THE EFFECT OF NITROGEN APPLICATION ON THE GROWTH RESPONSES AND COMPOSITION OF JONATHAN APPLE TREES

by

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Introduction

The investigations of Kraus and Kraybill (12) published in 1918 stimulated much interest among plant physiologists and horticulturists in the carbohydrate-nitrogen relationships of plants as related to their vegetative-reproductive activities. Horticulturists found that the explanations given by Kraus and Kraybill (12) of their results could be used in many cases in explaining differences in growth occurring in the plants which they had under investigation. It seemed in the case of apple trees to explain certain conditions of growth and fruiting through which they pass from the succulent, rapidly growing, unfruitful tree to the more mature, slower growing but fruitful tree and of the more or less decadent tree of poor growth and low yield typified in neglected orchards. It was also felt that apple trees might be changed from one class or condition of growth to another through varying certain fertilizer, pruning and cultural treatments.

Studies, as shown under Review of Literature, have been conducted to determine whether growth conditions of apple trees corresponded to the varying carbohydrate-nitrogen relationships in a manner similar to the tomato plant, but due to the type of material selected for analysis, and particularly to the fact that the trees used did not always differ materially in their growth relationships, the results have not all been in agreement.

Review of Literature

Due to the very large amount of literature dealing with the response in growth and fruiting of plants in relation to their composition, reference herein will be made only to that which is closely related to the problem at hand.

Kraus and Kraybill (12) in 1918, observed that tomato plants responded very differently in growth, blossoming and fruiting to a varying supply of nitrogen. With plants typical of different conditions of growth, chemical analyses revealed that a different C/N relationship existed for each. This led to the establishment of their well known four classes of growth and reproduction based on the carbohydrate-nitrogen relationship of plants.

In studies of the carbohydrate-nitrogen relationships of apple trees, pomologists have used several types of material, namely bearing and non-bearing spurs, terminal shoots and entire young trees. The investigations have developed along several different lines of thought. Knowing from observation that non-bearing spurs usually form fruit buds and that bearing spurs usually do not, the earlier investigations were conducted with the purpose in mind of comparing the composition of these two different types of spurs just prior to the time of blossom bud differentiation particularly, although some studies were conducted covering the entire year.

The first study conducted to determine the applicability of Kraus and Kraybill's (12) principles to apple trees was probably by Hooker (11). He studied the C/N relationships of barren, non-bearing and bearing spurs. He concluded that the Starch/N relationship was of more importance with the apple than the Total Carbohydrate/N relationship. He found the non-bearing spurs to have a higher starch and lower nitrogen content than bearing spurs.

Kraybill (13) found in the case of Yellow Transparent with which he worked that the vegetative spurs were higher in carbohydrates and lower in moisture and total nitrogen than bearing spurs, which is in accord with Hooker (11).

Harley (5) in a study of the normal variation in the chemical composition of fruit spurs and the relation of composition to fruit bud formation found greater variability in the old growth than in the new growth of non-bearing spurs. He pointed out also that spurs of varying length are more variable than those of similar length. His results on the relative composition of non-bearing and bearing spurs corroborate the results of Hooker (11) in that he found non-bearing spurs at the time of fruit bud differentiation to be relatively high in starch compared to nitrogen content, whereas bearing spurs at the same period were relatively low in starch compared to their nitrogen content.

The problem has also been attacked by noting the differences in the chemical composition of spurs and trees under different fertilizer treatments.

Roberts (21) as early as 1921 grew young trees in small containers under abundant and restricted nitrogen supply and then studied the C/N relationship of the two year wood. The trees were then reversed with respect to their nutrient conditions and the carbohydrate changes resulting noted. He found that carbohydrates decreased with an increase in nitrogen content and that blossom bud formation occurred only when intermediate amounts of nitrogen and aarbohydrates were present.

Potter and Kraybill, et al (19) made a study of fruit spur composition as related to fruit bud formation in the case of Baldwin apple trees under different fertilizer treatment. Most of their results were explainable on a C/N relationship basis with one exception which seemed difficult of explanation, namely, that " bearing spurs on the sod plots and non-bearing spurs on the nitrate fertilized plots are similar in carbohydrate-total-nitrogen relationships, while the former produced no fruit buds and the latter formed 42.4 per cent fruit buds." They suggest this similarity in chemical conditions but marked difference in fruit bud formation may be due to the dominant effect of fruit on the bearing spur. They found bearing spurs higher in nitrogen and moisture and lower in starch and total carbohydrates than non-bearing spurs from the same plot. They conclude that "the data is too meagre to permit drawing definite conclusions."

Schrader and Auchter (22) in studying the first year's effect of different nitrogen fertilizers on bearing apple trees low in vigor, noted an immediate response in color of foliage nitrogen content and terminal and spur growth. Analyses of the spurs showed that spur growth and soluble nitrogen content at blossoming time were most closely related.

Marsh (18) analyzed bearing and non-bearing spurs from twenty-six year old Winesap apple trees and found that all bearing spurs contained a higher percentage of nitrogen than non-bearing spurs.

Lagassé (14) working with Jonathan apple trees that had been under different fertilizer treatment for seventeen years noted a rather close agreement between the C/N relationship of the new growth of vegetative and bearing spurs (cluster base included) and the type of growth and productivity of the trees. Undoubtedly the great length of time the trees had been under treatment and the utilization of only the new growth of the spurs, as suggested by the work of Harley (5) had much to do with the results obtained.

Potter and Phillips (20) in a continuation of the study on composition and fruit bud formation in Baldwin apple trees, came to the conclusion that insoluble nitrogen is more closely correlated with fruit bud formation than any other constituent. They found carbohydrate-nitrogen ratios not to have been of significance.

Harvey and Murneek (7) early recognized and mentioned the greater difficulties encountered in studying the C/N relationships of apples as compared with the tomato plant. They found that defoliation of spurs increased the C/N relationship largely by decreasing the amount of nitrogen present.

Harvey (6) in studying the growth of summer shoots of the apple, particularly with respect to the role of carbohydrates and nitrogen, found that defoliation decreased the carbohydrate-nitrogen ratio in the upper portions of the shoots. He found the same to hold true in the bases of the shoots excepting to a less degree.

Kraybill (13) studied the C/N relationships of non-bearing spurs of young ringed and unringed McIntosh apple trees. He found that ringing increased the carbohydrate and decreased the nitrogen content of non-bearing spurs. Increased fruit bud formation also resulted on the ringed trees.

Thomas and Anthony (25), using Stayman Winesap apple trees on roots vegetatively propagated from the same parent, studied the effect of various cultural and fertilizer treatments on the composition of the leaves and one and two year branches. The results of the first year's analyses showed the Checks in both sod and tillage to have C/N relationship in the case of the one year wood than the trees receiving NPK.

Stuart (23) studied the effect of heavy nitrogen applications on the metabolism of young apple trees and found a higher nitrogen and lower carbohydrate content in the leaves of the trees receiving nitrogen which results in a narrower C/N ratio.

Thomas (24), who has gone into a more detailed study of the nitrogenous metabolism of the apple than other investigators, has found changes occurring in non-bearing spurs between the starting of growth and the time of blossoming which led him to believe that the material for the development of flowers was being drawn rapidly from the reserve proteins. He also notes that the course of the fluctuation of the non-bearing spurs follows that of the one and two year old branch growth.

Several workers in a somewhat more detailed study of the problem have separated the bearing and non-bearing spurs into several portions and analyzed each separately with respect to its C/N relationships.

Lagassé (15) found upon separate analysis of the cluster base and secondary vegetative growth of bearing spurs that the cluster base was, on a percentage basis, higher in nitrogen and total carbohydrates than the secondary vegetative portion of the bearing spurs. The same held on an absolute amount basis except in the case of starch in several instances. The percentage starch and total carbohydrate-total nitrogen ratios of the cluster base were only one-half to two-thirds as large as those of the secondary vegetative growth.

Heinicke (9) found that the C/N ratio of apple bud tissues may cover a rather wide range just prior to the time that they differentiate without reducing the percentage of flowers formed. He also found that the spur portion has a greater carbohydrate and a smaller nitrogen concentration than the bud. He suggests that, "it is probably too much to expect, with our usual methods of chemical analysis that we can determine the chemical factors which are primarily responsible for the differentiation of flowers. Such factor or factors may exist in concentrations of parts per million rather than in percentages and it may be a very illusive substance of the nature of vitamins, for example."

It is thus seen from this brief review of some of the literature on the subject that the growth relationships and fruit bud formation of apple trees as related to their chemical composition has been given serious consideration but that the problem is in need of further study.

Materials and Methods

History of the Trees Used

An excellent opportunity for a study of the chemical composition and growth behavior of apple trees under different levels of nutrition presented itself at the time the author assumed duties at the Delaware Agricultural Experiment Station in the fall of 1925. At that time a seventeen year old fertilizer study was concluded. Certain trees in this orchard had never received fertilizer of any kind, whereas other trees in the orchard had received nitrogen, phosphate, and potash in varying amounts during the seventeen year period. These fertilizer treatments had resulted in the development of trees very divergent in growth and size as well as in productivity. Those not having received nitrogen were small in size (Fig. I). The foliage was yellowish-green in color and the trees were making short spur and terminal growths and the yields were very low. Those which had received nitrogen alone or in combination with phosphorous or potassium were much larger in size, (Fig. II), carried dark green foliage, had made fair to excellent spur and terminal growth and had

FIGURE I

A seventeen year old Jonathan apple tree that has never received nitrogen. It is small of size, with poor terminal and spur growth and typical of the Check and PK trees studied.

Figure II

A seventeen year old Jonathan apple tree that has received nitrogen in addition to phosphate and potash since planting. It is of good size and carries many fruiting branches. It is making fairly good terminal and spur growth and its yields have been good. It is typical of the nitrogen trees studied.

yielded abundantly.

Horticulturists felt that trees in the different plots might be grouped into certain of the classes described by Kraus and Kraybill (12). A preliminary study of the C/N relationships of these trees was made in 1926 for the purpose of determining whether this was actually the case (14).

The results showed that the various growth conditions of the trees under study were correlated with internal composition with respect to carbohydrates and nitrogen, thus indicating that the C/N relationship was applicable in the case of apple trees in very different conditions of growth. It then seemed desirable to determine whether it was possible to change both the growth conditions of the tree and the C/N relationships. Accordingly, changes in fertilizer treatment were made in the spring of 1927. Certain of the Check trees that had been making poor growth and upon analysis were found to have a high C/N relationship were changed to heavy nitrogen treatments. Certain other Check trees were intended to serve as Checks but through accident received nitrogen so have been discarded from the study. Other trees that had received only P and K treatments during the previous seventeen years and which were also poor in appearance and high in their C/N relationships were also given heavy applications of nitrogen. Also certain of the trees formerly receiving nitrogen, phosphorous, and potassium which were normal in appearance and had yielded well, but which had been found to have a lower C/N relationship than the Check or P or K trees, were given additional amounts of nitrogen. From certain others of this group the nitrogen was withheld. At the end of a five year period (spring of 1932) when external changes such as color of foliage, terminal growth, spur growth, circumference and yield records indicated that the trees had been materially affected by the new fertilizer treatment, they were sampled to determine whether their internal composition had changed since 1926.

Description of Trees and Treatments.

Trees.

The Jonathan trees were located at the Delaware Agricultural Experiment Station and were eighteen years old in 1927. The soil was a clay loam deisgnated by the Agronomy Department of the Station as a Sassafras silt loam. The orchard sloped moderately from north to south with some slope occurring from west to east. Good drainage resulted, although washing also occurred in times of heavy storms. The orchard was originally set 20'x20' but in 1923 every other row was removed lengthwise of the orchard thus leaving the trees 40'x20'. With the trees this close some cross-feeding probably occurred during the latter part of this study. There were a number of varieties other than Jonathan remaining in the orchard so that ample cross-pollination was provided. A system of cultivation and sown cover crops was used during their earlier years but more recently cultivation has been practised during the early part of the growing season and natural weed growth permitted during the latter part. The trees have been cared for uniformly during their life with respect to spraying, pruning and cultural treatment and the study of the effect of fertilizer treatment on growth and yields has always been the main objective.

Treatments

The trees had been under fertilizer treatment since the time of planting (1909) in the orchard. These former treatments, henceforth referred to as the "Old Treatment", and the change in treatment made to each tree in the spring of 1927 and referred to in the future as the "New Treatment", are given in Table 1. Nitrogen, phosphorous and potassium wherever applied up to and including 1926, were applied at the rate of fifty pounds each per acre. The application of each of these materials and in these amounts is indicated respectively by N, P and K. Double or triple amounts of one or more of the elements is indicated by the appropriate numeral following the symbol, example N_2. Nitrogen, phosphorous, and potassium applied at the rate of fifty pounds per acre, when converted to a per tree basis (forty per acre) in terms of sodium nitrate, superphosphate, and muriate of potash is equivalent to 3.06, 2.88, and .92 pounds respectively. It will be noted in Table 1 that the applications of these fertilizers ranged from 0 to 9 pounds per tree in the case of nitrate of soda, from 0 to 6 pounds per tree in the case of superphosphate and from 0 to 1

TABLE 1

Presentation of the Fertilizer Treatment of Individual Trees Under Old and New Treatments - Newark, Delaware.

	Old Treatment in Pounds			New Treatment in Pounds		
Tree No.	$NaNO_3$	P_2O_5	K_2O	$NaNO_3$	P_2O_5	K_2O
34-4	0	0	.92	25	0	.92
34-6	0	0	.92	10	0	.92
*34-8	0	0	.92	25	0	.92
36-4	0	0	.92	0	0	.92
36-6	0	0	.92	10	0	.92
*36-8	0	0	.92	25	0	.92
34-10	0	0	0	15	0	0
34-12	0	0	0	25	0	0
*36-10	0	0	0	25	0	0
36-11	0	0	0	15	0	0
*36-12	0	0	0	25	0	0
34-24	3.06	2.88	0	0	2.88	0
*34-26	3.06	2.88	0	10	2.88	0
*36-26	3.06	2.88	0	0	2.88	0
34-30	0	0	0	0	0	0
34-32	0	0	0	0	0	0
36-30	0	0	0	0	0	0
36-32	0	0	0	0	0	0
34-40	3.06	2.88	.92	0	2.88	.92
*34-42	3.06	2.88	.92	10	2.88	.92
36-40	3.06	2.88	.92	0	2.88	.92
*36-42	3.06	2.88	.92	0	2.88	.92
*38-10	0	5.76	0	25	5.76	0
40-10	0	5.76	0	25	5.76	0
40-12	0	5.76	0	25	5.76	0
42-10	0	5.76	0	10	5.76	0
**42-12	0	5.76	0	10	5.76	0
38-20	0	0	0	15	0	0
*40-20	0	0	0	25	0	0
*40-22	0	0	0	15	0	0
42-22	0	0	0	25	0	0
38-26	3.06	0	.92	0	0	.92
40-24	3.06	0	.92	0	0	.92
*40-26	3.06	0	.92	0	0	.92
*40-28	3.06	0	.92	10	0	.92
42-28	3.06	0	.92	10	0	.92
44-10	0	0	0	25	0	0
**44-12	0	0	0	10	0	0
*46-10	0	0	0	10	0	0
46-12	0	0	0	25	0	0
*44-14	3.06	0	0	10	0	0
*46-16	3.06	0	0	0	0	0
44-26	9.18	2.88	.92	0	2.88	.92
46-24	9.18	2.88	.92	25	2.88	.92
*46-26	9.18	2.88	.92	25	2.88	.92
*46-28	9.18	2.88	.92	0	2.88	.92
44-30	0	0	0	25	0	0
44-32	0	0	0	10	0	0
*46-30	0	0	0	25	0	0

*Trees used in 1926 study.
**Received nitrogen by mistake.
P_2O_5 indicates superphosphate.
K_2O indicates muriate of potash with exception of several years during the war when sulphate of potash was used.

pound per tree in the case of muriate of potash.

Beginning in the spring of 1927 a change in the nitrogen fertilizer application to certain trees was made. These changes are indicated in Table 1. It is noted in Table 1 that changes in fertilizer treatment were made in 1927 to other trees in addition to those studied in 1926. It is seen from Table 1 that very contrasting changes were made in the treatment of the trees. The Check and PK, low yielding, high C/N trees were given heavy applications of nitrate of soda. Nitrogen was withheld from certain high yielding trees that had formerly received it. To certain others of this group the amount of nitrogen applied was increased greatly. These changes in fertilizer treatment were made for the purpose of studying the growth changes produced and their association with the C/N relationship of the trees. It should be kept in mind that the Old Treatment covered the period 1909 to 1926 and that the New Treatment began in the spring of 1927 and continued through 1932. In all instances where a tree had previously received superphosphate or muriate of potash or both, the application of these materials was continued regardless of whether the amount of nitrogen applied was increased or decreased. All fertilizer applications as in the past were made in the spring at about the time the buds began to swell.

Description of Methods

Growth Measurements*

Circumference:- The yearly circumference measurements were taken with a steel tape at a point about one foot above soil level marked by a nail driven part way into the tree.

Terminal Growth:- When the study was begun in 1927 it was considered advisable to determine the amount of terminal growth that the trees had made during the seasons of 1924, 1925, and 1926 before any change in fertilizer treatment was made. Such data were not obtained by those formerly in charge of the earlier experiments. Accordingly, forty terminal growths were selected at random from among the branches within reach from the ground. The annual growth made during the seasons of 1924, 1925, and 1926 was measured in centimeters with a steel tape. Measurements of forty terminal growths in centimeters were made yearly thereafter.

Growth of Vegetative Spurs:-

Length of Vegetative Spurs:- In order to obtain further information as to the condition or state of growth

*The author is especially grateful to those preceding him who secured the annual circumference and yield records of the trees used in this study from 1909 to 1925. Those having taken part in this work are: R.R.Pailthorpe, W.J.Young, C.C.Wiggans, N.L. Partridge, R.C.Nehf, G.F.Gray, L.R.Detjen, C.A.McCue, M.S.Gressner, Orchard Forman, J.E.Vaile, J.H.Clark, L.H.Strubinger and B. Davison.

that the various trees which were to be used in this study were in, forty-five spurs which had not blossomed the two previous seasons (1925-1926) were selected at random on each tree. Their length was measured in centimeters before growth began in the spring of 1927. Yearly thereafter (1928-1931) forty-five vegetative spurs of the previous season were selected at random on each tree and similarly measured in the spring before growth started.

Blossoming and Fruiting Records

Annual Per Cent Bloom:- An estimate of the per cent bloom of individual trees was made yearly from 1926 to 1932. This estimate was obtained by considering a tree which was practically white or in full bloom as 100%. Estimates between 0 and 100% were then made. It is acknowledged that this estimate is not as accurate as counting the number of possible blossoming points on a tree and determining the percentage of these that are actually in bloom, but with the large number of trees under study the latter method was impracticable. The value of the estimate lies in the fact that it is relative and might have served in case of emergency (such as loss of crop through hail) as an index to the general physiological condition of the trees that season. As actual crop yields per tree are available but slight importance need be attached to the blossoming records although they are presented.

Yield Records:- The annual yield per tree in pounds was obtained by placing the fruit, as brought to the ground by the pickers, in a tared one-half bushel basket and weighing to the nearest quarter of a pound. The total annual yield per tree, as used in this study, was obtained by summating the total weight of the several pickings, including drops, culls and picked fruit and rounding off the total weight in pounds and ounces to the nearest pound.

Chemical Methods

Sampling:- In sampling in both 1926 and 1932 vegetative spurs of a tree were selected of a length that would approximate the average for that tree. An attempt to do likewise for bearing spurs was made using the length of secondary vegetative growth as an index, but this was found impossible as most of the bearing spurs had made but very little to no secondary growth at the time the samples were taken. In fact plans had been made to separate the secondary growth from the cluster base for analysis but these had to be abandoned because there was not sufficient secondary growth present to permit of analysis unless prohibitive numbers of spurs were used. The lack of secondary vegetative growth on bearing spurs at the time of sampling (June 26, 1932) is shown in Figure III.

Only the new growth was used as information (5) to date indicated that it was more closely correlated with the

FIGURE III

Note the small amount of secondary growth that had been made by bearing spurs at time of sampling June 26, 1932.

performance of the spur than old wood.

Spur samples were taken in 1926 between June 24 and June 30 and in 1932 between June 25 and July 5. This period in the year was selected as being approximately the time of the beginning of fruit bud differentiation.

Days for sampling were selected which were clear and which followed a clear day. An attempt was made to sample at the same hours of the day, 10 A.M. to 2 P.M., but with the volume of the material to be sampled it was later than this on several of the days before the quota for the day was obtained.

The spurs were clipped from the trees with pruning shears, and the new growth, which was separated from the old, dropped with foliage attached to an assistant on the ground. The leaves of vegetative and bearing spurs from each tree sampled were removed and placed in separate paper bags and taken to the laboratory for weighing and counting. The new growth of the spurs was placed immediately in previously weighed and stoppered Erlenmeyer flasks. In the case of bearing spurs, the fruits were also removed. In 1926, they were placed in paper bags and weighed and counted upon arrival at the laboratory but this was not done in 1932. Upon arrival at the laboratory the flasks were reweighed and the green weight of spurs obtained by difference. They were then counted, cut into thin slices with pruning shears and dropped into boiling alcohol to which .25

grams of calcium carbonate was added. The contents were brought to the boiling point and refluxed.at 78°C for twenty minutes, cooled, stoppered, and set away for analysis.

Analytical Methods:- The alcoholic extract was separated from the residue by filtration and the residue dried for forty-eight hours at 70°C. At the end of this time it was cooled to room temperature and weighed in a covered dish, after which it was ground to pass an eighty mesh sieve. The dry matter of the alcoholic extract was determined by evaporating a 1/10 aliquot to a dryness at 70°C and weighing the remaining residue. The total dry weight of the sample was obtained by multiplying the weight of the dried aliquot by ten, adding to it the dry weight of the insoluble residue and subtracting .25 gms. to compensate for the $CaCO_3$ added at time of sampling.

Sugars

Aliquots of the ground residue for the determination of starch and for the determination of polysaccharides were placed in separate paper extraction thimbles and the open end of each was plugged with glass wool. They were then placed together in a Soxhlet extraction tube above 125cc of 50% alcohol and extracted for four hours at such a rate that the extract was siphoned seven or eight times per hour.

At the end of the extraction period the contants of the extraction flask were transferred to an evaporating dish and the proper aliquot of the original alcoholic extract was added. The evaporating dishes were placed on a hot water bath and the alcohol driven off, water being added from time to time to replace it. The alcohol free extract was transferred to a 250cc volumetric flask, and sufficient neutral lead acetate added to precipitate the proteins. After cooling to room temperature, it was made to volume and filtered. The excess of lead usually present was removed by the addition of a small quantity of anhydrous sodium carbonate. Filtration through a double filter paper yielded a clear extract, portions of which were used for the determination of free reducing and total sugars. The Bertrand modification of the Munson Walker method was used for all sugar determinations.

Free Reducing Sugars - The reducing power of a 50cc portion of this cleared sugar solution was determined and calculated as glucose.

Total Sugars - A 25cc portion of the cleared sugar solution was placed in a 100cc volumetric flask containing 25cc of distilled water. Five cc of 37% hydrochloric acid was then added and the sugar hydrolyzed at room temperature for twenty-four hours. The solution was then neutralized with anhydrous sodium carbonate, the contents made to volume and filtered. A 50cc portion was then used for the determination of total sugars and the results calculated as invert sugar.

Sucrose - Sucrose was calculated as the difference between total and free reducing sugars.

Acid-Hydrolyzable Substances

One of the aliquots of the insoluble residue from the sugar extractions was transferred to a 500cc Florence flask to which 150 cc of distilled water and 15cc of 37% hydrochloric acid were added. The mixture was then placed beneath a condenser and refluxed for three hours. At the end of this hydrolysis the mixture was neutralized with analydrous sodium carbonate, made to 250cc volume and filtered. Fifty cc of this solution was used in determining its reducing power. Results were calculated as glucose.

Starch 1926

Starch was determined by a modification of the method reported by Walton and Coe (26). The alcohol extracted tissue was transferred from the extraction cone to a 250cc Erlenmeyer flask, 50cc of water added and the contents brought to boiling to thoroughly mix them. The flasks were then placed in an autoclave at fifteen pounds pressure for one hour. Upon removal, the mixtures were allowed to cool to 40°C. whereupon 15cc of saliva was added to each as they were placed on a water bath held at 40°C. They were maintained at this temperature for one hour, tested for starch, transferred to a 250cc volumetric flask and handled from here on according to the method of Walton and

Coe which includes precipitation of gums and pectins with 60% alcohol, replacement of the alcohol by water and hydrolysis of maltose to glucose. A blank was run in duplicate with each set of determinations and its average reducing value subtracted from each determination.

Starch 1932

Starch was determined in 1932 by a modification of the method of Walton and Coe (26) as described by Boswell (1), excepting a 1% solution of taka-diastase was used in place of a 5% solution of diastase. A blank was run with each set of determinations and its reducing value subtracted from each determination.

Nitrogen

Total Nitrogen- Total nitrogen was determined by adding an aliquot of the original alcoholic extract to a Kjeldahl flask, adding one gram of salicylic acid, *placing on water bath and driving off the alcohol and moisture. Then a similar aliquot of the powdered residue was added and the usual Gunning-Kjeldahl method followed.

Soluble Nitrogen - Soluble nitrogen was determined by combining an aliquot of the original alcoholic

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*In 1932 a blower, as described by Gardner (4) with certain modifications was used to remove the alcohol, which saved much time.

extract with an aliquot of that obtained by extraction of the powdered residue, driving off the alcohol and water in the presence of salicylic acid and then following the usual Gunning-Kjeldahl method.

Alcohol Insoluble Nitrogen - Alcohol insoluble nitrogen was determined as the difference between total and soluble nitrogen.

Catalase

Catalase determinations* were run on the leaves from bearing and vegetative spurs sampled in 1932. A type of apparatus similar to that described by Heinicke (8) was used and each determination run in duplicate. Two discs, 1cm. in diameter, were cut from each of ten leaves which were of average size for the group. The twenty discs were weighed immediately and placed in a mortar. An equal weight of calcium carbonate and of finely ground sand was added and then one-fifth of the water required to give a dilution of 1 to 20. The discs were coated with this calcium wash and the tissue ground to a smooth paste in exactly two minutes. It was then diluted 1 to 50 and transferred to a small bottle which was at room temperature. Two cc. of Dioxygen previously neutralized by the addition of calcium carbonate was pipetted into one arm of a Bunzel reaction tube.

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*The writer gratefully acknowledges the receipt of helpful suggestions from Mr. I.C.Haut, of the Horticultural Department of the University of Maryland, relative to the determination of catalase activity.

After shaking the sample ten times and allowing fifteen seconds for it to settle, two cc. of the macerated leaf tissue extract and calcium wash was withdrawn with a pipette and placed in the other end. The reaction tube was connected with the burette and immersed in a water bath kept at 25°C. When the tube and contents had reached the temperature of the water bath and the water level in the burette adjusted to zero, the liquids in the reaction tube were mixed at the rate of one-half turn per second. A stop watch was started when the liquids were first mixed and the number of seconds required to displace successive cubic centimeters of water from the burette were recorded until a total of ten cc. had been removed or the reaction so slowed up that it became too prolonged. This served as the measure of catalase activity of each sample.

Statistical Methods.

In studying the significance of the difference in chemical composition of the spurs in 1926 and 1932, Students Odds were used as recalculated by Love (17). Odds of 30 to 1 have been considered significant. In making a comparison of the growth and yields of the trees during the five year periods before and after treatment, Fisher's (3) method for the analysis of variance was used by means of which variation due to trees and years was removed in the determination of the standard error.

Results

For convenience of expression the following terminology will be used in reference to the various groups of trees in discussing the results of the study. The untreated trees will be termed Check ⟶ Check. The Check trees which received applications of nitrogen will be designated as Check ⟶ N. The trees formerly receiving K or P and to which nitrogen was added will be designated as K-P ⟶ N. Those trees which had received NPK and from which nitrogen was withheld will be designated N ⟶ 0, and if additional amounts of nitrogen were supplied as N ⟶ N. Wherever trees had previously received K or P, such treatment was continued regardless of change in nitrogen treatment.

Growth Responses of the Trees

Circumference Growth (Table 2)

The trees receiving nitrogen showed the most growth in circumference during the period 1922-1926 and it is noted from Table 2 that their circumference at the beginning of the experiment in 1921 was considerably greater than that of either the Check trees or trees receiving P or K only. It is evident also that the trees receiving P or K alone were not as large as the Checks in 1921. Since the average yearly girth increments of the P-K trees from 1922-1926 inclusive, and the average circumference at the beginning of the experiment were smaller than that obtained from the Check tree, it would indicate that the P-K trees may have been adversely affected by the treatment prior to 1921 as well as during the years 1922 to 1926.

The group of P-K→N trees showed the greatest average gain 17.4 ± 2.31 millimeters per tree of any group. Nitrogen undoubtedly was a limiting factor in the growth of these trees and as has been mentioned, K or P under these conditions may have had a deleterious effect which was overcome by the nitrogen.

Figure IV depicts graphically the data in Table 2 showing more clearly the effect of the change in fertilizer treatment on the amount of circumferential increase made. It is seen that one group of the Check trees and the P-K trees were making about the same amount of circumference growth between 1922 and 1926. The other group of Check trees which were located in a slightly more favorable area of the orchard were making somewhat better growth but not nearly as much as the trees receiving nitrogen. Between 1927 and 1931 the Check trees without treatment continued in an almost straight line whereas the P-K and Check trees receiving the heavy applications of nitrogen immediately increased their rate of growth (1927), and continued to diverge from their former line of growth until 1931.

TABLE 2

Comparison of Yearly Gain in Circumference in Millimeters of Jonathan Apple Trees When Under Old and New Fertilizer Treatments

Old Treatment 1908-1926	Average Circumference 1921	No. of Trees	Average Girth Increase per Tree					New Treatment 1927-1931	Average Girth Increase per Tree					Ave. Annual Increase per Tree		Difference With Standard Error	% Gain or Loss
			1922	1923	1924	1925	1926		1927	1928	1929	1930	1931	1922-1926	1927-1931		
Check	510	4	7.3	7.0	12.3	9.5	19.0	Check	18.0	11.8	8.8	13.8	11.3	11.0	12.7	1.7 ± 1.81	+15.45
Check	509	12	20.3	13.4	17.9	12.3	15.7	N	40.4	19.6	33.9	30.3	19.8	15.9	28.8	12.9 ± 1.27	+81.13
P or K	493	5	10.0	5.0	10.4	8.4	8.2	NPK	41.0	19.0	23.8	27.2	18.2	8.4	25.8	17.4 ± 2.31	+207.14
NPK	651	11	30.5	29.2	34.5	20.5	18.4	PK	38.5	19.6	25.1	15.4	16.5	26.6	23.0	3.6 ± 1.77	- 13.53
NPK	695	7	29.1	28.1	31.4	24.7	18.1	NPK	35.8	17.5	29.4	19.7	20.7	26.3	24.6	1.7 ± 2.73	- 6.46

Explanatory Note -

Old Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

" " - P or K indicates trees have received at least 3 lbs. of superphosphate or at least 1 lb. of muriate of potash annually per tree.

" " - NPK indicates trees received at least 3 lbs. and not more than 9 lbs. of nitrate of soda annually per tree. P and K when applied was at least in quantity given under P or K.

New Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

" " - N indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree.

" " - NPK indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree and same quantity of P or K as under Old Treatment.

See Table A. for individual Tree Treatment.

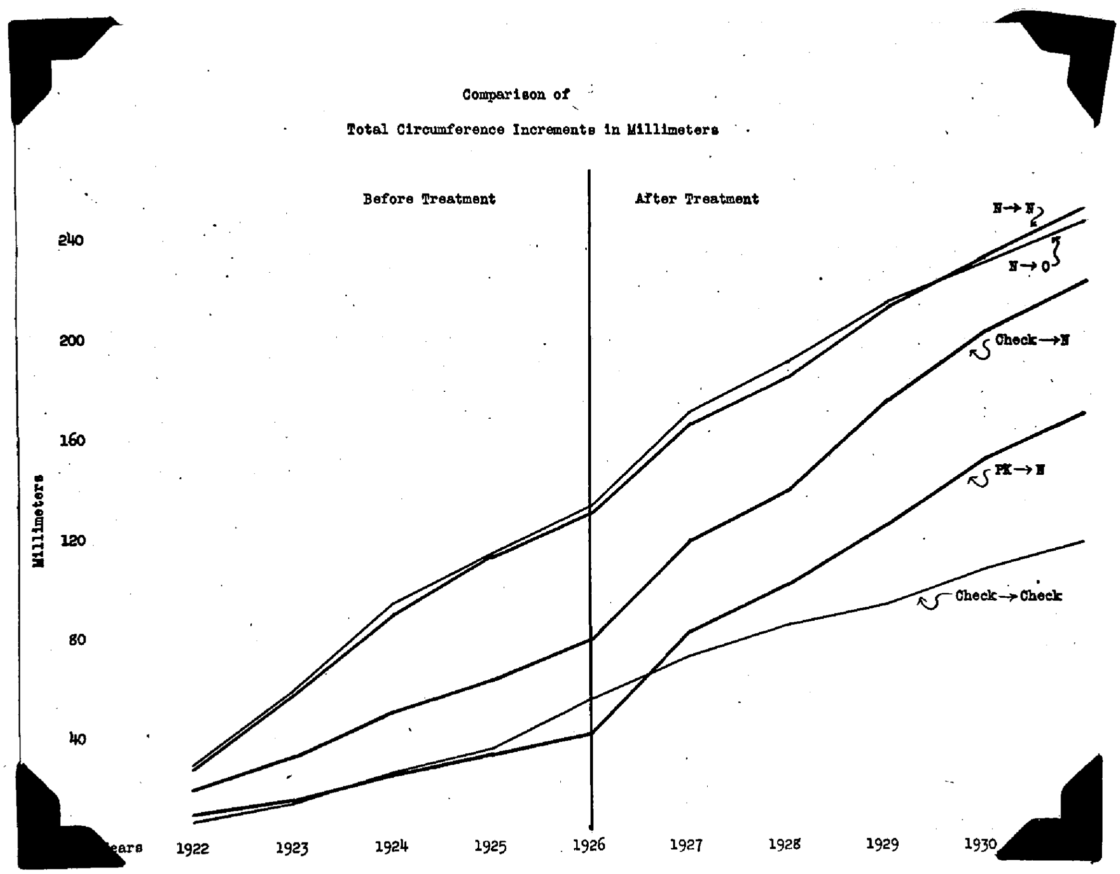
The group N→O trees showed (1927-1931) an average annual increase in circumference of 3.6 ± 1.77 millimeters less than in the earlier period. The standard error of the difference shows this to be a significant decrease. The N→N group of trees, it is observed, have made slightly less (1.7 ± 2.73 millimeters) than in the former period. The standard error shows, however, that this decrease is not significant.

It can be noted (Figure IV) that the almost straight and parallel lines of growth made by the N→O and N→N groups of trees before the 1927 change in treatment show that the trees were in a very similar condition of growth before any change in nitrogen treatment was made. During the 1927-1931 period there was a falling off in growth in both groups but as noted in Table 2 only that in the N→O group is significant. It is noted that during the last two years the N→O group have dropped slightly below the trees which have received heavy applications of nitrogen between 1927-1931. It also is apparent that nitrogen deficient trees increased in their rate of circumference growth the first year that nitrate of soda was applied, indicating that the nitrogen is utilized by the tree soon after application under such conditions.

The column in Table 2 presenting the above gains or losses on a percentage basis shows the direction and amount of

FIGURE IV

Comparison of the total circumference increment in millimeters made by the various groups of trees before and after treatment.



change but possibly unduly accentuates the gains made by the P-K group of trees due to the small amount of growth they made between 1922 and 1926.

Discussion

It is apparent from the circumference measurements that the Check trees which had not received fertilizer of any kind for a seventeen year period were able to utilize nitrogen readily when it was applied. It is seen also that trees having received P or K made a much greater percentage gain in circumference than the Check trees but less on an actual amount basis. The N—>0 group of trees showed a significant falling off in yearly girth increment. However, the nitrogen reserve of these trees, in addition to the possibility of cross-feeding, was apparently sufficient to enable them to make a fair amount of growth. Nitrogen analyses of these trees (Appendix Tables F and G) show that the nitrogen content of their spurs is higher in nitrogen even in 1932 than Check trees were in 1926. However, they are, in general, lower in nitrogen than they were in 1926, indicating that their reserves have been utilized to some extent. Roberts (21) has shown that young apple trees having been grown with a good supply of nitrogen would continue to make reasonably good growth the next season even though placed under conditions where the supply of nitrogen was very low. Crane (2) has also shown similar results with peaches. The application of large amounts of nitrogen to trees already well supplied with it did not increase the amount of circumference growth but seemed instead to have possibly a deleterious effect. It may be an accumulative toxic effect that will increase as time goes on, to the point where it will become significant. However, at present the standard error of the difference shows it to be entirely within experimental error.

Terminal Growth (Table 3)

It is noted first that there are several more trees included than was the case with respect to the circumference measurements presented in Table 2. This is due to the fact that several trees had to be omitted from the circumference study as result of error involved in making yearly circumference measurements. The terminal growth measurements of such trees, however, can well be included in this study. An examination of Table 3 shows that the different groups have in general responded much the same in terminal as in circumference growth although there is a significant gain in the N $\rightarrow$ 0 group instead of a decrease as noted in Table 2.

The graphs of Figure V based on the accumulated yearly terminal growth of the different groups depict clearly the beneficial effect of nitrogen treatment on the growth of the trees. It is noted that the effect of nitrogen does not appear to be quite as marked the first year (1927) as in the case of the circumference growth. The second season,

TABLE 3

Comparison of Yearly Terminal Growth in Centimeters Under Old and New Fertilizer Treatment.

Old Treatment 1908-1926	No. of Trees	Average Growth per Tree 1924	1925	1926	New Treatment 1927-1931	Average Growth per Tree 1927	1928	1929	1930	1931	Annual Ave. Growth per Tree 1924-1926	1927-1931	Difference with Standard Error	% Gain or Loss
Check	4	2.75	3.57	7.0	Check	9.17	6.50	11.27	9.32	10.80	4.44	9.41	4.97 ± .663	+111.93
Check	14	4.81	6.00	7.47	N	14.96	21.46	20.39	14.44	17.21	6.09	17.69	11.60 ± .592	+190.48
P or K	8	2.98	3.36	5.29	NPK	13.08	20.06	24.14	13.76	17.39	3.87	17.69	13.82 ± .860	+357.11
NPK	11	12.64	10.93	9.78	PK	12.04	13.10	14.09	10.60	13.77	11.11	12.72	1.61 ± .600	+ 14.49
NPK	7	14.16	11.49	11.14	NPK	15.30	17.17	18.68	11.35	15.17	12.25	15.54	3.28 ± .927	+ 26.78

Explanatory Note -

Old Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

" " - P or K indicates trees have received at least 3 lbs. of superphosphate or at least 1 lb. of muriate of potash annually per tree.

" " - NPK indicates trees received at least 3 lbs. and not more than 9 lbs. of nitrate of soda annually per tree. P and K when applied was at least in quantity given under P or K.

New Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

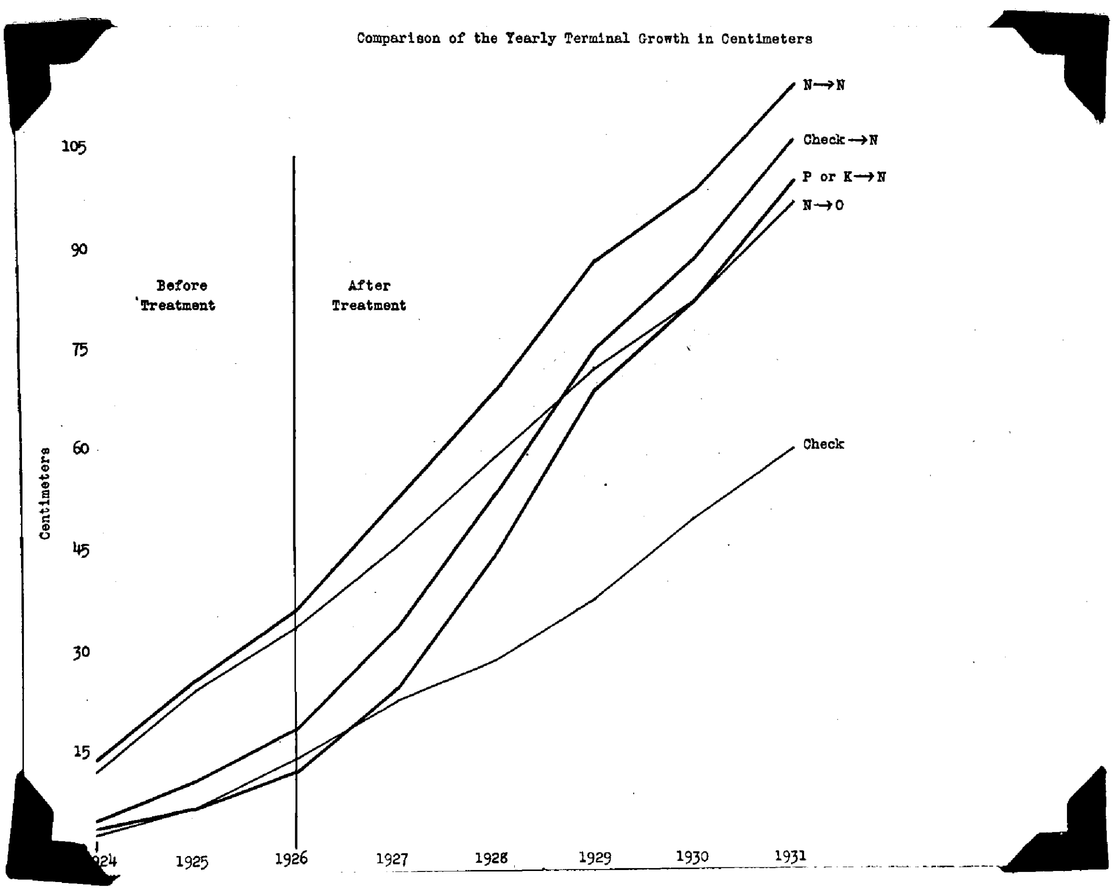
" " - N indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree.

" " - NPK indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree and same quantity of P or K as under Old Treatment.

See Table 13. for individual Tree Treatment.

FIGURE V

A comparison of the total terminal growth in centimeters made by the trees of the different crops before and after treatment. Note how those receiving nitrogen have diverged from the Check group.



however, shows a sharp upward trend in the groups receiving it as compared to the Checks. The N→0 group of trees have made considerably less total growth during the period than the N→N group of trees. It is thus seen that the terminal growth of the trees was affected in much the same way as circumference growth by the various treatments given the trees.

Growth of Vegetative Spurs

A comparison of the average amount of growth made by vegetative spurs of the same trees before and after treatment is presented in Table 4 and Figure VI. The same general trend as that noted in the case of circumerence is evident with the exception of the Check and N →N groups which here show a significant increase. It is noted that here also nitrogen applications have caused marked increases in the Check →N and P-K →N groups, although the results are not as striking as in the case of the more accurate circumference measurements.

TABLE 4

Comparison of the Yearly Growth of Vegetative Spurs in Centimeters Under Old and New Fertilizer Treatments.

Old Treatment 1908-1926	No. of Trees	Average Growth per Tree		New Treatment 1927-1931	Average Growth per Tree					Annual Average Growth per Tree		Difference with Standard Error	% Gain or Loss
		1925	1926		1927	1928	1929	1930	1931	1925-1926	1927-1931		
Check	4	.46	1.00	Check	2.81	3.28	3.44	1.92	1.54	.73	2.60	1.87 ± .387	+256.2
Check	14	.62	1.08	N	2.70	2.37	5.42	4.02	2.42	.85	3.39	2.54 ± .173	+298.8
P or K	8	.54	.98	NPK	3.72	2.19	4.95	3.23	2.02	.76	3.22	2.46 ± .721	+323.7
NPK	11	1.08	1.42	PK	2.63	2.24	5.01	2.71	2.06	1.25	2.93	1.68 ± .141	+134.4
NPK	7	1.58	1.30	NPK	2.96	2.61	6.09	3.76	2.32	1.44	3.55	2.11 ± .224	+146.5

Explanatory Note -

Old Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

" " - P or K indicates trees have received at least 3 lbs. of superphosphate or at least 1 lb. of muriate of potash annually per tree.

" " - NPK indicates trees received at least 3 lbs. and not more than 9 lbs. of nitrate of soda annually per tree. P and K when applied was at least in quantity given under P or K.

New Treatment

Groups labelled - Check indicates trees have not received fertilizer of any kind.

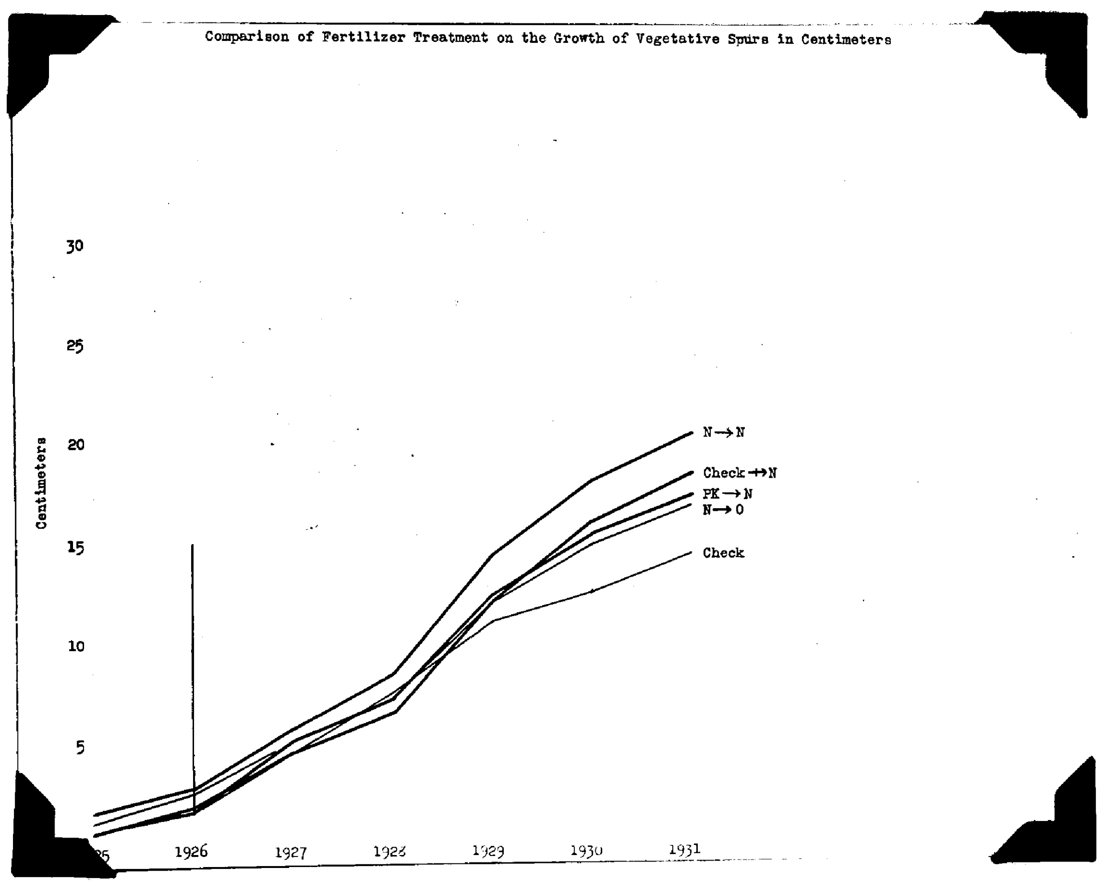
" " - N indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree.

" " - NPK indicates trees received from 10 to 25 lbs. of nitrate of soda annually per tree. and same quantity of P or K as under Old Treatment.

See Table C. for individual Tree Treatment.

FIGURE VI

A comparison of the total growth of vegetative spurs in centimeters before and after treatment. Note that all groups are above the Check trees but that the group from which nitrogen was withheld is next lowest.



Blossoming and Fruiting Response

Blooming Behavior

It is apparent from the average of the blooming records for the 1927-1933 period presented in Table 5 that all trees receiving nitrogen applications have averaged a higher percentage bloom than the Checks. The N ⟶ 0 trees maintained nearly as high blossoming as the N ⟶ N trees even though no nitrogen was applied. The nitrogen reserves of the latter trees apparently have helped in this respect. The biennial habit of the tree seems to be much more influential on the average percentage bloom produced than the treatment.

Yield Records

The yield records of the tree is one of the ultimate measures by which to judge whether the trees have been changed in growth and composition. It is also the measure by which one may determine whether a given fertilizer treatment has been profitable or not.

It is realized now that in the desire to have as many treated trees within a group as possible that there was not as many Check trees left as would have been desirable. Thus, four additional Check trees in the orchard have been used for comparison.

The annual yield in pounds per tree are

TABLE 5

Comparison of the Average Percentage Bloom of Trees Under Different Fertilizer Treatments 1926-1933 Inclusive - Newark, Delaware.

No. of Trees	Old Treatment	Average % Bloom 1926	New Treatment	Average Per cent Bloom 1927	1928	1929	1930	1931	1932	1933	Ave. % Bloom 1927-1933
4	Check	5.0	Check	40.0	38.0	14.0	55.0	1.4	34.2	41.2	31.97
13	Check	34.2	10-25 N	30.7	74.2	11.9	48.1	34.1	47.7	85.4	47.44
8	$K-P_2$	28.7	K or P ≠ 10-25 N	10.6	75.6	15.6	73.1	20.2	23.1	84.3	43.21
11	NPK	53.0	PK	30.9	80.9	16.3	65.9	13.6	39.1	53.5	42.88
6	NPK	78.3	PK ≠ 10-25 N	11.6	80.8	10.0	57.5	16.6	35.8	79.1	41.60
	TOTAL	199.2		123.8	349.5	67.8	299.6	85.9	179.9	343.5	
	AVERAGE	39.8		24.7	59.9	13.5	59.9	17.1	35.9	68.7	

presented for the years 1921 to 1932 inclusive in Appendix Table E. The average annual yield per tree of each particular treatment from 1921-1932 is presented in Table 6. It is noted first that the Check trees have yielded about 81 $\pm$ 8.86 pounds more per tree, or a 219 per cent increase, during the 1927-1932 period than during the 1921-1926 period which is a significant increase. The cause may be due to their receiving some wash from an adjoining alfalfa field. The individual yield record of these trees, Appendix Table E, shows that one tree decreased in yield whereas the other trees increased sufficiently to cause a significant difference. The possibility of a gradual increase in size of tree might be the cause but circumference measurements show that they have not gained significantly in growth rate during this latter period. The possibility of better growing conditions due to seasonal variation suggests itself, but with the well known drought years of 1929, 1930 and 1931 occurring during this latter period this thought becomes untenable. With a positive explanation of the cause of this large increase in yield of the Check trees lacking, it was felt justifiable to determine how other trees in the orchard which had not received nitrogen had reacted during this period with respect to yield.

Accordingly, the yields of seven Jonathan trees that had received acid phosphate and potash since time of planting were compiled and are also presented in Table 6. It is observed that these trees also yielded more during the

TABLE 6

Comparison of Average Annual Yield in Pounds per Tree When Under Old and New Fertilizer Treatments.

Old Treatment 1909-1926	No. of Trees	Average Yield per Tree 1921	1922	1923	1924	1925	1926	New Treatment 1927-1932	Average Yield per Tree 1927	.928	1929	1930	1931	1932	Ave. Ann. Yield per Tree in lbs. 1921-1926	1927-1932	Difference With Standard Error	% Gain or Loss
Check	4	10.5	.25	20.0	4.25	113.7	75.0	Check	74.5	40.7	50.5	224.5	17.2	204.2	37.11	118.60	81.49 ± 8.86	+219.58
Check	14	14.85	58.78	45.64	23.44	81.43	222.0	10-25 N	118.5	30.3	21.8	241.5	204.6	134.4	74.36	175.18	100.82 ± 30.05	+135.58
PK	7	16.1	139.7	63.1	98.8	115.3	357.7	PK	38.8	47.3	70.4	389.1	95.4	345.8	131.8	197.8	66.0 ± 18.15	+50.07
P-K	8	9.75	28.1	7.75	5.0	24.2	139.6	10-25 N + P-K	40.25	96.8	35.75	329.9	69.9	110.5	35.73	147.18	111.45 ± 13.01	+311.92
NPK	11	49.5	410.2	157.0	265.2	373.9	550.4	P-K	100.2	12.2	63.3	428.2	139.5	365.2	301.03	234.76	66.27 ± 23.00	-22.01
NPK	7	61.8	509.6	168.7	282.0	248.1	748.2	10-25 N +	48.9	19.6	36.6	442.1	206.3	433.7	336.4	281.2	55.20 ± 21.00	-16.40

1927-1932 period than during the 1921-1926 period but it was only a 50% increase as compared to the 219% increase of the Check trees. The standard error of the difference shows this to be a significant increase, however.
It is felt, therefore, that causes beyond the ones common to the other plots are responsible for the increase in yield of these Check trees but chief among them maybe the seepage of nitrogen from the alfalfa field above.

The group of P-K⟶N trees have shown the highest percentage gain (311%) of all groups. This greater response of the P-K trees when nitrogen was addes is noticeable with respect to circumference, terminal growth and vegetative spur measurements as will be recalled.

When nitrogen was withheld from trees that had formerly received it, a significant reduction in yield occurred of 22% due probably to a gradual reduction in nitrogen reserves. When 10-25 lbs. of nitrate of soda was applied to trees that had received nitrogen since time of planting, a significant decrease also occurred due possibly to a toxic effect although no outward signs of such a phenomena have as yet become evident.

It is felt that any abnormalities occuring during the progress of a study, whether they result from natural or other causes, should be given particular thought in the interpretation of the effect of treatment on yields. The two points in question involve the omission of the yields of 1926 and 1927 and the reasons for such a procedure are presented in the following paragraphs.

It will be noted from Table 6 that 1926 was a year of unusually heavy yield with the exception of the first group of Check trees which had borne a proportionally heavy crop in 1925. The trees receiving nitrogen bore more than they had ever borne in a single year (1921-1926) and the PK group and one group of Check trees bore more in 1926 than they had borne in the entire previous five year period. The explanation of this exceptionally heavy yield, particularly in the case of trees that had not received nitrogen, lies, it is believed, in a gradual accumulation of nutrient materials particularly carbohydrates and quantities of nitrogen until a point was reached in their composition in 1925 that was extremely favorable to fruit bud formation. With optimum weather for pollination prevailing during the blooming period in 1926, a heavy set resulted and as previously mentioned they produced more fruit in 1926 than in all of the previous five year period. Fortunately, this exceptional increase in yield occurred previous to, rather than several years after the application of large amounts of nitrate of soda to these nitrogen deficient trees, for otherwise the nitrogen treatment would surely have been credited with a result for which it would have been in no way responsible. The writer, therefore, feels justified in excluding the abnormal yields of 1926 in a proper interpretation of the results, as being not typical of the period under consideration.

The second point in question, namely the exclusion of the 1927 yields when interpretating results seems even more justifiable for it is based entirely on the bearing habit of the apple tree. It is a well known fact that the fruit of the apple is borne principally on wood that is at least two years old. Therefore the effect of the application or omission of nitrate of soda in the spring of 1927 is impossible of measurement in the yields of 1927 except with respect to its effect in increasing the set of fruit (10), (16). It is evident, therefore, that any influence it may have on yield through increased fruit bud formation, should it occur, cannot be measured until 1928 or thereafter.

With the above two points in mind, Table 7 was constructed which eliminates the years 1926 and 1927 and presents the yields for the two five year periods, 1921 to 1925 and 1928 to 1932. It is noted that an increase of 97 $\pm$ 24.47 in yield has occurred in the case of the Check trees compared with the increase 141.73 $\pm$ 48.63 produced in the case of the nitrogen treated Check trees. Of the various trees under study there were only seven others that might have received

TABLE 7

Comparison of Average Annual Yield in Pounds per Tree When Under Old and New Fertilizer Treatments.

Old Treatment 1909-1926	No. of Trees	Average Yield per Tree 1921	1922	1923	1924	1925	New Treatment 1927-'32	Average Yield per Tree 1928	1929	1930	1931	1932	Ave. Annual Yield per Tree in Lbs. 1921-1925	1928-1932	Difference and Standard Error of Difference	% Gain or Loss
Check	4	10.5	.25	.20	4.25	113.75	Check	140.75	50.5	224.5	17.25	204.25	29.75	127.45	97.70±24.47	+328.4
Check	14	14.85	58.78	45.65	23.42	81.42	10-25 N	330.35	21.85	241.5	218.93	134.43	44.82	186.55	141.73±48.63	+316.22
PK	7	16.1	139.7	63.1	98.8	115.3	PK	247.3	70.4	389.1	95.4	345.8	86.6	229.6	143.0±17.76	+165.12
P-K	8	9.75	27.12	7.78	5.0	24.25	PK + 10-25 N	296.75	35.75	329.87	69.75	110.5	14.78	168.52	153.74±14.70	+1040.18
NPK	11	49.54	410.1	157.0	265.18	373.9	P-K	312.18	63.36	428.27	139.54	365.18	251.14	261.71	10.55±26.13	+ 4.20
NPK	7	61.85	509.57	168.71	282.0	248.14	PK + 10-25 N	519.57	36.57	442.14	206.28	433.71	254.05	327.65	73.60±23.51	+28.97

some wash from the alfalfa field but all of these had previously been receiving nitrogen and it consequently would not have influenced them to a similar degree. This point is particularly well supported by comparison of the significant average increase +1041% made by PK trees to which nitrogen was added with that (28.97%) made by NPK trees to which additional nitrogen was applied.

The group of NPK trees from which the nitrogen was withheld showed an increase of 4.20% which was not significant. It is most interesting to note how well the average yield of this group of trees has been maintained over a five year period without the addition of nitrogen. These trees, however, as previously mentioned were subject to some cross-feeding due to their proximity to nitrogen treated trees.

Discussion

It is thus evident that quantities of nitrogen such as that apparently reaching the Check trees will cause large increases in yield. The Check trees that were nitrated made a greater yearly average gain in pounds (141) of fruit produced than the untreated Checks (97) but the latter group made a greater gain on a percentage basis. It also seems apparent that nitrogen applied to trees that have received K or P for a period of years has resulted in greater increases both in actual amounts and on a percentage basis than when applied to trees that had not previously received K or P. Trees that have received a reasonable supply of nitrogen for a long period of time were apparently able to maintain their yield fairly well for a five year period. Similar trees to which nitrogen was added gave a significant increase on an actual amount basis but it was very much less than that produced by the addition of nitrogen to the Check or KP trees. Apparently apple trees that have received nitrogen over a period of years do not respond to additional amounts as do those which have previously received little or none.

Chemical Studies (Percentage Dry Weight Basis).

As the difference in the carbohydrate and nitrogen content of the spurs of the trees before and after treatment is an important part of the chemical phase of this study, the increases or decreases of the various constituents in the spurs analyzed are presented in the tables found in the body of the paper. An increase is considered to have occurred if the analysis was higher for any constituent in 1932 than in 1926. The individual trees comprising the groups representative of the various New Treatments are presented in Table 8. For convenience the Check or K or P trees to which nitrogen was applied will be designated as Check—>N and K or P—>N, the NPK—>PK group as N—>0 and the NPK—>N + PK group as N—>N. The individual analysis of each tree in 1926 and 1932 can be found in Appendix Tables F and G respectively. As the changes in acid hydrolyzable materials closely resemble those changes occurring in the case of the total

Table 8.

Trees Analyzed for Their Carbohydrate and Nitrogen Constituents in 1926 and 1932 - See Appendix Tables F and G for Results of Individual Trees.

Vegetative Spurs.

Check—>N Tree No.	K or P—>N Tree No.	N—>O Tree No.	N—>N Tree No.
46-10	34-8	46-16	44-14
40-22	36-8	36-26	34-26
36-10	38-10	40-26	40-28
36-12		36-42	34-42
40-20		46-28	46-26
46-30			

Bearing Spurs.

Check or K—>N Tree No.	N—>O Tree No.	N—>N Tree No.
46-10	46-16	44-14
36-10	36-26	34-26
36-8	40-26	40-28
	36-42	34-42
	46-28	46-26

carbohydrates, only the latter are discussed in detail.

Vegetative Spurs

Sugars

Free Reducing Sugars - In Table 9 are presented the differences on a percentage dry weight basis of the various constituents of vegetative spurs in 1926 and 1932. It is noted that the free reducing substances decreased significantly under all treatments, even including the one where nitrogen was omitted from trees which previously had received it. They might have been expected to increase under this treatment due to the withholding of nitrogen and the theoretical retarding of growth but such apparently was not the case.

Total Sugars - Total sugars also decreased in all substances, but not significantly in the K-P ⟶ N or N ⟶ N groups.

Sucrose - Sucrose on the other hand has increased in all instances and significantly in the Check ⟶ N and nearly so in the N ⟶ 0 group.

Total Carbohydrates

The total carbohydrates have decreased in all groups and significantly in the case of the Check ⟶ N, N ⟶ 0 and N ⟶ N treatments. The reason that the odds are not significant in the K-P ⟶ N group is due to the small number of individuals

TABLE 9

Comparison of the Difference in Vegetative Spurs in 1926 and 1932 With Respect to the Constituents for Which They Were Analyzed. Expressed on a Percentage Dry Weight Basis.

See Appendix Tables F and G for Results on Individual Trees in 1926-1932.

Vegetative Spurs

Constituents	Check → N		P-K → N		N → O		N → N	
	Average Mean Difference	Odds	Average Mean Difference	Odds	Average Mean Difference	Odds	Average Mean Difference	Odds
Total Nitrogen	+.140	158	+.518	18	-.124	25	-.022	1
Insoluble Nitrogen	+.081	132	+.410	12	-.075	8	-.096	4
Soluble Nitrogen	+.036	11	+.108	37	-.058	454	+.074	168
Free Reducing Sugars	-.813	3,332	-1.00	322	-1.04	4,999	-.935	249
Total Sugars	-.476	98	-1.01	27	-.540	212	-3.198	132
Sucrose	+.335	51	+.256	5	+.398	28	+.214	2
Total Carbohydrates	-2.604	9,999	-2.309	11	-1.135	32	-1.438	86
Acid Hydrolyzable Substances	-2.15	4,999	-1.256	3	-.594	7	-.586	8
Starch	-4.968	1,999	-5.443	146	-3.046	908	-3.198	132

used for a decrease occurred in all three trees. As the changes occurring in the case of acid-hydrolyzable materials are of a very similar to those of the total carbohydrates they are not discussed.

Starch

Unfortunately starch was determined by a different method in 1932 than in 1926 (See pages 24 and 25). For greater convenience taka-diastase was used in 1932 instead of saliva and very much lower results were obtained even though tests of the samples with IKI indicated that all starch had been hydrolyzed. The cause is not explainable but the exceedingly lower results in all instances indicate that the two methods, at least on the type of material in question, probably yields different results. It is planned to carry out a study on the comparison of the two methods on apple spur material in the near future.

Nitrogen

Total Nitrogen - It is noted in Table 9 that only the Checks receiving nitrogen applications increased significantly in their percentage total nitrogen. The N—>0 group decreased to an extent approaching significance. The K-P—>N group increased considerably but not significantly. The surprising thing was that the N—>N group decreased very slightly.

Soluble Nitrogen - Soluble nitrogen increased significantly in the K-P—>N and N—>N groups and decreased significantly in the N—>0 groups where nitrogen was omitted. The Check —>N group showed an insignificant increase.

Insoluble Nitrogen - Insoluble nitrogen increased significantly in the Check—>N group but not so in the K-P—>N group. In the N—>0 group a non-significant decrease occurred as was also the case in the N—>N group. It is apparent from the above that the soluble nitrogen changes have been more consistent with respect to treatment given than Insoluble or Total Nitrogen.

Bearing Spurs

The differences in the various constituents (1926-1932) on a percentage dry weight basis with their respective odds are also presented in Table 10. It is noted that no bearing spurs of the K-P—>N group were analyzed in 1932. This was due to the scarcity of blossoming spurs present on these trees.

Sugars

Free Reducing Sugars - It is noted in Table 10 that the free reducing sugars decreased significantly in the Check—>N and the N—>0 groups. A decrease but not a significant one occurred also in the N—>N group. It will be recalled that similar decreases also occurred in the case of vegetative spurs and that all were significant.

TABLE 10

Comparison of the Difference in Bearing Spurs in 1926 and 1932 With Respect to the Constituents for Which They Were Analyzed. Expressed on a Percentage Dry Weight Basis.
See Appendix Tables F&G for Results on Individual Trees in 1926-1932.

Bearing Spurs

Constituents	Check → N		N → O		N → N	
	Average Mean Difference	Odds	Average Mean Difference	Odds	Average Mean Difference	Odds
Total Nitrogen	+.493	12	-.385	18	-.387	18
Insoluble Nitrogen	+.254	7	-.316	8	-.209	5
Soluble Nitrogen	+.219	66	-.069	4	-.186	60
Free Reducing Sugars	-.79	102	-1.098	168	-.612	17
Total Sugars	-.64	6	-.684	18	-.437	17
Sucrose	+.15	1	+.414	86	+.27	6
Total Carbohydrate	-3.72	30	-1.89	60	-.476	2
Acid Hydrolyzable Substance	-3.08	15	-1.21	12	-.20	1
Starch	-6.622	146	-3.318	1666	-3.187	908

Total Sugars - In the case of total sugars decreases occurred but none were of significance. Decreases occurred in vegetative spurs of these groups also but they were significant with the exception of the N—>N group.

Sucrose - Sucrose, as was the case with vegetative spurs increased in all of the groups. A significant increase is noted here only in the N—>O group whereas the N—>O group in the case of vegetative spurs was just below significance.

Total Carbohydrates

Total Carbohydrates decreased significantly in the Check-K—>N and the N—>O but not significantly in the N—>N group. The acid hydrolyzable materials also decreased in all instances but none were of significance.

Starch

As mentioned in the case of vegetative spurs, a different method analysis for starch was used in 1932 than in 1926 which it is felt is largely responsible for the very significant decreases obtained in all groups.

Nitrogen

Total Nitrogen - The total nitrogen content of the bearing spurs varied in a manner similar to those of the vegetative spurs in that an increase occurred in the Check—>N group and decreases in both the N—>0 and the N—>N groups. In the case of the vegetative spurs, however, the difference was significant in the Check—>N group but was not in the case of bearing spurs from those trees. The decreases which occurred in both the vegetative and bearing spurs in groups N—>0 and N—>N were not significant.

Soluble Nitrogen - Soluble nitrogen showed a significant increase in the case of the Check—>N group, a significant decrease in the N—>N group and a non-significant decrease in the N—>0 group. The trend of the Check—>N and N—>0 is the same as in the vegetative spurs but the N—>N group is just the reverse but significant in both instances.

Insoluble Nitrogen - There is a non-significant increase in the Check—>N group and non-significant decreases in both the N—>0 and N—>N groups. The same results occurred in the case of the vegetative spurs excepting the increase was significant in the Check—>N group.

Discussion

It is noted that on a percentage dry weight basis that both vegetative and bearing spurs on all nitrogen plots have decreased under all treatments with respect to their free reducing, total sugars and acid hydrolyzable materials. Starch decreased also but probably this was due to the different methods of determination used in the two seasons. Sucrose is the only carbohydrate to have increased consistently although not always significantly. Decreases in the carbohydrates of the Check—>N and K-P—>N trees might be expected as they were found in 1926 to be somewhat higher in carbohydrates and with the addition of nitrogen these carbohydrates probably were used in growth. The N—>0 group, however, might have been expected to have increased in carbohydrates for by the withholding of nitrogen less growth should have occurred and an accumulation of carbohydrates resulted. However, such was not the case. Sucrose increased in general in both vegetative and bearing spurs but significantly in only two of seven instances.

Total, soluble and insoluble nitrogen increased in all instances in the Check—>N and KP—>N treatments but significantly in only four of them. In the case of the N—>0, as might be expected, withholding of nitrogen has caused a decrease in all forms of nitrogen in both vegetative and bearing spurs, although these decreases have been significant in only one instance. The N—>N group behaved quite differently than one would expect for it showed decreases in five out of six instances, but only one of which was signifcant. The increase in the case of soluble nitrogen in vegetative spurs was significant.

Carbohydrate-Nitrogen Relationships. (Percentage Dry Weight Basis). Vegetative Spurs.

The changes resulting in the carbohydrate-nitrogen relationships of vegetative spurs, as a result of treatment, are presented in Table 11 on the total, soluble and insoluble nitrogen basis.

Sugars

Free Reducing Sugars-Total Nitrogen Relationship - The odds are very significant that a decrease in the relationships has occurred, under all treatments with respect to the Free Reducing Sugar-total, soluble and insoluble nitrogen relationships with one exception. This was in the case of soluble nitrogen under the N→0 treatment where a decrease that was not significant resulted.

Total Sugar-Total Nitrogen Relationship - In the case of total sugars, it is noted that significant decreases occur when all three forms of nitrogen are considered under the Check→N and K or P→N treatments. Non-significant decreases occur in the case of total and insoluble nitrogen and a non-significant increase with soluble nitrogen under the N→0 treatment. Under the N→N treatment non-significant decreases have resulted in the case of total and insoluble nitrogen whereas a significant decrease has occurred in the case of soluble nitrogen.

TABLE 11

Comparison of the Differences in the C/N Ratios of Vegetative Spurs in 1926 and 1932. Percentage Dry Weight Basis.

Constituents	Change in Ratio	Odds	Change in Ratio	Odds	Change in Ratio	Odds	Change in Ratio	Odds
Total Nitrogen								
	Check	N	K or P	N	N	O	N	N
Free Reducing Sugars	-1.41	Infinite	-2.33	83.0	-.96	269.0	-1.03	178
Total Sugars	-1.17	1999	-2.86	122.0	-.29	6.0	- .60	4.0
Sucrose	+ .09	1.0	- .54	25.0	+.54	32.0	+ .24	2.0
Total Carbohydrates	-9.13	666	-18.37	23.1	+2.23	8.0	-1.16	22.0
Acid Hydrolyzable Sub.	-7.97	499	- 15.54	18.7	+2.53	14.2	- .82	1.0
Starch	-7.73	1666	-10.45	102.0	-2.83	103.0	-3.24	40.0
Soluble Nitrogen								
Free Reducing Sugars	-13.72	86.0	-24.71	369.0	-4.04	16.0	-12.71	53.0
Total Sugars	-12.82	79.0	-31.16	322.0	+ .98	2.0	-11.67	49.0
Sucrose	+ .90	2.0	-6.45	30.0	+4.18	40.0	-2.34	2.0
Total Carbohydrates	-125.5	14.0	-229.0	66.0	+41.85	12.0	-95.47	35.0
Acid Hydrolyzable Sub.	-112.66	12.0	-197.78	51.0	+40.85	16.0	-83.78	32.0
Starch	-70.82	32.0	-108.4	66.0	-11.24	1.0	-39.64	72.0
Insoluble Nitrogen								
Free Reducing Sugars	-1.60	Infinite	-2.53	51.0	-1.32	212.0	1.0	60.0
Total Sugars	-1.27	269.0	-3.10	66.0	- .50	8.0	-.51	2.0
Sucrose	+ .32	6.0	- .57	20.0	+ .63	32.0	+.36	3.0
Total Carbohydrates	-8.78	322.0	-19.17	14.0	+1.29	2.0	+1.06	1.0
Acid Hydrolyzable Sub.	-7.51	269.0	-16.08	11.0	+1.78	4.0	+1.57	2.0
Starch	-8.25	555.0	-11.45	83.0	-3.75	111.0	-3.45	20.0

Sucrose-Total Nitrogen Relationship - In the case of sucrose three increases occurred with respect to total nitrogen but only that under the N→0 treatment was significant. A decrease occurred under the PK→N which was not significant. When based on soluble nitrogen it is noted that a significant increase occurred under the N→0 treatment and a significant decrease under the K or P→N treatment. An increase resulted under the Check→N group and a decrease under the N→N treatment, neither of which was significant.

Total Carbohydrates-Nitrogen Relationships - It is noted that a significant decrease resulted when total nitrogen is considered under the Check→N treatment. Decreases that were not significant resulted in the K or P→N and N→N groups and a non-significant increase in the N→0 group. The same trend was shown with respect to soluble nitrogen but the decreases were significant under the K or P→N and N→N groups. The decrease under the Check→N and the increase under the N 0 were not significant. Decreases occurred in the case of the Check→N and K or P→N group but was significant only in the former instance. Increases that were not significant resulted in the N→0 and N→N groups.

As the acid hydrolyzable-nitrogen relationships follow so closely those of the total carbohydrate substances, even to significance of odds under each treatment and with each form of nitrogen, they will not be discussed separately.

Starch-Nitrogen Relationships - The starch-nitrogen relationships decreased under every treatment with respect to total, soluble and insoluble nitrogen and with two exceptions these decreases were significant. One of these exceptions occurs in the N→0 group in the case of soluble nitrogen and the other in the N→N group in the case of insoluble nitrogen. However, as mentioned previously, it is felt that the results based on starch are subject to error due to the different methods used during the two seasons.

Bearing Spurs

It is noted from Table 12 that, in the case of bearing spurs, acid hydrolyzable materials and total carbohydrates again behave very similarly. Accordingly, only the acid hydrolyzable materials will be discussed as they form the greater portion of the total carbohydrate constituents. Insignificant decreases occur in the acid hydrolyzable-nitrogen relationships under the Check or K→N treatment with respect to total, soluble and insoluble nitrogen. Non-significant increases occur under the N→0 and N→N treatments with all three forms of nitrogen. Starch decreases in its relationship with all three forms of nitrogen and under the three treatments. All of these decreases are significant except one which occurs under the

TABLE 12

Changes in the C/N Ratios Between 1926 and 1932. (Percentage Dry Weight Basis)

Bearing Spurs

Total Nitrogen

Constituents	Check or K→N Change	Odds	N→O Change	Odds	N→N Change	Odds
Total Carbohydrate	-9.74	13	+1.61	5	+4.25	12
Acid Hydrolyzable Substances	-8.48	12	+1.76	8	+3.97	14
Starch	-6.70	36	-1.45	249	-1.35	199

Soluble Nitrogen

Constituents	Check or K→N Change	Odds	N→O Change	Odds	N→N Change	Odds
Total Carbohydrate	-57.35	22	+1.97	1	+16.99	25
Acid Hydrolyzable Substances	-50.27	19	+2.53	1	+15.86	25
Starch	-30.79	30	-5.27	86	-3.14	16

Insoluble Nitrogen

Constituents	Check or K→N Change	Odds	N→O Change	Odds	N→N Change	Odds
Total Carbohydrate	-10.68	9	+2.42	4	+6.66	3
Acid Hydrolyzable Substances	-9.28	8	+2.69	7	+6.18	4
Starch	-8.50	39	-2.12	122	-2.16	79

N—>N treatment.

Catalase Activity

At the time of taking spur samples in 1932, determination of catalase activity of the leaves was made of vegetative and bearing spurs and the results are presented in Tables 13 and 14 and Figures VII and VIII.

Vegetative Spurs.

It is noted from Table 13 that catalase is very low in the case of the Check trees to which no nitrogen applications had been made, for each cc. of water was displaced at a much slower rate than in the case of any of the trees receiving nitrogen. The graphs shown in Figure VII emphasize this point particularly well. It is noted that the trees from which nitrogen had been omitted in the second period were next lowest, with the N—>N, PK—>N and Check—>N being very much alike with respect to catalase activity.

Leaves of Bearing Spurs.

The catalase activity of the leaves of bearing spurs is presented in Table 14. It is noted that the catalase activity of the Check tree sampled was very low requiring 97 seconds to displace the five cubic centimeters of water. Three Check trees to which twenty-five pounds of nitrate of soda had been applied for six years showed very much higher

TABLE 13

Comparison of the Catalase Activity of the Leaves of *Vegetative Spurs, June 1932 - Newark, Delaware.

Old Treatment	New Treatment	No. of Trees	Number of seconds required to displace each cubic centimeter of water. Average of two determinations.									
			1st cc	2nd cc	3rd cc	4th cc	5th cc	6th cc	7th cc	8th cc	9th cc	10th cc
Check	Check	2	17.2	26.7	28.5	33.2	37.0	42.0	47.0	55.2	65.2	77.0
Check	N	6	8.5	8.5	9.7	11.4	12.0	13.5	13.9	15.4	16.0	17.9
K or P	N ≠ K or P	4	9.5	8.2	10.1	11.2	12.5	13.7	14.5	15.3	17.0	17.9
NPK	KP	7	10.9	11.7	13.1	15.4	16.7	18.3	19.9	22.1	23.8	26.6
NPK	N ≠ KP	6	9.2	9.3	10.5	11.8	13.1	14.5	15.3	16.5	17.8	19.8

* For trees making up the various groups see Appendix Table H.

Table 14.

Comparison of the Catalase Activity of the Leaves of *Bearing Spurs, June 1932 - Newark, Delaware.

Old Treatment	New Treatment	No. of trees	Number of seconds required to displace each cubic centimeter of water. Average of two determinations.									
			1st cc.	2nd cc.	3rd cc.	4th cc.	5th cc.	6th cc.	7th cc.	8th cc.	9th cc.	10th cc.
Check	Check	1	32.0	47.5	58.0	75.0	97.0	128.5	-	-	-	-
Check	N	1	26.5	34.0	45.5	59.0	90.5	-	-	-	-	-
Check or K	N	3	12.5	13.3	15.6	18.0	19.6	23.0	24.8	28.8	33.3	38.3
NPK	KP	7	16.3	19.6	23.3	27.4	31.1	36.4	36.7	43.7	55.1	69.0
NPK	N - KP	5	11.6	13.8	16.3	19.5	20.2	22.7	26.2	29.4	33.1	38.3

*For trees makimg up the various groups see Appendix Table I.

FIGURE VII

A comparison of the catalase activity of the leaves of vegetative spurs from the differently fertilizer groups of trees. It is noted that the leaves of the Checks are much lower in catalase activity than those having received nitrogen.

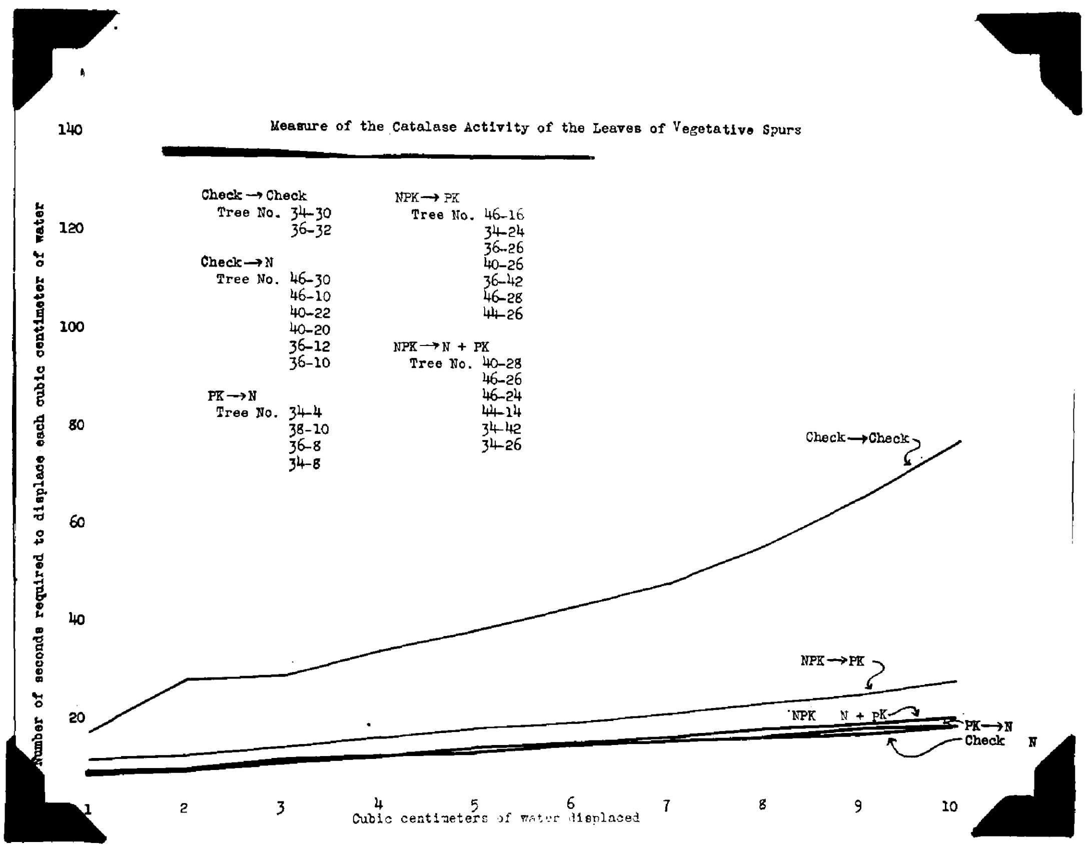
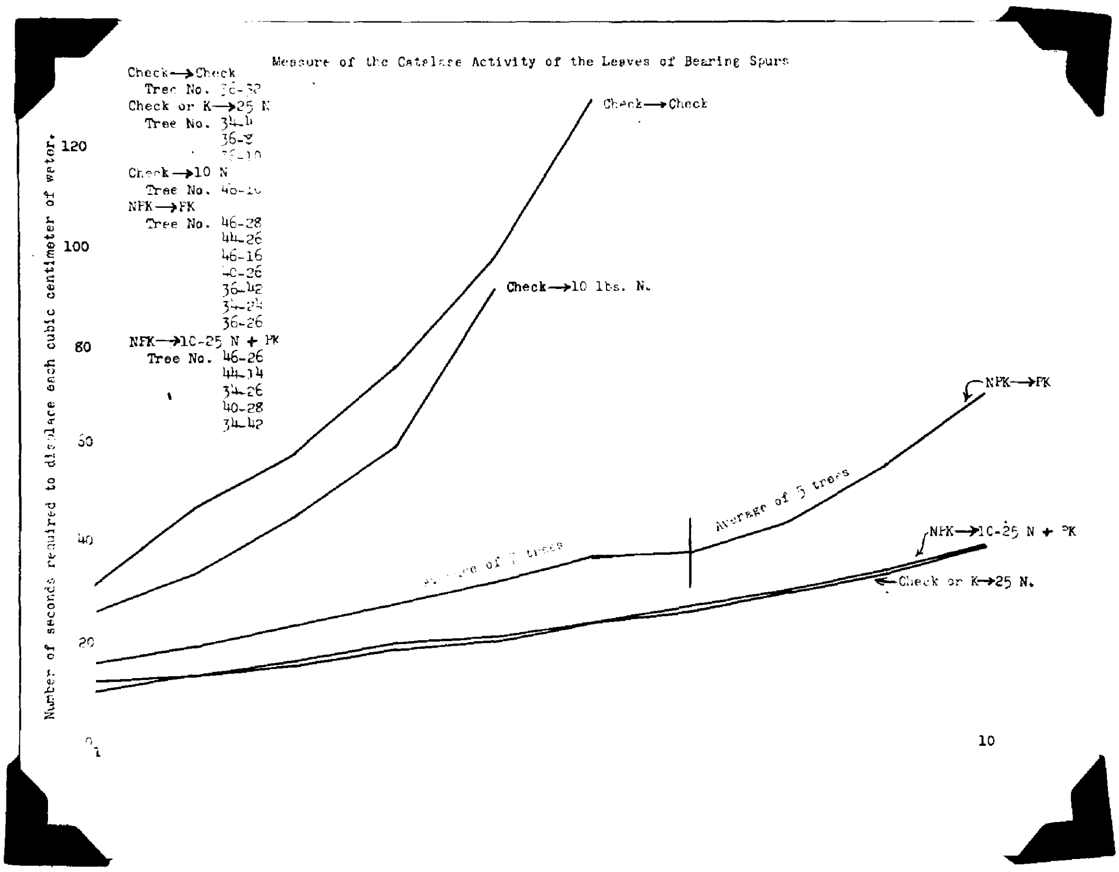


Figure VIII.

A Comparison of the catalase activity of the leaves of bearing spurs. It is noted that the Check is lowest in catalase activity but that a Check which has received nitrogen is also quite low. It is pointed out to show that exceptions do occur. The rest of the trees receiving nitrogen are higher in catalase activity than the NPK→PK.



catalase activity requiring only twenty seconds to displace ~~the~~ five cc. of water. A Check tree, however, to which only ten pounds of nitrate of soda had been applied yearly did not show nearly as much catalase activity requiring nearly as long to displace five cc. of water as the untreated Check tree. This extreme result is an exception but is presented as an example of what may occur. The NPK⟶PK group is less active with respect to catalase than trees receiving nitrogen, with the exception of the individual case just noted. The results are graphically depicted in Figure VIII and show the apparent effect of the nitrogen applications very well. The break in the graph of the NPK⟶PK group at seven cc. indicates that only five trees were averaged beyond this point.

Discussion

In general it seems that increase in the catalase activity of the leaves of vegetative and bearing spurs is often associated with high metabolic activity in the apple tree. It was noted that it appeared most active where the trees were growing most rapidly, as in the case of those receiving nitrogen. Also vegetative spurs which attain greater growth in length than bearing spurs bear foliage of greater catalase activity. When nitrogen is withheld from trees previously receiving it, the catalase activity of the leaves of their vegetative and bearing spurs becomes less than that of similar trees to which nitrogen was added.

A comparison of the catalase activity of the leaves of vegetative and bearing spurs of the same trees is graphically presented in Figures IX and X. It is noted in Fig. IX that in all instances the leaves from vegetative spurs have greater catalase activity than the leaves from bearing spurs of the same tree. However, the leaves of bearing spurs from the heavily nitrated tree (36-10) are seen to have exhibited greater catalase activity than the leaves from vegetative spurs of the Check tree 36-32. It is also evident Figs. IX and X that based on the averages of several trees the leaves of vegetative spurs displayed greater catalase activity than those from bearing spurs. The trees from which nitrogen has been withheld are less active in catalase activity than those that have been receiving it during the last five years.

A study of the average catalase activity of the leaves of vegetative spurs of a number of K or P or Check trees that had received varying amounts of nitrogen ten, fifteen, and twenty-five pounds revealed on the average slightly more activity where twenty-five pounds of nitrate of soda was added than where ten pounds was applied.

FIGURE IX

A comparison of the catalase activity of the leaves of vegetative spurs with those of bearing spurs from the same tree. The leaves of vegetative spurs are seen to have greater catalase activity in all instances.

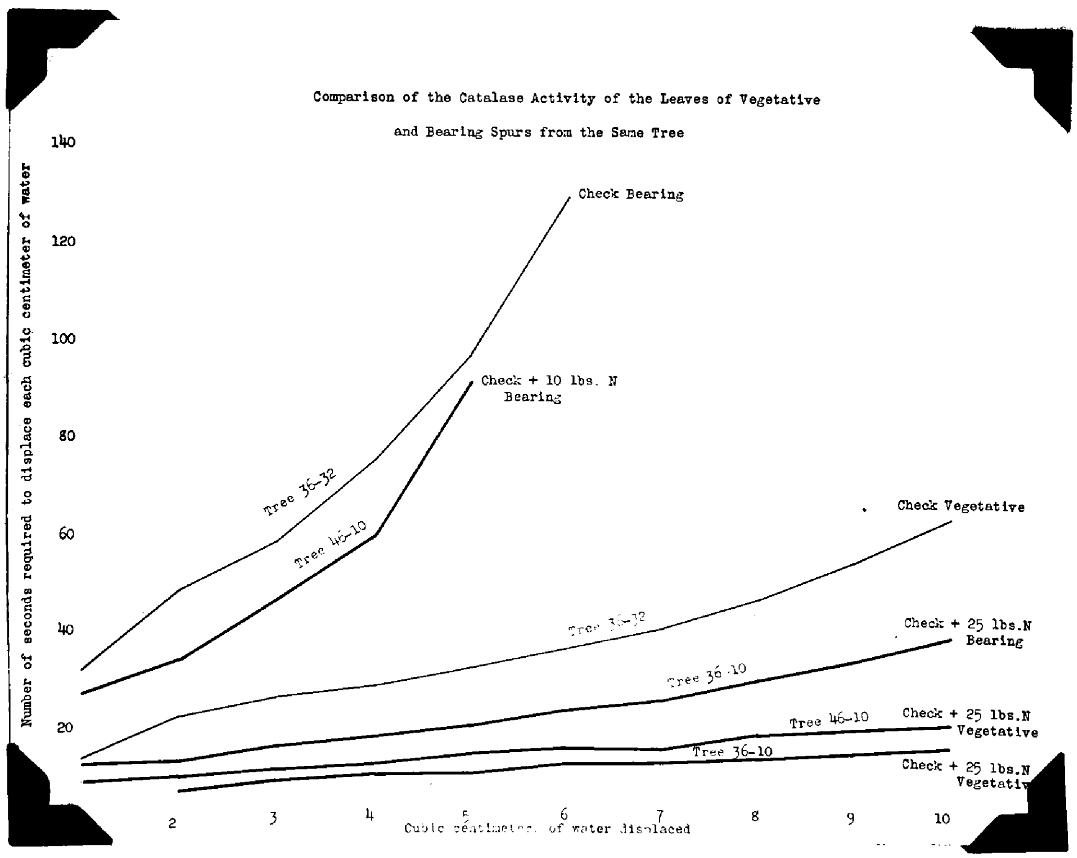
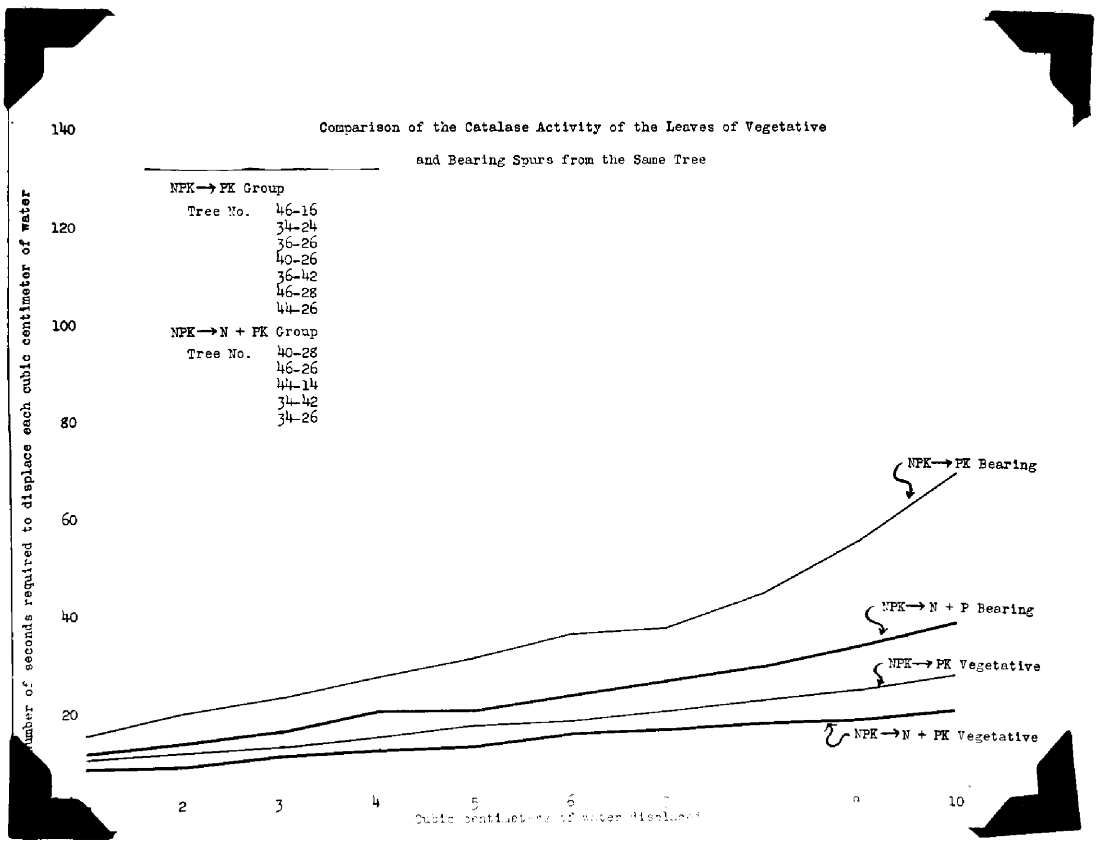


FIGURE X

A comparison of the catalase activity of the leaves of vegetative and bearing spurs. The leaves of the bearing spurs of nitrated trees are seen to be higher in catalase activity than the leaves from vegettative spurs of trees not receiving nitrogen.



Discussion

Having found (14) that after seventeen years of different fertilizer treatments Jonathan apple trees in the different plots could well be grouped according to their growth conditions and carbohydrate-nitrogen relationships into some of the classes established by Kraus and Kraybill, the plan of the experiment was radically changed. The trees which had not been receiving Nitrogen were divided into two groups. One group remained as a Check while nitrogen was added to the balance. The trees which had received nitrogen were also divided into two groups, one in which nitrogen was withheld and the other to which large applications of nitrogen were continued. The changes produced in growth of the trees following these changes in treatment were studied during a five year period and at the end of that time their carbohydrate-nitrogen relationships were determined so that they might be compared with those of 1926, before changes in treatments were made.

Very marked increases in circumference, terminal and vegetative spur growth occurred soon after the addition of nitrogen to the Check and PK, nitrogen deficient trees. Yields also increased, but as would be expected, more gradually for they are quite largely dependent on size of tree. The P-K trees that were deficient in nitrogen have made greater growth and yield responses than the Check trees which may indicate a better utilization of the nitrogen when it became available.

Both of these groups, however, are now making growth equally as great or greater than that of the former NPK trees were in 1926. Their foliage is of a good green color and they would ~~not~~ be classed as reasonably productive although they are still, of course, much smaller in size than the trees having received nitrogen since 1909. These trees showed a marked decrease in total carbohydrates and an increase in total nitrogen content, and their C/N relationship was in general reduced. In fact the decrease occurring in the Check group is such as to make the ratio (28.02) practically the same as that of the NPK group in 1926 (28.39) Table 15.

The K→N group of trees show a somewhat lower ratio (20.52) than the NPK trees in 1926 due largely to an increased nitrogen content. This closely approaches the N_3PK group of 1926 which were mentioned at that time as possibly moving from Class III to Class II which apparently has considerable latitude. In fact there is undoubtedly such a gradual merging of one class into another that distinct and sharp class lines do not exist and could hardly be expected to, with the large normal variation existing in this type of material.

The group of trees from which nitrogen was withheld have changed comparatively little in growth response or yield. The color of foliage has changed to a somewhat lighter green only in the last two years. It would seem that as shown by Roberts (21)

Table 15.

A Comparison of the Total Carbohydrate/Total Nitrogen Relationships of Vegetative Spurs 1926-1932.

Treatment 1926	Treatment 1932	C/N 1926	C/N 1932	Ave. Yield per tree per year in lbs. 1921-1925	Ave. Yield per tree per year in lbs. 1928-1932
Check	N	37.13	28.02	4.2	29.8
K	N	38.91	20.52	2.4	24.2
NPK	0	28.39	29.87	59.08	69.2
NPK	N	28.39	26.02	57.20	75.0

in the case of young trees that old apple trees also apparently build up a nitrogen reserve that they may utilize when an external deficiency occurs. The carbohydrate-nitrogen relationship of this group in contrast to that of the Check—>N and P-K—>N groups has increased but little between 1926 and 1932 (Table 15), and although the change is not a statistically significant one, it is in the direction that would be theoretically expected. As these trees have not changed significantly in growth and yield since 1926, their C/N relationship might be expected to be the same. As this is the case these trees may still be termed as of Class III.

The NPK—>N group of trees have in most instances made slightly increased growth although in the case of circumference a non-significant decrease in rate was noted. The increase in yield of this group was statistically significant. With the addition of large amounts of nitrogen to these trees one might expect that a decrease in their C/N relationships would result through a greater utilization of carbohydrates in growth and an increase in the nitrogen content of the tissues. A slight decrease did occur which was not statistically significant. There was a slight decrease in carbohydrates but practically no increase in nitrogen content indicating that at least under the conditions of this study that the spurs of trees already supplied with nitrogen were not increased in their nitrogen content by the addition of large amounts of nitrate of soda.

It is thus seen that large additional amounts of nitrogen applied to trees already well supplied with it has increased the growth in most instances, as well as yield, but after a five year period has failed to significantly change the C/N relationship of the trees.

The general trend of results is the same whether calculated on a dry weight or absolute amounts basis. In general total carbohydrates and total nitrogen show the most significant trends although changes in sucrose and soluble nitrogen have in some instances been of significance.

The results of this study have not shown as clear cut differences existing between the differently treated trees as those that were found to exist at the time of the analysis in 1926. Perhaps a five year period is too short a period of study when one considers the nature of growth and longevity of the apple tree. As mentioned in 1926 it was felt that the very contrasting results obtained were in part due to the great length of time (seventeen years that the trees had been under treatment) and it is now felt that the changes noted may continue and greater differences occur in the next five year period.

Summary

A study was conducted over a five year period in which radical changes were made in the nitrogen treatment of eighteen year old Jonathan apple trees.

Growth Response

Trees that had formerly received no fertilizer of any kind and those that had received only superphosphate or muriate of potash over a seventeen year period, responded greatly to heavy applications of nitrogen.

Yearly circumference increments were greatly increased, as well as the length of terminals and vegetative spurs in comparison to Check trees.

Yields were also greatly increased although even larger increases can be expected in the future.

The trees formerly having received either acid phosphate or muriate of potash in general made greater gains on a percentage basis, than former Check trees.

Trees formerly having received nitrogen but to which none has been applied for a five year period, have been able to make in general approximately the same amoung of growth as previously, due probably to the utilization of nitrogen reserves.

The yields of these trees, 1927-1931, has, however, decreased somewhat.

Trees formerly receiving nitrogen or nitrogen and acid phosphate and potash combined and to which much more nitrogen was added have decreased slightly (1927-1931) in circumference increment. Although they have increased in length of terminal growth and length of vegetative spurs. The yields of these trees decreased somewhat (1927-1932). The response of these trees to nitrogen, however, was not nearly as large as that made by the nitrogen deficient trees on a percentage basis and in certain instances was lower in actual amount.

Chemical Changes (Percentage Dry Weight Basis).

In general, there was a decrease in the carbohydrate content of the trees wherever nitrogen was applied, and nitrogen in general increased, although such changes were not always significant.

Trees formerly receiving nitrogen but from which it was omitted for five years also decreased in carbohydrates.

The same changes in general occurred in the various groups when the constituents were calculated as absolute amounts.

Carbohydrate-Nitrogen Relationships.

The changes having occurred in the carbohydrate-nitrogen relationships of vegetative spurs of the trees since change in treatment were not as clear cut as those found to exist between the trees of diffdrent fertilizer plots when analyzed in 1926. However, there does seem to have been quite a consistent decrease in the carbohydrate-nitrogen relationships of trees when they were given heavy applications of nitrogen.

Those trees from which nitrogen was withheld showed fewer decreases but not many of the increases were significant. The bearing spurs did not respond as consistently as the non-bearing spurs.

Catalase Activity

Catalase activity was greater in the leaves of spurs from heavily nitrated trees than in the Checks. It was also greater in the case of leaves from non-bearing spurs than in those of bearing spurs.

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APPENDIX TABLE I

Catalase Activity of Bearing Spurs - Average of Two Determinations

Tree No.	Old Treatment	New Treatment	Number of Seconds Required to Displace Each Cubic Centimeter of Water 1cc	2cc	3cc	4cc	5cc	6cc	7cc	8cc	9cc	10cc
36-32	Check	Check	32.0	47.5	58.0	75.0	97.0	128.5	-	-	-	-
34-4	K	K + 25 N	16.0	16.0	19.0	22.5	23.5	29.0	32.0	38.0	45.5	53.5
36-8	K	K + 25 N	11.5	12.5	15.0	16.5	18.5	22.5	23.0	26.5	30.5	34.5
36-10	Check	25 N	10.0	11.5	13.0	15.0	17.0	17.5	19.5	22.0	24.0	27.0
	TOTAL		37.5	40.0	47.0	54.0	59.0	69.0	74.5	86.5	100.0	115.0
	AVERAGE		12.5	13.3	15.6	18.0	19.6	23.0	24.8	28.8	33.3	38.3
46-10	Check	10 N	26.5	34.0	45.5	59.0	90.5	-	-	-	-	-
46-28	N_3PK	PK	23.0	25.5	31.0	34.5	42.0	50.5	-	-	-	-
44-26	N_3PK	PK	19.0	25.0	28.5	34.0	39.5	45.0	-	-	-	-
46-16	N	O	15.5	17.5	20.5	24.0	27.5	31.5	37.0	45.5	56.5	73.5
40-26	NK	K	17.5	23.0	27.5	33.0	36.0	42.5	50.0	63.0	80.0	107.5
36-42	NPK	PK	17.5	20.5	26.0	31.0	33.5	40.5	50.0	54.0	71.5	92.0
34-24	NP	P	10.0	10.0	11.0	14.0	15.0	16.0	18.0	18.5	22.5	22.5
36-26	NP	P	11.5	16.0	18.5	21.5	24.0	29.0	28.5	37.5	45.0	49.5
	TOTAL		114.0	137.5	163.0	192.0	217.5	255.0	183.5	218.5	275.5	345.0
	AVERAGE		16.3	19.6	23.3	27.4	31.1	36.4	36.7	43.7	55.1	69.0
46-26	N_3PK	25 N	9.5	10.5	12.0	13.5	15.0	17.0	18.5	19.5	22.0	24.5
44-14	N	10 N	10.0	12.0	14.5	17.0	17.5	19.5	21.0	23.5	25.0	28.0
34-26	NP	10 N	15.5	19.0	23.5	29.5	29.0	35.5	40.5	47.5	56.0	68.5
40-28	NK	10 N	12.0	15.5	19.0	21.0	22.5	23.0	30.5	33.5	38.0	44.0
34-42	NPK	10 N	11.0	12.0	12.5	16.5	17.0	18.5	20.5	23.0	24.5	26.5
	TOTAL		58.0	69.0	81.5	97.5	101.0	113.5	131.0	147.0	165.5	191.5
	AVERAGE		11.6	13.8	16.3	19.5	20.2	22.7	26.2	29.4	33.1	38.3

[illegible]																		
34-24	NPK	669	35	35	25	41	22	PK	38	44	22	25	22					
40-26	NPK	700	31	25	44	3	28	PK	35	10	31	19	13					
38-26	NPK	588	44	35	41	25	22	PK	47	25	28	13	16					
40-24	NPK	547	28	25	28	10	19	PK	31	13	10	19	22					
34-40	NPK	766	22	35	25	22	19	PK	31	38	28	3	25					
36-40	NPK	738	6	28	41	10	19	PK	38	3	35	10	16					
36-42	NPK	688	25	35	28	41	3	PK	53	16	25	16	19					
46-28	NPK	497	28	13	25	13	10	PK	31	10	13	13	16					
44-26	NPK	622	31	38	38	28	10	PK	47	19	28	10	13					
	Total	7159	335	322	380	225	202		423	216	276	169	181					
	Average	651	30.5	29.2	34.5	20.5	18.4		38.5	19.6	25.1	15.4	16.5	26.6	23.0	-3.6	±	1.77	-13.53
44-14	NPK	725	44	19	60	13	25	PK + 10-25N	50	16	16	47	25					
34-26	NPK	744	35	25	31	35	38	PK + 10-25N	6	25	38	3	35					
42-28	NPK	613	22	25	25	25	13	PK + 10-25N	31	10	25	25	22					
40-28	NPK	738	25	31	38	28	16	PK + 10-25N	44	25	41	16	16					
34-42	NPK	735	25	41	22	31	16	PK + 10-25N	35	31	35	3	28					
46-26	NPK	622	25	28	13	19	6	PK + 10-25N	38	13	13	19	13					
46-24	NPK	691	28	28	31	22	13	PK + 10-25N	47	3	38	25	6					
	Total	4868	204	197	220	173	127		251	123	206	138	145					
	Average	695	29.1	28.1	31.4	24.7	18.1		35.8	17.5	29.4	19.7	20.7	26.3	24.6	-1.7	±	2.73	-6.46

Explanatory Note -

Old Treatment

Check indicates no fertilizer was applied.
P indicates tree had received about 3 lbs. of superphosphate annually.
K indicates tree had received about 1 lb. of muriate of potash annually.
N indicates tree had received about 3 lbs. of nitrate of soda annually.
N_3 indicates the tree had received about 9 lbs.

New Treatment

Check indicates no fertilizer was applied.
K or P indicates tree received about 1 lb. of muriate of potash or 3 lbs. of superphosphate annually.
10-25 N indicates the tree received either 10 or 25 lbs. of nitrate of soda.

40-28	NK	10 N	12.0	15.5	19.0	21.0	22.5	23.0	30.5	33.5	38.0	44.0
34-42	NPK	10 N	11.0	12.0	12.5	16.5	17.0	18.5	20.5	23.0	24.5	26.5
	TOTAL		58.0	69.0	81.5	97.5	101.0	113.5	131.0	147.0	165.5	191.5
	AVERAGE		11.6	13.8	16.3	19.5	20.2	22.7	26.2	29.4	33.1	38.3

APPENDIX TABLE A

Comparison of Yearly Gain in Circumference in Millimeters of Individual Jonathan Apple Trees When Under Old and New Fertilizer Treatments at Newark, Delaware.

Tree No.	Old Treatment 1909-1926	Circumference 1921	Girth Increase 1922	1923	1924	1925	1926	New Treatment 1927-1931	Girth Increase 1927	1928	1929	1930	1931	Total Girth Increase 1922-1926	1927-1931	Difference with Standard Error	% Gain or Loss
36-30	Check	494	6	6	13	6	19	Check	6	25	6	13	19				
34-32	Check	597	0	10	10	13	19	Check	25	3	10	13	10				
34-30	Check	425	10	6	13	6	19	Check	22	6	13	19	6				
36-32	Check	525	13	6	13	13	19	Check	19	13	6	10	10				
	Total	2041	29	28	49	38	76		72	47	35	55	45				
Average		510	7.3	7.0	12.3	9.5	19.0		18	11.8	8.8	13.8	11.3	11.0	12.7	1.7 ± 1.81	+15.45
44-32	Check	581	25	28	28	28	22	10 N	31	44	47	28	19				
46-10	Check	500	38	13	31	6	22	10 N	44	10	41	38	22				
40-22	Check	444	3	6	10	3	10	15 N	31	19	25	25	19				
38-20	Check	422	16	6	13	13	13	15 N	41	28	38	28	25				
46-30	Check	391	31	19	22	13	25	25 N	56	19	38	38	10				
40-20	Check	435	10	10	10	6	10	25 N	31	16	16	22	25				
36-12	Check	438	6	3	10	3	6	25 N	47	13	38	38	25				
34-12	Check	481	3	6	6	3	10	25 N	16	13	16	25	10				
42-22	Check	481	10	13	16	19	13	25 N	41	28	28	22	16				
44-10	Check	600	35	16	19	10	19	25 N	47	19	44	31	19				
46-12	Check	625	28	22	19	22	10	25 N	50	13	38	31	35				
44-30	Check	713	38	19	31	22	28	25 N	50	13	38	38	13				
	Total	6111	243	161	215	148	188		485	235	407	364	238				
Average		509	20.3	13.4	17.9	12.3	15.7		40.4	19.6	33.9	30.3	19.8	15.9	28.8	12.9 ± 1.27	+81.13
34-6	PK	597	6	16	0	10	10	10-25N	38	25	19	22	28				
34-8	PK	506	6	3	10	10	3	10-25N	41	22	28	35	6				
36-8	PK	413	6	0	10	3	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				

34-6	K	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
	TOTAL	23.8	26.9	42.3										
	AVERAGE	2.98	3.36	5.29		13.08	20.06	24.14	13.76	17.39	3.87	17.69	13.82 - .800	+221.11
46-16	N	11.8	14.4	10.0	O	12.3	14.9	14.7	12.7	13.6				
36-26	NP	11.2	10.3	8.8	P	15.6	12.4	17.3	10.0	13.8				
34-24	NP	12.1	11.1	11.0	P	11.0	19.6	14.7	13.9	18.1				
40-26	NK	11.5	11.0	8.4	K	11.5	8.1	14.5	11.6	16.9				
38-26	NK	9.1	12.8	10.2	K	16.2	11.5	13.6	5.2	5.5				
40-24	NK	7.6	10.3	5.2	K	5.6	7.0	11.4	9.5	8.5				
34-40	NPK	6.6	5.4	7.4	PK	13.0	10.1	13.9	7.4	11.8				
36-40	NPK	12.7	9.3	9.9	PK	13.7	19.0	16.8	12.6	15.4				
36-42	NPK	20.7	12.8	10.7	PK	12.2	11.8	14.1	12.2	17.9				
46-28	N_3PK	12.2	10.8	6.3	PK	10.3	11.4	7.9	11.6	12.3				
44-26	N_3PK	23.5	12.0	19.7	PK	11.0	18.3	16.1	9.9	17.7				
	TOTAL	139.0	120.2	107.6		132.4	144.1	155.0	116.6	151.5				
	AVERAGE	12.64	10.93	9.78		12.04	13.10	14.09	10.60	13.77	11.11	12.72	1.61 t .600	+14.49
44-14	N	8.4	15.2	7.7	10 N	13.3	12.2	16.0	9.6	15.9				
34-26	NP	11.4	10.2	9.5	P + 10N	13.1	20.4	24.3	13.8	14.6				
42-28	NK	17.0	11.7	9.7	K + 10N	17.8	21.7	24.1	9.7	13.0				
40-28	NK	20.7	14.1	9.7	K + 10N	17.8	18.7	21.4	14.1	18.9				
34-42	NPK	13.5	10.7	10.7	PK + 10N	18.1	17.8	19.0	10.9	18.5				
46-26	N_3PK	9.2	7.6	8.9	PK + 25 N	13.5	9.8	7.4	10.1	11.3				
46-24	N_3PK	18.9	10.9	21.8	PK + 25 N	13.5	19.6	18.6	11.3	14.0				
	TOTAL	99.1	80.4	78.0		107.1	120.2	130.8	79.5	106.2				
	AVERAGE	14.16	11.49	11.14		15.3	17.17	18.68	11.35	15.17	12.25	15.54	3.28 t .927	+26.78

Explanatory Note -

Old Treatment

Check indicates no fertilizer was applied.

P indicates tree had received about 3 lbs. of superphosphate annually.

K indicates tree had received about 1 lb. of muriate of potash annually.

N indicates tree had received about 3 lbs. of nitrate of soda annually.

N_3 indicates the tree had received about 9 lbs. of nitrate of soda annually.

New Treatment

Check indicates no fertilizer was applied.

K or P indicates tree received about 1 lb. of muriate of potash or 3 lbs. of superphosphate annually.

O indicates that the former annual nitrogen application was not applied.

10-25N indicates the tree received either 10 or 25 lbs. of nitrate of soda.

APPENDIX TABLE B

Comparison of Yearly Terminal Growth in Centimeters of Individual Jonathan Apple Trees When Under Old and New Fertilizer Treatments at Newark, Delaware

Tree No.	Old Treatment 1909-1926	Terminal Growth in Centimeters 1924	1925	1926	New Treatment 1927-1931	Terminal Growth in Centimeters 1927	1928	1929	1930	1931	Average Terminal Growth in Centimeters 1924-1926	1927-1931	Difference with Standard Error	% Gain or Loss
36-30	Check	2.7	4.0	5.4	Check	10.7	7.5	10.7	11.2	12.8				
34-32	Check	2.7	3.1	9.2	Check	11.6	1.6	13.4	8.0	13.3				
34-30	Check	3.0	3.6	5.5	Check	7.8	9.5	12.0	11.2	8.5				
36-32	Check	2.6	3.6	7.9	Check	6.6	7.4	9.0	6.9	8.6				
	TOTAL	11.00	14.30	28.0		36.70	26.0	45.10	37.30	43.20				
	AVERAGE	2.75	3.57	7.0		9.17	6.5	11.28	9.32	10.80	4.44	9.41	4.97 ± .663	+111.93
44-32	Check	7.8	11.9	9.2	10 N	17.1	22.8	15.3	11.7	16.2				
46-10	Check	5.8	8.3	11.0	10 N	22.3	18.9	20.7	13.6	19.7				
40-22	Check	1.5	1.5	3.6	15 N	7.7	27.2	25.6	19.8	19.2				
34-10	Check	1.4	1.1	1.7	15 N	1.3	13.4	13.4	14.0	11.6				
38-20	Check	5.6	8.0	7.4	15 N	26.6	28.1	22.3	16.7	18.6				
46-30	Check	7.7	11.8	7.4	25 N	21.7	21.1	16.0	8.6	11.8				
40-20	Check	4.3	3.7	5.9	25 N	17.0	35.7	31.0	17.8	17.0				
36-12	Check	.8	.9	1.3	25 N	7.8	19.2	23.1	20.6	24.1				
36-10	Check	2.1	1.8	4.2	25 N	5.6	14.1	24.0	15.7	12.7				
34-12	Check	2.6	2.5	6.1	25 N	5.4	10.7	18.7	12.9	15.3				
42-22	Check	5.1	5.8	7.4	25 N	9.4	13.9	12.8	10.4	11.3				
44-10	Check	6.0	8.9	9.8	25 N	22.6	22.3	20.5	14.3	14.0				
46-12	Check	5.9	8.0	12.0	25 N	23.2	28.7	24.3	13.5	21.4				
44-30	Check	10.7	9.9	17.6	25 N	21.8	24.4	17.7	12.6	28.1				
	TOTAL	67.3	84.1	104.6		209.5	300.5	285.4	202.2	241.0				
	AVERAGE	4.81	6.00	7.47		14.97	21.46	20.39	14.44	17.21	6.09	17.69	11.60 ± .592	+190.48
34-6	K	[illegible]	5.9	7.5	K + 10N	6.9	19.6	19.0	15.8	21.4				
36-6	K	1.8	2.7	4.4	K + 10N	10.9	29.3	29.9	14.6	17.1				
[illegible]	K	1.7	2.5	4.1	K + 25N	13.6	18.5	21.9	18.3	20.5				

40-10	P_2	.71	1.13	P_2 + 25 N	3.69	2.21	3.88	2.2	.90				
40-12	P_2	.43	1.09	P_2 + 25 N	3.25	1.58	5.82	5.3	1.20				
	TOTAL	4.340	7.820		29.86	17.480	39.620	25.90	16.170				
	AVERAGE	.542	.977		3.73	2.185	4.952	3.237	2.021	.76	3.22	2.46 ± .721	+323.7
46-16	N	.82	.78	0	1.42	2.56	6.62	2.4	2.63				
36-26	NP	.62	.71	P	2.03	3.27	6.06	2.3	1.62				
34-24	NP	1.34	.96	P	2.94	2.47	4.33	2.3	2.95				
40-26	NK	1.30	1.88	K	2.74	2.76	6.28	3.2	2.40				
38-26	NK	1.33	2.88	K	3.31	2.97	5.01	2.5	1.34				
40-24	NK	1.38	2.31	K	2.51	1.11	2.44	3.4	1.70				
34-40	NPK	.98	1.05	PK	2.38	1.90	3.66	3.1	1.44				
36-40	NPK	.70	.86	PK	2.91	1.69	5.46	2.4	1.61				
36-42	NPK	1.17	1.30	PK	2.86	1.79	3.29	2.5	2.03				
46-28	N_3PK	1.06	.85	PK	2.36	2.58	6.05	3.5	2.14				
44-26	N_3PK	1.23	2.07	PK	3.53	1.60	5.92	2.2	2.83				
	TOTAL	11.93	15.65		28.99	24.70	55.12	29.80	22.69				
	AVERAGE	1.084	1.423		2.635	2.245	5.011	2.709	2.063	1.25	2.93	1.68 ± .141	+134.4
44-14	N	2.05	2.30	10 N	4.26	2.38	6.30	3.5	2.84				
34-26	NP	2.88	1.67	P + 10 N	3.55	1.94	6.36	4.4	2.17				
42-28	NK	2.48	1.32	K + 10 N	3.68	3.12	4.88	5.5	1.70				
40-28	NK	1.04	.93	K + 10 N	1.93	2.82	8.64	4.8	2.60				
34-42	NPK	.99	1.41	PK + 10 N	3.77	3.55	4.85	2.2	1.68				
46-26	N_3PK	.93	.68	PK + 25 N	1.86	2.14	4.58	2.6	2.37				
46-24	N_3PK	.72	.77	PK + 25 N	1.65	2.29	7.05	3.3	2.90				
	TOTAL	11.09	9.08		20.70	18.24	42.66	26.30	16.26				
	AVERAGE	1.584	1.297		2.957	2.606	6.094	3.757	2.323	1.44	3.55	2.11 ± .224	+146.5

Explanatory Note -

Old Treatment

Check indicates no fertilizer was applied.

P indicates tree had received about 3 lbs. of superphosphate annually.

K indicates tree had received about 1 lb. of muriate of potash annually.

N indicates tree had received about 3 lbs. of nitrate of soda annually.

N_3 indicates the tree had received about 9 lbs. of nitrate of soda annually.

New Treatment

Check indicates no fertilizer was applied.

K or P indicates tree received about 1 lb. of muriate of potash or 3 lbs. of superphosphate annually.

O indicates that the former annual nitrogen application was not applied.

10-25 N indicates the tree received either 10 or 25 lbs. of nitrate of soda.

APPENDIX TABLE C

Comparison of Yearly Growth of Vegetative Spurs in Centimeters of Jonathan Apple Trees When Under Old and New Fertilizer Treatments at Newark, Delaware.

Tree No.	Old Treatment 1909-1926	Growth of Vegetative Spurs in Centimeters		New Treatment 1927-1931	Growth of Vegetative Spurs in Centimeters					Average Growth of Vegetative Spurs in Centimeters		Difference with Standard Error	% Gain or Loss
		1925	1926		1927	1928	1929	1930	1931	1924-1926	1927-1931		
36-30	Check	.37	.78	Check	1.53	8.26	3.92	1.8	1.69				
34-32	Check	.51	1.25	Check	4.12	1.99	2.72	2.0	1.07				
34-30	Check	.57	1.01	Check	2.42	1.63	3.79	1.9	.87				
36-32	Check	.40	.97	Check	3.15	1.24	3.32	2.0	2.54				
TOTAL		1.850	4.01		11.22	13.12	13.75	7.7	6.17				
AVERAGE		.46	1.00		2.81	3.28	3.44	1.92	1.542	.73	2.60	1.87 ± .387	+256.2
44-32	Check	1.21	1.87	10 N	4.42	3.56	7.54	4.2	3.53				
46-10	Check	.56	1.11	10 N	2.55	2.78	5.47	3.5	2.55				
40-22	Check	.50	.71	15 N	1.82	1.82	4.80	3.3	1.88				
34-10	Check	.39	.47	15 N	1.33	.74	1.94	1.8	1.66				
38-20	Check	.64	1.12	15 N	3.77	1.79	4.70	5.6	1.49				
46-30	Check	.69	1.60	25 N	2.62	3.94	8.36	3.0	2.24				
40-20	Check	.49	1.14	25 N	2.12	2.57	7.78	5.1	2.33				
36-12	Check	.51	.86	25 N	3.40	1.65	6.59	2.5	2.14				
36-10	Check	.40	.67	25 N	2.34	2.55	1.24	3.9	2.33				
34-12	Check	.56	1.19	25 N	1.83	1.68	4.49	3.0	2.0				
42-22	Check	.52	1.08	25 N	3.16	1.62	4.94	5.0	4.1				
44-10	Check	.81	1.34	25 N	2.99	3.04	4.77	4.3	2.9				
46-12	Check	.41	.54	25 N	2.64	3.50	7.3	4.9	2.5				
44-30	Check	.93	1.48	25 N	2.75	2.00	5.98	6.2	2.28				
TOTAL		8.62	15.18		37.74	33.24	75.9	56.3	33.93				
AVERAGE		.6157	1.084		2.695	2.374	5.421	4.021	2.423	.85	3.39	2.54 ± .173	+298.8
34-6	K	.67	1.33	K + 10 N	3.55	2.06	3.55	3.1	3.67				
36-6	K	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				

APPENDIX TABLE D

Estimation of Percentage Bloom for Years 1926-1933 Inclusive, Newark, Delaware

Tree No.	Old Treat-ment	New Treatment	1926	1927	1928	1929	1930	1931	1932	1933
34-30	Check	Check	0	15	15	5	15	2	1	35
34-32	"	"	10	80	70	35	95	5	60	70
36-30	"	"	5	30	50	5	90	0	35	50
36-32	"	"	5	75	55	25	75	0	75	10
AVERAGE			5	40	38	14	55	1.4	34.2	41.2
34-12	Check	25 N	5	85	65	60	40	50	5	90
36-10	"	25 N	80	0	85	5	40	15	6	65
36-12	"	25 N	60	5	65	15	35	80	0	85
34-10	"	15 N	5	10	75	5	65	3	1	95
40-20	"	25 N	60	15	80	10	65	10	10	70
38-20	"	15 N	15	10	70	5	30	15	2	95
42-22	"	25 N	75	5	75	10	50	70	5	65
40-22	"	15 N	20	30	85	20	40	25	1	90
44-10	"	25 N	25	55	90	5	40	45	1	95
46-12	"	25 N	70	5	75	5	45	25	5	85
46-10	"	10 N	10	70	90	5	70	10	20	90
44-30	"	25 N	10	85	50	10	30	70	1	95
46-30	"	25 N	10	25	60	0	75	25	5	90
AVERAGE			34.23	30.76	74.23	11.92	48.08	34.08	47.69	85.4
34-6	K	K + 10 N	25	5	95	15	85	2	5	90
36-6	K	K + 10 N	40	0	55	5	80	5	5	80
36-8	K	K + 10 N	5	50	45	30	70	10	25	65
34-8	K	K + 25 N	65	5	75	50	75	50	5	90
34-4	K	K + 25 N	20	10	85	10	70	5	10	90
38-10	P_2	P_2 + 25 N	35	0	60	5	35	45	15	85
40-10	P_2	P_2 + 25 N	25	5	95	0	90	25	95	85
40-12	P_2	P_2 + 25 N	15	10	95	10	80	20	25	90
AVERAGE			28.76	10.6	75.6	15.6	73.1	20.2	23.1	84.3
36-26	NP	P	75	25	95	5	95	5	45	55
34-24	NP	P	90	5	80	5	70	5	15	60
34-40	NPK	PK	85	10	95	50	90	5	75	35
36-40	NPK	PK	75	10	70	5	50	20	10	25
36-42	NPK	PK	90	0	85	5	90	10	55	10
38-26	NK	K	10	40	80	15	75	30	25	85
46-16	N	0	10	75	65	35	50	40	20	95
40-24	NK	K	15	65	75	10	5	5	1	60
40-26	NK	K	10	90	75	30	65	10	50	45
44-26	N_3PK	PK	75	5	75	10	40	10	45	75
46-28	N_3PK	PK	50	15	95	10	95	10	90	45
AVERAGE			53.18	30.9	80.9	16.3	65.9	13.6	39.1	53.5
34-26	NP	P + 10 N	90	5	85	5	50	10	20	85
34-42	NPK	PK + 10N	75	35	75	10	70	40	60	65
40-28	NK	K + 10 N	70	20	75	5	25	20	25	85
42-28	NK	K + 10 N	70	5	75	5	25	10	35	50
44-14	N	10 N	90	5	95	5	80	5	25	95
46-26	N_3PK	PK + 25N	75	0	80	30	95	15	50	95
AVERAGE			78.3	11.6	80.8	10.0	57.5	16.6	35.8	79.1
36-4	K	K	0	0	1	15	0	45	0	20
42-12			5	20	90	10	65	15	5	95
44-12			90	0	80	10	65	45	10	95

APPENDIX TABLE E

Presentation of the Individual Annual Yields of the Trees From 1921 to 1932 in Pounds of Fruit per Tree

Tree No.		Old Treatment 1921	1922	1923	1924	1925	1926		New Treatment 1927	1928	1929	1930	1931	1932
34-30	Check	3	0	3	0	0	13	Check	0	65	0	50	4	0
34-32	Check	16	0	33	4	146	120	Check	137	187	78	528	51	367
36-30	Check	7	0	25	0	149	83	Check	55	155	40	290	77	178
36-32	Check	16	1	19	13	160	80	Check	106	156	84	30	7	272
36-4	K	0	0	0	0	0	0	K + 0	0	38	82	0	16	0
34-12	Check	17	7	27	6	65	16	N	134	280	148	171	243	26
36-10	Check	12	130	4	24	13	201	N	0	411	14	296	46	331
36-12	Check	3	19	0	0	10	78	N	8	241	18	138	244	0
34-10	Check	2	17	10	6	14	66	N	4	206	4	125	8	13
40-20	Check	21	0	37	20	85	157	N	37	187	15	174	33	94
38-20	Check	3	0	24	36	151	1	N	34	173	5	179	187	26
42-22	Check	18	76	30	15	23	290	N	13	124	10	196	193	524
40-22	Check	27	0	14	5	74	162	N	95	248	62	246	95	24
44-10	Check	13	121	74	17	90	355	N	258	622	8	412	377	24
46-12	Check	16	2	65	42	89	479	N	22	398	3	341	176	163
46-10	Check	16	2	40	14	49	147	N	300	451	7	319	71	229
44-30	Check	56	408	258	119	430	643	N	675	750	9	246	718	177
46-30	Check	0	0	23	11	8	74	N	47	115	3	235	108	28
44-32	Check	4	41	33	13	39	442	N	33	419	0	303	366	223
34-6	K	15	24	9	7	35	201	K + N	32	455	55	433	34	163
36-6	K	4	16	7	2	8	105	K + N	4	195	5	244	13	47
36-8	K	4	55	18	2	56	38	K + N	95	232	88	284	34	148
34-8	K	1	5	5	10	4	161	K + N	11	195	69	169	137	29
34-4	K	23	110	10	14	14	263	K + N	115	603	59	463	178	182
38-10	P_2	1	7	2	3	9	56	P_2 + N	6	137	0	123	90	84
40-10	P_2	20	0	2	1	28	149	P_2 + N	16	307	2	598	19	70
40-12	P_2	10	0	9	1	40	144	P_2 + N	43	250	8	325	54	161
36-26	N(PK)	94	411	275	260	406	482	(PK)0	202	437	77	423	118	417
34-24	N(PK)	37	403	127	371	171	676	(PK)0	55	330	18	349	322	258
34-40	N(PK)	43	675	227	555	971	946	(PK)0	99	231	256	471	118	635
36-40	N(PK)	3	688	268	461	524	751	(PK)0	51	370	24	846	81	464
36-42	N(PK)	62	755	124	497	340	1019	(PK)0	1	473	30	615	34	673
38-26	N(PK)	17	110	46	59	292	347	(PK)0	121	181	51	339	61	102
46-16	N(PK)	30	269	144	124	444	394	(PK)0	206	344	73	409	391	316
40-24	N(PK)	35	149	25	182	122	126	(PK)0	68	78	30	128	99	56
40-26	N(PK)	180	550	230	141	593	395	(PK)0	284	616	107	656	52	659
44-26	N(PK)	24	384	118	224	152	589	(PK)0	10	216	28	312	204	302
46-28	N(PK)	20	118	143	43	98	329	(PK)0	5	158	3	163	55	135
34-26	N(PK)	142	612	223	369	278	901	N	31	438	62	365	265	375
34-42	N(PK)	44	589	237	320	519	795	N	162	541	78	555	174	462
40-28	N(PK)	86	578	120	281	387	871	N	67	609	29	549	422	456
42-28	N(PK)	24	332	45	286	103	719	N	9	576	7	425	61	462
44-14	N(PK)	65	438	92	228	114	767	N	0	837	6	648	117	523
46-24	N(PK)	24	515	430	244	243	643	N	70	354	13	352	259	377
46-26	N(PK)	48	503	34	246	93	542	N	3	282	61	201	146	381

APPENDIX TABLE F

Chemical Analyses of Current Season's Growth of Jonathan Apple Spurs from Various Fertilizer Plots at Newark, Delaware.

June 25-30, 1926

Expressed on Percentage Dry Weight Basis

Tree No.	Treatment 1908-1926	% Bloom 1926	Yield in lbs. 1926	Type of Spur	% Moisture	% Dry Weight	Total Sugars	Free-Reducing Sugars	Sucrose	Polysaccharides	Starch	Total Carbohydrates	Total Nitrogen	Soluble Nitrogen	Insoluble Nitrogen
46-10	Check	10	147	B	58.833	41.167	3.473	2.389	1.084	24.618	9.445	28.091	1.238	.274	.964
				V	50.654	49.346	3.125	2.280	.845	24.364	9.610	27.489	.681	.102	.579
40-22	Check	20	162	B	61.476	38.524	2.910	2.169	.742	24.590	7.590	27.500	3.403	.489	2.914
				V	51.539	48.461	2.711	1.764	.947	24.397	6.862	27.108	.656	.084	.572
36-10	Check	80	201	B	64.021	35.971	3.980	2.702	1.278	23.797	7.931	27.777	1.293	.347	.946
				V	58.197	41.803	2.652	2.090	.562	23.999	9.457	26.651	.728	-	-
36-12	Check	60	78	B	62.324	37.676	3.377	2.446	.931	24.418	8.442	27.795	1.021	.218	.803
				V	57.586	42.414	2.743	2.160	.583	23.644	9.715	26.387	.799	.129	.670
40-20	Check	60	157	B	60.885	39.115	3.676	2.626	1.050	23.240	6.387	26.916	1.914	.111	1.803
				V	53.222	46.778	2.578	2.030	.548	23.972	6.444	26.550	.820	.139	.681
46-30	Check	10	74	B	59.626	40.374	2.547	1.716	.831	23.090	8.290	25.637	1.580	.404	1.176
				V	51.038	48.962	1.704	1.655	.049	24.400	9.254	26.104	.668	.047	.621
34-8	K	65	161	B	66.674	33.326	3.806	2.715	1.091	23.157	6.756	26.963	1.309	.393	.917
				V	60.781	39.219	3.395	2.550	.845	24.102	8.383	27.497	.627	.081	.546
36-8	K	5	38	B	62.105	37.895	3.158	1.981	1.177	26.620	11.132	29.778	.958	.212	.746
				V	53.673	46.327	2.782	2.150	.632	23.972	9.979	26.754	.652	.064	.588
38-10	P_2	35	56	B	61.260	38.741	3.450	2.543	.907	22.451	8.046	25.901	1.376	.360	1.016
				V	54.977	45.023	3.047	2.210	.837	20.409	9.054	23.456	.736	.070	.666
46-16	N	10	394	B	63.137	36.863	3.572	2.548	1.024	23.532	5.887	27.104	1.560	.452	1.108
				V	53.109	46.891	2.169	2.415	.246	22.175	8.411	24.344	.805	.117	.688
36-26	NP	75	482	B	63.525	36.475	3.720	2.866	.854	22.934	5.442	26.654	1.742	.569	1.173
				V	56.892	43.108	2.639	2.290	.349	21.878	4.738	24.517	.986	.190	.796
40-26	NK	10	395	B	63.772	36.228	1.808	1.704	.104	22.609	6.063	24.417	2.587	.458	2.129
				V	55.553	44.447	2.479	2.296	.183	24.618	6.386	27.097	.910	.166	.744
36-42	NPK	90	1019	B	67.355	32.645	3.934	2.898	1.036	20.793	5.130	24.727	1.819	.725	1.094
				V	58.972	41.028	2.722	2.020	.702	22.112	7.922	24.834	.867	.221	.646
46-28	N_3PK	50	329	B	61.297	38.703	1.892	1.472	.420	20.870	5.797	22.762	2.020	.662	1.358
				V	58.186	41.814	2.320	2.081	.238	20.894	6.519	23.214	1.132	.190	.942
44-14	N	90	767	B	60.266	39.734	2.803	1.805	.998	21.390	6.931	24.193	1.725	.576	1.149
				V	53.296	46.704	2.837	2.310	.527	21.783	6.842	24.620	.827	.073	.754
34-26	NP	90	901	B	65.695	34.305	1.752	-	-	23.410	4.992	25.162	1.867	.542	1.325
				V	57.435	42.565	2.144	1.508	.636	23.061	5.034	25.205	1.157	.155	1.002
40-28	NK	70	871	B	65.437	34.563	2.324	2.138	.186	21.434	5.320	23.758	1.437	.667	.808
				V	56.007	43.993	2.786	2.103	.683	23.404	5.004	26.190	.971	.164	.807
34-42	NPK	75	795	B	62.449	37.551	3.289	2.272	1.017	20.971	5.105	24.264	1.597	.651	.946
				V	56.288	43.712	2.862	2.010	.852	20.805	9.014	23.667	.926	.182	.744
46-26	N_3PK	75	542	B	64.350	35.651	2.480	1.640	.840	21.455	5.648	23.935	2.122	.704	1.418
				V	53.812	46.188	1.817	-	-	21.033	6.499	22.850	1.158	.087	1.071

Note -

B = Bearing

V = Vegetative

APPENDIX TABLE G

Chemical Analyses of Current Season's Growth of Jonathan Apple Spurs from Various Fertilizer Plots at Newark, Delaware.

June 25-July 5, 1932 — Expressed on percentage Dry Weight Basis

Tree No.	Treatment Old	Treatment New	% Bloom	Yield in lbs. 1932	Type of Spur	% Moisture	% Dry Weight	Total Sugars	Free-Reducing Sugars	Sucrose	Polysaccharides	Starch	Total Carbohydrates	Total Nitrogen	Soluble Nitrogen	Insoluble Nitrogen
46-10	Check	10 N	20	229	B	60.44	39.56	3.29	1.5	1.79	22.32	2.70	25.61	1.42	.45	.97
					V	51.52	48.48	2.88	1.5	1.38	21.96	3.78	24.84	.90	.19	.71
36-10	Check	25 N	60	331	B	61.09	38.91	2.53	1.8	.73	22.23	2.70	24.76	1.71	.54	1.17
					V	54.72	45.28	2.43	1.5	.93	21.33	2.97	23.76	.98	.17	.81
40-22	Check	15 N	1	24	V	54.04	45.96	2.02	1.2	.82	22.14	3.87	24.16	.83	.13	.70
36-12	Check	25 N	0	0	V	54.92	45.08	1.83	1.1	.73	21.51	3.78	23.34	.85	.12	.73
40-20	Check	25 N	10	94	V	53.36	46.64	1.87	.9	.97	22.50	3.96	24.37	.84	.12	.72
46-30	Check	25 N	5	28	V	49.08	50.92	1.60	.9	.70	22.59	3.15	24.19	.79	.12	.67
36-8	K	K + 25 N	25	148	B	61.99	38.01	2.87	1.4	1.47	21.24	3.24	24.11	1.78	.50	1.28
					V	56.78	43.22	2.31	1.2	1.11	21.33	3.42	23.64	1.49	.20	1.29
34-8	K	K + 25 N	5	29	V	54.55	45.45	2.13	1.4	.73	21.78	3.87	23.91	1.13	.14	.99
38-10	P_2	P_2 + 25 N	15	84	V	53.33	46.67	1.73	1.3	.43	21.60	3.78	23.33	.95	.20	.75
46-16	N	-	20	316	B	59.76	40.24	2.92	1.4	1.52	20.52	2.88	23.44	1.53	.48	1.05
					V	52.00	48.00	1.84	1.3	.54	21.60	4.68	23.44	.81	.14	.67
36-26	NP	P	45	417	B	59.62	40.38	2.45	1.3	1.15	21.42	1.89	23.87	1.54	.48	1.06
					V	54.94	45.06	2.37	1.2	1.17	22.05	2.70	24.42	.79	.12	.67
40-26	NK	K	50	659	B	60.39	39.61	2.01	1.1	.91	20.79	2.70	22.80	1.51	.48	1.03
					V	52.69	47.31	1.87	1.0	.87	22.59	4.32	24.46	.80	.10	.70
36-42	NPK	PK	55	673	B	60.89	39.11	2.39	1.2	1.19	21.60	2.97	23.99	1.43	.40	1.03
					V	54.06	45.94	1.81	1.1	.71	22.32	3.78	24.13	.83	.14	.69
46-28	N_3PK	PK	90	135	B	53.08	46.92	1.73	1.0	.73	20.34	1.26	22.07	1.79	.68	1.11
					V	59.56	40.44	1.72	1.3	.42	20.16	3.24	21.88	.85	.14	.71
44-14	N	10 N	25	523	B	60.32	39.68	2.91	1.4	1.51	22.14	2.61	25.05	.95	.48	.47
					V	53.43	46.57	2.63	1.3	1.33	21.42	3.33	24.05	1.01	.21	.80
34-26	NP	P + 10 N	20	375	B	61.91	38.09	2.15	1.3	.85	21.42	2.52	23.57	1.46	.42	1.04
					V	57.33	42.67	1.96	1.2	.76	20.97	2.79	22.93	1.02	.22	.80
40-28	NK	K + 10 N	25	456	B	60.78	39.22	1.91	1.1	.81	23.49	3.42	25.40	1.24	.33	.91
					V	54.59	45.41	1.13	.7	.43	22.59	3.60	23.72	.99	.20	.79
34-42	NPK	PK + 10 N	60	462	B	62.90	37.10	2.50	1.3	1.20	20.61	1.62	23.11	1.78	.59	1.19
					V	56.47	43.53	1.62	1.3	.32	20.88	3.06	22.50	1.10	.25	.85
46-26	N_3PK	PK + 25 N	50	381	B	58.76	41.24	1.82	1.2	.62	19.98	1.89	21.80	1.38	.39	.99
					V	51.79	48.21	2.16	.9	1.26	19.98	3.60	22.14	.81	.15	.66
36-32	Check	Check	75	0	B	58.09	41.91	2.34	1.3	1.04	22.23	3.24	24.57	1.27	.31	.96
					V	50.82	49.18	1.74	1.1	.64	22.95	4.05	24.69	.77	.07	.70
*34-30	Check	Check	1	0	V	51.78	48.22	1.53	1.0	.53	23.04	3.42	24.57	.74	.08	.66
*36-4	K	K	0	0	V	54.36	45.64	1.91	1.1	.81	21.51	3.51	23.42	1.00	.08	.92
*34-4	K	K + 25 N	10	182	B	62.61	37.39	2.69	1.4	1.29	22.05	3.15	24.74	1.93	.43	1.50
					V	55.02	44.98	2.46	1.5	.96	22.41	3.96	24.87	1.48	.22	1.26
*34-24	NP	P	15	258	B	61.96	38.04	2.24	.8	1.44	20.16	2.25	22.40	1.49	.52	.97
					V	56.02	43.98	1.86	1.4	.46	21.06	2.61	22.92	1.21	.31	.90
*44-26	N_3PK	PK	45	302	B	58.12	41.88	2.23	1.2	1.03	21.51	3.15	23.74	1.11	.30	.81
					V	51.81	48.19	1.36	.7	.66	19.53	3.78	20.89	.79	.13	.66
*46-24	N_3PK	PK + 25 N	10	377	V	51.51	48.49	1.48	1.1	.38	19.62	3.51	21.10	1.07	.21	.86
*42-12	P_2	P_2	5	59	V	51.13	48.87	1.79	1.1	.69	21.15	5.13	22.94	.82	.11	.71
*44-12	Check	Check	10	160	V	51.49	48.51	2.41	1.2	1.21	23.04	3.78	25.45	.73	.11	.62

Note -

B = Bearing Spurs

V = Vegetative Spurs

* = Analyzed only in 1932

** = 10 lbs. $NaNO_3$ applied by mistake in 1927.

APPENDIX TABLE H

Catalase Activity of Vegetative Spurs - Average of Two Determinations

Tree No.	Old Treatment	New Treatment	Number of Seconds Required to Displace Each Cubic Centimeter of Water: 1cc	2cc	3cc	4cc	5cc	6cc	7cc	8cc	9cc	10cc
36-4	K	K	25.0	59.0	98.5	145.5	198.5	271.5	374.5	-	-	-
34-30	Check	Check	20.5	31.5	31.0	38.5	42.0	48.0	54.5	65.0	77.0	91.5
36-32	Check	Check	14.0	22.0	26.0	28.0	32.0	36.0	39.5	45.5	53.5	62.5
	TOTAL		34.5	53.5	57.0	66.5	74.0	84.0	94.0	110.5	130.5	154.0
	AVERAGE		17.2	26.7	28.5	33.2	37.0	42.0	47.0	55.2	65.2	77.0
46-30	Check	+ 25 N	9.0	10.0	11.0	13.5	13.0	15.0	15.0	16.5	18.0	19.0
46-10	Check	+ 10 N	9.0	10.0	10.5	11.5	13.5	15.0	15.0	18.0	19.0	19.5
40-22	Check	+ 15 N	8.5	8.0	9.0	10.5	11.5	12.5	13.0	13.5	16.0	17.0
40-20	Check	+ 25 N	8.5	8.5	10.0	12.0	12.5	14.0	15.5	16.5	17.5	20.0
36-12	Check	+ 25 N	8.0	8.0	9.0	10.5	11.5	13.5	13.0	15.0	15.0	17.0
36-10	Check	+ 25 N	8.0	6.5	9.0	10.5	10.5	11.0	12.0	13.0	14.0	15.0
	TOTAL		51.0	51.0	58.5	68.5	72.5	81.0	83.5	92.5	96.5	107.5
	AVERAGE		8.5	8.5	9.7	11.4	12.0	13.5	13.9	15.4	16.0	17.9
34-4	K	K + 25 N	9.5	7.5	10.0	9.5	11.0	13.5	13.0	14.5	15.5	16.5
38-10	P_2	P_2 + 25 N	11.5	12.5	15.0	16.5	19.0	19.5	21.5	23.0	26.0	27.0
36-8	K	K + 25 N	8.5	6.0	7.0	8.5	9.0	10.0	11.0	11.0	12.5	12.5
34-8	K	K + 25 N	8.5	7.0	8.5	10.5	11.0	12.0	12.5	13.0	14.0	15.5
	TOTAL		38.0	33.0	40.5	45.0	50.0	55.0	58.0	61.5	68.0	71.5
	AVERAGE		9.5	8.2	10.1	11.2	12.5	13.7	14.5	15.3	17.0	17.9
46-16	N	O	11.0	11.5	13.5	15.0	16.0	19.0	19.5	22.5	23.5	27.0
34-24	NP	P	11.0	9.5	11.5	13.5	14.5	16.5	16.0	19.0	19.5	21.5
36-26	NP	P	12.5	15.0	17.5	20.5	23.0	24.5	28.5	30.5	34.5	38.5
40-26	NK	K	9.5	10.0	11.0	13.0	14.0	15.5	16.5	17.5	18.5	21.0
36-42	NPK	PK	12.5	16.0	16.0	20.5	22.0	21.5	27.0	28.5	33.0	35.0
[illegible]	N_3PK	PK	7.5	7.0	7.0	8.5	9.0	10.0	10.0	11.5	10.5	12.5
44-26	N_3PK	PK	12.0	13.0	15.0	17.0	18.5	21.0	21.5	25.0	27.0	30.5
	TOTAL		76.0	82.0	91.5	108.0	117.0	128.0	139.0	154.5	166.5	186.0
	AVERAGE		10.9	11.7	13.1	15.4	16.7	18.3	19.9	22.1	23.8	26.6
40-28	NK	10 lbs. N	10.5	10.0	11.0	12.0	14.5	15.0	16.0	17.5	19.5	21.0
46-26	N_3PK	25 lbs. N	8.5	9.0	10.0	10.5	11.5	13.0	14.0	15.5	16.0	18.0
46-24	N_3PK	25 lbs. N	9.0	9.0	10.0	11.5	12.5	13.0	14.5	14.0	15.5	17.5
44-14	N	10 lbs. N	8.5	8.5	9.5	11.0	11.5	13.0	14.0	14.5	14.5	16.0
34-42	NPK	10 lbs. N	8.5	8.5	10.0	12.0	12.5	14.0	14.0	16.0	17.0	18.5
34-26	NP	10 lbs. N	10.5	11.0	13.0	14.0	16.5	19.0	19.5	21.5	24.5	28.0
	TOTAL		55.5	56.0	63.5	71.0	79.0	87.0	92.0	99.0	107.0	119.0
	AVERAGE		9.2	9.3	10.5	11.8	13.1	14.5	15.3	16.5	17.8	19.8