# A NUTRITIONAL STUDY OF THE STRAWBERRY

by
W. E. Whitehouse.



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# INTRODUCTION

When the culture of the strawberry was in its infancy in the United States it was thought that the application of fertilizers was detrimental to the production of a maximum quantity of fruit. Fletcher (14) says that this contention held until 1850, the growers up to that time recommending that the strawberry be planted on a poor soil to prevent the plant from running to vines and producing a small quantity of fruit. It is not at all surprising that this general assumption was in vogue, for the majority of growers planted Scarlet, a variety which naturally produced a large number of runners and new plants and this tendency would be accentuated by the application of fertilizing materials. As strawberry growing developed, newer varieties were introduced and it became more and more evident that the strawberry plant was benefited by fertilization.

There is no factor, unless it be moisture, which more often limits the yield of berries by the strawberry plant, than the supply of mineral nutrients and organic matter in the soil. The nutrient requirements of the strawberry are not clearly understood and a review of the available literature on this phase of strawberry growing, with its contradictory results and recommendations, does not entirely clear up the situation. Until recently investigators have based the interpretation of their experimental results upon the yields and grades of berries harvested. Recent workers have turned their attention to the nutritional conditions within the plant, and the relationship of these conditions to the growth and development of the plant in an effort to correlate growth with yielding capacity.

The experiments reported here were designed, first, to determine in sand cultures in the greenhouse, whether a correlation exists between the factors which influence growth and those which influence fruit production, and to determine the relative effects on growth and fruiting of the three commonly used elements -- nitrogen, phosphorus, and potassium. Second, to undertake a chemical study of strawberry plants grown under varying nutritional conditions in an effort to correlate the chemical constitution of the plants with any differences in their growth and fruitfulness. Third, to conduct field tests in several of our large strawberry growing sections upon the Eastern Shore of Maryland to determine, under field conditions, the relative effects on growth and fruiting of the three commonly used elements -- nitrogen, phosphorus, and potassium.

At the present time, fertilization of the strawberry is practiced regularly by strawberry growers in practically all the regions where this fruit is grown. An analysis of the fruit indicated that only a relatively small amount of the plant food in the soil is utilized in the production of the berry. Van Slyke (34) estimates that the approximate amount of plant food constituents used in producing a crop of five-thousand pounds to the acre, are seven and one-half pounds of nitrogen, three pounds of phosphoric acid, and twelve pounds of potash. Loree (23) has shown that the growth and development of the rest of the plant, other than the fruit, requires a proportionally greater amount of the nutrients in the soil. Inasmuch as the amount of mineral nutrients in a soil is not as exact measure of the availability of the nutrients to the plant, neither soil nor plant analyses are true of the plant's need for these elements.

A study of commercial practices in Maryland reveals a wide diversity of opinion among growers, as to the amount, kind, and time of application of fertilizers for strawberries. Some of our best strawberry growers in Maryland have adopted a fertilizer program which consists of a mixture of 1700 pounds of raw bone meal, and 300 pounds of muriate of potash, at the rate of 600 pounds to the acre, applied to the soil just previous to planting. If the plants are growing vigorously in July, no more fertilizer is applied that year, otherwise, a topdressing of the same mixture, at the rate of 600 pounds per acre is applied in July, and cultivated in along the sides of the rows. Early the following spring, just as the plants show signs of starting growth, a topdressing of fertilizer analyzing seven percent nitrogen, six percent phosphoric acid, and five percent potassium is applied at the rate of three-hundred pounds per acre on the new fruiting beds, and at the rate of six-hundred pounds per acre on the beds which are fruiting for the second time. Strawberries are grown for two years, after which time the land is plowed and green manure grown to keep up the organic matter in the soil, following this with some cultivated crop such as potatoes or tomatoes before replanting the same ground to strawberries. This practice by successful growers indicates that in addition to plowing under organic matter in the form of green manure and rigid cultivation to keep weeds down, it is considered essential to use nitrogen, phosphorus, and potassium in fairly large quantities in an effort to stimulate the growth of the plant in the early spring just after planting, in the late summer and again in the spring before blooming occurs. This being true, the question immediately arises as to whether any or all of these elements are essential to the growth of the plant during these three periods, and if so, what is the relative importance of each?

## REVIEW OF LITERATURE.

### Field Studies.

1. Effect of Mineral Nutrients Applied at Planting Time on the Spring and Early Summer Growth of the Strawberry Plant:

Chandler (6) in Missouri found that nitrogen applied in the early spring when there was an abundance of moisture, stimulated a marked growth in the size of the plants and an earlier runner formation, but when applied as late as June 1st, on a new bed or upon an old bed after renewing, no observable results could be seen.

Macoun (25) found a decided correlation between the date the stolon of a strawberry plant took root, and the ultimate number of fruits it produced. Stolons formed as late as October 20th produced on the average only five fruits, whereas stolons formed about the middle of August produced an average of sixteen fruits. Stolons formed much earlier than this produced about nine to ten fruits, the development of large numbers of runners by these early formed plants depleting them of energy. The early formation of runners is dependent upon an available supply of plant food, including nitrogen, in the early part of the planting year. A heavy application of manure applied the year previous to planting, followed by a cultivated crop, gave, on a soil of average fertility, a sufficient supply of nitrogen and other plant food to encourage maximum runner formation in the early part of the season.

Tucker (33) in New Hampshire worked with Howard No. 17 strawberry plants set in a sandy loam soil which originally contained only a small amount of organic matter, and to which applications of stable manure and commercial fertilizers, and the turning under of green manure, had been made annually for eight years. Stable manure in different amounts, applied broadcast in the spring and worked in before planting, gave not only an increase in number of runners, but in the branching of each runner as well. The increase occurred in direct proportion to the amount of manure added, the stable manure as high as thirty-two tons per acre being the best.

Bailey (1) in a series of cooperative experiments in Oswego County, New York, compared nitrogen, phosphorus, and potassium, applying them upon the beds growing on the various soil types ranging from gravelly loam to black muck. The fertilizers were applied to the young plantations after the first tillage, a year before records were taken on the crop. Potassium and phosphoric acid markedly increased yields, and produced berries which were firmer and better colored. Nitrogen fertilizer gave too much plant growth and an inferior quality of fruit, the increase in yield being insufficient to pay the cost of the fertilizer.

Szymoniak (32) in Louisiana applied nitrate of soda, acid phosphate, and sulphate of potassium in various combinations, to strawberries growing in soils low in humus as well as fertility. The fertilizers were applied three weeks before setting the plants in September, October, and November. Acid phosphate increased yields strikingly when applied alone or in combination with nitrogen or potassium. Nitrogen alone as high as six-hundred pounds per acre gave hardly any increase over the check plots and the response from potassium was very slight.

2. <u>Effect of Mineral Nutrients Applied in the Spring of the Fruiting Year on the Growth and Yield of the Plants That Season:</u>

White (40) in New Jersey published an increase in yield of thirty-one percent from a spring topdressing of two-hundred pounds of nitrate of soda. The plants growing on a sandy loam soil had received a fertilizer mixture containing phosphorus and potassium at time of setting two years previous, but had not received a previous application of nitrogen. A similar application (40) of nitrate of soda in the spring of the fruiting year, to plants well fertilized with complete fertilizer at the time of setting a year before, gave an increase of only eighteen percent. The nitrogen increased the size of the berries, consequently the yield. Quaintance (29) in Georgia found that a complete fertilizer made up of four percent nitrogen, eight percent phosphorus, and eight percent potassium, gave higher yields in all cases. He applied the fertilizer in rows previous to planting in the fall, and drilled subsequent spring applications along on each side of the row, varying the carriers of different elements, as well as the amounts. Nitrate of soda gave better results than cottonseed meal, when used as a source of nitrogen. An additional top dressing of nitrate of soda in the spring increased the yield only slightly. Doubling the nitrogen applied during the season gave only slight increases. Increasing the amounts of phosphorus or potassium decreased the yields.

Bedford and Pickering (2) tested the respective merits of natural and artificial dressings and found differences too small to be significant. In another test (3) carried on over a seven year period, the artifically dressed plots were only two percent below the dunged ones, this difference also insignificant. Too large quantities of manure were detrimental. The fruit from the dunged plots during the last four fruiting years was far superior in size and quality to that from the other plots. They found (4) that land could be continuously cropped with strawberries over a period of fifteen years provided the fertility of the soil was kept up.

Condon (8) repeating his experiments many times, found that strawberries grown in France always responded to applications of complete fertilizer in March, an increased yield and a prolonged season resulting.

Keffer (20) in Tennessee found that strawberries growing on a good clay loam did not respond to applications of muriate of potash, acid phosphate, and cottonseed meal singly or in various combinations, applied the year of fruiting.

Ferris (13) in Mississippi applied a complete fertilizer of two-hundred pounds of cottonseed meal, two-hundred pounds of acid phosphate, and one-hundred pounds of Kainit per acre, one-half after the first picking, and one-half at the last cultivation in the fall. Varying this by leaving out or cutting the nitrogen, phosphorus, or potassium, his results for three years on the same bed showed that phosphorus was the element which limited the yields of his strawberry beds. This has also been found to hold for other crops on these soils.

Close (7) applied commercial fertilizer to the strawberry bed in the fall, at the time when they were ordinarily mulched, comparing this treatment with applications of manure as well as straw. The unfertilized plot was higher yielding than commercial fertilizer plot, and the plain straw mulch higher yielding than the manured plot. The authors mention high soil variability in varietal test blocks close by, which gives us soil variation as a possible explanation for their fertilizer results.

Chandler (6) found that nitrogen applied either as sodium nitrate or dried blood, in the spring of the year the crop was harvested, gave injurious results in every case. These fertilizers caused excessive plant and weed growth and greatly reduced the yield of fruit. His work also suggests that phosphorus was beneficial.

Seton (31) found that the yields from strawberry plantations, cropped over a period of three years, were increased by the addition of phosphates to the soil.

Hotchkiss (18) in Texas obtained a decided benefit from nitrogen in the form of cottonseed meal, as well as from acid phosphate, applying these fertilizers in January, ten months after planting. Nitrogen and phosphorus combined gave the best yields. Potassium gave no increase in yield, in fact seemed slightly injurious.

Whitten (41) in Missouri obtained best results from either acid phosphate or bone meal by applying them direct to the row. Bone meal had little effect on the yield, but acid phosphate applied either the current year or the year previous caused a marked increase in yield.

In Novia Scotia (44) commercial fertilizers made up of nitrate of soda and acid phosphate were compared with manure which was applied and worked in before planting the strawberries. Manure gave larger yields than commercial fertilizers. Since no further treatment was given during the first year, and all plots were treated uniformly with acid phosphate the spring of the second year, the manure may have influenced the yield by increasing the moisture holding capacity of the soil.

Brown (5) working with the Clark strawberry, a canning variety grown in Hood River, Oregon, found that heavy applications of nitrate of soda greatly increased the yield, when applied in the spring of the first fruiting year. The use of phosphorus or potassium alone gave poor yields. The best yields were obtained when a heavy application of sodium nitrate was applied, one-half in the spring, and the other half at blossoming time. Soils in this region are of volcanic ash origin, and very low in organic matter. All fruits have responded to the application of nitrogenous fertilizers showing an apparent deficiency of nitrogen in these soils.

Cooper (9) in Arkansas, as a result of experiments, recommends that small amounts of slowly available nitrogen, up to one-hundred and fifty pounds per acre, be applied in the summer after fruiting and early the following spring. Phosphorus gave greater direct results on strawberries, than on any other fruit, increasing the shipping quality as well as the yields.

Esbjerg (12) testing the substitution of artificial for natural manures used fertilizers of equal nutritional value, but differing in the amount of chlorine contained in the potassium salt. In all cases he found an increase in chlorine content reduced yields in direct proportion to the amount added. Artificial fertilizers with small chlorine content slightly increased yields above control plots on both sandy and loamy soils. Animal manures were, however, more effective in increasing yields.

Dyer and Shrivell (11) experimenting over a series of years, found that lack of potassium was detrimental to yields. Potassium salts were not necessary in conjunction with phosphorus and nitrogen provided a light dressing of stable manure was applied with these fertilizers.

Macoun (26) in Canada working on soil in a high state of fertility found that applications of nitrate of soda at time of planting, and at different intervals after planting, failed to have any observable influence on the vegetative growth of the strawberry plants. His highest yielding series was the one which received nitrate of soda on September 15th, and again just before bloom in the spring. There was an increase in yield in all the nitrated series, the increases becoming progressively more marked as the application approached the fruit bud forming period during September. When nitrate was applied to the beds the summer before they bore their second crop, fruit bud formation apparently took place a month earlier on the older beds and August 15th seemed to be as late as it was advisable to apply nitrogenous fertilizers for the second crop. He found (26) that early spring applications of nitrate of soda even on soil of high fertility had a tendency to cause increased size of fruit, which accounted for a slightly greater yield on plants fertilized both in the fall and in the spring before bloom. Spring applications were of doubtful value for the second crop. The total set (27) of all bloom was increased by about five percent by a spring application of nitrogenous fertilizers before bloom, the increase on the late blooms running as high as twenty-six percent.

Wentworth (39) found that applications of from two-hundred to three-hundred pounds of nitrate of soda applied about September 1st, and in the following spring about May 15th, did not increase the yield of Howard 17 (Premier) strawberries in New Hampshire.

## Summary of Field Results.

A review of field results has shown a wide difference in the response of strawberry plants to nitrogen, phosphorus, and potassium. No striking benefit from the use of potassium alone was shown. Nitrogenous fertilizers, when applied in the early spring at time plants were set, increased growth in size of plant and early runner formation. When applied as top dressing in the spring of the fruiting year, nitrogen increased the size of berries, and thus the yield in some soils, but decreased the yield in others. Investigators in many states, particularly those south of Maryland, found phosphorus aiding materially in increasing the yields of strawberries. In some instances a combination of nitrogen and phosphorus was better than either one above. Apparently the question of just what fertilizer to use, is a local one, but the above summary can be used as a general guide, and specific recommendations for any particular soil should be based on the results of experiments conducted in that region.

## Study of Growth and Fruiting of Strawberry Under Controlled Conditions

### 1. Effect of Mineral Nutrients on Early Growth of Plants.

Wallace (36) in England, grew Royal Sovereign strawberries in silver sand contained in unglazed waxed pots, and treated them as follows:

a. Fed with a complete nutrient solution.

b. Fed with a complete nutrient solution, but an extra amount of sodium sulphate given.

c. Nitrogen omitted from complete nutrient solution.

d. Potassium omitted from complete nutrient solution.

e. Phosphorus omitted from complete nutrient solution.

f. Calcium omitted from complete nutrient solution.

g. Magnesium omitted from complete nutrient solution.

h. Rain water only.

The growth of the plants were checked by the omission of nitrogen, or the omission of phosphoric acid. When the phosphoric acid was omitted the leaves turned bronze or purple in spots, and when nitrogen was omitted, the leaves turned yellow and sometimes red. Complete nutrient solutions gave green, well developed leaves and healthy plants.

Loree (23) in Michigan working with the Senator Dunlap, a variety which produces runners freely, grew plants in a very light sand, low in plant nutrients, and showed that ammonium sulphate at the rate of two-hundred pound to the acre, applied in the spring when the plants were established, stimulated the growth of the plants to the extent that their fresh weight, made during the spring period, was seventy percent above that of the unfertilized. Phosphoric acid added to the nitrogen, at the rate of four-hundred pound to the acre, gave a gain of one-hundred and eighteen percent over that of the unfertilized. Potash added to the nitrogen and phosphoric acid, at the rate of one-hundred and fifty pounds to the acre, gave no further increase, in fact the fresh weight was slightly less. Spring applications of nitrogen, either alone or in combination with phosphoric acid or potash, greatly stimulated runner production, the nitrogen having the greater effect of the three. Continued application of nitrogen during the summer period, particularly when in combination with phosphoric acid and potash, stimulated still greater runner production. Plants which received nitrogen in the summer only produced fewer runners, although the total weight of the individual plants was not reduced below the spring treated plants.

2. Effect of Mineral Nutrients on Late Growth of the Strawberry Plants.

Gardner (16) in Missouri working with Senator Dunlap strawberries potted in river sand and in potting soil, a portion of each respective lot of plants being defoliated, was able to study the influence of varying nutritive conditions upon the development of the plant. Plants grown in poor soil during summer and fall had less fruit buds formed, and the resulting clusters averaged a smaller number of flowers than those grown under more optimum conditions for plant growth. The development of flower clusters and flowers on plants which were not defoliated was directly proportional to the fertility of the soil in which the plant was grown. Defoliation caused a reduction of flower clusters and flowers.

Loree (23) applied nitrogen in the summer to plants which had not received fertilizer previously, and found that the plants grew vigorously until the end of the growing season, and were slightly larger than the spring treated plants. Phosphoric acid alone failed to produce any effect on vegetative growth, but when used in combination with nitrogen, or with nitrogen and potash, the growth was greater than with the use of nitrogen alone. Plants treated with fertilizers containing nitrogen during the spring and summer periods were larger at the close of the season than those which were treated during the spring period or the summer period only. Those treated with nitrogen and phosphoric acid were the largest and most vigorous of all. The general effect of fertilizers containing nitrogen was to increase the number of clusters per plant, and in some cases to increase the number of flowers per cluster.

### 3. Effect of Mineral Nutrients on Growth Just Previous to Fruiting.

Von Brehmer (35) forcing strawberries in pots, found that the use of a complete fertilizer plus calcium nitrate yielded more than ten times greater than where no fertilizer was applied, and the fruit ripened two weeks earlier in the season.

Gardner (16) applying fertilizer in the spring of the fruiting year found that when moisture and temperature are not limiting factors, number of flower clusters, number of flowers, and size of berries are dependent on nutritive conditions within the plant the preceding fall and winter, and they are practically independent of soil fertility conditions during the spring and at the time of fruiting.

Loree (23) found that although the number of flower clusters, and the number of flowers per cluster, were dependent upon nutritional conditions in the late summer and fall, the percentage of set was greatly influenced by nutritional conditions in the soil during the blooming season. Application of nitrogen in the spring of the fruiting year increased the yields by inducing a better set of flowers and increasing the size of the berries.

Wallace (36) growing the same strawberries in silver sand for three seasons found that lack of nitrogen, phosphorus and potassium cut yields eighty-three percent, fifty-six percent, and thirty-five percent respectively. It is interesting to note that lack of nitrogen or phosphorus was more injurious than the lack of potassium, since this checks up with most of the results secured previous to this work, but under field conditions.

## Summary of Results Obtained Under Controlled Conditions.

Nitrogen stimulated growth of plant whenever applied. Phosphorus alone failed to produce any effect on vegetative growth of plant, but when used in combination with nitrogen, gave greater growth than when nitrogen was used alone. Nitrogen and phosphorus, when applied in the late summer and fall increased the number of clusters per plant, and in some cases the number of blossoms per cluster. The percentage of flowers to set was greatly influenced by applications of nitrogen in the spring of the fruiting year. It is interesting to note that lack of nitrogen or phosphorus was more injurious than the lack of potassium, since this agrees with most of the results secured previous to this work, but under field conditions.

Correlations Between the Chemical Composition of the Strawberry Plant and Its Growth and Fruitfulness: Plenty of evidence has been accumulated indicating that the carbohydrate-nitrogen relation at certain periods of growth of a plant has an important bearing on the development of the plant and its fruitfulness. Klebs (21) has shown that the process of flower formation in Sempervivum Funkii was influenced by light. The balance between the formation of elaborated foods as influenced by light, and the supply of salt nutrients was found to be the controlling factor. Low temperature reduced respiration and led to an accumulation of soluble sugars by hydrolysis of insoluble carbohydrates. Fischer (15) made it more definite by considering the nitrogen supply as the most important formative factor furnished by the salts. He came to the conclusion that a very high carbohydrate-nitrogen ratio favored flowering, while a lower carbohydrate-nitrogen ratio favored vegetation. His conclusions were based largely on his work dealing with effect of increased partial pressure of carbon dioxide upon the development of plants, but not on chemical analysis of the tissue. Crocker (10) points out that Fischer failed to show that a very high carbohydrate-nitrogen ratio not only reduces vegetative growth, but diminishes reproduction.

Kraus and Kraybill (22) show that fruitfulness in the tomato is correlated with a balance between nitrogenous and carbohydrate materials in the plant.

Walster (37) studied the effect of high and low temperatures and accompanying variations in the supply of nitrogen, phosphorus, and potassium respectively, upon the course of development of the barley plant. Nitrate nitrogen began to affect the subsequent course of development at high temperatures at the time of germination. The tendency to excessive vegetation, thus inaugurated, could not be counteracted by the addition of phosphorus or potassium salts. A high nitrogen supply at low temperatures resulted in normal vegetation and normal culm formation. Chemical analysis of the leaves showed high soluble nitrogen and low soluble carbohydrates when grown at high temperatures, and a low soluble nitrogen and high soluble carbohydrate content when grown at a lower temperature.

Loree (23) studied the chemical composition of strawberry plants fertilized at different dates. Upon analysis, August 1st, and again on October 26th, he found a large amount of the nitrogen and potassium absorbed by the plant up to August 1st, was lost later in the season, the phosphorus staying constant. He says that this loss was probably due to utilization in the development of runners, and the dying of the outer leaves. On August 1st, the carbohydrate-nitrogen relationship of the spring treated plants was nearly identical with that of the summer treated plants, which were analyzed on October

26th. In the spring treated plants the response to this condition was mainly runner formation followed by very little fruit bud formation in the fall, whereas in the summer treated plants, the same condition occurring later in the life of the plant brough about fruit bud formation almost entirely. In the spring treated plants, the nitrogen decreased and carbohydrates increased slightly after August 1st, but the nitrogen remained constant and the carbohydrates decreased slightly if plants were treated both spring and summer.

## MARYLAND EXPERIMENTS

### Materials and Methods.

A. Greenhouse Experiments:

The work was conducted in the greenhouse at College Park in wooden benches about eight inches deep, and four feet wide supplied with bottom heat. The benches were cleaned thoroughly, separated into plots, and filled with quartz sand to be utilized as one type of soil, and a soil mixture containing two parts of sandy loam and one part of river sand, as another. The latter gave a soil low in fertility, but not as poor as the quartz sand which contained very little if any plant food. Howard 17 (Premier) strawberries were used. The plants were graded to a uniform size, using the thickness of the crown and development of root system as a guide, and planted about eight inches apart each way. The plants were allowed to grow for a week in order that they might send out new rootlets for absorption of nutrients. There were approximately ninety plants to each plot.

Description of Plots: Each type of soil was divided into four plots: (1) treated with a complete mineral nutrient solution in which the nitrogenous elements were high, (2) treated with a complete mineral nutrient solution, (3) treated with a mineral nutrient solution from which all nitrogenous elements had been omitted, (4) untreated as a check.

The following nutrient solutions were used:

| Solution A. | Solution B. |
| --- | --- |
| 2% $Mg\ SO_4$ | 3% $Ca\ Cl_2$ |
| 2% $KH_2\ PO_4$ | 2% $Ca\ SO_4$ |
| 2% $KNO_3$ | 4% $Ca(NO_3)_2$ |

Each solution was diluted one part to six parts of water, mixed and applied. The above solutions when combined respresented the complete nutrient solution which was applied to Plot 2. Plot 1. received the same solution with the exception that the $KNO_3$ and the $Ca\ NO_3$ were doubled. On Plot 3 the following solutions were used:

| Solution A. | Solution B. |
| --- | --- |
| 2% $Mg\ SO_4$ | 4% $Ca\ Cl_2$ |
| 2% $KH_2\ PO_4$ | 2% $Ca\ SO_4$ |

The check plot received nothing except the tap water used to water the beds. On March 13th, 1924, a few days after planting, 50 cc of the complete nutrient solution was applied to each plant in the quartz sand to aid the plant to establish itself, before the different treatments were started. When a new series of plants were put out in 1925, this initial application was not given, since it was felt that the plants would grow without it. No application was given the plants on the river sand mixture which had sufficient mineral nutrients to start the plants. Subsequent applications of mineral nutrients were 75 cc to each plant.

The plants in all the beds started growth shortly after they were planted. In view of the response to the application of the varying nutrient solutions obtained by investigators, who had worked with other types of plants, it was decided that the applications of nutrients should be governed to some extent by the growth of strawberry plants in each plot. Plot 1, the high nitrogen plot, had more applications than Plot 2. Plot 3 received application upon all dates that solutions were applied to the beds. In general the nutrients were applied at two to three week intervals from April 1st to May 22nd, and at monthly intervals from then until August 3rd, at which time the last application was made. As soon as blossom clusters appeared on the young plants, they were removed.

Records Taken: Records were taken of the following: (1) number of leaves and of runners produced by each plant, (2) number of crowns formed, (3) average stem height of leaves, (4) color of leaves, (5) and rate at which outer leaves died off. A block of twenty plants exactly in the center of each bed was labeled for these observations, thus eliminating the outside plants which were subject to variations in water supply. The plants in the beds were allwed to grow until cold weather, at which time the ventilators were opened, growth was checked, and the plants rendered inactive until the following February. Heat was turned on February 1st, 1925, and a record made of the number of flower clusters and flowers per cluster produced by each plant in each plot. Record of the fruit was not taken because of imperfect pollination.

These experiments were duplicated in 1925. Samples were taken for a study of time of fruit bud differentiation in the plants grown under the various nutritional conditions.

B. Field Experiments:

The experiments carried on under field conditions at Marion Station, Salisbury, and Ridgely, Maryland, will be outlined, and a detail of procedure and records taken will be given later, under the subject of "Field Studies."

C. Methods of Chemical Analysis:

Sampling and Preservation of Material: All samples of strawberry plants were taken on aclear day about the middle of the morning. Four plants were taken at each sampling, the plants representing an average of the plot. The growth of the plants under each treatment was quite uniform. Roots and tops were preserved separately and kept separate for analysis. The crown of the plant was included in the top. This same procedure was carried out on samples taken in the series started in 1925, with the exception that after weighing,the samples were cut into small pieces, one-fourth to one-half inch long, and transferred to a wide mouthed Erlenmeyer flask containing .25 grams of calcium carbonate. Sufficient hot ninety-five percent alcohol was added to bring the final concentration of alcohol to seventy to seventy-five percent. The flask was placed in a boiling water bath under a reflux condenser, and brought to a boil as quickly as possible to inactivate all enzymes. Refluxing was continued for thirty minutes at eighty degrees C.

At intervals during the growing season, samples of four plants each were removed from each plot; the roots washed free of all sand, and dried by placing them between sheets of water absorbing paper, which removed the excess moisture from the roots. Approximately fifteen minutes after removal from the bed s the roots and tops were separated, and the green weight of each determined. After weighing, the leaves and crowns were cut up in small pieces and dried in an oven at eighty-five to ninety degrees C. for seventy-two hours for dry weight and chemical determinations.

Moisture and Dry Weight: The samples were prepared for analysis by decanting off the preserving extract into a 250 cc. volumetric flask, rinsing the insoluble matter once with seventy percent alcohol, and pouring the rinsings into the volumetric flask. The residue was transferred to a small evaporating dish, dried for twenty-four hours at seventy-five degrees C., cooled in a dessicator, and weighed, this operation being repeated until a constant weight within afew milligrams was attained. After transferring the residue, the inside of the flask was rubbed down with a policeman and the flask rinsed twice with alcohol, adding the rinsings to the volumetric flask as before. After weighing, the residue was ground to pass a sixty mesh sieve. The extrace was made up to volume, shaken well, and a one-tenth aliquot withdrawn placed in a 50 cc beaker and dried to constant weight in an oven at seventy-five degrees C for the determination of the dry matter in the extract. The total dry weight of the extract was calculated and added to the dry weight of the solid material to obtain the dry weight of the sample. The dry weight of other samples not preserved in alcohol was obtained directly after drying. Moisture was determined by difference.

Reducing Substances: An aliquot of the dried sample, about three grams, was placed in a Sohxlet siphon extraction apparatus. A corresponding aliquot of the preserving extract was placed in the extraction flask below the tube, making the volume of the extract up to 100 cc with eighty percent alcohol. The sample was extracted for three hours, heating it just enough to make the solvent siphon out of the tube seven or eight times an hour. After extraction, an aliquot of the extract was removed and placed in a Kjeldahl flask for determination of soluble nitrogen. The remaining aliquot was placed in an evaporating dish over a water bath until all the alcohol had been driven off. It was transferred to a 200 cc volumetric Kohlrausch flask, water added to make volume around 150 cc, and a few drops of a saturated solution of lead acetate added to clear the solution. The extract was made up to volume, filtered, and the excess lead removed with anhydrous sodium carbonate. The reducing power of the extract was then determined by the Bertrand modification of the Munson Walker method as given by Matthews' Physiological Chemistry, 1921. The result was expressed in terms of dextrose.

Total Sugars: A 50 cc. portion of the cleared sugar extract was hydrolyzed by HCl (5 cc of sp. gr. 1.125) allowing the extract to stand twenty-four hours at room temperature. It was neutralized with anhydrous sodium carbonate and made up to 100 cc. volume. The reducing power of this solution was determined as in the method for reducing substances and reported as dextrose.

Sucrose: The difference between the reducing substances and the total sugars is reported as sucrose in terms of dextrose.

Starch: About a two gram portion of the dry residue from the sugar extract was ground to a fine powder (to pass a 100 mesh sieve) in a mortar, using a small quantity of white quartz sand to facilitate grinding. The powder was transferred quantitatively to a 250 cc. beaker, barely enough distilled water being added to thoroughly moisten the material, or to make a thick pasty mass. After standing for a few minutes, 50 cc. of boiling, distilled water was poured into the beaker and it was placed over a burner and brought to a boil for a minute. Care was taken that the residue did not burn on the sides or the bottom of the beaker, nor froth over. The sides of the beaker were washed down, the beaker covered and transferred to a boiling water bath, and held there for one hour in order to gelatinize the starch as completely as possible. After gelatinization, the solution was cooled to fifty degrees C. the side of the beaker washed down and 5 cc. of saliva solution added. The mixture was stirred thoroughly, covered with a watch glass and placed in an incubator at a temperature of fifty degrees C. for one hour. At the end of an hour it was replaced on the water bath, brought to a boil and held for fifteen minutes to produce a second gelatinization in case some of the starch escaped the first time, cooled to fifty degrees C. treated a second time with 5 cc of saliva solution, and digested as before. At the end of the second digestion, a drop of the residue was tested with I K I and examined under the microscope for any trace of starch. If starch was present a third gelatinization and digestion was carried on and the residue again tested.

Due to the presence of certain polysaccharide materials other than starch, which would interfere with the starch determination as ordinarily carried out, it was necessary to use a modification of the method devised by Walton and Coe (38) for determining starch in the presence of interfering polysaccharides. After digestion had been completed, the solution was placed on a water bath, brought to a boil, cooled, transferred to a 250 cc. volumetric flask, using 160 cc. of ninety-five percent alcohol to wash the beaker out, and the beaker given a final rinse with distilled water to remove any material precipitated by the alcohol. After shaking thoroughly and allowing to stand over night in this sixty percent alcoholic solution, the muscilagenous, gummy, and pectin like materials precipitated out of solution and the solution was made up to volume and filtered. A suitable aliquot of this starch solution was drawn off for analysis,it being necessary to use 200 cc. to get a sizable titration with N/20 permanganate.

The aliquot of solution was freed from alcohol on a water bath, made up to volume of 100 cc. in a 500 cc. Florence flask, 10 cc. of HCl (sp. gr. 1.125) added, and boiled gently under a reflux condenser for two and one-half hours. The addition of 10 cc. of HCl gave a concentration of 2.5 percent acid. Since this work was done the committee on methods has recommended a concentration of two percent. The extract was neutralized with anhydrous sodium carbonate and the reducing power determined as in the above procedure. The result is expressed in terms of dextrose.

Total Acid Hydrolyzable Substances: About a half gram portion of the dried residue from the sugar extraction was hydrolyzed by refluxing gently for two and one-half hours with HCl, (10 cc. of HCl sp. gr. 1.125 to 100 cc. of water) added to the residue. This extract was neutralized with anhydrous sodium carbonate and made up to 250 cc. volume. The reducing power was determined and the results expressed in terms of dextrose.

Nitrogenous Substances:

1. Alcohol-Insoluble Material: In the first year's work an aliquot of the extracted residue was analyzed by the Gunning-Kjeldahl method for determining total nitrogen, modified to include nitrates (31). The following year it was found more convenient to determine total nitrogen in an aliquot of unextracted material, then find the total soluble nitrogen and let the difference represent the in-

soluble nitrogen fraction. An aliquot of the preserving extract was placed in a Kjeldahl flask and boiled on a water bath until the extract had been reduced to a gummy mass, which ran very slowly as the flask was turned. All water was removed and a corresponding aliquot of dried sample was weighed and placed in the flask. The total nitrogen was then determined by the above method.

2. Total alcohol-Soluble Nitrogen: The aliquot of the extract taken after Sohxlet extraction as described under reducing sugars was placed in a Kjeldahl flask and evaporated to a gummy mass, upon a water bath as described above. The soluble nitrogen was then determined by the Gunning Kjeldahl method.

## EXPERIMENTS AND RESULTS.

### A. Growth Studies of Strawberry Plants Growing Under Varying Nutritional Conditions in the Greenhouse:

1. Effect on Plant Development: Plate I. presents a view of the strawberry plants grown in quartz sand under the different treatments. A striking difference in vegetative growth may be seen between the plots receiving nitrogen (3 and 4), and the plots which received no nitrogen (1 and 2). The high nitrogen plot (4) made a more vegetative type of growth than the one receiving a normal supply of nitrogen in a complete nutrient solution.


PLATE I. Showing Growth Made by Strawberry Plants in Quartz Sand. (Picture taken October, 1924).

1. Check.

2. Complete nutrient solution minus nitrogen.

3. Complete nutrient solution.

4. Complete nutrient solution with high nitrogen content.

Differences in the vegetative growth between the check plot (1) and the one receiving all mineral nutrients except nitrogen (2) were not discernable. Apparently in a soil as poor as quartz sand, the most important element for vegetative growth is nitrogen not phosphorus or potassium. In 1927 four new plots were started in quartz sand and were treated as above, except that a complete nutrient solution from which phosphorus and potassium were omitted, was used in place of the high nitrogen nutrient solution.

The plot which received nitrogen alone made a strong vegetative type of growth, However, the plot which received phosphorus and potassium as well as nitrogen, not only made as vigorous a vegetative type of growth as measured by stem height, but had broader, stalkier leaflets and stem. This growth response agrees with the results obtained by Loree in 1924 (23) and Wallace in 1924 (36). Although nitrogen is one of the most important elements in strawberry plant growth, phosphorus, when combined with it, appears to give an additional response.

Tables I. and II. give a summary of the growth responses of the plants under the different treatments in quartz sand.

TABLE I.

Summary of Growth Responses of Strawberry Plants Grown on Quartz Sand Under Varying Nutritional Conditions. 1924-1925

| TREATMENT | Average No. of Runners Formed by Plant | Average Stem Height of Leaves. | Average No. of Leaves Produced Per Plant. | Average No. of Crownd Developed Per Plant. |
|---|---|---|---|---|
| Complete nutrient Solution with high nitrogen content. | 4.65 | 8" | 35.45 | 2.50 |
| Complete Nutrient Solution. | 3.7 | 5.5" | 21.80 | 1.95 |
| Complete nutrient solution minus nitrogen. | 0 | 2" | 20.10 | 1.75 |
| Check. Tap Water Only. | 0 | 2" | 20.70 | 1.68 |

TABLE II

Summary of Growth Responses of Strawberry Plant Grown on Quartz Sand Under Varying Nutritional Conditions. 1925-1926.

| TREATMENT. | Average No. of Runners Formed by Plant (20 Plants) | Average Stem Height of Leaves. | Average No. of Leaves Produced Per Plant. | Average No. of Crowns Developed Per Plant. |
|---|---|---|---|---|
| Complete nutrient Solution with high nitrogen content. | 10.0 | 6" | 24.35 | 1.65 |
| Complete nutrient solution. | 4.20 | 4.2" | 23.62 | 1.55 |
| Complete nutrient solution minus nitrogen. | 0 | 2" | 20.44 | 1.55 |
| Check. Tap water only. | 0 | 2" | 17.55 | 1.51 |

The growth made by the plants which received an abundant supply of nutrients, particularly nitrogen, is readily seen in these tables, for the plants made more runners, grew taller, and broader leaves, and produced a greater number of them. There were slightly more crowns produced, but this was more apparent in 1924-1925 than in 1925-1926. This plot was in a very vegetative condition. The plot supplied with a complete nutrient solution made a less vigorous growth, but one which appeared normal in all respects. The leaves on both of the complete nutrient solution plots had a dark green, healthy color -- this color being retained until the time growth was checked.

The decided lack of vegetative growth made by the two plots receiving no nitrogen is shown in the lack of runner formation, the short weak stems, fewer leaves and fewer crowns formed. About three weeks after planting the first formed leaves on these plants turned a red or light yellow at the margin, this color spreading over the entire leaf in a short time, the leaf soon dying. Each new leaf formed, acted in a similar manner and these plots presented striking contrast to all times during the season, to the plots which had received nitrogen. Wallace (36) observed this same thing occurring on strawberry plants which were grown on silver sand without nitrogen.

Plates II. and III. show photographs of the individual plants grown under the different treatments,


PLATE II. Strawberry Plants After They Had Blossomed in the Spring of 1925, Showing Growth Made in Quartz Sand Plots in Greenhouse.

1. Complete nutrient solution with high nitrogen content.
2. Complete nutrient solution.
3. Complete nutrient solution minus nitrogen.
4. Check -- tap water only.

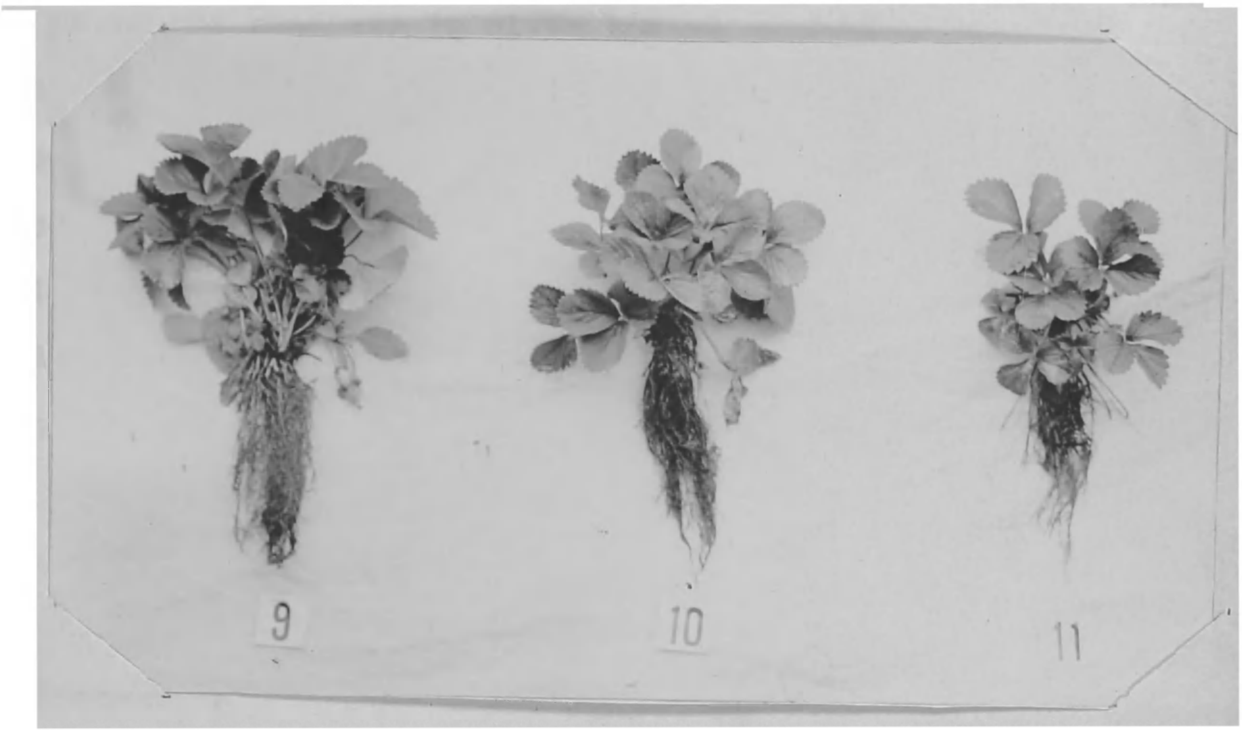


PLATE III. Strawberry Plants After They Had Blossomed in Spring of 1925 showing growth Made By Plants in River Bottom Sand Mixture.

9. Complete nutrient solution with high nitrogen content.

10. Complete nutrient solution.

11. Check -- tap water only.

both in quartz sand and in river bottom sand mixture. These pictures show clearly the differences in growth made by the plants in the different plots. Differences between the no nitrogen and nitrogen plots on river sand were similar to those on quartz sand, although hot as striking. The differences in high nitrogen and medium nitrogen plots are not brought out as clearly as shown in Tables I. and II.

Effect on Runner Formation: Table III. summing up the formation of runners on the quartz sand plots shows that only the plots which received nitrogen (3 and 4) produced runners. The high nitrogen plot (4) produced a greater number of runners, this formation extending over a longer growing period than the plants in the medium nitrogen plot (3). This indicates that the high nitrogen plants were making a very strong vegetative type of growth. Loree (23) has shown that this same relation holds true in light, sandy soil.

In his work, plants fertilized in the spring and again in the summer with a fertilizer containing nitrogen, potassium, and phosphorus, produced many more runners than those fertilized in the summer alone.

TABLE III.

Amount and Time of Runner Formation on Strawberry Plants Grown in Quartz Sand.*

| Date. | Complete Nutrient Solution With High Nitrogen Content. | | Complete Nutrient Solution. | | Complete Nutrient Solution Minus Nitrogen. | | Check. | |
|---|---|---|---|---|---|---|---|---|
| | 1924 | 1925 | 1924 | 1925 | 1924 | 1925 | 1924 | 1925 |
| May 3rd, | 18 | | 15 | | 2 | | 1 | |
| May 10th, | 15 | | 24 | | 0 | | 0 | |
| May 20th, | 18 | | 23 | | 0 | | 1 | |
| June 2nd, | | 28 | | 19 | | 1 | | 0 |
| June 4th, | 16 | | 8 | | 0 | | 0 | |
| June 10th, | | 26 | | 12 | | 0 | | 0 |
| June 20th, | 17 | 29 | 3 | 17 | 0 | 0 | 0 | 0 |
| July 2nd, | 9 | 29 | | 12 | | 0 | | 0 |
| July 15th, | | 27 | | 10 | | 0 | | 0 |
| July 25th, | | 29 | | 10 | | 0 | | 0 |
| August 3rd, | 0 | 16 | 1 | 4 | | 0 | | 0 |
| Sept. 1st, | | 10 | | 0 | | 0 | | 0 |
| Sept. 10th, | | 7 | | 0 | | 0 | | 0 |
| Sept. 25th, | | 0 | | 0 | | 0 | | 0 |

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Record of twenty plants.

<u>Effect on Fresh and Dry Weight of Plants:</u> The average fresh and dry weight of plants taken for sampling at the beginning and toward the end of the growing season is given in Table IV. In quartz sand both fresh and dry weight of the plants fertilized with a nutrient solution containing a high nitrogen content was greater than the remaining plots. The plants grown without a supply of nitrogen were two to three times smaller than the plants which received nitrogen. The plants receiving phosphorus and potassium were generally slightly larger than those receiving nothing except tap water, provided weight is used as a measure of size. These differences were more striking in 1925 than in 1924. When a complete nutrient solution was applied to the plants growing in the river sand, the plants made a stronger vegetative growth, and had a greater weight than those to which a complete nutrient solution with a high nitrogen content was added. There is no explanation of this decreased growth except that the nitrogen content may have become too high for best plant development.

(See next page for Table IV).

TABLE IV.

Average Weight of Strawberry Plants Grown Under Different Treatments.

| Treatment. | Quartz Sand. | | | | River Sand. | | | | Quartz Sand. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6-30-24 | | 9-24-24 | | 6-30-24 | | 9-24-24 | | 8-8-25 | | 9-26-25 | |
| | Fresh | Dry | Fresh | Dry | Fresh | Dry | Fresh | Dry | Fresh | Dry | Fresh | Dry |
| Complete Nutrient Solution With High Nitrogen Content. | 31.79 | 7.31 | 46.04 | 10.50 | 19.36 | 4.41 | 39.54 | 9.31 | 28.01 | 6.29 | 42.52 | 10.32 |
| Complete Nutrient Solution. | 26.93 | 6.03 | 39.81 | 10.91 | 21.68 | 5.50 | 46.63 | 11.80 | 21.71 | 5.31 | 35.28 | --- |
| Complete Nutrient Solution Minus Nitrogen | 23.36 | 6.45 | 27.28 | 6.80 | --- | --- | --- | --- | 17.10 | 4.46 | 14.41 | 3.48 |
| Check. | 19.16 | 5.25 | 21.14 | 5.08 | 20.07 | 5.40 | 32.67 | 9.45 | 11.20 | 3.40 | 14.50 | 3.90 |

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Effect on Top and Root Development: The root growth on the plants receiving a complete nutrient solution, either with or without an excess of nitrogen, was slow during the first part of the season, when the runners were produced; the amount of growth increasing after runner formation had stopped. (Tables V. and VI). The plants which did not receive nitrogen had, with one exception, a greater weight of root system formed during the first half of the season than the plants which received nitrogen. Where the supply of nitrogen was small the plants developed a very fine extensive root system and a small crown. The picture (Plate II) does not show the root system clearly because of the matted effect caused by washing the roots to remove the sand.

Schrader (30) found a definite relation between the chemical content of tomato cuttings and the kind and amount of regeneration of roots and tops on these cuttings. High carbohydrate content plus a relatively low supply of soluble nitrogen,favors regeneration of roots. Chemical analysis of the plants receiving no nitrogen (Table X) shows a relatively high carbohydrate content plus a relatively low supply of soluble nitrogen due to lack of nitrogen, and this resulted in relatively poor top growth. Tops suffer first from lack of nitrogen, a relatively heavy root system, and light, weak, top developing under these conditions. Increased nitrogen resulted in increased top growth as well as root growth.

TABLE V.

The Effect of Nutrients on Top and Root Development of Strawberry Plants in Quartz Sand.

| TREATMENT. | Average Dry Weight* on Tops and Roots. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6 - 30 - 24 | | | 8 - 15 - 24 | | | 9 - 24 - 24 | | |
| | Tops | Roots | Ratio of Tops to Roots. T/R | Tops | Roots | Ratio of Tops to Roots. T/R | Tops | Roots | Ratio of Tops to Roots. T/R |
| Complete Nutrient Solution With High Nitrogen Content. | 6.13 | 1.18 | 5.47 | 7.31 | 1.00 | 7.31 | 8.82 | 1.68 | 5.25 |
| Complete Nutrient Solution. | 4.87 | 1.15 | 4.23 | 7.88 | 1.64 | 4.80 | 8.91 | 1.99 | 4.47 |
| Complete Nutrient Solution Minus Nitrogen | 4.53 | 1.93 | 3.79 | 3.09 | 1.68 | 1.84 | 4.51 | 2.31 | 1.95 |
| Check. | 3.67 | 1.57 | 2.35 | 3.56 | 1.66 | 2.14 | 3.27 | 1.81 | 1.86 |

* Grams.

TABLE VI.

The Effect of Nutrients on Top and Root Development of Strawberry Plants in Quartz Sand.

| TREATMENT. | Average Dry Weight* of Tops and Roots. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 8 - 8 - 25 | | | 8 - 27 - 25 | | | 9 - 26 - 25 | | |
| | Tops | Roots | Ratio of Tops to Roots. T/R | Tops | Roots | Ratio of Tops to Roots. T/R | Tops | Roots | Ratio of Tops to Roots. T/R |
| Complete Nutrient Solution With High Nitrogen Content. | 5.07 | 1.21 | 4.18 | 6.96 | 1.65 | 4.21 | 8.68 | 1.64 | 5.29 |
| Complete Nutrient Solution. | 4.12 | 1.19 | 3.45 | 5.57 | 1.38 | 4.07 | ---- | 2.17 | ---- |
| Complete Nutrient Solution Minus Nitrogen. | 3.01 | 1.41 | 2.13 | 2.91 | 1.16 | 2.57 | 2.58 | 1.06 | 2.43 |
| Check. | 2.32 | 1.07 | 2.16 | 1.95 | 1.38 | 1.41 | 2.44 | 1.46 | 1.67 |

* Grams.

The top root ratio shows that in the plots receiving no nitrogen, the growth of tops with relation to the roots was much less than in the plants which received nitrogen. Loree (23) has shown this same thing occurring in his plants, although to a lesser degree than reported here.

<u>Effect on Fruit Bud Differentiation</u>: Under field conditions strawberry plants form fruit buds in the fall about September 20th. In order to determine the time fruit buds were formed, under the greenhouse conditions in our experiments, samples for sectioning were taken every week or ten days, beginning early in the season and continuing until after September 20th. These plants had started growth in the greenhouse during the early part of March, 1925. The plants were dug up, washed, leaves and roots carefully removed, and the crown cut down until a small section of the woody crown and leaf scales around the growing point remained. These samples were placed in fixing solution and run up into paraffin for sectioning by the usual paraffin method. In the samples taken during 1925, the initial stages of fruit bud differentiation occurred on all plots between August 3rd and August 13th, the development of the floral parts proceeding rapidly after the first stages of differentiation had occurred.

B. Chemical Composition of Strawberry Plant at Different Stages of its Growth.

1. Carbohydrate -- Nitrogen Relation at time of Fruit Bud Formation: The widespread use of nitrogenous fertilizers by strawberry growers and the work of investigators indicating that the relative proportions of carbohydrates and nitrogen in plants at certain stages of their growth bear an important relationship to fruit bud differentiation within the plants, lead to a study of the chemical composition of the plant throughout its growth, particularly at the time of fruit bud differentiation.

Kraus and Kraybill (22) found fruitfulness in the tomato plant correlated with a balance between nitrogenous and carbohydrate material in the plant. A large amount of either one of these materials in relation to the other was detrimental to floral initiation and development. Tables VII. and IX., and Fig. 1 show the relation of nitrogen and carbohydrate material in the tops of the plants on August 8th, 1925, a few days after fruit bud differentiation had begun. Table VIII. shows this relation on August 15th, 1924.

Relatively wide ranges of carbohydrate and both soluble and total nitrogen content of the tops were found under the different treatments. The relatively high soluble nitrogen in the plants making the vigorous growth (Plots 3 and 4), as compared to those plants making a weak type of growth (Plots 1 and 2) is interesting. (Fig. 1). The plants receiving a complete nutrient solution plus

TABLE VII.

Showing Total Carbohydrate, Starch, and Nitrogen Relation in Top of Strawberry Plant at Time of Fruit Bud Formation. Growing in Quartz Sand, August 8th, 1925.

| | Treatment | Dry Weight of Tops Per Plant. (Grams) | Total Nitrogen. | | Starch | | Starch Nitrogen Ratio S/N | Total Carbohydrate | | C/N | Average No. Blossom Clusters Per Plant. | Average No. Blossoms Per Cluster | Average No. Blossoms Per Plant. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per-Cent. | Mgms. Per Plant. | Per-Cent. | Mgms. Per Plant | | Per-Cent. | Mgms. Per Plant | | | | |
| 4. | Complete Nutrient Solution Plus Additional Nitrogen. | 5.07 | 2.04 | 103 | 6.94 | 352 | 3.41 | 21.14 | 1071 | 10.39 | 2.03 | 2.80 | 5.68 |
| 3. | Complete Nutrient Solution. | 4.12 | 1.46 | 60 | 11.52 | 474 | 7.90 | 27.59 | 1136 | 18.93 | 3.50 | 4.90 | 17.15 |
| 2. | Complete Nutrient Solution Minus Nitrogen. | 3.01 | 1.068 | 32 | 14,34 | 431 | 13.46 | 25.61 | 770 | 24.06 | 1.45 | 3.40 | 5.85 |
| 1. | Check. | 2.32 | 0.887 | 21 | 20.02 | 464 | 22.09 | 28.26 | 656 | 31.23 | 1.07 | 3.30 | 3.52 |

TABLE VIII

Showing Total Carbohydrates, Starch, and Nitrogen Relation in Top of Strawberry Plants.

Growing in Quartz Sand, August 15th, 1924.

| TREATMENTS | Dry Weight of Tops Per Plant (Grams) | Total Nitrogen | | Starch | | Starch Nitrogen Ratio S/N | Total Carbohydrate | | C/N | Average No. Blossom Clusters Per Plant. | Average No. Blossoms Per Cluster | Average No. Blossoms Per Plant. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Per-Cent. | Mgms. Per Plant | Per-Cent. | Mgms. Per Plant | | Per-Cent | Mgms Per Plant | | | | |
| 4. Complete Nutrient Solution Plus Additional Nitrogen. | 7.31 | 1.305 | 95 | 7.13 | 521 | 5.48 | 26.40 | 1930 | 20.31 | 1.01 | 4.17 | 4.21 |
| 3. Complete Nutrient Solution | 7.88 | 0.852 | 67 | 7.60 | 699 | 10.43 | 26.80 | 2112 | 31.52 | 2.80 | 4.43 | 12.40 |
| 2. Complete Nutrient Solution Minus Nitrogen | 2.06 | 0.973 | 20 | 13.32 | 274 | 13.70 | 25.47 | 525 | 26.25 | 1.45 | 3.80 | 5.57 |
| 1. Check | 2.37 | 1.033 | 24 | 15.22 | 361 | 15.04 | 27.28 | 647 | 26.95 | 1.22 | 3.33 | 4.06 |

## TABLE IX

Chemical Changes in Strawberry Plants Grown in Quartz Sand and Treated With Different Nutrient Solutions. (1925)

| DATE OF SAMPLE. | | Moisture | | Dry Matter. | | Free Reducing Substances. | | Sucrose | | Total Sugars. | | Starch | | Acid Hydrolyzable Substances. | | Total Carbohydrates. | | Soluble Nitrogen. | | Total Nitrogen. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots |
| August 8th, 1925. | ++ N* | 77.20 | 78.85 | 22.80 | 21.15 | 2.72 | 1.49 | 1.65 | 0.93 | 4.37 | 2.42 | 6.94 | 3.26 | 16.77 | 18.78 | 21.14 | 21.20 | 0.243 | 0.235 | 2.04 | 1.233 |
| | + N | 74.21 | 79.19 | 25.79 | 20.81 | 2.60 | 1.89 | 1.77 | 0.61 | 4.37 | 2.50 | 11.52 | 4.60 | 23.22 | 18.84 | 27.59 | 21.34 | 0.110 | 0.138 | 1.46 | 1.099 |
| | -N | 71.10 | 77.99 | 28.90 | 22.01 | 2.47 | 1.73 | 1.42 | 0.19 | 4.89 | 1.92 | 14.34 | 5.29 | 20.72 | 23.73 | 25.61 | 25.65 | 0.047 | 0.079 | 1.068 | 0.802 |
| | Check | 67.30 | 73.65 | 36.70 | 26.35 | 2.59 | 1.49 | 1.79 | 0.68 | 4.38 | 2.17 | 20.02 | 6.93 | 23.88 | 20.65 | 28.26 | 22.82 | 0.009 | 0.048 | 0.897 | 0.823 |
| August 27th, 1925. | ++N | 75.50 | 78.85 | 24.50 | 21.15 | 3.87 | 1.29 | 1.98 | 0.90 | 5.85 | 2.19 | 6.81 | 4.27 | 17.07 | 18.67 | 22.92 | 20.86 | 0.332 | 0.192 | 1.930 | 1.446 |
| | +N | 72.60 | 83.21 | 27.40 | 16.79 | 3.96 | 1.37 | 1.86 | 0.83 | 5.82 | 2.20 | 10.06 | 3.60 | 17.02 | 15.18 | 22.84 | 17.38 | 0.198 | 0.151 | 1.614 | 1.298 |
| | -N | 69.92 | 77.30 | 30.08 | 22.70 | 3.93 | 1.72 | 2.19 | 0.87 | 6.12 | 2.59 | 12.07 | 5.33 | 20.14 | 20.25 | 26.26 | 22.84 | 0.119 | 0.095 | 1.062 | 0.812 |
| | Check | 68.71 | 77.55 | 31.29 | 22.45 | 2.14 | 1.29 | 3.21 | 0.57 | 5.35 | 1.86 | 12.87 | 5.00 | 21.11 | 19.84 | 26.46 | 21.70 | 0.103 | 0.098 | 0.995 | 1.023 |
| September 26th, 1925. | ++N | 74.95 | 79.50 | 25.05 | 20.50 | 4.08 | 1.64 | 2.86 | 0.84 | 6.94 | 2.48 | 9.05 | 5.21 | 17.61 | 19.80 | 24.55 | 22.28 | 0.207 | 0.168 | 1.722 | 1.329 |
| | +N | --- | 78.65 | --- | 21.35 | --- | 1.99 | --- | 0.37 | --- | 2.36 | --- | 5.86 | --- | 19.54 | --- | 21.90 | --- | 0.087 | --- | 1.044 |
| | -N | 71.55 | 79.20 | 28.45 | 20.80 | 3.06 | 1.54 | 2.51 | 0.26 | 5.57 | 1.80 | 11.81 | 6.30 | 21.37 | 19.16 | 26.94 | 20.96 | 0.165 | 0.138 | 1.222 | 0.931 |
| | Check | 70.45 | 78.52 | 29.55 | 21.48 | 2.87 | 1.41 | 2.01 | 0.89 | 4.88 | 2.30 | 13.06 | 7.36 | 23.32 | 19.70 | 28.20 | 22.00 | 0.142 | 0.143 | 0.987 | 0.727 |

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*++ N = Complete nutrient solution with high nitrogen content.
+ N = Complete nutrient solution.
- N - Complete nutrient solution minus nitrogen.

**Fig. I.** Showing Relative Percentage of Starch, Total and Soluble Nitrogen in the Tops of Strawberry Plants at Different Dates Throughout the Growing Season. (Quartz Sand Plots).

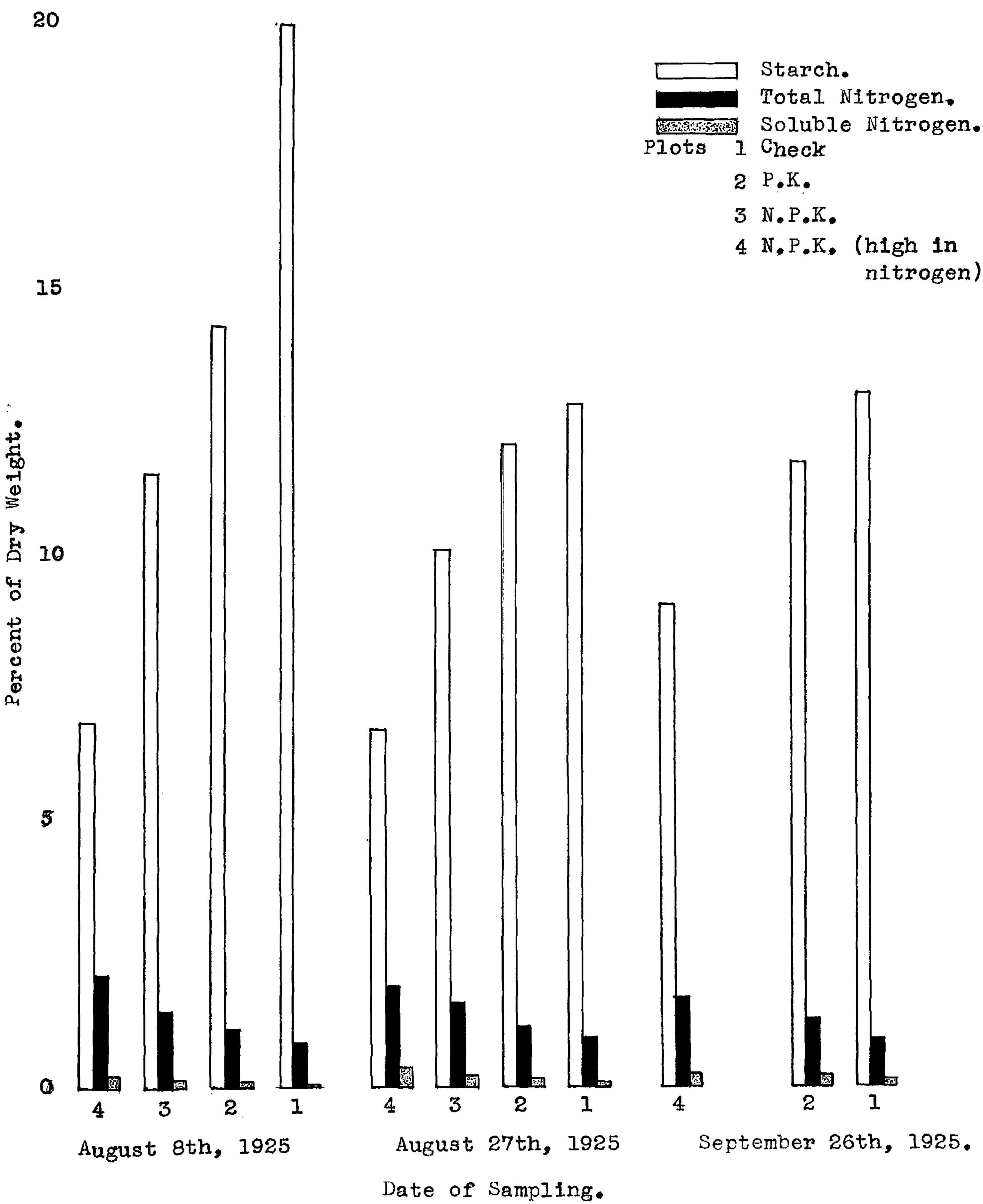


TABLE X.

Chemical Changes In Strawberry Plants Grown In Quartz Sand and Treated With Different Nutrient Solutions, (1924).

| DATE OF SAMPLE. | | Moisture. | | Dry Matter. | | Free Reducing Substances. | | Sucrose. | | Total Sugars. | | Starch. | | Acid Hydrolyzable Substance. | | Total Carbohydrates. | | Soluble Nitrogen. | | Total Nitrogen | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots | Top | Roots |
| June 30th, 1924. | + + N* | 77.10 | 77.50 | 22.90 | 22.50 | 2.97 | 1.15 | 1.96 | 0.61 | 4.93 | 1.76 | 4.18 | 3.55 | 27.7 | 17.94 | 36.41 | 19.70 | 0.325 | --- | 2.167 | 1.649 |
| | + N | 75.65 | 83.10 | 24.35 | 16.90 | 4.13 | 1.83 | 0.70 | 0.26 | 4.83 | 2.09 | 6.21 | 9.37 | 20.0 | 20.92 | 24.83 | 23.01 | 0.192 | .141 | 1.305 | 1.148 |
| | - N | 69.45 | 77.71 | 30.55 | 22.29 | 3.58 | 2.09 | 1.17 | 0.84 | 4.75 | 2.93 | 15.42 | 13.81 | 20.2 | 30.65 | 24.95 | 33.58 | 0.173 | --- | 0.887 | 0.724 |
| | Check | 68.98 | 78.50 | 31.02 | 21.50 | 3.72 | 2.03 | 0.65 | 0.76 | 4.37 | 2.79 | 11.93 | 18.56 | 18.2 | 29.80 | 22.57 | 32.59 | 0.126 | .087 | 0.820 | 0.807 |
| August 15th, 1924. | + + N | 77.70 | 79.90 | 22.30 | 20.10 | 3.61 | 1.32 | 0.79 | 0.05 | 4.40 | 1.37 | 7.13 | 7.38 | 22.0 | 26.60 | 26.40 | 27.97 | 0.262 | .847 | 1.305 | 2.674 |
| | + N | 73.42 | 80.10 | 26.58 | 19.90 | 3.46 | 1.24 | 0.80 | 0.74 | 4.26 | 1.98 | 7.60 | 10.80 | 22.6 | 31.90 | 26.80 | 33.88 | 0.162 | .603 | 0.852 | 1.876 |
| | - N | 69.90 | 80.30 | 30.10 | 19.70 | 2.15 | 1.27 | 0.52 | 0.35 | 2.67 | 1.62 | 13.32 | 16.60 | 22.8 | 24.05 | 25.47 | 25.67 | 0.102 | .512 | 0.973 | 1.162 |
| | Check | 69.35 | 79.95 | 30.65 | 20.05 | 2.42 | 1.02 | 0.86 | 0.33 | 3.28 | 1.35 | 15.22 | 14.85 | 24.0 | 20.28 | 27.28 | 21.63 | 0.124 | .568 | 1.033 | 1.322 |
| September 24th, 1924. | + + N | 76.65 | 79.00 | 23.35 | 21.00 | 4.35 | 1.48 | 3.38 | 0.83 | 7.73 | 2.31 | 6.83 | 11.98 | 24.5 | 24.20 | 32.23 | 26.51 | 0.251 | --- | 1.705 | 1.419 |
| | + N | 69.95 | 80.70 | 30.05 | 19.30 | 4.41 | 1.50 | 2.34 | 0.33 | 6.75 | 1.83 | 12.37 | 17.82 | 27.1 | 29.58 | 33.85 | 31.41 | 0.217 | --- | 1.657 | 1.107 |
| | - N | 72.70 | 78.39 | 27.30 | 21.61 | 3.93 | 1.14 | 1.29 | 0.74 | 5.22 | 1.88 | 10.00 | 25.98 | 30.3 | 34.61 | 36.52 | 36.49 | 0.182 | --- | 1.130 | 0.879 |
| | Check | 71.30 | 80.71 | 28.70 | 19.29 | 3.73 | 1.89 | 2.94 | 0.53 | 6.67 | 2.42 | 12.92 | 11.15 | 30.3 | 28.61 | 36.97 | 31.03 | 0.117 | --- | 0.944 | 0.617 |

* + + N = Complete nutrient solution with high nitrogen content.
+ N = Complete nutrient solution.
- N = Complete nutrient solution minus nitrogen.

additional nitrogen had a relatively high nitrogen and low carbohydrate content at all dates sampled, particularly so if we consider starch alone, rather than the total carbohydrate content. The plants receiving complete nutrient solution without additional nitrogen made a good growth, but as we have noted before, were not as vegetative as the plants on the high nitrogen plot. Analysis of the plants receiving a complete nutrient solution with a moderate amount of nitrogen showed a smaller amount of nitrogen and a larger amount of carbohydrates present, than in the plants receiving high nitrogen nutrient solution.

A comparison of the clusters and blossoms formed by the plants in these two plots shows that a larger number of flower clusters, and a larger number of blossoms per cluster formed on the plants receiving a moderate supply of nitrogen. Apparently the plants on the complete nutrient solution plot had a more balanced relation existing between the carbohyate and nitrogen supply at the time of fruit bud differentiation.

Plot 2. which received a complete nutrient solution without nitrogen, and Plot 1. which had tap water only, had. a comparatively low nitrogen and high carbohydrate content. Comparing these two plots with plot 3, which received a complete nutrient solution, we find that the wide range between nitrogen and carbohydrate in the plants of Plots 1. and 2. has resulted in a restriction of floral initiation and development.

Summarization of these results shows that fruitfulness in the strawberry plant is correlated with a balance between nitrogenous and carbohydrate materials in the plant at the time of fruit bud differentiation.

A weak vegetative type of growth, and a reduction in the number of blossoms formed were associated with a comparatively high carbohydrate and low nitrogen content in the plants grown in the no nitrogen plots.

A strong vegetative type of growth and a reduction in the number of blossoms formed were associated with a comparatively low carbohydrate and high nitrogen content in the plants grown in the high nitrogen plots.

On the moderately nitrated plots a vegetative type of growth intermediate between that made by the plants on the high and no nitrogen plots was associated with a carbohydrate and nitrogen content intermediate between that of the high and no nitrogen plots. Likewise an increase in blossom formation on the moderately nitrated plot was associated with a carbohydrate and nitrogen content intermediate between that of the high and no nitrogen plots.

It is interesting to note that flower bud formation occurred under all treatments, the initiation and development being restricted rather than entirely prevented. Nitrogen may be a limiting factor in fruit bud formation on soils which are very low in fertility. Loree (23) found this true with the Senator Dunlap strawberry growing on a light sand.

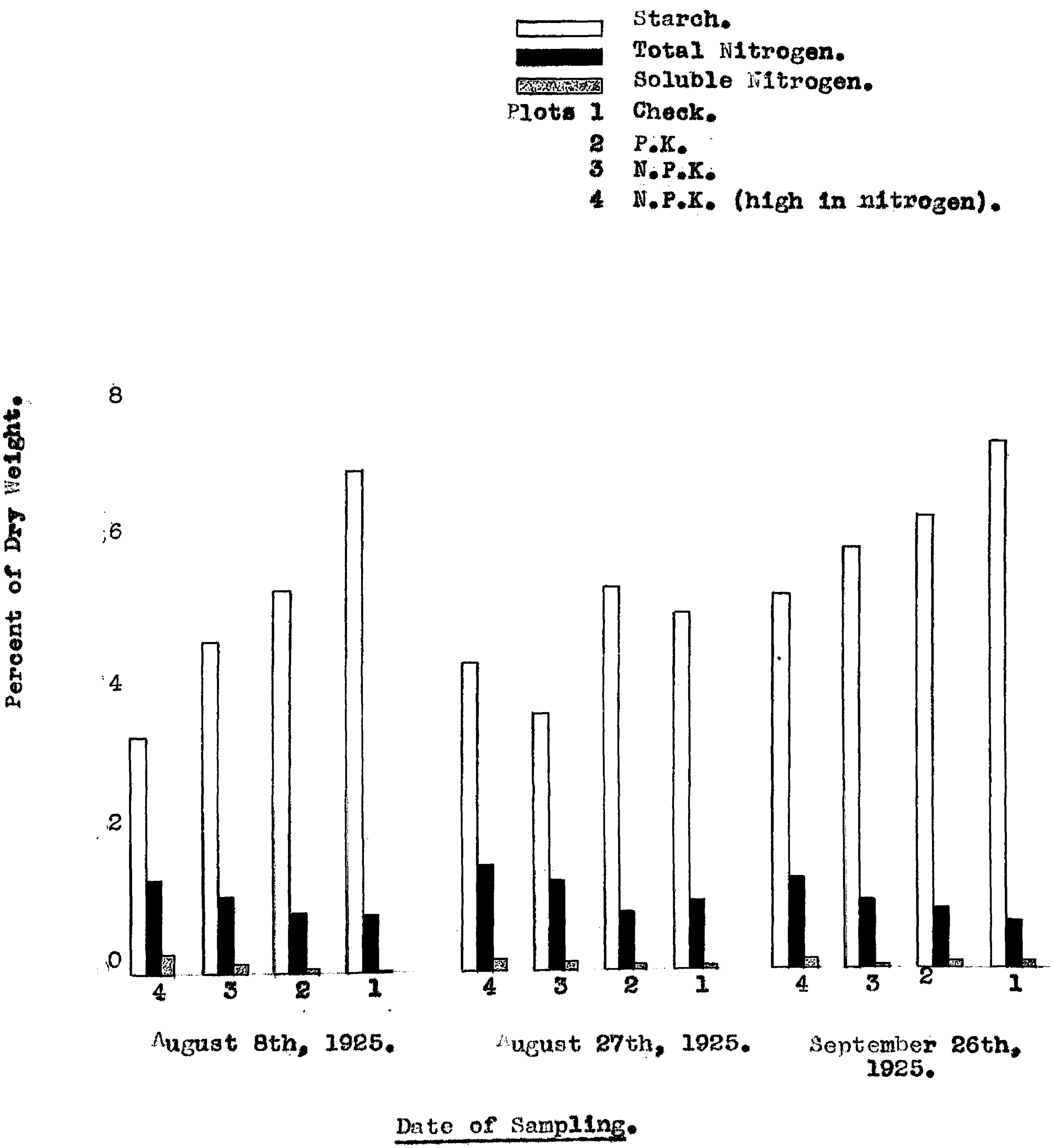
2. <u>Chemical Composition of Strawberry Plant on Different Date of Sampling:</u> On all dates of sampling wide differences in starch and nitrogen content in the tops of these different plots are shown. (Fig I). The relatively high nitrogen nitrogen and low starch content of plots 3 and 4, which received nitrogenous nutrients and the low nitrogen and high starch content of those not receiving nitrogen (plots 1 and 2) is clearly shown.

It is interesting to note that plots 3 and 4, which had the largest runner formation, also showed a relatively high nitrogen and low carbohydrate content. A similar relationship was found between the carbohydrate and nitrogen content of the roots. (Fig. II).

A summary of the chemical analysis of plants grown under similar conditions in 1924 (Table X.) shows that these same relationships held true in both the tops and the roots on the dates the samples were taken for analysis.

In the period after August 27th, the percentage of starch in the tops increased in the plot which had made a large top growth and consequent leaf surface, and did not increase

**Fig. II.** Showing Relative Percentage of Starch, Total and Soluble Nitrogen in the Roots of Strawberry Plants at Different Dates Throughout the Growing Season. (Quartz Sand Plots).



in those plots which received no nitrogen and made a weak growth of tops. (Fig. I.) The starch content of the roots increases and the nitrogen content decreases slightly after August 27th, (Fig. II). This is particularly true of plots 3 and 4 which made a vigorous top growth. This change may be associated with the active root growth which occurs according to Mann and Ball (27) in the late summer and autumn. They have found, that in the field, the root system grows very little in the spring -- a vigorous shoot growth usually preceding root growth. If this translocation of starch from top to roots is associated with active root growth at this period, then the plants with the largest leaf surface are enabled to supply the roots and at the same time increase the percentage of starch in the tops, whereas the plants with small leaf surface cannot supply starch for both root and top and as a result do not show an increase in percentage of starch in the top. (Fig. I).

A study was made of the acid hydrolyzable substances, free reducing, sucrose, and total sugars present in the plants throughout the season. (Tables IX. and X.) In general a slightly higher percentage of reducing sugars was found throughout the season in the tops of those plants which were making a vigorous vegetative type of growth. This held true in both 1924 and 1925. Reducing sugar content of the roots varied in no consistent manner. The percentage of sucrose and total sugar was changeable throughout the season in both tops and roots, but varied in no consistent manner.

The percentage of acid hydrolyzable substances was slightly variable until the last part of the season during which period it increased in those plants which received no nitrogen and were making a weak, vegetative type of growth.

C. Field Studies.

The review of experimental results obtained in various parts of the United States as results of field trials shows apparent benefit from nitrogen in some soils, from phosphorus in others, and from combination of both of these elements in others. Reports from strawberry growers in various parts of the country showed wide difference of opinion as to the kind, amount, and season to apply fertilizers to the strawberry plant. Results secured in quartz sand under greenhouse conditions showed that of the three elements: nitrogen, phosphorus, and potassium, nitrogen was apt to be the most important limiting factor in soils very low in these elements. Apparently strawberry growers in Maryland are using various combinations of commercial fertilizers, and applying them at different seasons of the year, without being certain as to the benefit, if any, derived from such applications.

## Location and Outline of Field Experiment:

A leading strawberry grower in Salisbury, one at Marion Station, and one at Ridgely, all situated in the heart of our strawberry growing areas, agreed to cooperate with us in conducting field trials. One of the limiting factors in strawberry growing in Maryland is, without doubt, the lack of control of weeds, and the resultant loss of moisture. Field experiments must be carried on in cooperation with growers who give their patches the best of care and attention. An example is the field of Mr. P. L. Gunby of Marion Station, where plots were selected from level, uniform land, on which plants were making a steady, uniform growth. (Plate. IV).

Experiments were started in the spring of 1926 which included the following features on the Missionary and Howard 17 (Premier) strawberries.

A. Application of fertilizers in the spring of the year just before planting strawberry plants in order to study the effect on plant growth, fruit bud formation, size and yield of fruit of:

   1. Varying the amounts of nitrate of soda applied with a constant amount of superphosphate (acid phosphate).
   2. Varying the amounts of superphosphate applied with a constant amount of nitrate of soda.
   3. Varying the carrier of nitrogen.
   4. Adding potash to nitrogen and phosphorus.

B. Application of fertilizer in the late summer to study its effect on fruit bud formation.

C. Application of fertilizers in the spring of the fruiting

PLATE IV. Missionary Strawberries After One Year of Growth. P. L. Gunby's, Marion Station, June, 1926.

year to one and two year old strawberry beds, to study effect on growth, blossoming, size, and yield of fruit.

D. Application of lime at time of planting to study effect of decreasing soil acidity on growth and yield of plant.

Application in Spring Before Planting: Table XII. shows an outline of the fertilizers applied to the strawberry bed just before the plants were set. The plots consisted of two matted rows, one-hundred and fifty feet long, making 1/39 acre plots. The plots were duplicated in such a manner that variation in soil might be observed, and considered in interpretation of results. Six checks were scattered over the experiment. On March 15th, when the ground had been prepared for planting, a furrow was plowed out with a potato planter and the fertilizer applied evenly along the bottom of the furrow. The furrow was then covered, using the planter with the plow blade removed, small discs on each side of the furrow pushing the soil into the furrow and above it in the shape of a mound, about six inches above the surface. A plank drag levels this mound to within a few inches of the field level, so that after the plant had been set, the roots were still about four inches above the mixture of fertilizer and soil.

Effect of Different Fertilizers on the Formation of Runners and New Plants: All plots started growth at the same time, some plots having a slightly better stand than others when examined on June 10th. Table XI. records the count of the stand of plants, number of runners and new plants formed by plants in each plot.

Plants fertilized with fertilizer mixtures containing sodium nitrate always produced more runners over eleven inches long, the ends of which had taken root by June 10th than did similar mixtures containing ammonium sulphate as a nitrogen carrier. This indicates that the kind of nitrogen carrier, as well as the time it is applied, must be taken into consideration for each variety of strawberry. A variety such as Missionary, which has been used here, and which produces runners freely, will be stimulated to an overproduction of runners and plants. The majority of the plants formed during the early part of the season expend their energy in developing runners, at the expense of their own development. This results in a crowded bed of plants, each one of which suffers if the soil moisture supply becomes low. If fertilized at all at this time, a fertilizer in which the nitrogen is only slowly available would be better. On the other hand a variety such as Chesapeake, which forms runners very slowly, might be stimulated into forming an increased number of runners and plants during the first half of the season by using a nitrogen fertilizer which is quickly available in the spring. Growers of strawberries for the plants and not for the fruit would be interested in using the more

## TABLE XI

**Runners Formed on Missionary Strawberry Plants, June 10th, 1926.**

**Fertilizer Applied March 17th, 1926, Before Planting.**

| Treatment. | No. of Plants in Plot. | No. of Runners Over 11" in Length With New Plants Upon Them. | | No. of Runners 3" to 10" in Length Without Plants Upon Them. | | Total No. of Runners Per Plant. |
|---|---|---|---|---|---|---|
| N-P-K | | Total | Average Per Plant. | Total | Average Per Plant. | |
| 2-8-0 | 140 | 278 | 1.99 | 18 | .128 | 2.02 |
| 2-8-0 | 134 | 267 | 1.99 | 9 | .090 | 2.08 |
| 2-8-0 | 145 | 209 | 1.44 | 22 | .151 | 1.59 |
| 2-8-0 | 146 | 152 | 1.03 | 14 | .136 | 1.17 |
| 4-8-0 Na $NO_3$ | 144 | 321 | 2.23 | 30 | .240 | 2.47 |
| 4-8-0 Na $NO_3$ | 150 | 287 | 1.91 | 17 | .113 | 2.02 |
| 4-8-0 and Lime | 134 | 141 | 1.05 | 13 | .097 | 1.15 |
| 4-8-0 and Lime | 136 | 129 | 0.95 | 33 | .243 | 1.19 |
| 4-8-0 $(NH_4)_2SO_4$ | 138 | 94 | 0.68 | 17 | .123 | 0.80 |
| 4-8-0 $(NH_4)_2SO_4$ | 134 | 116 | 0.87 | 25 | .178 | 1.05 |
| [illegible] Na $NO_3$ | [illegible] | 201 | 1.45 | 19 | .127 | 1.59 |
| 4-8-8 Na $NO_3$ | 137 | 211 | 1.54 | 30 | .219 | 1.76 |
| 4-12-0 Na $NO_3$ | 138 | 252 | 1.82 | 33 | .239 | 2.06 |
| 4-12-0 Na $NO_3$ | 138 | 226 | 1.77 | 21 | .152 | 1.92 |
| 6-8-0 Na $NO_3$ | 141 | 219 | 1.55 | 21 | .149 | 1.70 |
| 0-8-4 | 137 | 283 | 2.06 | 19 | .139 | 2.20 |
| 0-8-4 | 140 | 219 | 1.56 | 15 | .107 | 1.67 |
| 3-9-0 Diss.Bone | 140 | 226 | 1.62 | 25 | .178 | 1.80 |
| 3-9-0 Diss.Bone | 129 | 157 | 1.22 | 19 | .118 | 1.34 |
| 4½ - 48 Bone Meal | 133 | 123 | 0.93 | 13 | .098 | 1.03 |
| 4½-48 Bone Meal | 132 | 178 | 1.36 | 19 | .145 | 1.51 |
| 3-4/5 - 40 -7½ | 149 | 205 | 1.37 | 24 | .162 | 1.53 |
| 3-4/5 -40 - 7½ | 145 | 154 | 1.06 | 25 | .172 | 1.23 |
| Check | 154 | 121 | 0.79 | 46 | .299 | 1.09 |
| Check | 150 | 89 | 0.58 | 24 | .160 | 0.74 |
| Check | 140 | 120 | 0.86 | 12 | .086 | 0.95 |
| Check | 139 | 59 | 0.43 | 18 | .302 | 0.73 |
| Check | 140 | 76 | 0.54 | 16 | .210 | 0.75 |
| Check | 133 | 149 | 1.12 | 22 | .147 | 1.27 |

TABLE XII.

Effect of Fertilizing in Spring of 1926 at Time of Planting and Again in Spring of 1927 Just Before Fruiting. Arrangement of Plots and Yields From Each. Spring 1927.

| Missionary at P. L. Gunby's, Marion Station, Maryland. | | | | | | | | Premier. Ridgely, Maryland. | |
|---|---|---|---|---|---|---|---|---|---|
| Series A. Treatment. | | Series B. Treatment. | | Series A. Yields (1) Spg. 1927 (Qts.) | | Series B. Yields. Spg. 1927. (Qts.) | | Series B. Yields Spg. 1927. | |
| Spring | Summer | Spring | Summer | Topdressed 7-0-0 | Not Top-Dressed. | Topdressed 7-0-0 | Not Top-Dressed | Topdressed 7-0-0 | Not Top-Dressed. |
| N. P. K. Check. | | 2-8-0 | 2-0-0 | 48.1 | 47.8 | 46.0 | 38.6 | 44.0 | 33.0 |
| 4*-8 - 0 | | | 4-8-0 | 40.0 | 41.9 | 38.4 | 37.8 | 57.0 | 40.0 |
| 4 - 8 - 0 | | 3-9-0 Diss.Bone | | 46.0 | 46.2 | 44.9 | 47.0 | 54.0 | 41.0 |
| 4 - 8 - 8 | | Check | | 33.4 | 50.0 | 35.0 | 35.3 | 50.0 | 43.0 |
| 6 - 8 - 0 | | 4-12-0 | | 39.5 | 38.1 | 39.7 | 37.8 | 41.0 | 42.0 |
| 4 - 8 - 0 (Lime) | | 4-1/2-48 Bone Meal | | 32.5 | 31.5 | 25.5 | 34.5 | 54.0 | 59.0 |
| Check | | 0-8-4 | | 46.9 | 41.8 | 43.1 | 54.9 | 58.0 | 60.0 |
| - - - | 4-8-0 | 2-8-0 | | 38.7 | 51.7 | 43.7 | 38.8 | 55.0 | 56.0 |
| 2 - 8 - 0 | 2-8-0 | 4-8-0 (Lime) | | 41.9 | 52.0 | 36.5 | 27.6 | 60.0 | 53.0 |
| 2 - 8 - 0 | | Check | | 42.4 | 46.1 | 28.1 | 48.0 | 54.0 | 42.0 |
| 0 - 8 - 4 | | 6-8-0 | | 49.2 | 58.6 | 37.4 | 53.3 | 53.0 | 56.0 |
| 4-1/2-48 Bone Meal | | Check | | 34.8 | 43.0 | 25.6 | 49.2 | 54.0 | 45.0 |
| 4 -12 - 0 | | 4-8-8 | | 43.3 | 46.0 | 42.2 | 46.8 | 73.0 | 55.0 |
| 3 - 9 - 0 Diss.Bone | | 4-8-0 | | 43.9 | 43.4 | 40.0 | 58.8 | 65.0 | 72.0 |
| Check | | 4*-8-0 | | 41.0 | 45.0 | 27.2 | 51.1 | 64.0 | 65.0 |
| 12.7 | | | | | | | | | |
| 2 - 8 - 0 | 2-8-0 | 4-8-0 (Lime) | | 41.9 | 52.0 | 36.5 | 27.6 | 60.0 | 53.0 |
| 2 - 8 - 0 | | Check | | 42.4 | 46.1 | 28.1 | 48.0 | 54.0 | 42.0 |
| 0 - 8 - 4 | | 6-8-0 | | 49.2 | 58.6 | 37.4 | 53.3 | 53.0 | 56.0 |
| 4-1/2-48 Bone Meal | | Check | | 34.8 | 43.0 | 25.6 | 49.2 | 54.0 | 45.0 |
| 4 -12 - 0 | | 4-8-8 | | 43.3 | 46.0 | 42.2 | 46.8 | 73.0 | 55.0 |
| 3 - 9 - 0 Diss.Bone | | 4-8-0 | | 43.9 | 43.4 | 40.0 | 58.8 | 65.0 | 72.0 |
| Check | | 4*-8-0 | | 41.0 | 45.0 | 27.2 | 51.1 | 64.0 | 65.0 |
| 3-4/5-18-7 Bone Meal | | | | 34.8 | 34.1 | 35.6 | 52.5 | | |
| and Potash. | | | | 45.0 | 50.0 | 45.4 | 48.2 | | |

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* $(NH_4)_2 SO_4$

(1) = 1/77.4 acre plots.

available form of nitrogen early enough to stimulate runner formation with accompanying plant production.

Macoun (25) found a decided correlation between the date the stolon of a strawberry plant took root and the ultimate number of fruits it produced. The best yields came from those stolons taking root in the middle of August under his condition in Canada. He says that the formation of stolons by the earlier formed plants, even though depleting them of energy, are necessary for a good stand of plants.

Loree (23) found that the Senator Dunlap variety was stimulated to a heavier runner production by application of nitrogen in the spring, than when the same amount was applied in the summer, and that summer applications increased development of plants, but did not stimulate runner production.

Effect of Lime on Runner and Plant Formation: The soils of Marion Station are very strongly acid. A lime test was made which showed a requirement of five-thousand pounds of raw ground limestone to the acre to correct this acidity. Raw ground limestone at the rate of five-thousand pounds per acre was applied to plots which received lime to correct this acidity. It can be seen that when the acidity of these plots was corrected, a lower average number of runners over eleven inches were produced per plant. Many growers have found that heavy liming of fields hinders the growth of strawberry plants.

Wright (42) has shown that lime when applied to strawberries in New York prevented the formation of runners. On the other hand Hartwell and Damon (17) in Rhode Island, seemed to find slightly beneficial results on growth from use of lime. Morris and Crist (28) have shown that strawberry plants grew satisfactory within a pH range of 5.0 to 7.0.

Effect of Fertilizers on the Number of Blossom Clusters Formed and the Number of Blossoms Per Cluster: In the spring of the fruiting year the number of clusters formed and the number of blossoms on each cluster were counted in order to determine whether, under field conditions, the formation of blossoms was a limiting factor in the yield of strawberries from the various fertilizer plots. Thirty plants of a uniform size were selected on each plot and counts made. No significant differences were found between the plots, all plants producing from two to three clusters, occasionally only one. The same thing was true of blossoming, the number of blossoms running from four to fifteen per cluster. There was no correlation between the number of clusters formed per plant and the number of blossoms produced by these clusters, the plants having three clusters, producing the highest number of blossoms on some of the clusters. The number of blossoms on the cluster usually ran high when only one cluster was produced. This condition was found on strawberries growing on the lighter soils near Salisbury, as well as the heavier soils around Marion Station. The soil upon which the strawberries at Marion grew was a heavy loam about seven to eight inches deep, underlaid with a yellow clay subsoil. Previously this ground had been in berries from the spring of 1923 until June of 1925. A crop of cow peas was then sown, plowed under on September 1st, and followed by a crop of rye. This in turn being plowed under in the spring of 1926 before setting. Apparently nitrogen may be a limiting factor in fruit bud production on plants growing in the lighter, sandy soils, very deficient in plant food, but in these heavier soils of fair fertility, in which the organic matter is replenished, and in which various crops, other than strawberries are grown, and to which commercial fertilizers are added, the soil is in a good state of fertility, and nitrogen is not a limiting factor in blossom production.

Effect of Applications of Fertilizers Before Planting on Yield of Strawberries the Following Spring: In all plots the stand of plants was carefully examined before picking began and the percentage stand of each plot calculated so that yields could be recalculated to a comparative basis. In the majority of the plots the stand was excellent.

The yields of the plots located at Marion and at Ridgely are given in Table XII. under the "not topdressed" column. The coefficient of variability of the six check plots scattered over the entire Missionary strawberry test is 11 percent of the mean which is comparatively small.

The yields from all plots in these fertilizer tests were good. The results show that when strawberries are grown on land, which through intelligent soil treatment, has been worked up to a high state of fertility, the application of fertilizer at planting time does not give increased yields, the following spring. These tests unfortunately do not indicate the amount and kind of fertilizer which might be needed under poor soil and poor soil management conditions.

The Effect of Lime on Yields: The effect of lime on the growth of the strawberry plants was discussed earlier in this paper.

Table XIII. shows that in all cases where raw ground limestone was added to satisfy the lime requirement of these soils, a decrease in yields from these plots resulted. These results indicate that on good strawberry soils on the Eastern Shore of Maryland, the application of lime, enough to satisfy the lime requirement, is detrimental to the yields of berries from these soils.

It is possible though that on some of the very acid soils a light application of lime, which would not entirely correct the acidity, would be beneficial. In fact some beneficial results have been secured by certain growers in Somerset and Marion counties from the judicial use of lime.

Wright (42) found that lime applied in varying amounts was detrimental in all cases tried to the yield of strawberries in New York.

TABLE XIII

Showing the Effect of Applying Lime to Strawberries at Planting Time in the Spring of 1926 on Their Yield the Spring of 1927.

| Treatment in Spring 1926 at Planting Time. | Location. | No Topdressing Spring, 1927. | | Topdressed 7-0-0 Spring, 1927. | |
|---|---|---|---|---|---|
| | | Lime | No Lime | Lime | No Lime |
| 4-8-0 | Marion Sta. | 31.5* | 46.2 | 32.5 | 46.0 |
| 4-8-0 | Marion Sta. | 27.6 | 58.8 | 36.5 | 40.0 |
| 4-8-0 | Ridgely. | 56.0 | 72.0 | 60.0 | 65.0 |

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*quarts.

Effect of Fertilizing (Topdressing) Strawberry Plants in the Spring of the Fruiting Year: Many growers topdress their strawberry beds in the spring of the fruiting years with three-hundred pounds of 7-6-5 fertilizer to the acre. In order to study the effect of nitrogen alone as a top dressing, each of the plots which had been fertilized in the spring of 1926, were divided in half, applying a fertilizer made up to contain seven percent nitrogen, composed of the same ingredients and equivalents used by the manufacturers to make up the nitrogen in the above 7-6-5 fertilizer. The yields of these plots are also given in Table XII. With the use of Student's Method, it was found that the odds were 999:1 that topdressing of Missionary strawberries instead of helping the yield was actually instrumental in decreasing the yield. On the other hand a study of the yield obtained from Premier strawberries at Ridgely gave odds of 171:1 that this treatment was beneficial. We have two varieties of strawberries under consideration; also two different locations in which the soil and previous soil treatment is different. At Ridgely the soil is a sandy loam with a light clay subsoil, and the following crops have been grown in this ground previous to the planting of strawberries in the spring of 1926 -- 1923 peas, 1924 soybeans, and 1925 tomatoes.

On the plots at Marion, the soil fertility has been built up by a carefully planned soil management program. At Ridgely the soil is poorer and until very recent years has not received soil management which would build up its physical condition or its fertility. These results suggest that topdressing, with a nitrogenous fertilizer in the spring of the fruiting year will increase yields on the medium to poorer types of soil, but will not increase yields on the better types of soil which are in better physical condition and in a higher state of fertility.

The use of a certain fertilizer in one section may give good results; in another it may not pay for its cost. Growers must be guided, to some extent, by a knowledge of the plant response to various fertilizers under their local conditions. Even then, caution must be employed for the response in growth and yield of strawberries in different plantings on the same ground varies with the treatment received in the years previous to planting. Fertilizer is only one of the factors involved. Moisture is one of the most important of the factors governing good strawberry yields, and often the texture of the soil and its ability to hold moisture is of greater importance than the addition of fertilizer. Strawberries planted on newly cleared ground at P. G. Gunby's, gave yields as high as four to five times as great as any received from the same ground in later years. Newly cleared ground is very rich in humus and its physical condition is excellent for holding moisture, thus reducing this factor as a limiting one.

In addition to the above topdressing work, a uniform section of the field was selected and eight 1/30 acre plots staked out each of which included fifteen matted rows twenty-nine feet long. These one year old plots had received a uniform application of fertilizer applied in the furrow before planting consisting of one-thousand seven-hundred pounds of bone meal, and three-hundred pounds of muriate of potash applied at the rate of six-hundred pounds to the acre. One series of plots was held for two seasons to study the effect of fertilizer treatments on a two year old bed receiving no intermediate treatment between crops. The object of this work was to study the influence of the nitrogen carrying fertilizers, sodium nitrate and ammonium sulphate, both with and without phosphorus and potassium, upon the size and firmness of berry, time of picking, and yield.

Counts made on all plots when the plants had bloomed, showed no difference in the number of clusters, or blossoms per cluster, produced by the plants in the different plots. In all cases a surplus of small, well formed, green berries were present on the plant when the season was over, and picking stopped. The factors of blossom production and proper pollination, fertilization, and subsequent development into berries were not limiting ones, and a discussion of the sterility and fertility of the strawberry will not be touched upon in this paper.

Gardner (16) found no change in the number of fruits on plants of the Dunlap variety following application of nutrients in the spring.

Loree (23) doubled the set of fruit on the variety by applying nitrogen in the spring of the fruiting year.

Leading strawberry growers of Maryland say that the problem of the Maryland grower is not how to increase the set of fruit, but to bring to maturity a greater number of those berries which start forming on the plants.

Effect on Yield of Strawberries: A summary of total yields on the different top dressing plots at Marion Station and at Salisbury is given in Table XIV.

( See Next Page for Table XIV.)

TABLE XIV.

Yield of Strawberries Topdressed With Fertilizer in Spring of Fruiting Year.

| Treatment at Rate of 600 lbs Per Acre | Missionary (Marion Station) | | | Premier (Salisbury) |
|---|---|---|---|---|
| | Spring 1926 1 year old (qts.) | Spring 1927 2 years old (qts.) | Spring 1927 1 year old (qts.) | Spring 1926 1 year old (qts.) |
| 5-8-5 | 215.8 | 124.0 | 140.5 | ---- |
| 5-8-0 | 222.0 | 100.0 | 145.6 | 15.73 |
| 0-8-0 | 243.8 | 91.1 | 132.0 | 210.3 |
| Check | 242.8 | 87.9 | 104.8 | 173.3 |
| 5*-0-0 | 254.5 | 110.9 | 120.5 | 126.1 |
| 0-8-5 | 265.0 | 112.5 | 133.8 | 145.3 |
| 5-0-0 | 248.8 | 136.8 | 134.3 | 173.3 |
| 10-0-0 | 194.3 | 97.6 | 121.8 | 171.8 |

The yields from the different plots of one year old Missionary and Premier strawberries topdressed in the spring of 1926, showed no definite response to the application

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*$(NH_4)_2SO_4$

of fertilizer at this time of the year. The check plots were high at both places. Applications of nitrate of soda as high as ten percent appear to reduce the yields. Early berries have a short growing period from time of topdressing with fertilizer until the berries are ready for picking. Differences in yield may be due to differences in availability of nitrogen. In 1927 the application of fertilizers to both one and two year old beds increased yields over the check plots. A study of the yields in Table XIV. shows that of the three elements: nitrogen, phosphorus and potassium, no one element, either singly or in various combinations with the others, consistently increased the yields.

It is interesting that during the years 1926 and 1927, the picking seasons have been more or less dry ones. In 1926 the moderately dry season was accompanied by considerable cool, cloudy weather, and occasional rains were well distributed throughout the season. The year 1927 had a series of rather clear, hot days and nights, with very little high yield of check plots in 1926, and the comparatively low yield in 1927, this differences in weather conditions is of interest. The absorption of mineral nutrients in the soil is closely correlated with the moisture supply. In 1926 the cool, cloudy weather, intersperwed with rain, not only kept up the moisture supply inthe soil, but reduced the transpiration from the leaves. This may have given the check plots a chance to utilize the mineral nutrients present in the soil, which resulted in a comparatively high yield on the check plots. On the other hand, the dry season of 1927 may have had just the opposite effect on the check plots reducing the yield on the check plots. The addition of nitrogen as high as ten percent resulted in a very vigorous, vegetative growth, and a reduced yield of strawberries. The use of different elements showed no significant differences.

Effect on Size of Strawberries: Variety, size, and color of strawberry influence the buyer when berries are placed on the auction block, provided, of course, that there is a good demand for the produce at that time. What effect does spring fertilization have upon the size of berries? Samples consisting of berries from all parts of the plot were selected from each plot. The circumference of the berry at its point of greatest cross section was used as an index of size. A string was used to encircle and measure this circumference to the nearest one-eighth inch on a ruler. There was a range of from one-hundred to two-hundred berries, the number in any particular sample depending upon the plot the sample was taken from.

There was a rapid reduction in size after the first picking (Fig. III. and IV). This reduction occurring

**Fig. III.** Showing Average Circumference of Missionary Berries in Plots Topdressed in Spring of First Fruiting Year, (1926).

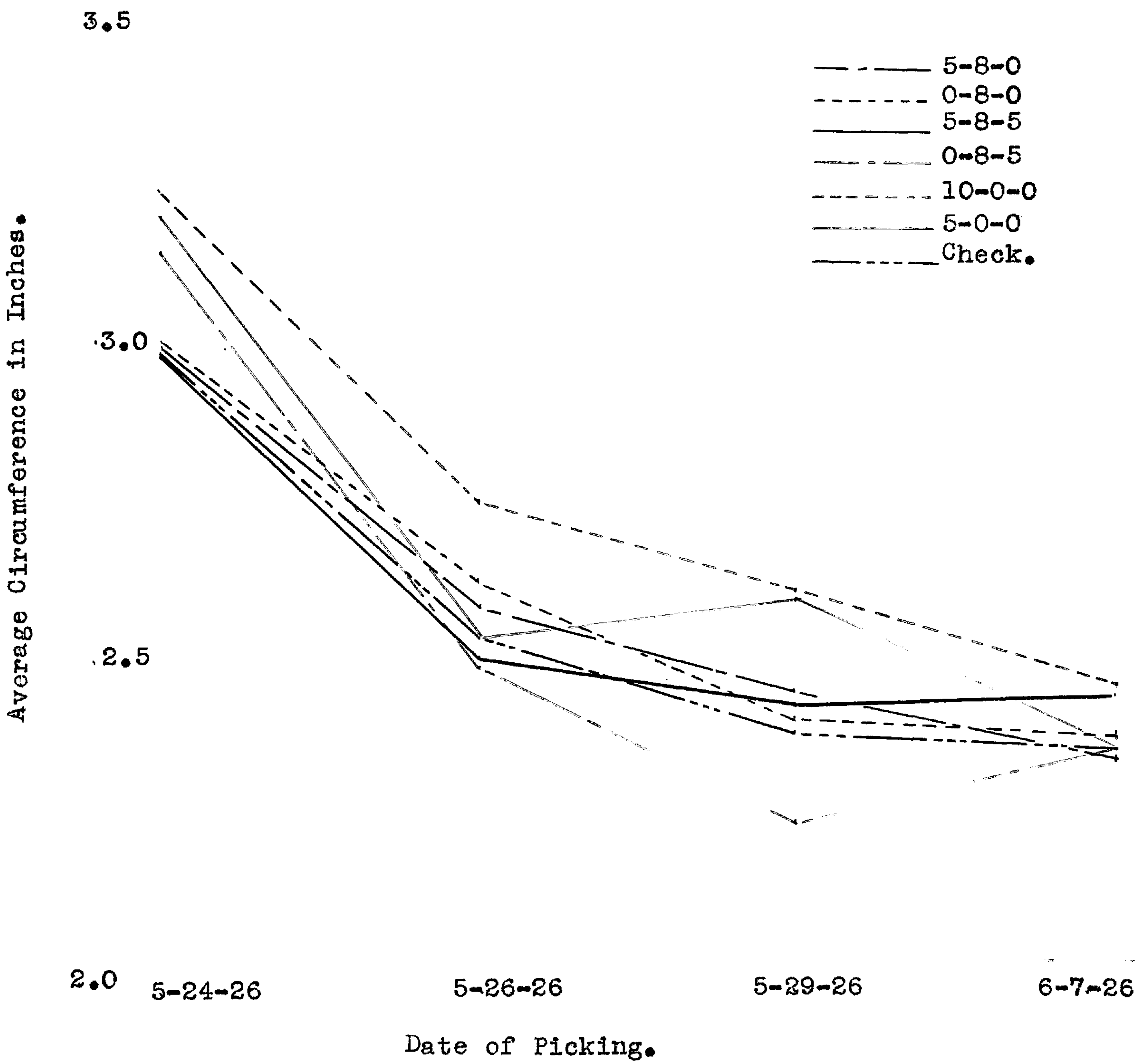


Fig. IV. Showing Average Circumference of Missionary Berries in Plots Topdressed in Spring of First Fruiting Year. (1927).

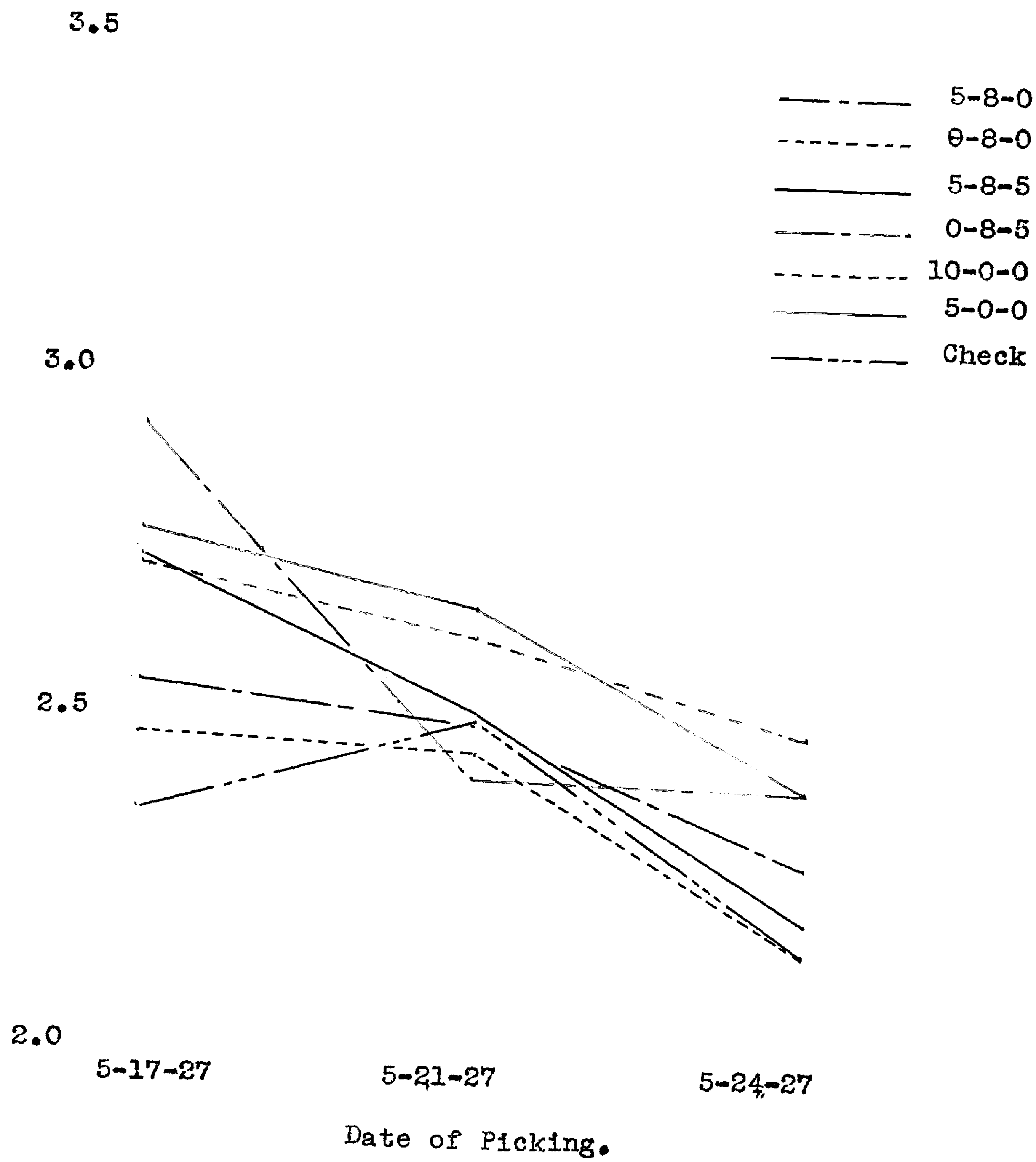
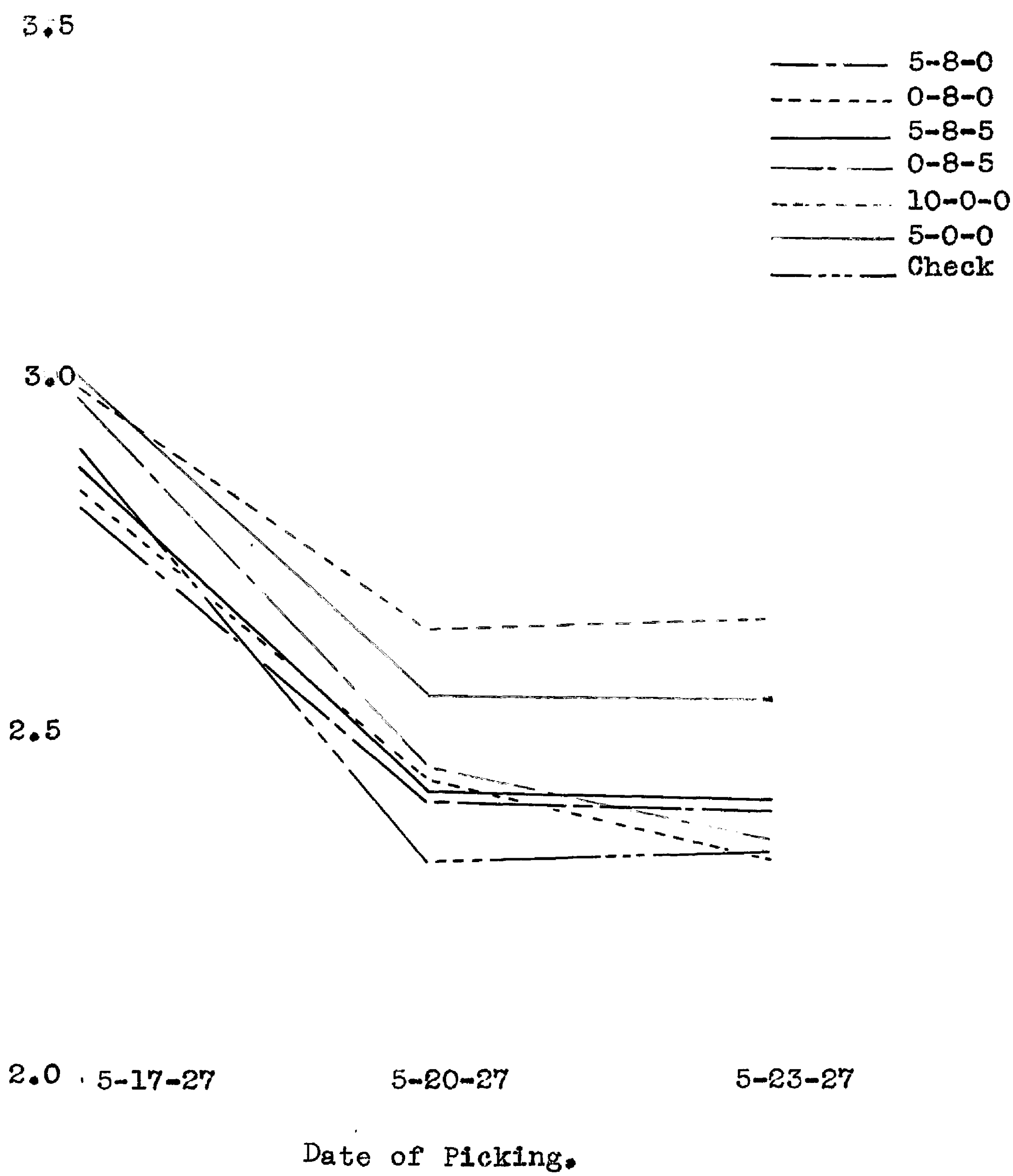


**Fig. V.** Showing Average Circumference of Missionary Berries in Plots Topdressed in Spring of Second Fruiting Year. (1927).



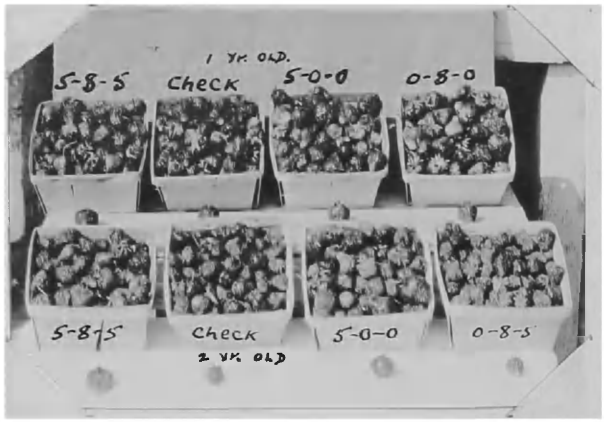
faster on the two year beds. (Fig.V).The average circumference of each plot at each picking in years 1926 and 1927 is summarized in Table XV. Photographs of the samples from which these measurements were made are shown in Plates V. VI. and VII. Table XV. shows that the berries on the two year old plots were larger at the first picking in all cases. In the second picking, the one year old beds were slightly larger. In the third picking, the berries from all two year plots were larger than the one year plots. This is of interest since it is just opposite to what might be expected. This difference in size was noticed at the time of the first picking, and a careful examination of each series of plots showed that on the field containing the two year old bed, the strawberry weevil had harbored over the winter. In the spring these beetle like insects cut the flower stems and were evidently present in large numbers for the number of flowers and berries produced were less than on the two year plots. As previously discussed, the number of blossoms and resultant berries, was not reduced to the point of become a limiting factor, although the number of developing berries on each plant was naturally reduced. Evidently in the dry seasons such as 1927, such thinning has a beneficial effect on the size of the remaining berries, acting very much as it does when applied to our tree fruits. There is no consistant difference in average size of berries from check and from fertilized plots, topdressed at the age

TABLE XV

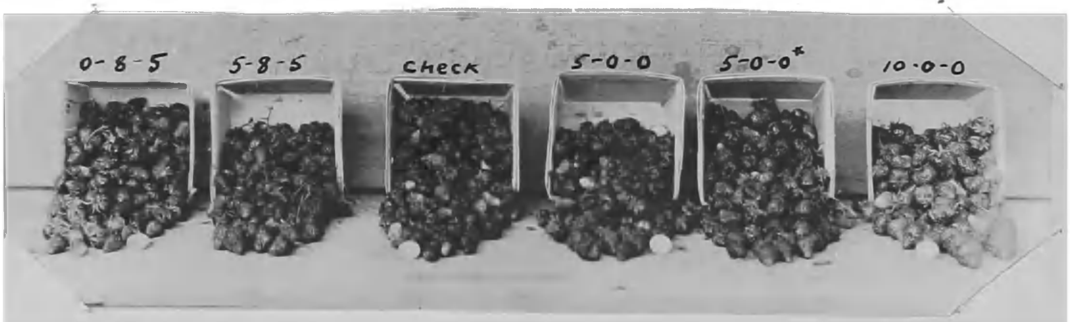
Average Circumference in Inches of Missionary Strawberries Picked from Plots Topdressed With Different Combinations of Fertilizers in the Spring of 1926 and 1927.

| Treatment. | First Picking | | | Second Picking. | | | Third Picking. | | | Fourth Picking |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 Year Old 1926. | 2 Years Old 1927. | 1 Year Old 1927 | 1 Year Old 1926. | 2 Years Old 1927. | 1 Year Old 1927. | 1 Year Old 1926. | 2 Years Old 1927. | 1 Year Old 1927. | 1 Year Old 1926. |
| 5-8-5 | 2.99 | 2.88 | 2.73 | 2.52 | 2.40 | 2.51 | 2.44 | 2.40 | 2.20 | 2.46 |
| 5-8-0 | 3.09 | 2.83 | 2.55 | 2.59 | 2.40 | 2.49 | 2.47 | 2.39 | 2.29 | 2.37 |
| 0-8-0 | 3.02 | 2.85 | 2.48 | 2.63 | 2.41 | 2.41 | 2.42 | 2.32 | 2.17 | 2.39 |
| Check. | 2.98 | 2.92 | 2.36 | 2.54 | 2.31 | 2.49 | 2.40 | 2.33 | 2.17 | 2.39 |
| 5-0-0* | 3.16 | 2.82 | 2.47 | 2.64 | 2.57 | 2.57 | 1.94 | 2.46 | 2.22 | 2.41 |
| 0-8-5 | 3.15 | 2.97 | 2.94 | 2.50 | 2.43 | 2.45 | 2.26 | 2.34 | 2.16 | 2.40 |
| 5-0-0 | 3.20 | 3.05 | 2.77 | 2.52 | 2.55 | 2.66 | 2.63 | 2.54 | 2.40 | 2.40 |
| 10-0-0 | 3.24 | 2.98 | 2.67 | 2.76 | 2.65 | 2.62 | 2.65 | 2.68 | 2.38 | 2.48 |

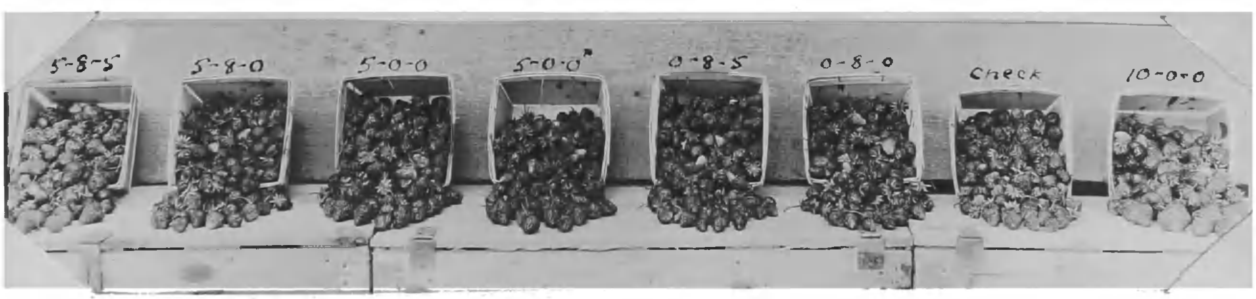
*$(NH_4)_2SO_4$




A. First Picking, 5-17-27.




B. Second Picking, 5-20-27.




C. Third Picking, 5-23-27.

PLATE V. Showing Size of Missionary Strawberries Picked From Two Year Old Beds Topdressed in Spring of 1926 and in Spring 1927.

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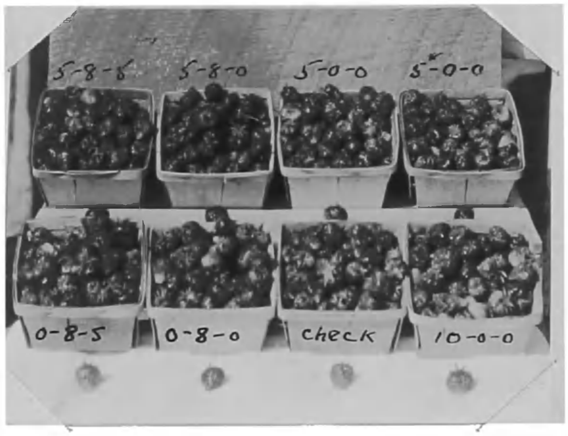
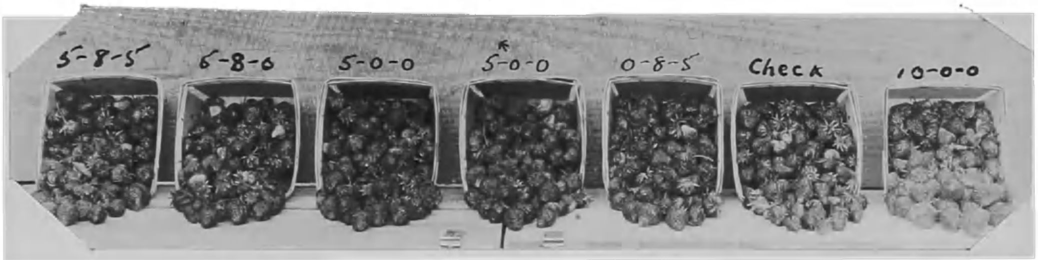
*$(NH_4)_2 SO_4$




A. First Picking, 5-17-27.




B. Second Picking, 5-21-27


C. Third Picking, 5-24-27

<u>PLATE VI</u> Showing Size of Missionary Strawberries Picked From One Year Old Beds Topdressed in Spring 1927.

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*$(NH_4)_2 SO_4$

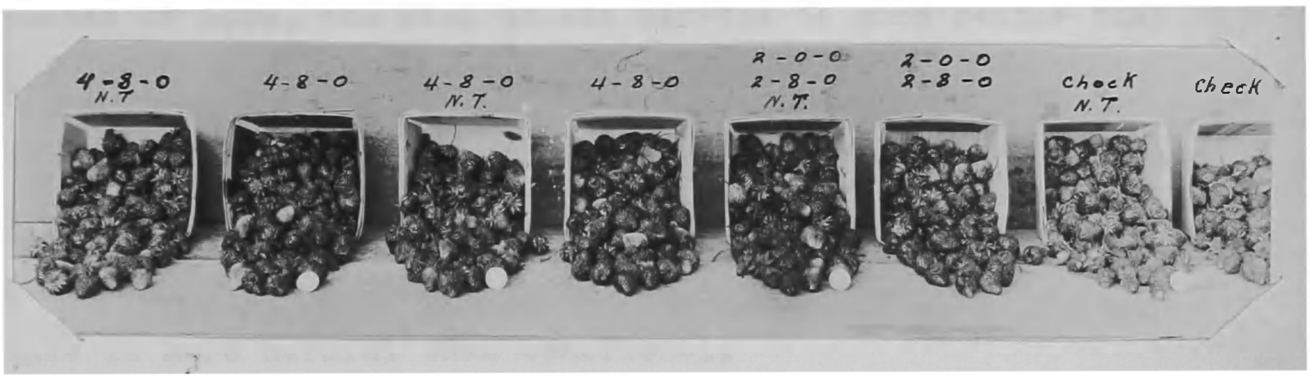


PLATE VII. Showing Size of Missionary Strawberries Picked From Beds Fertilized Just Before Planting. The Boxes From Plots Not Topdressed in Spring of 1927 with 7-0-0 Fertilizer Are Marked (N.T.)

of one year, in the spring of 1926, with the exception of the high nitrogen plot (10.0.0), which had the largest berries at each picking, also the smallest yield of berries. It is of interest to note that during the cool, moderately moist season of 1926, the size of the berries is much better than on one year plants in a dry, hot season such as 1927. On moderately rich soils, such as we evidently have at Marion, topdressing, in the spring, may increase the set of fruit and increase the berries on the plants. In more or less dry seasons, this is more harmful than beneficial.

<u>Effect on Earliness of Yield</u>: The strawberry grower usually receives the best prices for his strawberries in the early part of the season. The amount of strawberries picked at this time is very important, for in a year of good prices, his cash return from the total crop may be greatly influenced by the time his berries ripen. In the spring of 1926 the price of the berries started off at $7.00 a crate and as the crop increased the price decreased very gradually until a price around $3.20 a crate was received at the fourth and fifth picking. Fig. VI. shows that the plots receiving a topdressing of nitrogen, phosphorus, and potassium, and phosphorus alone, had the largest yields during the early part of the season. The plot receiving five percent nitrogen alone in the form of nitrate of soda had the lowest yields at the beginning of the season and the highest near the end. This is a reflected in the cash return from

each plot. (Fig. VI). On the other hand, in a year of low prices, when the range between the highest and lowest price received during the season is very small, the cash return from the straight nitrogen plots may be as good or better than the plots to which all three of these elements are added.(Fig.VI)Nitrogen alone delays the ripening of the strawberries. It appears that plots which received phosphorus and potassium in addition to nitrogen, ripened earlier than plots receiving nitrogen alone.

Table XVI gives a complete summary of the percent of total yield picked from the various plots at each picking. In order to avoid confusion, records of only three of these plots were used in making up the graphs, in Fig. VI.

TABLE XVI.

Showing Effect of Different Fertilizers Applied in the Spring of the Fruiting Year On Earliness of Yield of Missionary Strawberries.

| TREATMENT. | Percent of the Total Yield Picked at Each Picking. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | One Year Old Bed, 1926. | | | | | One Year Old Bed, 1927 | | | | Two Year Old Bed, 1927 | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| N - P - K 5 - 8 - 5 | 29.4 | 16.9 | 22.0 | 22.0 | 10.4 | 29.0 | 28.5 | 17.2 | 24.3 | 33.2 | 26.7 | 23.5 | 16.5 | |
| 5 - 8 - 0 | 21.8 | 15.3 | 24.8 | 23.6 | 14.4 | 24.0 | 29.6 | 19.5 | 19.9 | 31.5 | 22.2 | 22.2 | 24.1 | |
| 0 - 8 - 0 | 24.6 | 16.4 | 24.7 | 19.9 | 14.3 | 23.1 | 33.5 | 19.3 | 34.1 | 31.2 | 26.0 | 19.6 | 23.2 | |
| Check. | 23.1 | 16.0 | 26.0 | 20.0 | 14.9 | 23.9 | 28.7 | 19.4 | 28.0 | 32.3 | 25.7 | 21.0 | 21.0 | |
| 5*- 0 - 0 | 12.4 | 15.1 | 23.2 | 26.3 | 23.0 | 13.0 | 25.2 | 21.5 | 36.2 | 18.0 | 23.1 | 26.5 | 32.4 | |
| 0 - 8 - 5 | 13.8 | 15.5 | 24.5 | 23.9 | 22.3 | 25.8 | 22.8 | 20.0 | 31.1 | 24.6 | 21.8 | 22.5 | 31.1 | |
| 5 - 0 - 0 | 11.6 | 12.7 | 22.7 | 27.1 | 25.9 | 13.6 | 33.5 | 21.6 | 31.0 | 20.9 | 19.3 | 23.0 | 36.9 | |
| 10 - 0 - 0 | 10.3 | 14.5 | 23.9 | 30.7 | 20.4 | 16.0 | 30.6 | 19.7 | 33.7 | 17.7 | 26.0 | 22.2 | 33.6 | |

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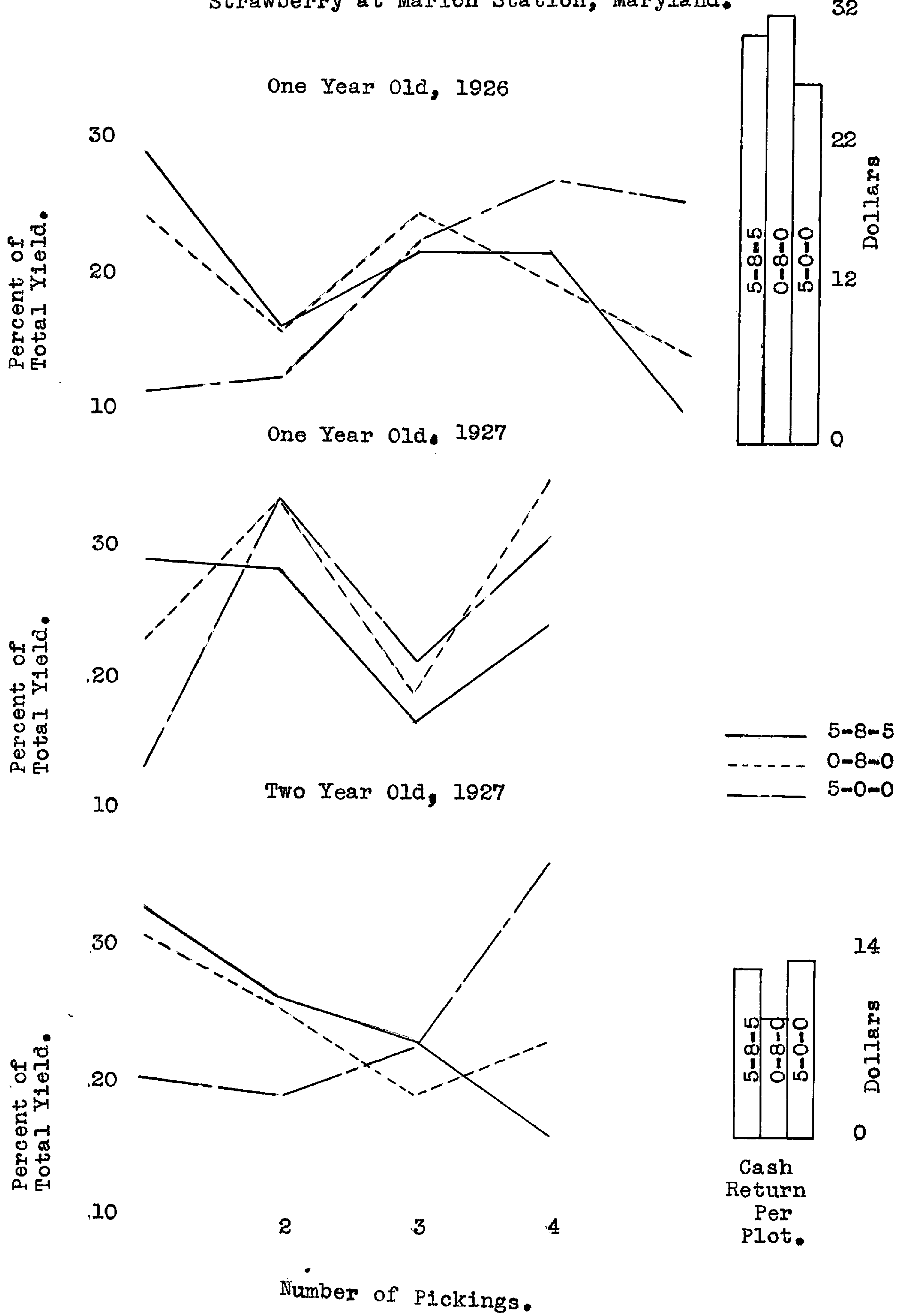
* $(NH_4)_2SO_4$

Fig. VI. Showing Effect of Nitrogen, Phosphorus and Potassium on Earliness of Yield and Cash Return From Missionary Strawberry at Marion Station, Maryland.



## Summary and Conclusions.

1. A review of the literature dealing with fertilizers for strawberries shows that on the poorer types of soil, low in organic matter, which are often found in Maryland, some of the other southern states, and as far west as Missouri, the application of phosphorus aided materially in increasing the yields of strawberries. Nitrogen fertilizers when applied in the early spring at the time the plants were set, increased growth of the plants and early runner production. When applied as a topdresser in the spring of the fruiting year, nitrogen increased the size of the berries and thus the yields in some cases, but decreased the yields on others. No striking benefit was shown from the use of potassium alone. In some instances a combination of nitrogen and phosphorus was better than either one alone. In the soils rich in organic matter and of better fertility found in some sections, applications of fertilizers have not been beneficial in most cases.

2. A study of the strawberry plant was made: (1) to determine in sand culture in the greenhouse, whether a correlation existed between the factors which influence growth and those which influence fruit production, and to determine the effects on growth and fruiting of the three commonly used elements -- nitrogen, phosphorus, and potassium, (2) to correlate by a chemical study, if possible, the chemical constitution of the plants with any differences in their growth and fruitfulness, (3) to determine under field conditions the effects on growth and fruiting of the above mentioned elements.

3. In sand cultures, nitrogen is the chief limiting element. It is an important factor in vegetative growth.

4. In sand cultures, phosphorus and potassium alone produced a weak type of vegetative growth, but when combined with nitrogen appeared to influence growth favorably. The leaflets were wider and slightly longer, and the stems were thicker on plants grown with nitrogen alone. Other investigators have shown that phosphorus alone, when combined with nitrogen, appears to have this beneficial effect.

5. Plants receiving a limited supply of nitrogen formed a root system which was large in proportion to the top. Plants receiving nitrogen had larger tops in proportion to the roots.

6. Fruitbud differentiation in strawberry plants growing in quartz sand occurred under all conditions of nutrition. A larger number of flower clusters and a larger number of blossoms per cluster formed on the plants receiving a moderate supply of nitrogen, phosphorus and potassium than in those plants where the nitrogen was limited or in those where it was excessive.

7. The results of the experiments carried on in quartz sand in the greenhouse indicate that fruitfulness in the strawberry plant is correlated with a balance between nitrogenous and carbohydrate materials in the plant at the time of fruit bud differentiation.

A weak vegetative type of growth, and a reduction in the number of blossoms formed were associated with a comparatively high carbohydrate and low nitrogen content in the plants grown in the no nitrogen plots.

A strong vegetative type of growth and a reduction in the number of blossoms formed were associated with a comparatively low carbohydrate and high nitrogen content in the plants grown in the high nitrogen plots.

On the moderately nitrated plots a vegetative type of growth intermediate between that made by the plants on the high and no nitrogen plots was associated with a carbohydrate and nitrogen content intermediate between that of the high and no nitrogen plots. Likewise an increase in blossom formation on the moderately nitrated plot was associated with a carbohydrate and nitrogen content intermediate between that of the high and no nitrogen plots.

8. The same relative differences in carbohydrate and nitrogen content of the plants growing under different conditions of nutrition, were found on all dates when the plants were sampled.

9. The same relative differences in carbohydrate and nitrogen content were found in the roots as in the tops, suggesting that these relative differences held true in the plant as a whole, as well as the tops.

10. The percentage of reducing sugars, sucrose, total sugars, and acid hydrolyzable substances was changeable throughout the season in both tops and roots, but with the exception of the reducing sugar content of the tops, did not vary in a consistent manner. In general a slightly higher percentage of reducing sugars was found throughout the season on those plants making a vigorous, vegetative type of growth.

11. In a soil of good fertility, applications of fertilizer mixtures containing nitrate of soda at the time of planting resulted in a greater runner and new plant production, than when the same mixture was used with ammonium sulphate substituted in place of nitrate of soda.

12. Applications of lime sufficient to satisfy the lime requirement of acid soils decreased runner production and the formation of new plants in the spring and early summer. The application was also detrimental to the yields on these soils, but it is possible that on some of the very acid soils a light application of lime, which would not entirely correct the acidity would be beneficial. Some beneficial results have been secured by certain growers in Somerset and Marion Counties from the judicial use of lime.

13. Topdressing with nitrogenous fertilizer in the spring of the fruiting year will increase the yield on the medium to poorer types of soil, but will not increase the yields on the better types of soil which are well supplied with organic matter and are in a higher state of fertility.

14. In our field experiments applications of different fertilizer mixtures to strawberry plants in the spring of their first fruiting year gave no consistent increases in yields in favor of topdressing in 1926, but on one and two year old beds gave favorable results in 1927. Weather conditions during these spring periods suggest that the supply of moisture available to the plant at the time may be an important factor in limiting or increasing the yield of berries.

15. In the field applications of different fertilizer mixtures as topdressers to strawberries in the spring of the fruiting year, did not aid in materially increasing the size of the berries. Fertilizer applied at this time of the year may increase the set of blossoms and thus in a direct way decrease the size of all the berries produced if the available supply of moisture is limited.

16. In the field plants receiving a topdressing of nitrogen, phosphorus and potassium, or phosphorus alone, had the largest percentage of their crop picked in the early part of the season, while plants receiving nitrogen alone had the largest percentage of their crop picked in the latter part of the season. It appears that berries on plants receiving phosphorus and potassium in addition to nitrogen ripened earlier than those on plants receiving nitrogen alone. In a year of good

prices for strawberries the net cash return from an acre of strawberries is increased by having as much of the crop as possible ripen early, even though the size of the berries or the yields are not materially effected by the use of topdressing with a fertilizer in the spring of the fruiting year. On rich soils where the plants have a tendency to ripen their berries late in the season, the use of phosphorus or phosphorus and potassium may aid in causing the berries to ripen sooner.

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