	170	34,735.37	204.33	0.3564		
Total*	174	47,274.18				

* One degree of freedom dropped for substituted average.

significant, while in the low moisture plots the yield of one of the two plots receiving nitrogen fertilizer was abnormally low and the total yield for treatment may be questioned. The behavior of the one plot was probably due to environmental conditions other than the treatment applied experimentally.

The results of the present investigation showed quite strikingly that increasing soil moisture not only will increase the average weight of berry, but the total yield as well. The increased yields, no doubt, may be largely attributed to the increase in size of the individual berries.

Moisture Content of the Fruit.

The results of the moisture determinations on the berries are given in Tables 23 and 23 (a). The Z-valuesgiven are found in the table of one per cent points of the distribution of Z giving odds of 99:1 that the variance is significant. It will be seen that the effect of treatment was significant. The effect of periods was not significant and consequently the data by periods is not given, but only the seasonal averages by plots. In comparing the moisture content of fruit from the different treatments, that of the high moisture treatments exceeded the high nitrogen-low moisture treatment by twice the value of the standard error, and may be considered significantly different. The low nitrogen-low moisture fruit

Table 23 -- Average Moisture Content of the Fruit for the Season. (Expressed as Percentage of the Fresh Weight).

Block	Treatment			
	High nitrogen: High moisture	High nitrogen: Low moisture	Low nitrogen: High moisture	Low nitrogen: Low moisture
	%	%	%	%
I	91.46	90.68	92.65	91.04
II	92.02	87.75	92.06	90.21
Average	91.74	89.21	92.36	90.62

Standard error of the difference between means: 0.82

Table 23 (a) — Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	1	9.00	9.00	1.0986		
Treatment	3	57.12	19.04	1.4732	1.3269	0.8138
Period	4	10.50	2.63	0.4834	0.3371	0.7607
Period x Treatment	12	5.72	0.48	-0.3670		
Error	18	24.16	1.34	0.1463		
Total*	38	106.50				

* One degreeof freedom dropped for substituted average.

was intermediate in moisture content. In general, then, the high moisture treatments produced berries with a higher moisture content than did the low moisture treatments.

Nitrogen Content of the Fruit

The total nitrogen content of the fruit was determined for both of the plots in each treatment at the different times of harvest. These data are shown in Tables 24 and the analysis of variance in Table 24 (a).

It will be noted in Table 12 (a) that both period and treatment made a significant contribution to the total variance of nitrogen content of fruit. The Z-values given in the table are for the one per cent points of the distribution of Z. In determining the logarithms the decimal points were moved two places to the right.

In comparing the seasonal averages for treatments on the basis of the standard error of the difference between means it will be seen that high nitrogen plots exceeded the low nitrogen plots in total nitrogen content by more than twice this value. Thus, nitrogen fertilizers applied to the soil actually increased the nitrogen content of the fruit.

The variance due to periods also made a significant contribution to the total variance. In general the total nitrogen content of the fruit decreased from the first picking to the last. Although the size of berries decreased, likewise from the first to the last

Table 24 — Average Total Nitrogen Content of the Fruit.

(Expressed as Percentage of Dry Weight).

Date of Harvest	Treatment			
	High nitrogen High moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
	%	%	%	%
April 11	1.7636	1.6788	1.2434	1.1708
April 16	1.4464	1.4642	1.1972	1.2274
April 20	1.4333	1.3366	1.1563	1.0425
April 25	1.3458	1.2742	1.0586	1.0268
April 30	1.7668	1.1572	0.9071	1.0585
Average	1.5512	1.3736	1.1125	1.1052

Standard error of a single observation: .129

Table 24a— Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	$\frac{1}{2}\log_e$	Z-value Found	Z-value Necessary
Blocks	1	.0170	.0170	.2653		
Treatment	3	1.3881	.4627	1.9172	1.6638	0.8138
Period	4	.4317	.1079	1.1890	0.9356	0.7607
Period x Treatment	12	.4255	.0355	0.6335	0.3801	0.6075
Error	18	.2990	.0166	0.2534		
Total*	38	2.5613				

* One degree of freedom dropped for substituted average.

picking, this was probably not a causal relationship between the nitrogen content and size.

The alcohol-soluble and insoluble nitrogen content of the fruit is shown in Table 25. Since these determinations were made on composite samples of the two replicates, no statistical analysis of the data is given. The results showed that both the soluble and insoluble nitrogen were higher in the fruit harvested from the plants receiving nitrate of soda than it was in the fruit from plants not receiving this treatment. The soluble nitrogen was lowest in the low moisture plots, as was the case for total nitrogen. Insoluble nitrogen occurred in approximately two and one-half times the concentration in a given treatment as did the soluble nitrogen. These data show quite strikingly that the nitrates of the soil were absorbed by the plant and translocated to the fruit, resulting in a higher percentage of soluble, insoluble, and total nitrogen.

Carbohydrate Content of the Fruit

In Table 26 are shown the results of the carbohydrate analyses. No statistical analysis of the data is given since the fruit from the replicate plots was composited at the time of harvest. Reducing substances, total sugars, and total carbohydrates were higher in the high moisture plots than they were in the low moisture plots. Total sugars and total carbohydrates were the

Table 25 -- Alcohol-soluble and Insoluble Nitrogen Content of the Fruit. (Average for Season Expressed as Per Cent of the Dry Weight).

Nitrogen fraction	Treatment			
	High nitrogen High moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
Soluble nitrogen	0.4192	0.3380	0.3242	0.3019
Insoluble nitrogen	1.0605	0.9470	0.7656	0.7861

Table 26 -- Average Carbohydrate Content of the Fruit for the Season.

(Expressed as Percentage of the Dry Weight).

Treatment	Reducing Substances	Sucrose	Total Sugar	Acid Hydrolyzable Polysaccharides	Total Carbohydrate Content
	%	%	%	%	%
High nitrogen High moisture	32.44	11.40	44.44	3.94	48.38
High nitrogen Low moisture	29.50	10.47	40.52	4.09	44.61
Low nitrogen High moisture	33.34	10.21	44.08	4.09	48.17
Low nitrogen Low moisture	30.88	12.05	43.57	4.41	47.98

lowest in the fruit from the high nitrogen and low moisture plots. The nitrogen treatments,independent of moisture,produced no measurable effect on the concentration of these carbohydrate fractions in the fruit. It would seem,then,that moisture is essential for the development of a high total carbohydrate content in the fruit including total sugars. The difference between individual treatments, however, is small with the exception of the fruit in the high nitrogen-low moisture plots. The fruit from this treatment was considerably below the others in reducing substances, total sugar, and total carbohydrates. The acid hydrolyzable polysaccharides did not vary much with the treatment. Fruit from the low nitrogen-low moisture plots had the highest content of acid hydrolyzable polysaccharides, while that from the high nitrogen-high moisture plots was lowest. The fruit from the other two treatments was intermediate.

Transpiration Rate of the Leaves.

From observations made in the field on several occasions and from published reports, nitrogen fertilized plants have been found to wilt and to show other affects of moisture shortage which probably are related to a large leaf surface, excessive transpiration or both. An experiment was set up to measure these effects under as nearly comparable conditions to the previous studies as possible. The transpiration rate of six potted plants per treatment was studied in the greenhouse from March 3 until April 16.

The results of this study are briefly summarized in Tables 27 and 27 (a).

As will be observed from Table 27 (a) the variance due to the interaction of treatment and periods was significantly larger than the residual error. This would indicate that the plants in the different treatments responded differently in the various periods. Since this was true the larger variance , that of the interaction of treatment x periods was used to estimate the effect of the different sources of variation. The significant variance for replications shows that the plants in a treatment were quite variable and that it proved worthwhile to remove the effect of plants from the total variance. A comparison of the Z-values (5 per cent point) shows that treatment did not make a significant contribution to the total variance. The variance in the transpiration rate of the plants at the different periods was large and was to be expected as the humidity and temperature conditions of the greenhouse in which the plants were grown were not controlled. Although under the conditions of this experiment the treatments had a slight affect on the transpirations rate, the fact that the treatments did not produce the same effect at all periods makes it impossible to make any general statement as to the affect of nitrogen fertilizer on the transpiration rate.

Leaf Area.

The leaf areas of the plants grown in the six

Table 27 -- Effect of Nitrogen Fertilizer and Soil Moisture on the Transpiration Rate of Plants. (Expressed as Average Daily Loss in c.c. of 10 Square Inches of Leaf Surface for Period from March 3 to April 16).

Treatment			
High nitrogen High moisture	High nitrogen Low moisture	Low nitrogen High moisture	Low nitrogen Low moisture
c.c.	c.c.	c.c.	c.c.
13.4	14.2	14.2	13.7

Standard error of difference: .23

Table 27 (a) — Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value Found	Z-value Necessary
Blocks	5	413.39	82.68	2.2087	1.1907	.4311
Treatment	3	60.72	20.24	1.5037	0.4857	.5073
Period	17	9,544.63	561.45	3.1653	2.1473	.3255
Period x Treatment	51	390.72	7.66	1.0180	0.4771	
Error	349	1,027.93	2.95	0.5409		
Total *	425	11,437.39				

* Six degrees of freedom dropped because one plant was not included in the experiment during the last six periods.

inch pots for the transpiration studies was determined at intervals during the course of the experiment. The data on the leaf area are presented in Table 28 and the analysis of variance in Table 28 (a). The variance due to treatment, periods, and the interaction of periods and treatment was greater in each case than that for error. The Z-value given as that being necessary for significance is for the one per cent points of the distribution of Z. In Table 28 the striking affect of treatments on leaf area may be seen. The average leaf area of the high moisture plants was nearly twice that of the low moisture treatments. However, there was no difference due to the effect of the nitrogen treatment. Hence, moisture had a very great effect in increasing the leaf area of the strawberry plants grown under the conditions of this experiment.

The significant differences in leaf area for the different periods would be expected from the above results concerning the effect of treatment. It is of interest to note, however, the percentage increase and the actual increase in area. The leaf area of the plants receiving the low moisture treatments approximately doubled in size, while the plants receiving the high moisture treatments trebled in area. This would account for the significant interaction of periods x treatment.

Table 28 -- Effect of Nitrogen Fertilizer and Soil Moisture on Leaf Area. (Average of Six Plants Expressed in Square Inches).

Treatment	Date measured				Average
	March 2	March 10	March 24	April 7	
High nitrogen High moisture	11.31	15.30	20.76	31.53	19.73
High nitrogen Low moisture	7.82	9.62	12.88	15.38	11.43
Low nitrogen High moisture	10.56	13.77	20.80	32.57	19.43
Low nitrogen Low moisture	8.26	10.27	13.36	15.90	11.95

Standard error of the difference: 2.32

Table 28 (a) -- Analysis of Variance.

Variance due to:	Degrees of Freedom	Variance	Mean Variance	1/2 $\log_e$	Z-value	
					Found	Necessary
Blocks	5	216.53	43.31	1.8836		
Treatment	3	1,498.03	499.34	3.1066	1.7606	0.6651
Periods	3	2,427.05	809.02	3.3418	1.9958	0.6651
Periods x Treatment	9	1,077.19	119.69	2.3924	1.0464	0.4604
Error	75	1,108.08	14.77	1.3460		
Total	95	6,326.88				

DISCUSSION

The entire life history of a plant may be divided into two cycles -- that in which the vegetative processes predominate and that in which the reproductive processes predominate. In an annual plant the two processes are relatively short and distinct. The plant grows from the seed and after completing its vegetative growth, it flowers and produces fruit and seeds. The plant dies soon after and within the space of a growing season the life cycle is completed. The strawberry plant, however, is a perennial, growing year after year and producing fruit and seeds each year. In common practice, however, strawberry plants are not allowed to fruit more than one year. Fruiting beds are developed from runner plants produced the year previous to fruiting. A bed may be fruited two or more years, but yields are generally less each succeeding year and usually it is not profitable to renew a bed more than once at the most. This is accomplished after harvest by narrowing down the rows by means of a plow or other tool and new runner plants allowed to form which will produce the crop of fruit the following season. When a new field of strawberries is started the plants set in the spring grow vegetatively until the conditions of light and temperature, and probably other environmental factors as well, become more favorable for the reproductive processes. When this occurs, the plants form fruit-buds which will flower the following growing season and produce the crop of fruit.

Because of the habit of the strawberry plant forming fruit-buds one season and blossoming and fruiting the next, a consideration of this behavior must be taken into account when applying fertilizers to the plant.

An application of fertilizer, particularly nitrogen fertilizer,because of its effect on vegetative vigor in many plants, in the season during which the vegetative growth of the plant is being made, might greatly affect the size of plant and potential fruit-bud formation. Increased soil moisture during the vegetative period might also affect the size of plant and the potential development of fruit-buds. After the fruit-buds are once formed it is impossible to see how nitrogen or soil moisture treatments could in any way influence the actual number of flower buds. Of course there might possibly be an influence on the set and size of fruit, but as far as the number of flowers is concerned, treatment would undoubtedly have no effect. This condition is similar to fruit trees or any other plant in which fruit-buds are formed the season previous to that in which the crop is produced.

Although nitrogen and soil moisture treatments applied in the spring of the fruiting year would not have any effect on the number of blossoms produced per plant, they may have a decided affect on the size of plant produced during the fruiting year. They also may have a striking effect on the size of berry and its chemical composition. If a treatment resulted in an increase in leaf area then the shading caused by the excessive vegetative growth would make the berries more subject to rots in the field with a subsequent reduction in yield. If a large plant were obtained by excessive vegetative growth early in the spring and droughts followed, then it is quite possible that the transpiration by the large vegetative growth would be quite deleterious in its effect on the crop. It would seem quite important to consider the time of application of nitrogen fertilizers, whether in the year preceeding fruiting or in the fruiting year, in an evaluation of strawberry fertilizer experiments.

In the present investigations a study was made of the responses of strawberries to the application of nitrogen fertilizer and soil moisture in both the year previous to fruiting and in the year of fruiting in an endeavor to correlate these responses, if possible, and also to determine in what manner the responses might differ in the two different cycles of growth. It must be remembered that the plants for fruiting were grown in the greenhouse in these experiments.

It was found that the application of nitrogen fertilizer during the year previous to fruiting quite definitely reduced the number of runner plants formed. This is in agfeement with the results reported by Macoun (23) and by Darrow (5), who stated that "a member of a large strawberry plant propagating firm of Maryland stated that in their experience bone and fish meal were helpful but nitrate of soda was injurious" in stimulating plant production. In New Hampshire Tucker (38) found that the application of commercial fertilizers increased the mortality of newly set plants and apparently decreased growth. This response is somewhat contrary to the effect that is generally observed when nitrogen fertilizer is applied to plants.

Nitrogen fertilizer was found to have a depressing effect on the length of the runner between plants. The average length of the runner between plants at all positions on the runner series was approximately one-half inch shorter in the plants to which nitrogen fertilizer had been applied than in the plants to which it had not been applied. This may be in some way related to the effect of nitrogen fertilizer on dominance. Moreland (25) found evidence with the bean that the failure of the buds at the cotyledonary nodes to develop to be due to a deficiency of some material, which he thought was probably nitrogen. It is merely suggested here as a theory that with the strawberry,nitrogen might have some effect on dominance. In general, the distance between runner plants was the shortest between plants one and two, with a gradual increase in length from this position to the end of the runner series.

Nitrogen fertilizer was found to have no significant effect in increasing the number of leaves per plant, when applied in the year previous to fruiting. In the fruiting year nitrogen caused a slight decrease in the number of leaves. In the year previous to fruiting, moisture was found to have no significant effect on the number of leaves, but it did have a significant effect in increasing the number when applied in the fruiting year. Thus, under the conditions of the present experiment, nitrogen and moisture had a pronounced effect on the number of leaves formed during the fruiting year, while no effect of these treatments was observed the year previous to fruiting.

The length of the leaf petiole and the total leaf area were found to be significantly greater when moisture was supplied to the plants during the fruiting year. Nitrogen had no effect. No measurements were made in the year of vegetative growth. In the fruiting year the great effect of moisture in comparison with the lack of measurable nitrogen responses was very striking. Whitehouse (45) and Darrow and Waldo (6) have, however, noted similar effects of nitrogen fertilizer on the length of petiole and leaf area of the strawberry plant.

The application of nitrogen fertilizer the year previous to fruiting resulted in a difference in the number of blossoms produced by the various treatments. The plants on the no nitrogen and non-irrigated plots produced the greatest number of blossoms. The production of blossoms in these plants was correlated with the number of leaves, the number of runner plants formed, the length of runner between plants, and a high carbohydrate-nitrogen ratio. On the other hand, the no-nitrogen-irrigated plots produced the fewest blossoms, even though the plants produced as many leaves as those in the above treatment. If the number of blossoms as determined under this test is an indication of the conditions favorable to flower bud differentiation, then there must be some more underlying factor than leaf area. It may be that differentiation of fruit-buds may have progressed at a slower rate or that the low nitrate nitrogen content of the soil and plants were factors in the case of these plants. The nitrogen plants were intermediate in the production of blossoms, produced fewer leaves, less runner plants and had a shorter distance of runner between plants than did the plants not receiving nitrogen and these were intermediate in blossoming. Since the soil nitrates were considerably higher in the nitrogen plots than in the no-nitrogen plots, it may be that the concentration of nitrogen in the soil was too great for optimum plant development. In contrast to these effects in the vegetative year, nitrogen fertilizer and soil moisture treatments when applied in the spring of the fruiting year, had no effect on the number of blossoms produced.

This perhaps was to be expected inasmuch as the buds were differentiated the fall previous.

There seemed to be no influence of treatment on the time of fruit-bud differentiation. It was thought that perhaps the application of additional soil moisture to the plants might result in later differentiation of fruit-buds, but this effect was not apparent from histological studies of the plants. Such a condition might lead to fewer buds being formed because the period favorable for fruit bud formation might be correspondingly shortened. That no effects were noted may have been due to the fact that during the early part of September, about the time that fruit-bud differentiation was beginning, heavy rains occurred which may have obliterated the effects of irrigation.

When plants were subjected to an eleven hour day there was, however, a very profound influence on the time of fruit-bud formation. Under normal conditions of length of day, the strawberry forms fruit-buds only in the fall in the states from Virginia northward (7).

The present investigation has shown that the Howard 17 variety responds very quickly to an eleven hour light period. Definite fruit-bud formation was found first in a lot of plants sampled on August 13 and which had been grown under an eleven hour day from July 9. At this time the plants were 52 days of age and had been under the eleven hour day for 35 days. During the latter part of August fruit-bud formation was found in plants which had been subjected to the eleven hour day for a period of but 27 days. These results show quite definitely that fruit-bud differentiation in the strawberry is at least partly a photoperiodic response. These results substantiate those of Sudds (35) in Pennsylvania, with the Howard 17 variety. Darrow (9) found that the Howard 17 variety when shaded from May until the end of October bloomed by the end of July, but after July 28 no blossoms were produced. He considered that this was due to the high summer temperatures and that apparently length of day and temperature were factors involved in the differentiation of fruit-buds in the strawberry. The results secured with the strawberry are similar to those of Laurie and Poesch (21) and Post (29) with the chrysanthemum. By reducing the daily light period to eleven hours the chrysanthemum plant bloomed much earlier than did the plants receiving the normal length of day.

The chemical analysis of the plants grown under the eleven hour day showed a marked increase in the total carbohydrate/total nitrogen ratio. This was largely accounted for by the increase in carbohydrates. It would seem that in the strawberry the differentiation of fruit-buds is closely associated with a balance between the carbohydrates and nitrogen, if not caused by it.

In the plants grown under the nitrogen and soil moisture treatments the carbohydrate/nitrogen ratios were lower at all times than those grown under the eleven hour day. The ratios increased as the season advanced. The ratios were higher in the roots than in the tops.

In the transpiration experiment it was found that the plants in the different treatments responded differently at different times. In cases where nitrogen fertilizers affect the leaf area, the rate of transpiration per unit area might be the same, although the total loss of moisture from the plant would be greater. The increase in moisture transpired, would undoubtedly not be in direct proportion to the increase in leaf area. This was indicated by the present results and those of Darrow (8) in which he found that plants with small leaf areas transpired more per unit area than those with large leaf areas. The strawberry, because of its shallow root system, probably has a more delicate balance between leaf area and soil moisture than many other more deeply rooted plants. This would be indicated by the decreased yields obtained in certain instances where nitrogen has been used. As has been mentioned previously, also, such plants often wilt badly in severe drought conditions.

In this experiment no general conclusions could be drawn concerning the effect of nitrogen fertilizers on the transpiration rate of strawberries, although there seemed to be little if any effect. In this connection it might well be mentioned that when nitrogen fertilizers were applied to <u>Atriplex semibaccatum</u>, Petrie (28) found that the transpiration rate was markedly reduced.

From these investigations and from field observations, however, this does not seem to be the case with the strawberry.

These investigations showed, moreover, that the responses of the strawberry to nitrogen fertilizer and soil moisture may be considerably different, according to the time of application, i.e., whether in the year of vegetative growth or in the year of fruiting.

SUMMARY

1. A study was made of the effects of nitrogen fertilizer, soil moisture, and photoperiodism in relation to some growth responses, chemical composition, fruit-bud differentiation, and yield of the Howard 17 strawberry. The nitrogen and moisture treatments were studied in both the non-fruiting and fruiting years.

2. The applications of nitrate of soda and of moisture to the soil resulted in a distinctly higher content of nitrates in the soil and in a higher soil moisture content, respectively.

3. When applied the year the plants were set, nitrogen fertilizer resulted in the formation of fewer runner plants, a shorter length of runner between runner plants, and a reduction in the number of leaves per plant. Soil moisture apparently had little effect on any of these growth responses when applied the non-fruiting year. However, an increased moisture content of the soil during the fruiting year resulted in the production of considerably more leaves per plant.

4. The oldest plants in the runner series had the most leaves and there was a gradual decrease in number of leaves per plant with a decrease in age of plant.

5. In the fruiting year, increased soil moisture resulted in leaves with longer petioles and with larger leaf area than plants grown under conditions of low soil moisture. Nitrogen fertilizer had but little if any

effect on these responses when applied in the fruiting year.

6. With the different treatments applied during the fruiting year, the rate of transpiration per unit area of leaf surface varied considerably at different periods, and were not consistent. Consequently, no general conclusions can be drawn from the results of this experiment as to the effect of nitrogen fertilizers on the rate of transpiration in strawberry plants.

7. The time of fruit-bud differentiation apparently was not affected by the nitrogen and soil moisture treatments. On the other hand, an eleven hour photoperiod caused the plants to form fruit-buds approximately a month earlier than they did under the normal length of day.

8. When treatments were applied the year previous to fruiting the no nitrogen fertilizer and no irrigation treatment resulted in the production of the largest number of blossoms in the fruiting year. However, nitrogen fertilizer and irrigation resulted in more blossoms than in the case of either treatment applied alone. In the greenhouse the berries were larger on the high soil moisture plots than on the low soil moisture plots and the total yield, as well, was higher on the high soil moisture plots. Nitrogen fertilizer had little effect on either side of fruit or yield.

9. In all cases the moisture content of the fruit

was higher in fruit from the high moisture plots than in that from the low moisture plots.

10. On a dry weight basis, the percentage total nitrogen was higher in fruit from the high nitrogen plots than it was in the low nitrogen plots. There was no significant difference in the carbohydrate content of the fruit from the different treatments, although there was a tendency for the high nitrogen plots to have a higher carbohydrate content than the low nitrogen plots. The insoluble nitrogen content of the fruit was approximately two and one-half times that of the soluble nitrogen content. The application of nitrogen fertilizer in the non-fruiting year resulted in a higher nitrogen content of the plants.

11. Plants subjected to an eleven hour day had a decidedly higher C/N ratio than did the normal day plants. In nearly all cases the plants grown under the normal length of day had a higher C/N ratio in the unfertilized than in the plots receiving nitrogen fertilizer. Soil moisture apparently had little effect in this respect.

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