A PHYSIOLOGICAL STUDY OF THE EFFECTS OF DIFFERENT NITROGEN CARRIERS ON THE NITROGEN NUTRITION OF ORCHARD PLANTS

by

A.lbert FREEMAN MASON

A thesis submitted to the Faculty of the Graduate School
of the University of Maryland, in partial
fulfillment of the requirements
for the degree of Doctor
of Philosophy

1929

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS.

PLATE I. Well-loaded branch on a typical fertilized tree.

A PHYSIOLOGICAL STUDY OF THE EFFECTS OF DIFFERENT NITROGEN CARRIERS ON THE NITROGEN NUTRITION OF ORCHARD PLANTS.

by

A. Freeman Mason.

INTRODUCTION.

Recent years have seen a great expansion in the use of nitrogen on orchard trees. It is impossible to state how widespread was the use of mineral fertilizers in orchards previous to 1900, but allusions to the practice in the literature are comparatively few. The rapid increase came after 1910,- particularly did it increase following the publication of the results secured by many experiment stations showing the value of nitrogen as an orchard fertilizer. The fall in price of nitrogen products following the close of the war, probably had some effect also. Experiments with nitrate of soda, sulfate of ammonia, cyanamide, dried blood, and manure had been conducted since the opening of the century, using many species of fruit plants. Recently there have been several new nitrogen carriers put on the market, and little information is available as to the value of these as orchard fertilizers. A few of these are calcium nitrate, urea, leuna salpeter (ammonium-nitrate-sulfate), cal-nitro (ammonium nitrate coated with calcium carbonate), diammonphos, nitrophoska (containing nitrogen phosphorus and potassium), nitro-chalk, and calurea (an urea-calcium nitrate compound).

The investigation reported here concerns eight materials, three of them,- nitrate of soda, sulfate of ammonia and cyanamide, of long standing, and five new ones, calcium nitrate, urea, leuna salpeter, calurea, and cal-nitro. Sodium nitrate, ammonium sulfate, cyanamide, calcium nitrate, leuna salpeter, calurea and urea will be given particular attention.

HISTORICAL REVIEW.

At least one hundred years ago controversy raged in England and on the continent over the question of the place of nitrogen in the program of soil fertility, and about the nature of the carrier of that element. That nitrogenous materials promoted plant growth had long been known. Kimberley (35) tells us that Virgil understood the advantages of saltpeter, while Bacon, in his Sylva, as early as 1670, speaks highly of nitre, or nitrous waters.

It was not until the second quarter of the 19th century that the discussion became really heated. About that period nitrate of soda, sulfate of ammonia, and South American guano had been introduced in quantity in the European markets. Hitherto "saltpeter" or potassium nitrate had been the only common mineral source of nitrogen, and but slight amounts of it had been used. In 1841 2,881 tons of guano were imported into England alone, and only four years later the imports reached 283,300 tons, according to Lipman (38). The chemists and agriculturists were quick to recognize the need of experiments which would appraise the true value of these new materials. But the net results of one hundred years of experimentation has established only one fact incontrovertibly, - that nitrogenous fertilizers generally stimulate plant growth. It has not established any one form of nitrogen as superior to all others under all conditions, nor has the final word been said as to carriers.

The difficulties encountered by early workers still oppress. In 1828 Hawkins (23) describes the variations and apparently inexplicable differences in results from saltpeter (potassium nitrate) and regrets their effect on the use of this material. In 1928, the writer finds results with ammonium sulfate hereinafter reported considerably at variance with those found by Schrader and Auchter (50) in 1925. However, the ever widening field of agricultural chemical and physiological experience is slowly clarifying the situation, and many of the difficulties encountered by earlier workers can now be explained. Present day workers can avoid some of the pitfalls which trapped the early experimental workers.

Previous to 1825 little distinction was made between the various forms of nitrogen. The wide use of guano resulted in general acceptance of the idea that ammonia nitrogen was the important form, because guano was rich in ammonium salts. Boussingalt, growing sunflowers in quartz sand, with nitrate as the only form of nitrogen present, was probably the first to prove that nitrate nitrogen was sufficient to supply all the nitrogen needs of the plant. Knop offered similar evidence, with a comparison of nitrate and ammonium nitrogen, as did also Johnson (33), while according to Lipman (38), Sachs, Stohman, Rautenberg and Kuhn, Lawes, Maercker, Deherain, and others, in the decade following 1850, all found that nitrate nitrogen was superior to the ammonium form. Another school headed by the great chemist, Liebig, opposed the use of mineral nitrogenous fertilizers, forecasting the exhaustion of the other essential elements in the soil if these were used. He promoted "natural" nitrogen fertilizers, such as manure and cover crops. His opposition temporarily retarded the development of the use of mineral carriers of nitrogen.

Wagner (60), in 1881, developed the use of pot and cylinder experiments, and he later proposed the theory of denitrification, about 1895 (61).

Lipman and Blair (38) started cylinder experiments in 1898, and in 1912 reported that yields of dry matter, and percentages of nitrogen recovered was better from nitrate of soda than from sulfate of ammonia, when used on a rotation of crops. At the end of twenty years (39) they report that nitrate of soda was better than any other fertilizer, and that there was a loss of gaseous nitrogen and ammonia during nitrification of the ammonium sulfate.

Kellner (34), in 1884, found that rice, growing in nutrient solutions, did better during the early stages on ammonium nitrogen, and this work was later corroborated by Nagaoka, Krauss, Diakuhara, Kelley, Trelease, Trelease and Jurade, and Trelease and Paulino. Lehman (36) concluded that some plants require nitrate nitrogen for their normal development, and others require ammonium nitrogen during the first half of their growth period and nitrate nitrogen during the latter half. Hutchison and Miller (67) in 1911, grew wheat and pea plants in nutrient solutions with ammonium sulfate as the source of nitrogen, taking care to prevent nitrification. They believe that it is possible for agricultural plants of various kinds to produce normal growth on ammonium salts. Other investigators have scouted the statement that nitrification did not occur in their experiments.

Jacob, Allison and Braham (32) found that decomposition of urea in a fertile Susquehanna loam soil was very rapid, sixty-five percent of the urea having disappeared within twenty-four hours, while at the end of three days no trace of undecomposed urea could be detected. After twenty-eight days nitrification of urea was 91.8% complete.

Cyanamide, according to their investigations, rapidly decomposed into urea and ammonia, with small amounts of dicyanodiamid and guanylurea as probable products in addition. The larger the ammounts of cyanamide which were used, the slower did nitrification proceed, due to the toxicity of dicyanodiamid and other decomposition products to the nitrifying bacteria.

in the soil. Nitrification of urea proceeded most rapidly at one-half to three-fourths soil saturation, while with cyanamide it was highest at only one-fourth saturation, and at 40% saturation there was little if any nitrate formation.

Urea nitrified at all temperatures, while with cyanamide at room temperature no nitrification had taken place after forty days. At 38,5° C. nitrification proceeded rapidly and completely. At 30° C. results were intermediate.

Fudge, (19) found ammonium sulfate, ammonium nitrate, Leuna saltpeter, and urea to increase the soil acidity, while sodium nitrate and calcium cyanamide decreased soil acidity. The acid-forming fertilizers caused a decrease in phosphate availability, but increased water soluble potassium. The basic fertilizers increased phosphorus availability, and decreased water soluble potassium.

Davis (17), in 1927, reports experiments with two year old apple trees grown in pot cultures, and shows significantly that apple trees take their nitrogen in the nitrate form, and that the nitrogen in ammonium sulfate and cyanamide were not only not taken up, but that in certain weak concentrations, were toxic in their effect on the trees. When nitrifying bacteria were present, the ammonium sulfate was as good as nitrate of soda.

Skinner (52) and Skinner and Schreiner (53) list the sources of nitrogen in the soil. They find nitrates the most important and directly used; ammonia salts and nitrates are used to a limited extent, different plants showing variation in the amounts used, and thirdly, organic nitrogen, in the forms of nucleic acid, hypoxanthine, xanthine, guanine, creatinine, creatine, histidine, choline, and arginine, serve as sources of nitrogen when nitrates are absent, but not to any extent when large amounts of nitrates are present.

Review of Literature Pertaining to Orchard Crops..

The experimental use of nitrogenous fertilizers for orchards extends back to about 1890. Since that time investigations have been under way in all sections of the United States, and in many foreign countries. Casual examination of the evidence might lead to the conclusion that there are no specific recommendations to be drawn from the results. More critical review, with particular attention paid to the conditions under which the experiments have been conducted, only serves to impress one with the importance which nitrogen assumes in horticultural practice.

Experimental evidence available on the effects of nitrogen from manure, and nitrate of soda, sulfate of ammonia, and blood or tankage is quite abundant. Information about urea, calcium nitrate, ammonium nitrate, calcium cyanamide and other products of more recent introduction as fertilizers, is meagre, particularly from the standpoint of its use on orchard crops.

Hilgard (28) without giving experimental evidence to back his recommendation, advises California citrous growers to use one hundred and fifty to two hundred pounds per acre of nitrate of soda or its equivalent in sulfate of ammonia, on orange and lemon groves, when they are unable to get stable, corral or sheep manure for this use. He advises against excessive applications, stating that such would lead to sappy fruit, lack of flavor and woody growth.

The Massachusetts Agricultural Experiment Station (13) started an apple orchard fertility experiment in 1890 on the station grounds, in which manure was compared with phosphorus, potassium and check. The soil was quite heavy. The trees, planted in 1890 were in sod until 1911, when strips eight or twelve feet wide between the rows, were cultivated. The manured trees were superior to all other treatments, particularly before cultivation was practiced. Cultivation improved the yield of all plots. Lack of duplication of treatments, and certain easily recognized irregularities in the moisture conditions in this experiment detracts from the significance of the results, but the response of the trees to manure, coupled with the response of all plots to cultivation suggests the importance of nitrogen. In a neighboring orchard (51) on cultivated soil manure gave less growth and yield than some of the other plots.

In New York, an experiment with apples was begun in 1896 in which manure, phosphoric acid, potash, and phosphoric acid, complete fertilizer and checks with no fertilizer were compared. The orchard was planted on a heavy clay soil and the ground was cultivated and cover crops sown. At the end of eight years (25), twenty years (26), and again after twenty-five years (27), there have been no consistent significant benefits in yield or growth, from the use of fertilizers containing nitrogen. The nitrogen used was in one hundred pounds sodium nitrate and 346 pounds of dried blood per acre.

Lyon, Heinicke and Wilson (40) found that the addition of nitrate of soda to apple trees from one to four years old greatly increased growth if the trees were in timothy sod but made but little difference to trees under cultivation with cover crops. They used 0, 100, 300, and 900 pounds per acre, (0, .05, .15, and .45 pounds per tree).

Tukey (59) applied nitrate of soda, ammonium sulfate, urea, cyanamide, and hen manure, to yearling apple trees in a cultivated orchard, and observed increased growth only from urea, which gave a marked result. Cyanamide in any quantity injured the trees as was indicated from tip burn on the foliage, or defoliation, or death of the trees. Heavy applications of other materials also were injurious.

Stewart (54,55,and 56), in Pennsylvania, secured great increases in yield from applications of nitrogen either in the form of manure or as nitrate of soda and dried blood, in the Kie Brown, and Johnston apple orchards, both of which were in sod. His experiments elsewhere with cultivated apple orchards gave conflicting results, largely due to tree and soil variability, but in general, the plots receiving nitrogen were superior in yield and growth to other treatments. He seemed to find manure to be the best carrier of nitrogen.

Reimer (37) found that ammonium sulfate, nitrate of soda, and calcium nitrate gave increases in crop on Winter Nelis pears at Talent, Oregon. On Spitzenberg apples early spring applications of sulfate of ammonia and nitrate of soda to cultivated orchards gave increases in yield of 345% and 471% respectively over unnitrated checks.

Alderman and Crane (1) using very small applications of nitrate of soda in cultivated bearing apple orchards, where cover crops were sown, obtained only slight responses from treatment, and they conclude that in well-cared-for cultivated apple orchards commercial fertilizers are of doubtful economic value. They failed to get any marked difference between sodium nitrate applications a month before buds broke, and those made in late May, but this is to be expected when none of the nitrogen treatments gave them marked increases over checks. In an experiment with greatly devitalized trees using from one to six pounds per tree, good responses were seen, the six pound application giving particularly good gains over check in growth and yield,

In Ohio, Ballou (10) secured marked increases on apples from nitrate of soda, alone or in combination with phosphorus or potash, over other fertilizers or checks. The trees were devitalized, and were growing in sod, in the hill lands of Southeastern Ohio. Manure was slower than either nitrate of soda or tankage. Later (9) Ballou reports a similar although not as marked response from nitrate of soda in a cultivated orchard in the same section and he corroborates his earlier findings with a part of this orchard in sod-mulch.

Blake and Farley (11) report an apple experiment started in 1896. After continuing for fifteen years, nitrogen gave better foliage and twig growth than did fertilizers containing no nitrogen or checks. It gave no effect on early yields the nitrogen plots made distinct gains. The trees were on a gravelly soil with clay subsoil, and were cultivated and cover crops were sown.

Walker (62) found in Arkansas that three pounds of nitrate of soda gave a deep green color to foliage, and promoted general vigor of apple trees, and helped to retain the foliage until November, long after unnitrated trees had shed their foliage. The fruit was increased in amount and size, but it matured later, and was not so well colored. No other fertilizer alone produced such effects. Later reports (16a) show that nitrogen has greatly increased the set of fruit except in very vigorous orchards.

Cooper (16) found that nitrogen gave definite gains in trunk and terminal growth, number of spurs per tree, set, and total apples. Nitrate of soda was somewhat more effective than sulfate of ammonia the first year, but the disparity was smaller the second year and had entirely disappeared by the third year. Nitrogen delayed ripening and depressed the development of red color because of shading by dense foliage. These experiments were in a well cared for Ben Davis apple orchard at Springdale, Arkansas, the trees being cultivated and cover crops being sown.

Bedford and Pickering (10) have summarized the results of twenty-two years experiments with fertilizers on orchards at the Woburn Agricultural Experiment Station Fruit Farm, England. Cultivated apple trees on the Ridgmont farm gave no response to dung or artificial manures, except for one case, in which nitrate of soda was applied in the summer, resulting in increased size of crop and weight of fruits. At Millbrook, on poor, light, sandy soil, apple trees under cultivation gave no response to nitrogen. On gooseberries, large quantities (thirty tons of dung or its equivalent in artificials) of fertilizer gave remarkable gains over normal (twelve tons) amounts. They conclude:- "The more probable explanation at present is that dung contains its nutrients, particularly the nitrogenous nutrients, in a form which is particularly suited to the requirements of gooseberries, though comparatively inefficient in the case of apples".

In New Hampshire (21, 22), nitrate of soda applied to a cultivated apple orchard receiving various cover crops, showed no early benefits, but in time the nitrated trees forged slowly ahead of the others. There was more nitrate nitrogen in the surface and subsoil of the plots receiving nitrogen than elsewhere. No increase in yield occurred.

In Missouri, Hooker (29) found an increase in nitrogen in the spurs a few weeks after a spring application of nitrogen as $NaNO_3$, $(NH_4)_2SO_4$ and dried blood, to apple trees. This influence did not carry over to the spring of the following year. Set of fruit was increased from 23.7% on check trees to 32.0% on treated trees. Applications of nitrate of soda made in the fall increased the nitrogen content of the spurs the following March more effectively than spring applications. Hooker (30) recognizes no distinction between nitrate of soda and sulfate of ammonia in orchard fertility practice, but advises using nitrate of soda on acid soils.

Schrader and Auchter (50) found nitrate of soda far superior to ammonium sulfate in stimulating growth and color of foliage in devitalized bearing apple trees growing in sod, the first season following application. They found more total nitrogen and soluble nitrogen in the spurs at the "pink bud" stage from nitrate of soda than from sulfate of ammonia, whether applied in the spring or fall. Large applications of ammonium sulfate smoothed out the differences between it and similar amounts of nitrogen in nitrate of soda. In later years continued applications of fertilizers tended to reduce the superiority of nitrate of soda over ammonium sulfate.

Marsh (42), using nitrate of soda, sulfate of ammonia, and cyanamide in varying amounts on a twenty-six year old Winesap orchard in sod, found, upon analysis of spurs, that all forms increased total nitrogen over the check in mid-May, with nitrate of soda first, sulfate of ammonia second, and cyanamide third. In late June, $NaNO_3$ and $(NH_4)_2SO_4$ had exchanged places, but cyanamide was still third. No difference in color of foliage or leaf size were seen in the nitrate and sulfate blocks, but smaller leaves were apparent on the cyanamide block. Two years later (43) Marsh reports a smoothing out of the differences between nitrate of soda and sulfate of ammonia, but reports cyanamide as being more slowly available than the other materials.

Davis (17), growing two year old apple trees in pots, in sterile quarts sand and nutrient solutions, in which the nitrogen was supplied by either $NaNO_3$ or $(NH_4)_2SO_4$ found that apple trees would not take up nitrogen in appreciable amounts except in the nitrate form. But when nitrifying bacteria entered the pots, ammonium sulfate greatly improved the trees, although they did not equal the nitrated trees. Root growth was less in the ammonium sulfate pots. Using higher concentrations than optimum, the toxicity was as follows: -

Most toxic - Cyanamide
Next most toxic- Ammonium Sulfate
Least toxic - Nitrate of Soda

Davis found that ammonium sulfate became oxidized to nitrate even on very poor sand if nitrifying bacteria were present.

Breazeale (12) tested the toxicity of nitrogen salts to citrus seedlings, and found them toxic in the following order: -

$(NH_4)_2SO_4$ - 1,000 ppm.
$NaNO_3$ - 1,800 ppm.
KNO_3 - 3,500 ppm.
$Ca(NO_3)_2$ - 10,000 ppm.

Two to three pounds per tree would supply seventy to one hundred ppm. for the surface foot of soil where most feeding roots are.

Remy (46) working with dwarf pear and apple trees in tubs, used combinations of nitrogen, potassium and phosphoric acid and found that where nitrogen was omitted the trees remained far behind all others in blossoming and in yield. He believes that the nitrogen content of the leaves in the fall should be above 1.25% of the dry weight for best growth and fruiting.

Gardner, Bradford and Hooker (20) say:- "Very little is known regarding the varying crop-producing value of nitrogen carried in different fertilizers when they are used on fruits".

Review of Literature Pertaining to Crops Other Than Orchard Plants.

Anderson and Nelson (5, 6, and 7) report organic fertilizers such as fish and tankage to have given best yields on tobacco over a five year period, when compared with nitrate of soda and sulfate of ammonia. Reduction of yield by mineral nitrogen was largely compensated for by cheaper cost of fertilizer. Two years results with urea show it to be satisfactory for at least a part of the nitrogen for tobacco.

Troffantit and Bizssonoff (57) believe that the effectiveness of nitrogenous fertilizers are due more to their effect upon soil bacteria than the direct effect of plant nutrition. They believe that urea plays an important part in the nitrogen nutrition of the bacteria. In pot experiments with white mustard, phosphate of urea gave increases when used to replace part of sulfate of ammonia in an acid soil; while on an alkaline soil, in a field experiment on white mustard, barley, mangels and potatoes, replacement of five to ten percent of the ammonium sulfate in a complete fertilizer with urea gave considerably increased yields. On an acid soil, a combination of $NaNO_3$ and urea outyielded $NaNO_3$ alone in growing carrots, potatoes and white mustard.

O'Kelly and Cowart (44a) studied the effects of fifteen pounds of actual nitrogen per acre from four sources, as side dressings for cotton, (except cottonseed meal, which was applied before planting). A four year average showed nitrate of soda to be slightly superior to ammonium sulfate and calcium nitrate, and much superior to cottonseed meal. Approximate standing of the fertilizers was fifteen, fourteen, eleven, and three respectively in the order above.

Anders and Hull (4) found, upon testing the relative efficiency of six nitrogen carriers, on one-half acre plats, replicated three or four times, for three years, on seed cotton production, that the materials produced the following increases over checks:-

Leuna Saltpeter	-	121 pounds
nitrate of soda	-	120 "
Ammonium sulfate	-	114 "
Urea	-	112 "
Calcium nitrate	-	92 "
Calcium cyanamide	-	42 "

There was great variation in yearly yields with all materials.

Wallace (64) seemed to find nitrate of soda, Leuna saltpeter, urea, calcium nitrate, and ammonium sulfate much superior to cyanamide in a three years' test on yield of seed cotton. The standings were:-

Nitrate of soda	-	282 Pounds
Leuna saltpeter	-	279 "
Urea	-	254 "
Calcium nitrate	-	249 "
Ammonium sulfate	-	236 "
Cyanamide	-	191 "

The amounts used were 150 pounds nitrate of soda or its equivalent in other carriers.

On corn, using two hundred pounds of nitrate of soda or its equivalent per acre, two year's averages show the following increases over check: -

Urea	-	60.4 bushels of ears
Calcium nitrate	-	58.9 " " "
Nitrate of soda	-	55.1 " " "
Cyanamide	-	39.2 " " "
Leuna Saltpeter	-	30.5 " " "
Sulfate of ammonia	-	23.9 " " "

At the South Mississippi Branch Experiment Station, Ferris (18) found nitrogen to increase the yield of seed cotton.

The gains over check were as follows: -

Nitrate of soda	-	27.24%
Ammonium nitrate	-	26.24%
Ammonium sulfate	-	25.09%
Calcium nitrate	-	23.96%
Urea	-	22.18%
Cyanamide	-	10.13%

The test was replicated three times.

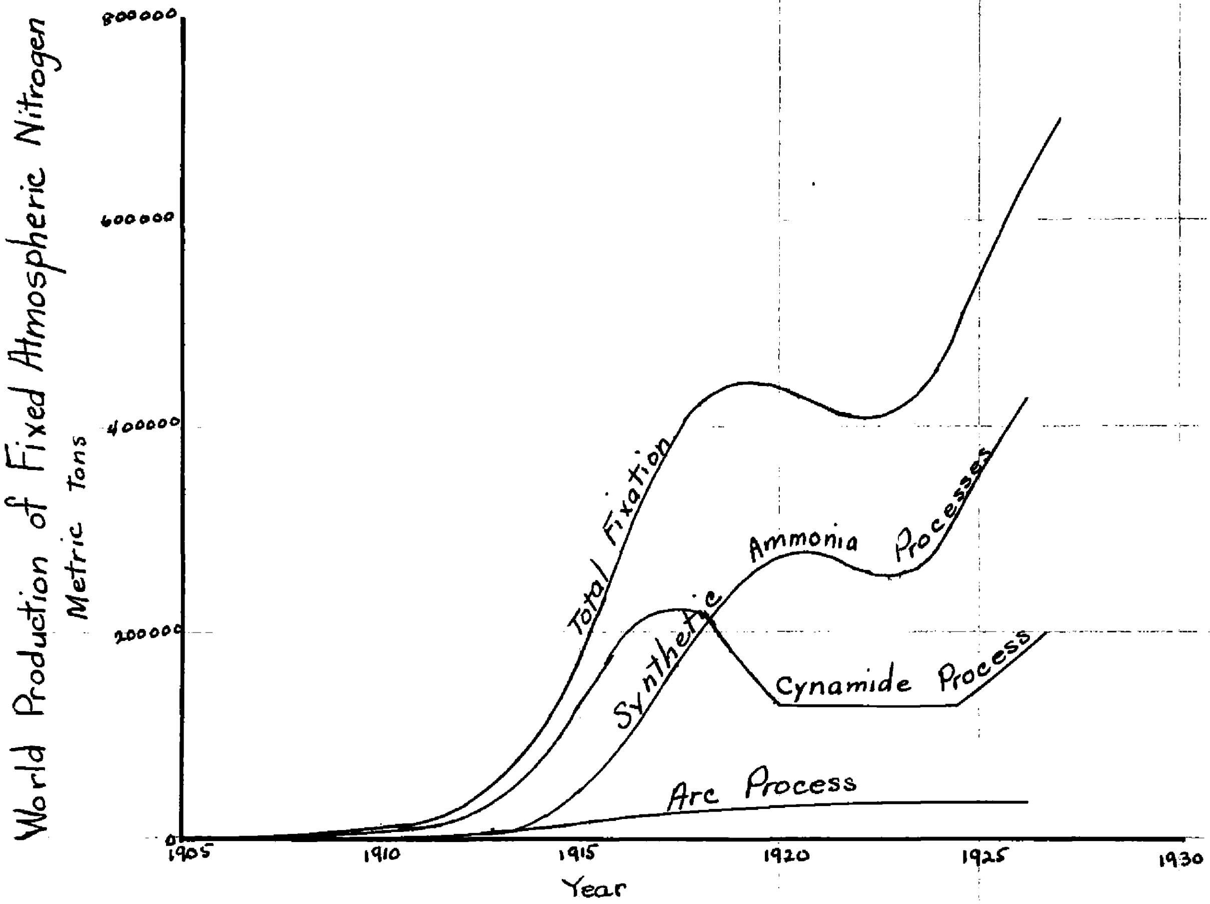
Wallace and Anders (63) found, with a two year test on tomatoes, that urea and cottonseed meal seemed to be superior to the mineral sources of nitrogen, $NaNO_3$ and $(NH_4)_2SO_4$. Four years' averages, reported later (64) show no particular differences when these carriers are used in fifteen hundred pounds of an eight-four-three 8 - 4 - 3 mixture, but urea and cottonseed meal lead slightly when two thousand pounds are used.

Ames (31) also found nitrogen beneficial as a fertilizer on cotton on unimproved sandy loam land. The plats were triplicated. All received a uniform application of phosphorus and potash. The increases over check made by the nitrogen carriers were as follows:-

Nitrate of soda	-	63.29%
Leuna saltpeter	-	53.23%
Urea	-	51.44%
Ammonium sulfate	-	48.82%
Calcium nitrate	-	43.97%
Cyanamide	-	17.70%

Status of Nitrogen Industry. Starting with the opening of the world war there has been a large increase in the manufacture of synthetic nitrogen compounds. Nitrogen is the basis of the most important high explosives, and the world war centered the interest of every major power on the necessity of becoming independent in the manufacture of nitrogen compounds. Previous to the war the world was largely dependent upon Chile for this important element. The remainder of the supply was in the form of ammonium sulfate from coke plants. During the past twenty

Fig. 1. Growth and Trend of Nitrogen Fixation Industry
Prepared by Fixed Nitrogen Res. Lab. U.S.D.A.



years the production of nitrogen has been revolutionized, new processes having been discovered, and great plants having been erected on the continent, in England, and in the United States. Figure 1 shows graphically the phenomenal rise in world production of nitrogen.

In the United States the domestic production of by-product ammonia has risen from 195,000 tons in 1913 to approximately 800,000 tons in 1928, or more than the entire world output of synthetic nitrogen. The imports of "natural" nitrate of soda from Chile for all purposes, amounted to 838,636 tons in 1927, according to the National Fertilizer Association.

Data on the world production of nitrogen, and imports and exports from the United States follow in Table I.

TABLE I

WORLD PRODUCTION OF NITROGEN FOR THE FERTILIZER YEARS 1926-27 and 1927-28, AS ESTIMATED BY THE BRITISH SULPHATE OF AMMONIA FEDERATION LTD.

short tons

	1913	1926-27	1927-28
Byproduct sulphate of ammonia	319,667	334,000	370,000
Synthetic sulphate of ammonia		330,000	403,000
Cyanamid (excluding cyanamid in Japan, which is incl. under synthetic sulphate of ammonia)		198,000	217,000
Nitrate of lime		89,000	111,000
Other forms of nitrogen from synthetic processes (incl. aqua ammonia)	90,491	147,000	232,000
Other forms of byproduct nitrogen (incl. aqua ammonia)		44,000	61,000
Chile nitrate	429,897	220,000	430,000
Total	840,055	1,362,000	1,824,000

Sources: Chemical & Metallurgical Engineering for 1926-27
and 1927-28.
January, 1929, page 39
Industrial and Engineering Chemistry for 1913 figures.
November 1928, page 1133.

TABLE I-A

IMPORTATION OF NITROGENOUS FERTILIZER INTO THE UNITED STATES.

From the National Fertilizer
Association.

Service Letter 3, Vol. IV February 26, 1929.

1928	Long Tons
Calcium cyanamide	135,727
Calcium nitrate	23,315
Sodium nitrate	1,032,911
Ammonium sulfate nitrate	81,214
Guano	22,584
Dried blood	9,511
Tankage	43,461
Sulfate of ammonia	42,066
Nitrophoska	4,122
Other nitrogenous materials	82,296
Total	1,477,207

TABLE I- B

IMPORTATION OF NITRATE OF SODA INTO THE UNITED STATES

From the American Fertilizer Handbook 1928.

	Long Tons
1910	529,171
1915	772,190
1920	1,321,892
1925	1,112,226

TABLE I - C

EXPORTATION OF NITROGENOUS FERTILIZER FROM THE UNITED STATES

From The National Fertilizer Association.

Service Letter 3, Vol. IV February 26, 1929.

1928	Long Tons
Sulfate of ammonia	93,015
Other nitrogeneous materials	7,772
Total	100,787

TABLE I - D

IMPORTATION OF SULPHATE OF AMMONIA INTO THE UNITED STATES

in tons

1910	92,342
1915	36,374
1920	1,994
1925	23,762

TABLE I - E

EXPORTATION OF SULPHATE OF AMMONIA FROM THE UNITED STATES

in gross tons

1920 (8 months)	66,714
1925	123,141

From The American Fertilizer Handbook 1928

But the output of ammonium sulfate will not increase rapidly during the next few years, according to Ramsburg (45) due to the present saturation of the coke market, and the relatively small amounts of ammonia produced by gas manufacturing plants. On the other hand the production of synthetic nitrogen is on the increase, and due to the much lower power requirements for manufacture, it will outstrip nitrogen manufactured by the ore and cyanamide processes. Consequently, there is coming before the farmers a new group of nitrogenous fertilizers. The agricultural value of these materials cannot be truly appraised on the basis of nitrogen content as the nitrogen may be in one or more forms, and in combination with one or more carriers. The value of a new material may not be the same for all crops nor on all soils. Thus, Truog, et al. (58) found differences in availability of certain materials used in his experiments. On corn, planted on a Miami silt-loam, an 0-12-2 (NPK) fertilizer produced a vigorous growth, while an 0-12-4 gave no response; a 2-12-2 with nitrogen in the form of $(NH_4)_2SO_4$ was better than this formula with the nitrogen as $NaNO_3$, but a 4-10-2 with nitrogen in the form of $(NH_4)_2SO_4$ was poorer than the same formula with nitrogen in the form of $NaNO_3$. Those authors believed that-"high amounts of potash salts or ammonium sulfate on acid soils liberate so much soluble acidity that nitrification and other bacterial activity is hindered". If available nitrogen is applied along with high amounts of potash, the detrimental effect of high potash is overcome due to the crop not having to depend upon nitrification for available nitrogen.

Thus it may be seen that new nitrogen carrying materials cannot be accepted as being empirically satisfactory without thorough test, under a wide range of conditions and using many plant families.

STATEMENT OF PROBLEM.

A comparative study of the stimulative effect of these newer synthetic nitrogen fertilizers on both devitalized and vigorous apple trees and on vigorous peach trees was made to determine whether or not they were as satisfactory as the ones already in use. It was planned to measure the following effects:

1. Stimulative effect on devitalized apple orchards, as measured by:
    - (a) color of foliage
    - (b) length of annual terminal growth
    - (c) length of annual fruit spur growth
    - (d) annual increase in trunk circumference
    - (e) percent of spurs blossoming
    - (f) percent of spurs setting fruit
    - (g) yield of fruit
    - (h) chemical composition of spurs
        1. Total, soluble and insoluble nitrogen
        2. Starch content
        3. Starch/N ratio
2. Effectiveness in maintaining vigor and productiveness of well-cared-for mature apple orchards, as indicated by:
    - (a) color of foliage
    - (b) length of annual terminal growth
    - (c) length of annual fruit spur growth
    - (d) annual increase in trunk circumference
    - (e) percent of spurs blossoming
    - (f) percent of spurs setting fruit
    - (g) yield)

4. The best time for application.

MATERIALS USED AND METHODS OF ATTACKING PROBLEM.

Fertilizers Used.

Of the fertilizers used, nitrate of soda was selected as the standard of comparison, because of its long use, and because experimental evidence has shown it to give very satisfactory results when used either to stimulate trees lacking in vigor, or in maintaining fertility in well-cared-for orchards. It is available from two sources, the nitrate of soda deposits in Chile, Peru and Bolivia, or from synthetic manufacture. The Chilean deposits are thought by some to be the leachings from dung and carcasses, of prehistoric birds. These leachings collected in large flat basins between the ridges of the Tarapacca plateau. The nitrates occur in two layers below the sandy surface, the "costra" containing from one to five feet of sand, clay, salt and sodium nitrate, running five to twelve percent sodium nitrate, and the "caliche", containing from one to five feet of nitrate-bearing rock, analyzing from eighteen to sixty percent sodium nitrate. The "caliche" is blasted out, sorted from waste materials, extracted with water, and the solution recrystallized to separate the nitrate of soda from impurities. The material is then ground, bagged, and shipped.

There are three important commercial processes of fixing atmospheric nitrogen, the arc process, the cyanamide process and direct synthesis. The arc process is similar to the fixation of nitrogen by lightning, and requires about sixty thousand kilowatt hours of electricity per ton of nitrogen produced. In the cyanamide process calcium carbide is heated to one thousand degress C and nitrogen gas passed over it, being caught as calcium cyanamide. It requires about fifteen thousand kilowatt hours to produce one ton of nitrogen by this process. In direct synthesis the Haber, Haber-Bosch, Casale and Claude processes require the passing of a mixture of one part of nitrogen gas and three parts hydrogen, under a pressure of two hundred atmospheres into contact ovens, where a partial combination of the gasses occurs, forming a mixture of ammonia and the two gasses. The ammonia is washed out, and forms the basis for the manufacture of all the synthetic nitrogen products. This process requires from four thousand to five thousand kilowatt hours per ton of nitrogen produced. It would appear that until some better processes are discovered, the direct synthesis is the process by which the world's supply of nitrogen will be increased.

To make nitrate of soda the ammonia is oxidized to nitric oxide, with the assistance of a catalyst. $2NH_3 + 8O \longrightarrow N_2O_5 + 3H_2O$. The combustion takes place in large pit-ovens. The nitric oxide gas is then dissolved in water, and this is neutralized with soda, the resulting nitrate of soda solution being evaporated to make the crystalline form.

$2H\ NO_3 + (Na)_2\ CO_3 \longrightarrow 2NaNO_3 + CO_2 + H_2O$

<u>AMMONIUM SULFATE</u> is made most cheaply as a byproduct of coke and artificial gas manufacture. The ammonia is distilled off as a gas, and is caught in sulfuric acid. The method used by the Badische Soda and Analin Fabrik is to churn finely pulverized gypsum ($Ca\ SO_4$) with an ammonium carbonate solution, forming ammonium sulfate and calcium carbonate. $(NH_4)_2\ CO_3 + CaSO_4 \longrightarrow (NH_4)_2\ SO_4 + CaCO_3$. The lime sludge is filtered off and the sulfate of ammonia separated out in large centrifuges, and dehydrated and ground.

<u>CALCIUM NITRATE</u> is manufactured by oxidizing ammonia to nitric oxide with the aid of a catalyst as above and absorbing it in water, making nitric acid. Then limestone is dissolved in the nitric acid and neutralization completed by the addition of milk of lime. $2H\ NO_3 + CaCO_3 \longrightarrow Ca(NO_3)_2 + H_2O + CO_2$. It is then filtered, and the clear solution is evaporated somewhat, placed in churns, and about five percent of ammonium nitrate is added to improve the physical condition of the product. The hot liquid is then sprayed with compressed air to dry it.

Ammonium nitrate, which is used in making leuna salpeter and potassium ammonium nitrate, is itself used as a fertilizer. In crystalline state it is highly deliquescent and explosive. These drawbacks

PLATE II. Leuna salpeter dries out easily and becomes lumpy. Sprinkling the bags and allowing them to stand for 24 hours before using solves this difficulty without resorting to the maul.

are overcome by coating small grains of the substance with precipitated calcium carbonate, the result being a granular material of excellent physical qualities for spreading. Material thus treated is called calnitro. The ammonium nitrate is made by combining synthetic ammonia with nitric acid in large combustion chambers, in the presence of a catalyst. Half of the nitrogen is in the nitrate form and half in the ammonium form. The reaction is $HNO_3 + NH_3 \longrightarrow NH_4NO_3$.

LEUNA SALPETER is produced by mixing the hot ammonium nitrate just described, with ammonium sulfate, the product being a double salt of ammonium nitrate - ammonium sulfate. It is then dried and pulverized.

UREA is made from ammonia and carbonic acid. Both are liquified at a high temperature, and mixed, making a fused mass containing urea, water, and ammonium carbonate. The latter substance is distilled off, and the remaining liquid filtered, dried, and ground. The formula for the reaction is: $2NH_3 + CO_2 \longrightarrow CO(NH_2)_2 + H_2O$.

CALUREA is made by bringing together calcium nitrate and urea in solution. The resulting mixture is either crystallized and ground, or sprayed with compressed air to dry it, the resulting material not needing to be ground.

CYANAMIDE is made by heating together coal and limestone, to make calcium carbide. This is heated to high temperatures, (1000° C), and nitrogen gas is passed over it, the nitrogen being fixed in the form of calcium cyanamid. This is then hydrated with about 8% water, following which about three and one-half percent of mineral oil is added to improve the physical condition of the product.

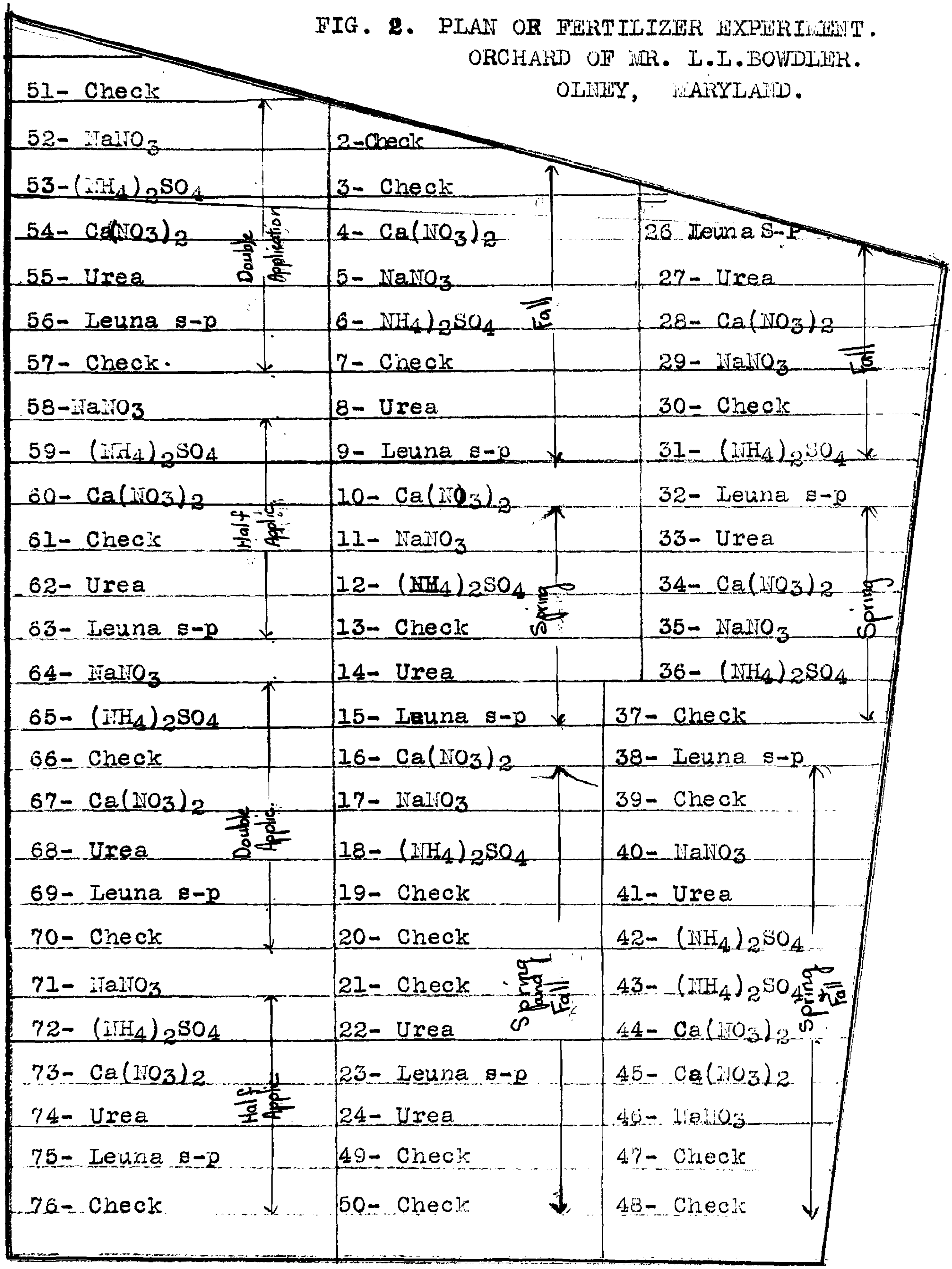
Orchards Used.

Four apple orchards were used, embracing four widely prevalent soil types, of the middle Atlantic seaboard. The sandy loam of the coastal plain, the Chester clayloam of the lower levels of the Piedmont, and the shale and limestone soils of the east slopes of the Alleghany Mountains, all produce vigorous orchards when properly managed. Commonly all have been found deficient in available nitrogen, particularly for bearing orchards.

The Orchard at Olney. This orchard was owned by Mr. Ralph Brodie, when the experiment was started, but was sold in 1928 to Mr. Louis L. Bowdler. Planted about 1910 this orchard had received care during its early years, but for several years prior to the inception of the experiment, had received no cultivation, fertilization, or pruning. The trees had grown quite well during their early life, but in 1926 were yellow, and quite lacking in appearance of vegetative vigor. They bore a fair crop during 1926, the trees usually having from four to seven bushels. The varieties were Stayman, Grimes and Delicious, the experiment here being laid out to embrace the Stayman. This variety, which is self sterile, was planted in too large a block for best pollination, but Delicious along one side, Grimes along another side, a small farm orchard of mixed varieties along a part of the third side, and three seedling trees scattered thru the center of the block apparently took care of this problem, as three crops in four years have been secured without apparent variation thruout the block due to this source.

The soil is Chester clay loam. The land slopes gently to the southeast, and the soil appears to be deeper and better toward the

FIG. 2. PLAN OR FERTILIZER EXPERIMENT.
ORCHARD OF MR. L.L.BOWDLER.
OLNEY, MARYLAND.



southeast corner, as indicated by larger size of the trees in this portion of the planting.

The owner did not expect to give the orchard any cultivation. Therefore there were no complicating cultural practices to interfere with the work. It is considered that for trees of the average size in the experiment, (400 to 600 mm. in trunk circumference) growing in poor sod, an application of eight pounds of nitrate of soda would be the most satisfactory normal treatment, and this was adopted as the standard amount, and equivalent amounts of nitrogen in the other forms were applied for comparison.

In the fall of 1926 the orchard was divided into three plats, running across the slope. As shown in the diagram, Figure 2. The upper two plats were divided into three blocks each. Each of these blocks contained six or more rows of from six to nine trees each. Each of these rows was used as the unit for treatment with one form of fertilizer, or else as a check. The rows ran up and down the hill, with only slight opportunity for any cross-wash in case of heavy rains. The trees were planted thirty by thirty feet apart.

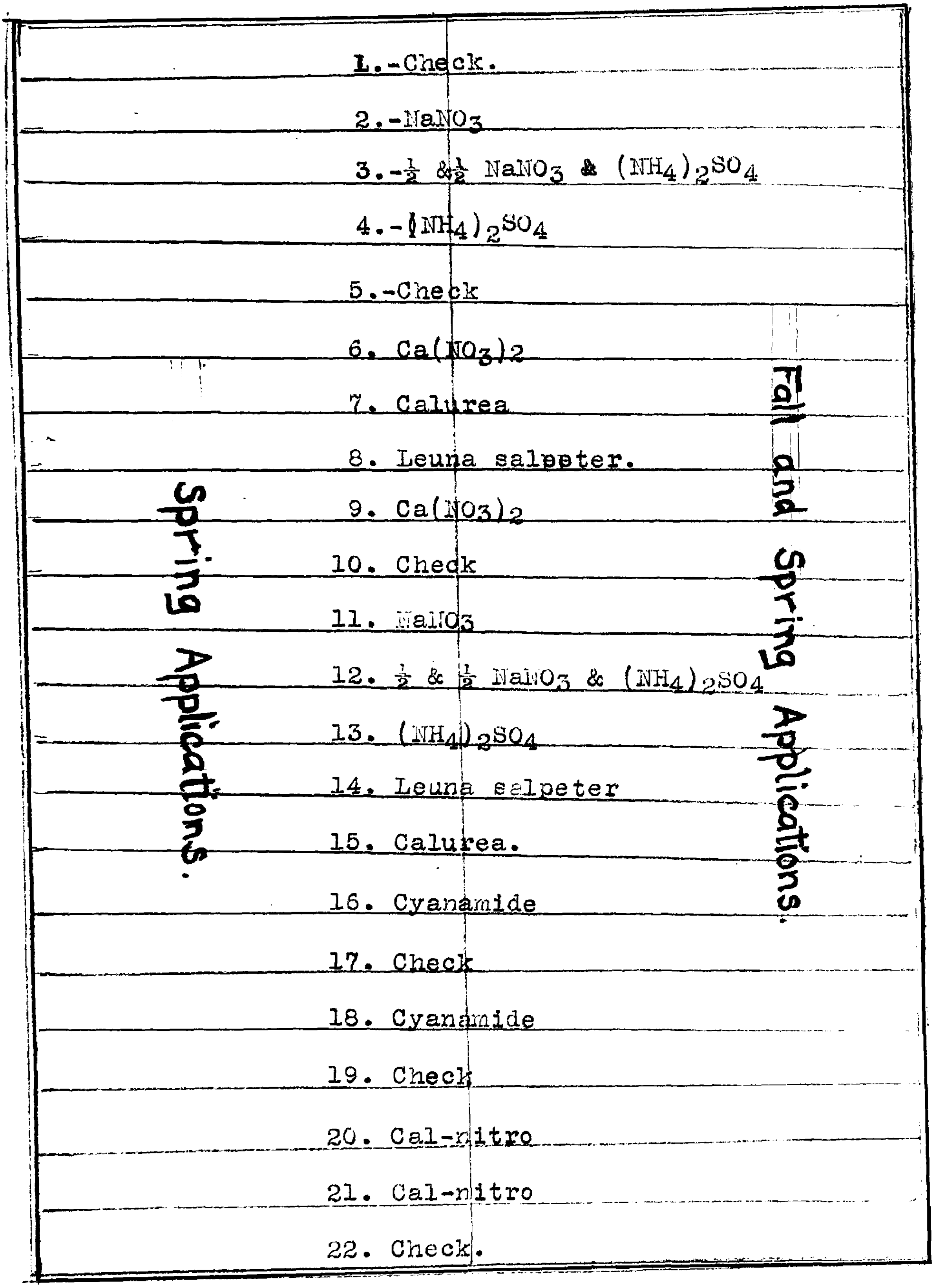
The fertilizer was sown broadcast to cover an area from two or three feet from the trunk to one or two feet beyond the tips of the branches. There were approximately eight or ten feet between the tips of the branches of adjoining trees. Thus the possibility of any appreciable cross-feeding was slight.

Of the three blocks in the upper plat, the first received its fertilizer application in mid-September in the fall of 1926. The second block received a spring application in 1927, two or three weeks before the terminal buds broke, while in the third block each tree received half of its application in the fall and the other half in the spring. The middle plat was a duplicate of the first. The lower plat was divided into four blocks similar to the above. Of these, the first and third received double amounts each spring - i.e. sixteen pounds per tree of $NaNO_3$ or its equivalent, - while the second and fourth received half amounts, or four pounds of $NaNO_3$ or its equivalent per tree each spring. The accompanying diagram shows the layout of the Olney experiment.

The Orchard at Hancock. This orchard lies about two miles west of Hancock and is owned and operated by J. Andrew Cohill. The experiment was located in a block of trees about fifteen years old, on a somewhat infertile shale soil, the Berks shale-loam, and they were badly in need of nitrogenous fertilizer. Some of the trees had borne several crops, but on many trees the fruit spurs showed no evidence of ever having borne fruit. The trees were far below normal size for their age. The bulk of the trees had a trunk circumference ranging from two hundred and fifty to four hundred mm. They are planted on the hexagonal system, and are sixteen feet apart. There was evidence of crowding in many places. At the start of the experiment the soil was largely devoid of vegetation in most places. A ragged weed growth grew in others. An occasional cultivation was given, the orchard being harrowed once with a double disc in 1928. The trees were too close together to permit satisfactory cultivation. Figure 3 shows a diagram of this orchard.

The experiment consisted of one row blocks of sixteen trees in each, without buffer rows between. The fertilizers were first applied in the fall of 1927 (see plan), and were broadcast well under the

Fig. 3 PLAN OF FERTILIZER EXPERIMENT.
ORCHARD OF MR. A.J.COHILL.
HANCOCK, MARYLAND.



branches, but in spite of this, some cross-feeding occurred. This was evidenced by the steady improvement in the color of the check rows during the summer of 1928, but it was not sufficient to cover up the differences in growth between the treated and check trees. The accompanying diagram shows the layout of the experiment.

Four pounds of $NaNO_3$ annually was considered a fair application for these trees. That or its equivalent in nitrogen carried in other materials, was applied to each tree. One portion of the experiment received all of the material in spring two or three weeks before the buds broke, while the other portion received half of the material in the spring and the other half in mid-September. In the spring of 1928 calurea was substituted for urea on rows seven and fourteen and row seventeen was added, to receive urea. In the spring of 1929 two rows of calnitro were added, together with another check row. In the spring of 1929 calurea failed to arrive from Germany, necessitating delay in its application until April 28, a month after the other materials were applied. The cyanamid failed to arrive, until May 10/and those rows received no spring application. until May 17.

The varieties involved are York Imperial, Rome Beauty, Stayman and Grimes, planted in alternate rows, as follows:

Stayman
Rome
Stayman
Rome
Grimes
York
Grimes
York
Stayman
Rome
etc.

<u>The Orchard at Tonoloway.</u> This orchard is owned and operated by the

American Fruitgrowers, Inc. A three row experiment, comparing heavy applications of nitrate of soda with a check row, was started in 1926. In the spring of 1927 rows were added to this block to permit trials with various synthetic nitrogen fertilizers, the original three rows being maintained. Therefore the check has received no fertilizer since 1925. The experiment is located in the Stein unit, consisting of a block of York Imperial containing 16 rows, with forty-eight trees in each row. The block runs from the floor of the narrow valley up over the top of Tonoloway Mountain, six hundred feet above. The trees are about thirty years old. The rows are planted forty feet apart, with the trees thirty feet apart in the rows. At frequent intervals York trees have been grafted over to Grimes Golden. The treatments consist of single rows running from the bottom to the top of the Mountain. The fertilizers were sown by hand under the outer spread of the branches.

The soil is limestone, with frequent outcroppings. Cultivation was practiced on alternate rows for many years, but in 1927 the orchard was put down in a sod consisting of orchard grass, blue grass and sweet clover. The trees were in a high state of vegetative vigor, making an annual terminal growth of from six to twelve inches on the lower lateral branches, and fifteen to thirty inches in the tops of the trees, when the experiment started. The block has been a regular blossomer, but crops have been light as a rule due to loss of blossoms by spring freezes. Due to the fact that the lower trees are more frequently and more seriously damaged by frost, the lower sixteen trees on each row were discarded when measurements were taken, and only the upper thirty-two trees considered. For color observations and crop records all the trees were considered.

FIG. 6. PLAN OF FERTILIZER EXPERIMENT.
ORCHARD OF AMERICAN FRUITGROWERS, INC.
TONOLOWAY, MARYLAND.

No.1.-Nitrate of soda; 3# at dormant, 5# fall.

No.2.- " " " 8# just as buds start.

No.3.-Calurea; 3.5# " " " "

No.4.-Leuna salpeter 4.6# # " " "

No.5.-Calcium nitrate; 8# " " "

No.6.-Sodium nitrate; 15# " " " "

No.7.- " " 10# as buds start, 5# at pink.

No.8.-Check. no treatment.

No.9.-Sodium nitrate; 20# as buds start.

no.10.- " " 15# " " " 5# at pink

No.11.-Calcium nitrate; 10# " " "

No.12.-Leuna salpeter; 5.7# " " "

No.13.-Calurea; 4.5# " " "

No.14.-Sodium nitrate 10# " " "

No.15.-Urea; 3.3# " " "

No.16.Sodium Nitrate; 3# as buds start, 5# in fall.

In 1927 and 1928 considerable mouse injury occurred in the block, and made irregularities in the trees which are difficult to evaluate, because much of the mouse injury was located out on the main roots away from the trunks. However, many of these trees have been marked and eliminated from consideration.

In this orchard both time of application and quantity of materials have been tested. The diagram of the orchard, and list of treatments, are shown on the accompanying diagram. Figure 4.

The Orchard at Salisbury. This orchard is owned and operated by the W. F. Allen Co. The experiments were started in the spring of 1927. Three experiments, one on apples and two on peaches are under way here. The apple orchard is about twenty years old, and consists of Stayman, except for an occasional grafted Grimes tree for pollenization. The trees are planted thirty by forty, with forty feet between the rows. The fertilizer experiment consists of three single rows of eighteen trees each. Only calcium nitrate, calurea and Leuna salpeter are being used here. ~~Nitrate of soda and sulfate of ammonia are being used in an adjoining experiment, and records are available from this for comparison.~~ See Figure 5.

The soil is a light sandy loam, and a difference of three feet in elevation on this comparatively level orchard makes a very appreciable difference in tree size due to difference in moisture in the soil. Ten pounds of nitrate of soda was chosen as the standard treatment, broadcast under the trees two or three weeks in advance of the bursting of the buds. Clean cultivation is maintained by discing, and each fall a rye cover crop is planted.

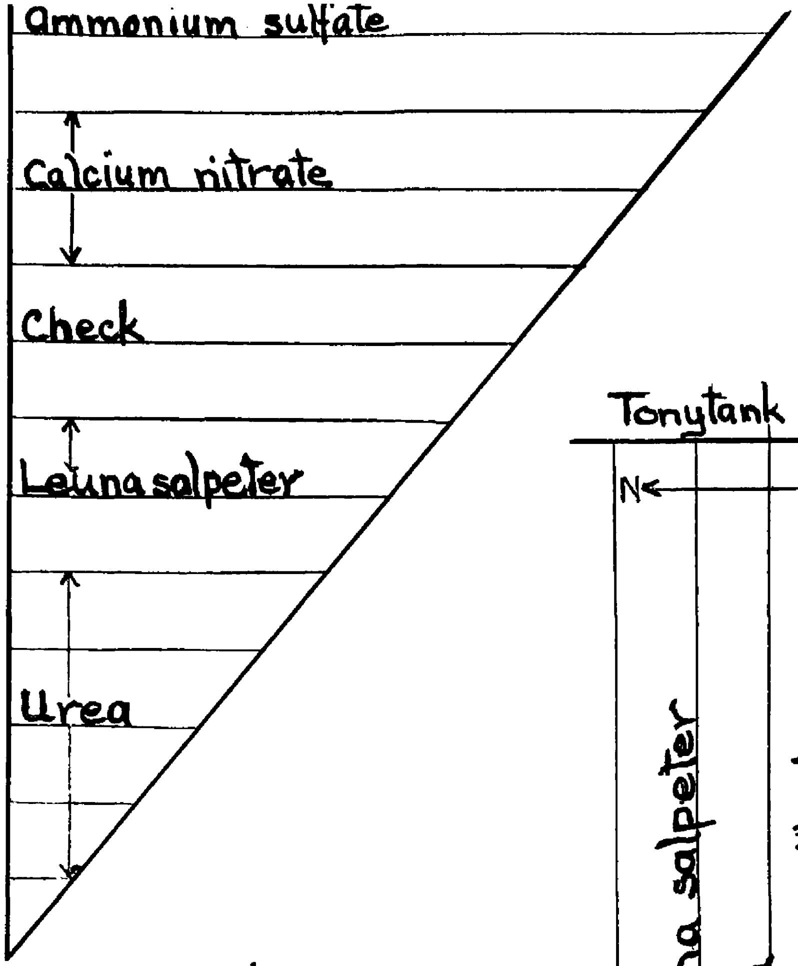


Fig.7. Triangle Block
Elberta Peaches

Tonytank Block.

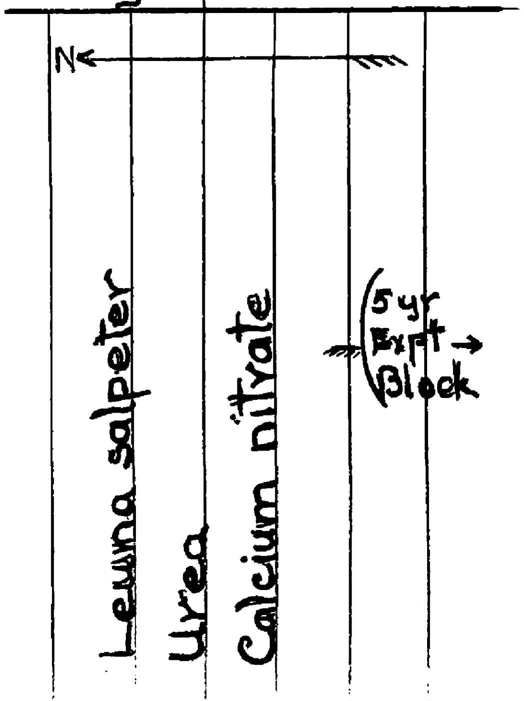


Fig.6. Belle of Ga. Peaches.

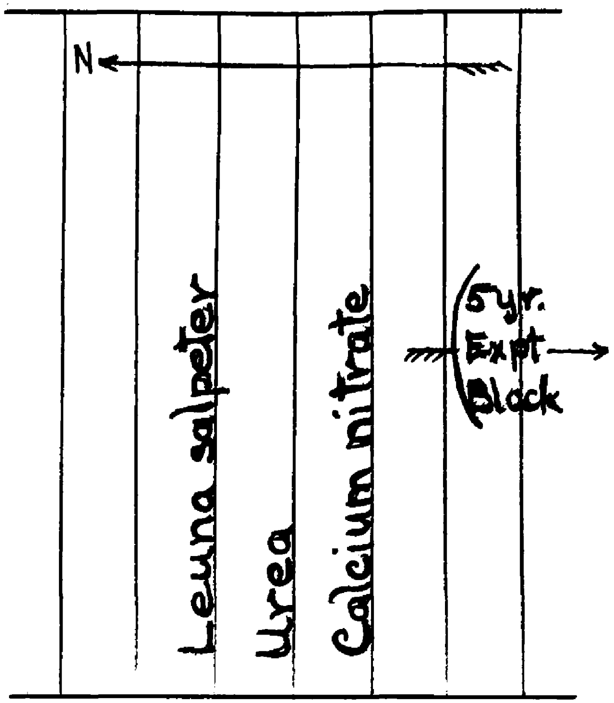


Fig.5. Ruark Farm.
Stayman Apples.

Plan of Fertilizer Experiments: Allen's. Salisbury.

One peach experiment is on a similar piece of ground, and embraces three rows of Belle of Georgia trees, eleven years old in 1927. There are ten trees to the row. The same materials named above are being tested here. When the experiment was initiated the trees were eighteen feet apart and there were twenty trees in each row. Half of the trees were removed, making the remaining trees twenty-five feet apart. Five pounds of $NaNO_3$ was adopted as the standard application, to be broadcast under the branches in the spring, two or three weeks in advance of bloom. ~~This experiment also adjoins adjoins a fertilizer experiment including nitrate of soda and ammonium sulfate, which are used for comparison.~~ See Figure 6.

The other experiment on peaches, also started in 1927, is on a heavier loam soil, of apparently higher moisture content at most seasons. The variety is Elberta, aged about eight years at the start. Here five pounds of nitrate of soda was taken as the standard, and $(NH_4)_2SO_4$ $Ca(NO_3)_2$ Leuna salpeter, and calurea are compared. One check row was left in the center for comparison. After the 1928 season half of the trees were removed in this orchard, as described for the Belle of Georgia block. This removal allowed approximately ten trees in each treatment, in from one to five rows. See Figure 7.

In August, 1928 this entire block received by mistake $(NH_4)_2SO_4$ at the rate of about one hundred pounds per acre, (½ pound per tree), and in 1929 the crews fertilizing adjoining trees again covered the experiment, using five pounds $NaNO_3$, in spite of the fact that the trunks were heavily marked with whitewash to bound the experiment. Therefore the experiment was abandoned with but two years growth records, and no crop record. In both 1927 and 1928 the crop was destroyed by frost.

The accompanying diagram shows the plan of the three experiments at Salisbury.

Method of Securing Measurements.

1. Size of Tree. In each orchard at the beginning of the experiment the trees were ranked according to size. The size of greatest frequency was given a rating of five, and the remaining trees were assigned numbers larger or smaller than five, according to whether they were larger or smaller in size.

2. Terminal Growth. Two methods were used in securing an accurate knowledge of the terminal growth made by the trees. One was to measure twenty terminals on side branches below shoulder height, and twenty above this height, yet within reach. The measurement was made with a thirty cm. rule, individual measurements being recorded to the nearest millimeter. These were then averaged. The terminals above shoulder height have been used generally for comparisons.

The second method of securing terminal growth measurements was to measure twenty of the higher lateral terminals with a long tape, adding each measurement to the tape, and reading the total after twenty measurements had been taken. The objection to the latter method is that no indication is obtained as to the variability of terminal growth.

In cases where there was a strong growth of shoots in the tops of the trees, the average length of this growth was estimated from the ground.

All the measurements were made during the dormant season. Usually it was possible to measure the terminal growth made for one or two seasons preceding the start of the experiment, in order to gain some knowledge of the previous performance of individual trees.

3. Trunk Circumference. A steel tape was used to measure each tree trunk every winter. The point midway between the lowest branch and the ground was selected. In case of an abnormality such as a cultivation scar, or old pruning wound on the trunk at this point, the measurement was made at the first normal point above the center. In the Olney orchard the exact spot at which the measurement was made was marked with white lead paint, and this mark renewed from time to time. Before making a measurement the trunk was brushed free of loose bark. Measurement was made to the nearest millimeter.

4. Spur Measurements. From five hundred to one thousand spurs on from three to six year old wood on typical trees in each treatment were measured each winter to determine the millimeters of growth made the preceding summer. Customarily from one hundred to two hundred spurs were measured from each of several trees to secure a representative sample. The class of spur usually measured was one bearing a blossom bud, and had not borne the previous season. In some cases it was necessary to use buds which had blossomed but not set the preceding season, due to frost. In any case, spurs behaving uniformly over the entire orchard were chosen, to get strictly comparable material. The growth measured included neither the blossom bud nor cluster base, but only the actual shoot growth. Exceptions to this, where made, have been noted. Wherever practicable, the data were treated biometrically to insure the justification of such conclusions as have been drawn.

Detailed statistical analysis has been made only on the results secured at Olney and records from other orchards are merely used to indicate to what degree these other orchards support or refute the conclusions derived from work done at Olney.

Statistical Procedure. Comparison of growth measurements by averaging did not give consistent results, due to variability. Comparison of measurements by Bessels Formula showed such large probable errors significa~~tion~~nce. Even the use of "Student's" method to remove correlation due to place effect would not serve to eliminate enough of the variability in terminal growth to render significant quite considerable differences in averages. In other words, the variability lay deeper than merely place effect. It may have been due to rootstock differences, to bud or scion variability, or to the influence of previous crops on the growth being made during the present years. A study of some of the factors correlated with terminal growth was made, to see if more correlated variability could be removed.

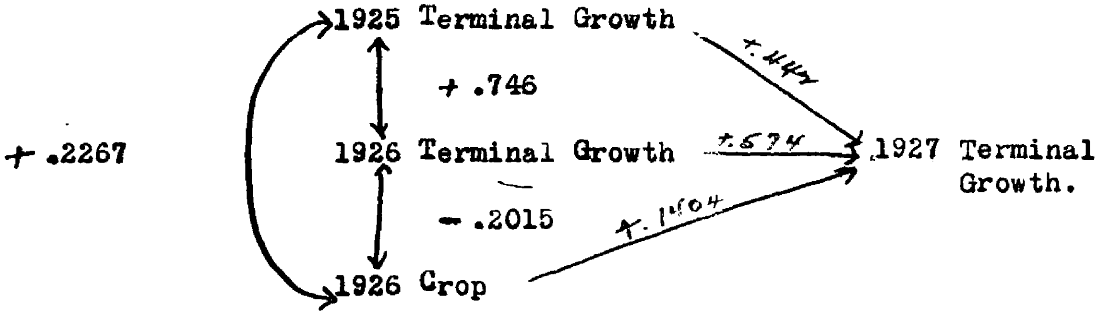
As commonly used by horticulturists, "Student's" method is used as a means of eliminating place effect by pairing of individuals or units which adjoin each other in the test. This is only one feature of "Student's" method. It offers also a means of removing correlated variability from whatever source, so long as the correlation can be measured.

Numerous correlations could be made between terminal growth and other factors at Olney. Record had been taken of terminal growth in 1925 and 1926, and the crop in 1926, all before the experiment was started. Correlations were then run, by means of dot charts, as follows:

1. 1925 terminal growth vs 1926 terminal growth.
2. 1925 terminal growth vs 1927 terminal growth.
3. 1925 terminal growth vs 1926 crop.
4. 1925 terminal growth vs 1926 trunk size.
5. 1925 terminal growth vs 1927 trunk increment.
6. 1926 terminal growth vs 1926 crop.
7. 1926 terminal growth vs 1926 trunk size.
8. 1926 terminal growth vs 1927 trunk increment.
9. 1926 terminal growth vs 1927 terminal growth.

10. 1926 trunk size vs 1926 crop.
11. 1926 trunk size vs 1927 terminal growth.

When definite correlation was found between most of these factors, it was possible, by multiple correlation and multiple regression, to predict the most probable growth of each of the trees for 1927. The multiple correlation system set up was as follows:



From this, a degree of determination (R^2) of .4240 was secured, with the corresponding coefficient of multiple correlation (R) of .6512. Figure Two shows the calculations incidental to arriving at the coefficient of multiple correlation. In other words, 42% of the variability was due to correlated causes, and could be removed. The coefficient of multiple correlation (R) is an index of the degree of relationship between a single dependent variable, and a number of variables in combination. Prediction from correlation data may be made thru the use of the regression formula:

$$P_{t_{25}t_{27}}\left(\frac{t_{25}-\overline{t_{25}}}{\sigma\, t_{25}}\right)+P_{t_{26}t_{27}}\left(\frac{t_{26}-\overline{t_{26}}}{\sigma\, t_{26}}\right)+P_{c_{26}t_{27}}\left(\frac{c_{26}-\overline{c_{26}}}{\sigma\, c_{26}}\right)=\frac{t_{27}-\overline{t}}{\sigma\, t_{2}}$$

Where P = path coefficient, c = crop,
t = terminal growth, '25, '26, '27 = years under consideration.

From the ninety-one check trees it was possible to determine with an accuracy sufficient to remove 42% of the variability, the average terminal growth for untreated trees for 1927, and its standard deviation. Thus the most probable terminal growth for each treated tree for 1927 could be established, and 42% of the deviations from it could justifiably be attributed to treatment, while the remaining 58% remained as error. All results are calculated as increases (or decreases) over predicted growth.

For example, using the formula given above for tree two, row five, t = .263 cm., which represents its superiority over the average untreated or check trees. The checks averaged 8.14 cm. in 1927. Therefore on the basis of past performance, tree two, row five, should grow 8.77 cm. if it had not been treated. Actually it grew 22.5 cm., and the increase is attributed to the eight pounds of nitrate of soda which it received.

When the formula is applied to the adjoining tree in that row, it shows that the tree is expected to grow 2.165 cm. less than the checks (8.14 cm.). Thus, any gain over 5.975 cm. would be attributed to treatment. Actually this tree grew 11.50 cm., and this gain of (11.50 - 5.975 =) 5.525 cm. is attributed to the nitrate of soda applied.

To summarize the previous paragraphs, - it was found that before any treatment was given some trees were growing consistently well, while others were doing consistently poorly. Thru multiple correlation and regression it was possible to correlate past performances so that a prediction of the future growth of each tree could be made. Thus the most probable performance for 1927 was established for each tree, had it been left untreated. Deviation from this most probable performance was deemed due to the fertilizer applied, within the limits of accuracy of the prediction formula.

This same method could well be applied to evaluating increase in trunk circumference, were sufficient data available. It was not possible to secure data on past year's increases in circumference, however, so this material was handled in a somewhat different manner. The trunk size of each tree was measured in March, 1927 and again in March, 1928, the difference in size of each trunk representing the 1927 growth. Increase in trunk circumference has been shown to be a good index to the growth of the tree. Tufts (68) found a correlation of .92 between the diameter of the trunk and the weight of the tops of young peach trees, while Waring (69) and Cooper (16) seemed to find increase in trunk circumference a safer indication of cropping ability of apple trees than terminal growth measurements when these factors are used alone. Judging from this, it would seem that if the growth in the tops was so variable as to preclude the use of "Student's" or"Bessel's" Formula in calculating the significance of increases in terminal growth due to fertilizer treatments, the trunk growth would probably reflect this same variability. If so, it should be possible to apple the same method of predictions as was used on terminal growth. Lacking certainty of this, it was not done. Instead, the average of the check trees on either side of a treatment was secured, and the trunk increase made by each tree between these check rows was compared with the average of these checks. Thus the performance of each tree is expressed as increase over the average of its nearest checks. Place effect was at least partly removed by this means, and the resulting figures could be used in comparing one treatment with any other in the orchard, while "Student's" method, as commonly used, allows for pairing of merely adjacent trees in adjacent treatments. It also permitted of combination of plots to increase the number of trees, thus increasing the accuracy of the averages and lowering the probable errors.

Comparison of yields was made by averaging the yield of the trees in each treatment, calculating the probable errors and making direct comparison between treatments or with checks. Data from one crop are not sufficient for accurate measure of the effect of fertilizers. The information is presented here more to show that all forms of nitrogen gave marked increases over the check trees, rather than to show differences between treatment.

Comparisons of color of foliage are not treated statistically.

In all considerations, increase of terminal growth, trunk circumference and yield in the orchard at Olnay, probable errors were calculated according to the formulae:

P.E. of mean

$$\text{P.E. of mean} = \pm .6745\sqrt{\frac{\Sigma d^2}{n(n-1)}}$$

$$\text{P.E. of difference} = \pm\sqrt{\text{Sum of squares of P.E. of means.}}$$

Method of Taking Chemical Samples.

Harley (22a) has shown that there is considerably more variation in the chemical composition of fruit spur samples taken without regard to uniformity in size, age of wood, and function, than in uniform spurs. Therefore samples taken in this experiment were as near alike as it was possible to select them. Three to five trees of uniform size and vigor, as indicated by terminal growth in 1925 and 1926 and crop in 1926 were selected in each treatment. Fruit spurs on three to five year old wood on representative exposed limbs which could be reached from the ground were selected. Inasmuch as the trees had borne a considerable crop in 1926, and did not appear to have sufficient fruit buds to produce a crop in 1927, non-blossoming spurs, with new wood approximately 3/8 inch long were taken in every case. These were not measured with a rule, but this length was estimated as closely as possible. All spurs taken had blossomed the preceding year.

Samples for chemical analysis were taken at Olney at three periods in 1927. The first sampling was on March 11 and 12, while the trees were dormant; the second on April 21, when the blossom buds were at the full pink; and the third on June 30 and July 1, when fruit buds were probably differentiating.

The samples were divided as follows:-

- a. Dormant Sampling: (200 to 300 spurs per sample)
    - 1. Secondary growth, including bud
    - 2. Cluster base (last years)
    - 3. Older wood (2 to 4 years)
- b. April 21 Sampling: (Non-blossoming spurs used; 90 to 105 spurs per sample)
    - 1. Leaves plus the newly extending shoot
    - 2. One year old wood including cluster base
    - 3. Older wood
- c. July 1 Sampling: (75 spurs for leaf and old wood samples, plus 50 more to get sufficient shoot growth for a sample.)
    - 1. Leaves
    - 2. New shoot
    - 3. Older wood

The samples were counted, weighed, and killed in the orchard. It was necessary to carry considerable equipment into the field for this purpose. A truck with side-curtains was used as a travelling laboratory. Erhlenmeyer flasks or small milk bottles with cork stoppers were used for storage of the samples. A water-bath heated by alcohol burners, large funnels with watch-glasses for covers to be used as condensers, small torsion balances, aluminum weighing cans, ninety-five percent alcohol, distilled water, a supply of CaCO3, thermometers, one liter Pyrex bottles for heating alcohol and distilled water, a fifty cc and a two hundred fifty cc graduate comprised the equipment. The water bath and scales were set up in the back of the truck used for transportation. The writer gathered all the samples, brought them to the truck where two men divided the spurs into appropriate parts, counted them and placed them in bottles, poured in sufficient hot ninety-five percent alcohol to make a fifty-fifty alcohol-water concentration with the water of the tissues, added sufficient fifty percent alcohol to cover the samples, added 0.25 gm. of $Ca(CO3$ to neutralize acids in the tissues, and placed the bottles on the water-bath where they were kept at simmering temperature (approximately 75°C). for one hour. This killed all enzyme action in the cells. To prevent evaporation of the alcohol the bottles were fitted with corks, in each of which a hole had been bored of the proper size to admit the stem of a fifteen cm. funnel. A watch glass over each funnel completed a condenser above each bottle. After simmering for one hour, the bottles were removed, fitted with tight corks, cooled, and the corks sealed with paraffin and stored until opportunity was presented for analysis.

To determine the amount of ninety-five percent alcohol to add to bring the water of the tissues up to fifty-fifty alcohol and water it was estimated that the leaves had approximately eighty-five percent water, the new shoots sixty percent and the old wood fifty percent. The formula was

$$x = (\text{Wt. of sample} \overset{x}{\cancel{\#}}\% \text{ water in sample x } 1.1)$$

The 1.1 is a factor for converting ninety-five percent alcohol into one hundred percent. Thus, for a leaf sample weighing twenty-five gramms, the amount of alcohol was

$$x = 25 \times .85 \times 1.1 \quad \text{or} \quad 23.4 \text{ cc.}$$

Analytical Procedure

The bottle containing the sample was heated to 75° C to dissolve any crystalline material such as arginine which might have separated out, cooled, and the alcohol extract decanted off and filtered thru a Whatman #1 filter, into a volumetric flask, and made to volume. It was then stored in Ehrlenmeyers or milk bottles with very tight stoppers. The residue on the filter paper was air-dried, and scraped as clean as possible from the filter paper, and added to the solid portion. The solid matter was placed in an evaporating dish, and dried to constant weight in an oven @ 70° to 75° C. It was then ground until it would pass thru a forty mesh sieve, thoroughly mixed, and stored in a small sample bottle until needed for use. Before aliquots were taken, the bottled sample was oven dried @ 70° C for forty-eight hours to bring it to constant weight again, and then kept in a dessicator until the aliquots were weighed out. If the liquid portion stood more than ten days, it was brought to 70° C and cooled again before aliquots were taken. This was to re-dissolve any crystalline substance which might have separated out upon standing. The solid matter in the alcohol extract was determined by evaporating an aliquot to constant weight in an oven at 70° to 75° C.

Total Nitrogen The bottle holding the alcohol extract was thoroughly agitated. Duplicate aliquots were placed in five hundred cc Kjeldahl flasks, and the alcohol and water were driven off over a boiling water bath until only a thick amber syrup remained. To these were added corresponding aliquots of the dried ground matter, and total nitrogen determined by the Kjeldahl method as modified by Gunning to include nitrate nitrogen. The total dry weight of each sample for analysis was kept below two grams. Thirty cc of sulfuric-salicylic acid mixture (1 gm. salicylic acid to thirty cc of sulfuric acid) was added, and thoroughly mixed with the sample by gentle rotation of the flask. The flask was tightly stoppered with a rubber cork, and allowed to stand for an hour, when it was mixed again, and allowed to stand over night, or until all of the solid matter had been digested to a black syrupy mass.

Five cc of crystalline sodium thiosulfate was added to the contents of the flask,

and the flask was then heated gently on the digestion shelf over a one inch flame for five minutes. At this time heavy grey-white sulphur fumes were pouring from the flask. It was cooled for fifteen minutes and ten cc of $K_2 SO_4$ added to raise the boiling point, and the flask again placed on the shelf, over an inch flame, and digested until the heavy fumes ceased to emanate. The flame was increased slightly, and digestion continued until the mixture became clear, when the flame was raised until the mixture boiled gently. Heating was continued for an hour after the mixture was perfectly clear. During the early stages of digestion frequent agitation of the mixture was necessary to wash down the undigested materials from the sides of the flask.

Digestion being concluded, the flask was cooled and two hundred twenty-five cc of distilled water added and mixed thoroughly, and after becoming perfectly cool, the flask was transferred to the distillation outfit, which had previously been cleaned by distilling over two hundred cc of water.

The neck of the Kjeldahl was wet with distilled water to insure a tight joint with the cork on the condenser. A few drops of phenolphthalien indicator and a knife-point of powdered zinc were added, the latter to prevent bumping. Then eighty cc of forty percent (by weight)

NaOH was poured carefully down the slanting neck of the flask, care being taken not to mix it with the acid solution, and the Kjeldahl was quickly connected to the still. A slow flame was started, the flask was shaken vigorously, and heating proceeded until the contents were boiling vigorously, when full flame was turned on.

To catch the distillation product, containing the ammonia, a five hundred cc wide-mouthed Erhlenmeyer flask, or pint milk bottle was used. In it was placed from ten to fifty cc of approximately N/10 sulfuric acid, the exact normality of which had been determined. The amount used depended upon the quantity of nitrogen known approximately to be in the sample. Sufficient distilled water was added to cover the end of the distillation tube. Three or four drops of methyl red indicator were added, and the flask placed under the tube.

The phenolphthalien indicator turned a faint pink upon shaking. Disappearance of this color after a few moments indicated that the solution in the Kjeldahl flask was strongly alkaline.

The color of the solution in the receiving flask was closely watched. Any change to orange or green color would indicate that ammonia had neutralized all of the acid, and was thenceforth being lost.

Distillation was allowed to proceed until only about an inch of material was left in the Kjeldahl. The usual procedure calls for discontinuation of distillation after about one hundred fifty cc have passed over into the receiving flask. Test indicated that ammonia continued to come over until almost all of the mixture in the Kjeldahl had evaporated, hence the longer distillation.

As this point was reached, the Erhlenmeyer receiving flask was lowered, and the end of the condenser tube washed out with distilled water, the Erhlenmeyer catching the washings, then removed, and the flame turned off.

The acid remaining in the receiving flask was then titrated with N/10 NaOH, and the total nitrogen calculated. Several blank determinations were run with each lot of reagents, to determine the nitrogen in these materials. The amount of this blank was subtracted during the calculations.

Formula for calculations:

$$\frac{(\text{CC } H_2SO_4 - (\text{CC NaOH} \times \frac{\text{acid}}{\text{base}} \text{ ratio})) \times \text{acid normality} \times 14.01}{1000} = \text{N in gms.}$$

Alcohol Insoluble Nitrogen An aliquot of the dried, ground material was placed in an extraction thimble, and extracted in a Soxhlet extraction tube for three hours, or until the extract in the tube was clear, with fifty percent alcohol, over a gentle flame. The extraction tube siphoned off about every ten minutes. The material in the shell was dried in the oven at 70° C, removed to a Kjeldahl flask, and nitrogen determined as above.

Alcohol Soluble Nitrogen Soluble nitrogen was determined by difference between total and insoluble nitrogen.

Starch An aliquot containing about a gram of the dried ground material was placed in a paper extraction shell in a Soxhlet tube, and refluxed with 150 cc, of fifty percent alcohol for two and one half hours, or until the extract in the tube was clear. The thimble was removed and dried in the oven at 70° C, the material transferred to a mortar, and ground with acid-cleaned sand until it would pass thru a one hundred mesh sieve.

Modified Method of Starch Analysis. For the purpose of this experiment a method of starch analysis which reduced the amount of time by eliminating acid hydrolysis, and gave good values for comparative purposes was adopted. Kraybill et al (70) used this method in analyzing fruitspurs for starch, except that he did not plot his data from pure starch, to enable him to read his sample values directly. His starch values ran from 95% to 102% of theoretical values, when using this method. Gardner, (71) found the method, including the curves, satisfactory for starch analyses with pear wood. Fletcher (72) has found that with fruit tissue the presence of pectic substances interferes with filtering after reduction of copper, but that this can be avoided if these interfering substances are removed by alcoholic precipitation before taking a sample for reduction of copper in Fehlings solution.

Pure corn starch was digested with saliva, and an aliquot was analyzed for sugar by determining its power to reduce copper in Fehlings solution. This result was then compared with a sample of pure corn starch digested with saliva and in addition hydrolyzed with HCL. Curves were then drawn to show the comparative reducing power before and after acid hydrolysis. A factor is then obtained by determining the ratio between saliva-digested and saliva-acid-hydrolyzed pure starch. Samples of tissue run with saliva digestion alone are multiphied by this factor to obtain the values for starch, as dextrose in the tissue.

Saliva instead of takadiastase was used for digestion of the starch because it is more specific than takadiastase. The latter is prepared from a mold, and contains many enzymes. Saliva also contains a mixture of enzymes, ptyalin or amylase being the chief one. It also contains some maltose. When using saliva one avoids the possibility of larger error thru the large blank usually obtained with takadiastase.

The Starch Curve. It was convenient to construct a graph to show the relation between the products of saliva digestion and saliva-digestion-acid hydrolysis of pure starch. With such a curve available, direct values for actual starch could be read from the graph as soon as the amount digested by saliva could be determined.

Treatment of samples of pure starch and construction of the curves is as follows:

Ten grams of commercial corn starch were weighed from an oven dried supply, moistened and then transferred to a litre volumetric and made to volume with distilled water and thoroughly agitated. It would be an easier procedure to make a starch paste at this point by boiling the ten grams vigorously for a few minutes. This would make it easier to keep the starch in suspension while withdrawing the samples. Fifty cc containing five hundred mg. of starch were then pipetted into a five hundred cc volumetric, and the flask brought to volume with distilled water. Fifty cc more of the original suspension containing five hundred mg. of starch were pipetted into a two hundred fifty cc columetric and brought to colume. These, with the original sample in the litre flask furnished the stock solutions from which the aliquots for digestion were drawn. By having starch suspensions of three strengths it was possible to use pipettes of twenty cc volume or larger for all withdrawals, thus insuring greater accuracy than if smaller pipettes had been used.

From the five hundred cc volumetric four fifty cc aliquots containing fifty mg. starch each were pipetted into separate beakers, two for saliva digestion alone, and two for saliva digestion plus acid hydrolysis. In a similar manner four sets of aliquots to contain one hundred, two hundred, three hundred, four hundred and five hundred mg. of starth, were pipetted off into beakers, two of each concentration to be used for saliva digestion alone, and two each to be used for saliva digestion plus acid hydrolysis.

To each beaker was added about fifty cc of boiling distilled water and the beaker was set over a flame and boiled vigorously for approximately three minutes to gelatinize the starch grains. The sides of the beaker were then washed down with a rubber policeman and boiling distilled water, and the beaker placed on a boiling water bath where it remained for one hour. It was then cooled to 40° C.

Meanwhile a saliva supply had been secured by vigorous mastication of paraffin. The pure saliva was diluted with an equal volume of distilled water, and filtered thru a Whatman No. 1 filter.

Five cc of this filtered saliva solution was added to each beaker when the temperature of the contents cooled to 40°, and the beakers were placed in the oven and held for one hour at 40°. Following this they were moved to the boiling water bath for fifteen minutes, to destroy the enzymes in the first charge of saliva, and to complete gelatinization. They were then cooled to 40° C, and another five cc of the saliva solution was added, and the beakers were removed to the oven, and held for one more hour at 40° C. Followed then sterilization on the boiling water bath for fifteen minutes, and a test of each solution with IKI for presence of starch. No traces were found in the dilute solution, but slightest traces were found in the five hundred mg sample. A third charge of saliva was added, and the beakers were returned to the oven @ 40° C for another hour, sterilized, tested under a microscope with IKI, and all starch had disappeared.

At this juncture the samples were divided into two sets, two beakers of each concentration in each set. The first set was treated as follows: The beakers were cooled, and the contents of each beaker were transferred to a two hundred fifty cc volumetric, the sides of the beakers carefully washed down with a rubber policeman, and thoroughly rinsed into the volumetrics. The latter were brought to volume, and fifty cc withdrawn from each for determination of the sugar by determining their power to reduce copper in Fehlings solution.

The second set was treated as follows: The contents of each beaker were transferred to a two hundred fifty cc Florence flask~~s~~, and brought to a volume of one hundred cc by estimation (comparison with a flask containing exactly one hundred cc.) Ten cc of H Cl (specific gravity 1.125) were added to each, and the flasks were transferred to the sand bath and hydrolyzed gently for two and one-half hours, under a reflux condenser. After hydrolysis the solutions were cooled, neutralized by running into each flask exactly enough $Na_2(CO_3$ solution to neutralize the ten cc of Specific gravity 1.125 H Cl. The contents were then transferred to two hundred fifty cc volumetrics, agitated thoroughly to remove the CO_2 and brought to volume. Fifty cc was then withdrawn from each for determination of sugars by testing its power to reduce copper in Fehlings solution.

That there is a constant ratio between the saliva digested and saliva-acid-hydrolyzed starch is shown by the accompanying graph, where each series, ranging in starch content from ten mg to one hundred mg makes a straight line. The ratio is as follows:

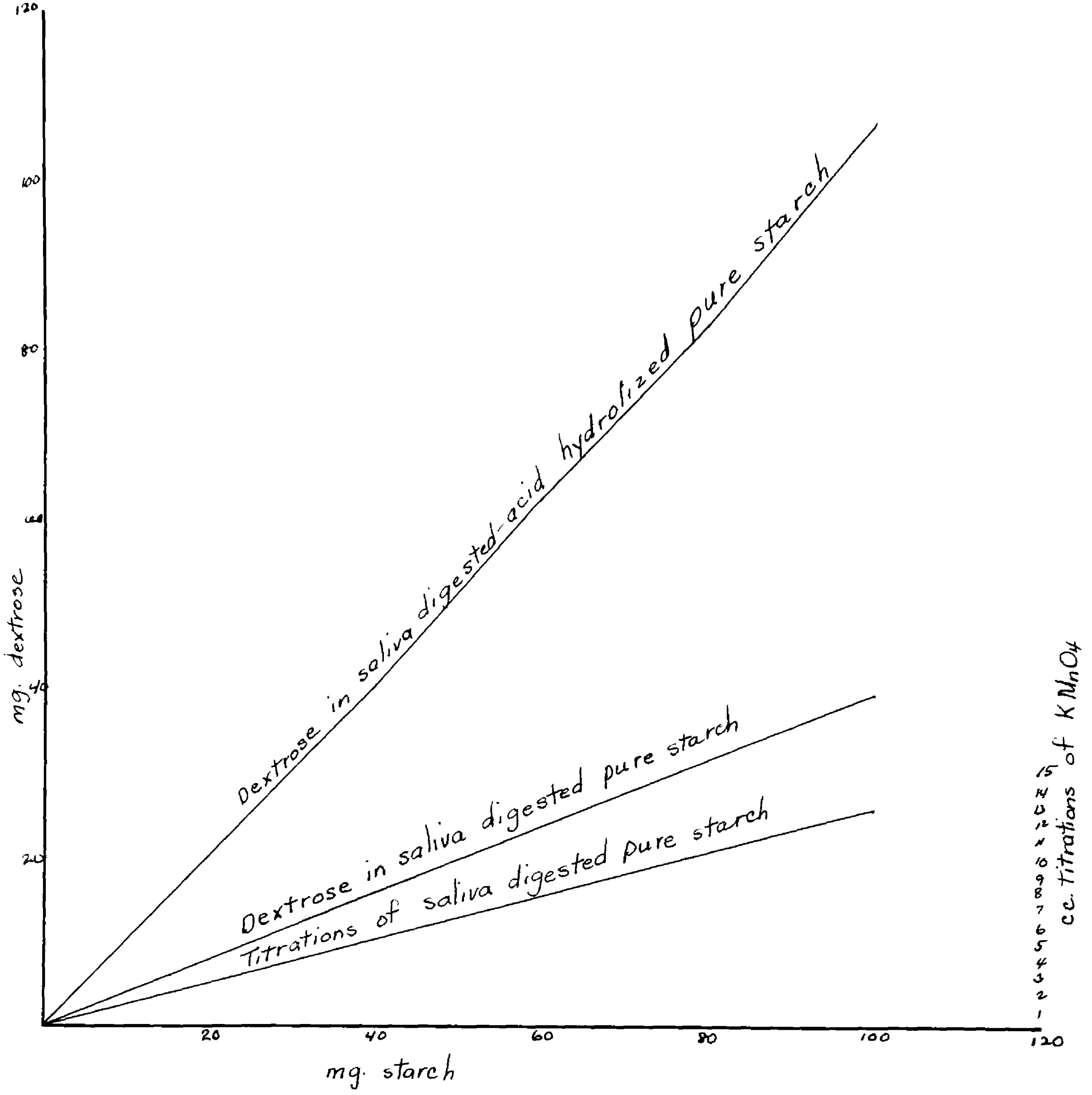
mg starch in aliquot for reduction test	Titrations			Dextrose		
	saliva digested	saliva-acid-hydrolyzed	Ratio acid/saliva	Saliva-digested	Saliva-acid-hydrolyzed	Ratio acid/saliva
10	2.75	7.40	2.69	3.50	10.02	2.86
20	5.75	14.15	2.46	7.70	20.22	2.63
40	10.88	26.23	2.43	15.20	40.26	2.65
60	16.28	39.00	2.40	23.63	62.30	2.64
80	21.05	53.86	2.56	31.42	82.90	2.64
100	25.60	66.14	2.58	38.90	106.20	2.74
	Average.		2.52	. . . .		2.68

Each titration is an average of two determinations which checked within 0.15 cc of K MnO_4.

Standardization of $KMnO_4$ and Apparatus. Instead of standardizing the $KMnO_4$ with sodium oxalate, as is customarily done, Bureau of Standards Dextrose was used. With it, any irregularities in the equipment and

Curves Showing Relation of Acid-Hydrolized Pure Starch to Saliva-Digested Starch

Fig. 8



method would be corrected for, because an exactly known quantity of dextrose was taken for reduction of copper, and the titrations for different concentrations of dextrose could be compared with the expected titrations and factors arrived at which would enable one to correct his future titrations.

One gram of pure dextrose was placed in a two hundred fifty cc volumetric, and brought to volume. It was thoroughly agitated. Each cc of the solution bore four mg. of dextrose. Fifty cc were pipetted off into another two hundred fifty cc volumetric, and another fifty cc into a five hundred cc volumetric, and these were brought to volume. Thus there were two solutions, one with twenty mg. and the other with forty mg. of dextrose in each fifty cc for reduction of copper in Fehlings solution.

Upon titration the twenty mg. samples required 13.8 cc of $KMnO_4$ and the forty mg. samples 26.2 The factors are markedly different. Therefore, another series of solutions were prepared in the same way and titrations after copper reduction were

Sample	Titrations	x 3.15 = Cu.	Correct Value	Factor Obtained Value/correct value
20 mg.	14.0 14.0	44.1	41.7	.9455
40 mg.	26.0 26.1	82.08	82.15	1.00089

These were approximately the same as were received in the first determination, so were assumed to be correct.

It is apparent that for values between twenty and forty mg. of dextrose, the factor would probably vary with the determined values as limit. Therefore titrations were plotted against correction factors on a graph, and a line drawn between the points and the subsequent

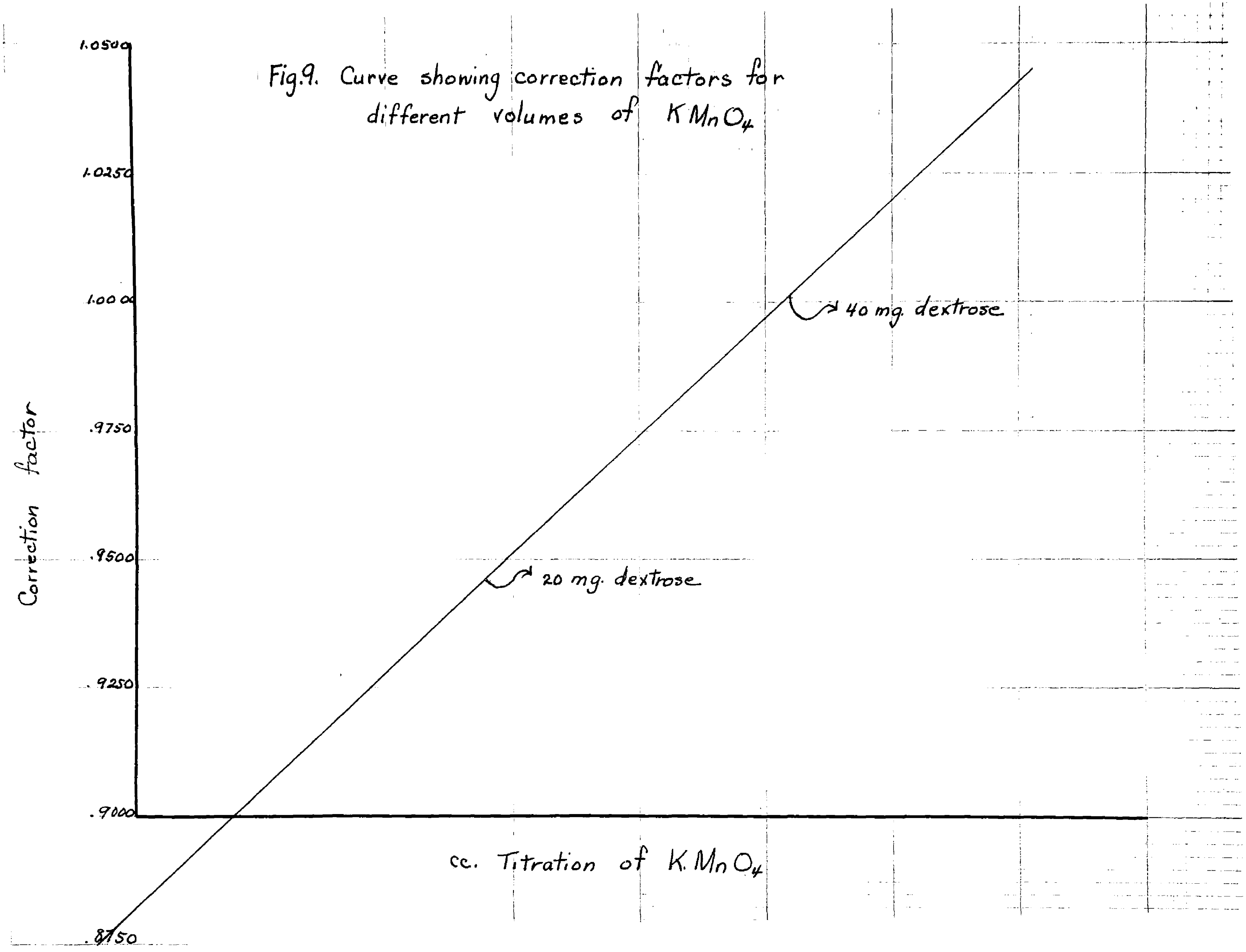


Fig. 9. Curve showing correction factors for different volumes of $KMnO_4$

titrations corrected, from this line, according to the volume of the titration (See figure 9)

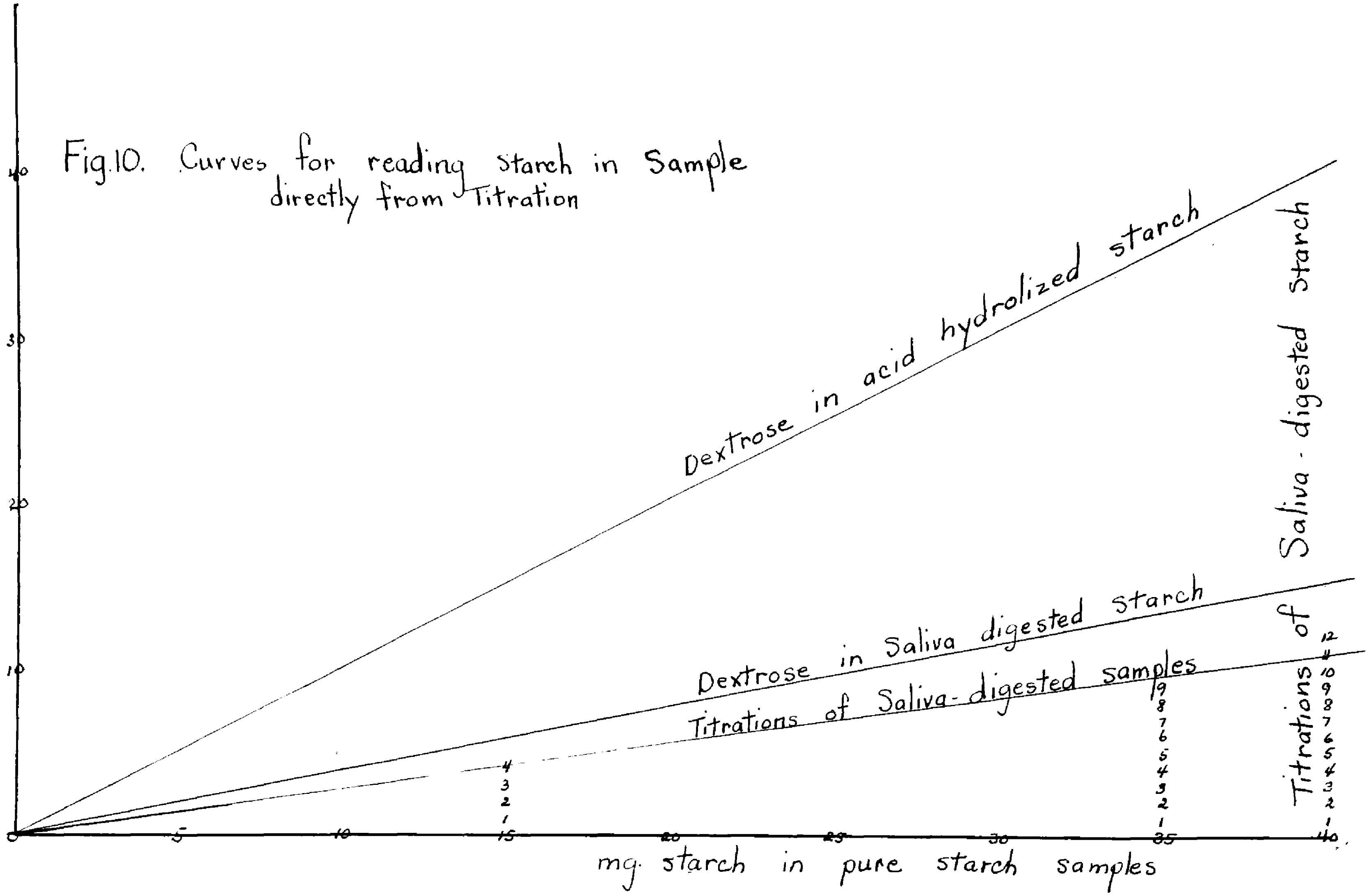
The assumption that the change between the two determined factors is a constant and gradual one is open to question. But when corrections are made in this way the curves on figures 8 and 10 are obtained, which would substantiate the assumption. Incidentally, all of the titrations in the analysis were within, or slightly below the limits of the two factors above determined.

To further justify this method of analyzing apple wood tissue for starch a comparison was made of the two methods using three samples (Nos. two hundred thirty-one, two hundred thirty-four, and two hundred thirty-seven) of which there was ample material. The following values were obtained:

Sample	% Dextrose by saliva-acid-hydrolysis	% Dextrose by saliva digestion alone	% error based on acid hydrolized method
231	8.80%	8.27%	6.03%
234	10.45%	10.26%	1.82%
237	12.22%	12.02%	1.63%

It is noteworthy that all values as determined by saliva digestion alone are slightly and consistently lower than by saliva digestion plus acid hydrolysis. The writer makes no attempt to account for the larger discrepancy in the results for sample No. Two hundred thirty-one,-probably some error in technique. It is not beyond the realms of possibility that the technique of the new method could be improved until it yielded the same quantitative values as the longer more tedious method. The results here reported surely justify its use where comparative results are desired.

Fig.10. Curves for reading starch in Sample directly from Titration



RESULTS OF ORCHARD STUDIES.

In presenting results of orchard studies, the principal emphasis will be placed on the work at Olney. Roberts (48) has shown that vigorously growing trees will build up a nitrogen reserve. After a certain total growth is reached it is difficult to stimulate further growth and yield increases with fertilizers. But devitalized trees have no nitrogen reserve, and responses secured the first and second year to nitrogenous fertilizers is more marked than that of later years. The weak trees at Olney offer a better opportunity for study than could be found in a more vigorous orchard. Data secured in the devitalized orchard at Hancock, and in vigorous orchards at Tonoloway and Salisbury will be presented also.

EFFECT OF NITROGENOUS FERTILIZERS ON COLOR OF FOLIAGE.

Differences in color of foliage were apparent among the treatments soon after growth started in the spring of 1927, at Olney. It will be recalled that this was a devitalized orchard. Color is an intangible evidence of vigor, and cannot be measured easily by numerical standards. Comparative values, however, may be obtained accurately. In attempting this, we chose one particularly vigorous row, receiving a standard treatment, and gave it a rating of one hundred. The checks showing least vigor and green color were rated as 0. The remainder of the treatments were given ratings based on their comparative vigor and green color.

The first observations on comparative color of the foliage was made on May 22nd. This was about three weeks after full bloom. Dr. E.C.Auchter, Dr. A. Lee Schrader and the writer chose the range of color differences independently and without knowledge of the treatments we were judging.

Project L-69

Table II. RANK OF NITROGEN TREATMENTS AT BRODIE'S
BASED ON GREEN COLOR - 1927

			* April 24	May 22	May 28	June 20	Aug. 19	
	1.							
	2.	Check		40	25	25	15	
	3.	Check		0	20	25	15	
Fall	4.	$Ca(NO_3)_2$		85	90	80	90	
	5.	$NaNO_3$		70	75	70	80	
9/17/26	6.	NH_4SO_4		90	85	85	90	Fall
	7.	Check		0	15	25	10	
	8.	Urea		65	55	65	35	
	9.	Leuna S-P		85	80	80	80	
	10.	$Ca(NO_3)_2$		60	70	75	75	
	11.	$NaNO_3$		80	85	90	90	Spring
Spring	12.	NH_4SO_4		80	75	90	65	
3/25/27	13.	Check		15	20	30	15	
	14.	Urea		40	45	65	40	
	15.	Leuna S-P		70	75	80	95	
	16.	$Ca(NO_3)_2$		75	75	75	80	Variable
	17.	$NaNO_3$		70	75	75	85	
	18.	NH_4SO_4		80	85	75	90	
Fall	19.	Check		0	5	0	0	
& Spr.	20.	Check		0	10	10	0	
	21.	Check		0	5	0	0	
	22.	Urea		0	20	25	30	
	23.	Leuna S-P		80	95	85	90	
	24.	Urea		40	60	60	40	
	49.	Check		0	20	30	0	
	50.	Check		0	30	40	20	Variable
	25.	Check						
	26.	Leuna S-P	* 55	90	80	85	75	
	27.	Urea	50	50	50	45	40	
Fall	28.	$Ca(NO_3)_2$	31	50	45	45	65	Fall
9/17/26	29.	$NaNO_3$	73	70	65	55	55	
	30.	Check	0	10	15	15	0	
	31.	NH_4SO_4	29	60	75	80	85	
	32.	Leuna S-P	100	90	90	95	80	
	33.	Urea	31	60	50	45	40	Spring
Spring	34.	$Ca(NO_3)_2$	50	50	45	50	50	
3/25/27	35.	$NaNO_3$	35	80	75	95	85	
	36.	NH_4SO_4	37	80	85	85	85	
	37.	Check	0	0	5	15	0	
Fall &	38.	Leuna S-P	80	70	70	70	60	
Spring	39.	Check	0	0	10	35	0	
	40.	$NaNO_3$	66	85	85	85	80	
	41.	Urea	12	35	35	45	40	
	42. 43.	NH_4SO_4	40	70	70	60	70	
	44. 45.	$Ca(NO_3)_2$	45	70	75	80	75	
	46.	$NaNO_3$	93	100	100	100	100	
	47. 48.	Check	0	0	0	0	0	

All applications were based on a standard application of 8 lbs of nitrate of soda per tree per year. The equivalent amount of nitrogen is in each of the other fertilizers.

Fertilizers were spread under the trees, from about four or five feet from the trunk to about four or five feet past the outer tips of the branches.

*Color percentages were based on the following: The yellowest checks, making only slight growth, were called 0% x The most vigorous fertilized plots, such as 46, & 52 to 55, were called 100%. The other plots were given comparative ratings.

* Values for April 24 taken from green wt., of leaves from 100 spurs from each treatment.

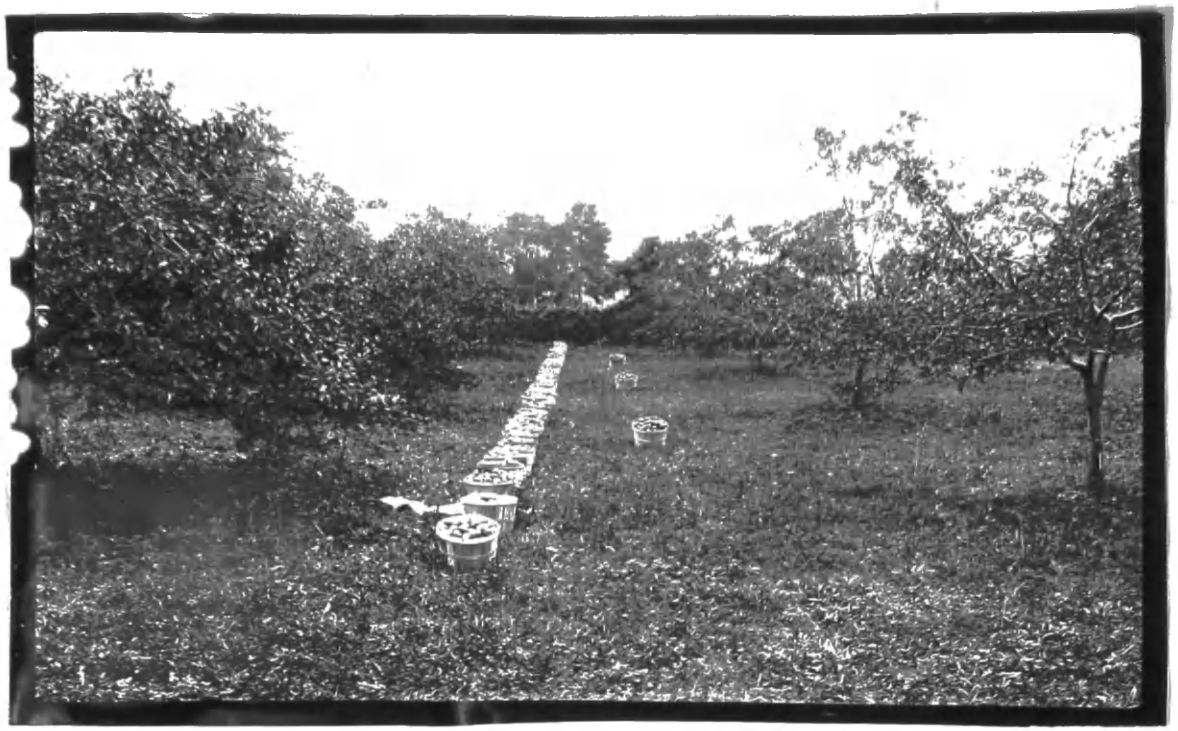


PLATE III. Nitrate of soda (left) vs Check (right).

Thereupon we compared notes, and in case of more than slight differences in opinion on any treatment each judged the block again, and then, together, ironed out such differences. Such observations were repeated three times during the summer, by the writer and the comparison of treated and check trees is shown in Table II.

Throughout the late spring and summer three normal treatments stood out, whether the fertilizers were applied in the spring, fall, or both. Nitrate of soda, leuna salpeter and ammonium sulfate were the leaders. There was little to choose among these three.

Sodium nitrate stands out as a spring, or fall and spring treatment, and did not show as good results when applied in the fall. Leuna salpeter shows up well both as a fall or spring treatment but for some unaccountable reason does not appear in nearly as good a light when applied part in the fall and part in the spring. Ammonium sulfate appears slightly the better as a fall treatment than as a spring treatment, and is significantly better than nitrate of soda in that role, as is also Leuna saltpeter.

Calcium nitrate applied in the fall was as good as nitrate of soda applied at that time, and when applied half in the fall and half in the spring it is as good as ammonium sulfate applied in that manner, but not as good as the other two leaders at either of those seasons. Urea does not approach any of the other materials at any time. This is brought out in the following table:

Table II-A Comparison of Foliage Color Stimulated by Different Nitrogenous Fertilizers When Applied at Various Seasons, Olney, Md., 1927.

Scored on the basis that the treated block showing best color is 100 and the yellowest check row 0.

Treatment	Leuna Salpeter	$NaNO_3$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	Urea
Fall	83.1 ± 1.20	68.8 ± 2.13	81.3 ± 2.40	68.8 ± 4.74	51.3 ± 2.34
Spring	84.4 ± 1.33	85.6 ± 1.75	80.6 ± 2.02	60.0 ± 3.16	48.1 ± 2.34
½ Fall) ½ Spring)	78.1 ± 2.72	88.1 ± 3.30	75.6 ± 2.31	75.6 ± 0.92	44.4 ± 2.50

Schrader and Auchter, using twenty year old, devitalized York Imperial trees, receiving five, ten, fifteen or twenty pounds of nitrate of soda or equivalent amounts of ammonium sulfate found that spring or fall applied nitrate of soda was better than ammonium sulfate at either period the first year. In the experiment reported here, ammonium sulfate is significantly better than nitrate of soda when the material is applied in the fall, but the findings of Schrader and Auchter are substantiated when spring treatments are considered, or when the fertilizers are applied half in the spring and half in the fall.

By throwing all trees receiving each material into a group regardless of time of application, the relative values of the different carriers is brought out a little more smoothly and sharply, although at the expense of indicating the best time to apply certain materials. This has been done in the following table:

Table II-B Comparison of Foliage Color Stimulated by Various Nitrogenous Fertilizers. Olney, Md. 1927. Time of Application Disregarded.

Treated row having most intense green foliage taken as 100, and yellowest check row as 0.

	Material					
Date	Leuna Salpeter	$NaNO_3$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	Urea	Check
May 22,1927	80.8 ± 2.68	78.2 ± 3.50	76.6 ± 3.48	65.0 ± 3.91	48.3 ± 3.41	0
May 29,1927	81.7 ± 2.65	79.2 ± 3.25	79.2 ± 1.84	66.7 ± 4.98	49.2 ± 2.34	0
June 20,1927	82.5 ± 2.39	80.8 ± 5.43	79.2 ± 2.99	67.5 ± 4.40	54.2 ± 2.80	0
Aug. 9,1927	85.0 ± 3.09	81.7 ± 2.78	82.5 ± 2.96	73.3 ± 3.96	39.2 ± 0.32	0
Season 1927	81.9 ± 1.16	80.8 ± 1.82	79.2 ± 1.25	68.1 ± 1.64	47.7 ± 1.41	0

Considered in this way, no distinction can be made between the first three materials listed. But all of them are significantly better than urea and calcium nitrate.

In 1928, the second year of the experiment, there were somewhat inconsistent differences between sodium nitrate, ammonium sulfate and leuna saltpeter, as regards color of foliage. Calcium nitrate moved up among the leaders. Urea improved considerably and when, in the spring of 1928, calurea was substituted for urea, the score of the urea block moved up to 82.5. The entire orchard bore a very heavy crop of fruit, which would use up much of the stored carbohydrates and would result in a general increase in green color over all blocks. Anthocyan and carotin pigments develop with increase of carbohydrates, and their yellow colors may mask the green of the chlorophyll in the leaves. Carbohydrates would be moved out of the leaves into the fruit when a

L - 69
November 18, 1928
STAYMAN

Table IIe Percent Color of Foliage, 1928.

Bowdler Orchard, Olney Md.

A. F. Mason.

	Block	Treatment	Percent Color of Foliage					
			May 28	June 8	June 19	August 27	Ocotber 5 to 15.	
							(foliage)	(fruit)
	1	---	---	---	---	---	---	----
Fall Treatment	2	Check	0	20	40	30	10	100
	3	Check	0	20	35	30	0-15	80-100
	4	$Ca(NO_3)_2$	80	80	85	90-100	100	50-70
	5	$NaNO_3$	90	95	95	90-100	100	60-65
	6	$(NH_4)_2SO_4$	70	80	85	90-100	100	40-65
	7	Check	0	20	45	20	10	100
	8	Urea	70	70	75	70	70	75-85
	9	Leuna	85	85	95	90	80-90	75-80
Spring Treatment	10	$Ca(NO_3)_2$	80	85	80	90	100	60-80
	11	$NaNO_3$	90	85	75	80	90	70-80
	12	$(NH_4)_2SO_4$	(4-85) (2-30)	85	80	90	100	50-60
	13	Check	30	25	40	80	0-25	100
	14	Urea-Calurea	90	80	85	90	80-90	75
	15	Leuna	(4-90)(2-0)	90	85	90	100	60-65
Fall and Spring	16	$Ca(NO_3)_2$	80	85	80	80-90	100	60-65
	17	$NaNO_3$	(4-60) (2-90)	85	80	60-90**	50-100	60-75
	18	$(NH_4)_2SO_4$	50	80	80	80-90	100	70-75
	19	Check	0	10	20	20	0-20	100
	20	Check	0	15	25	20	0-25	100
	21	Check	0	10	10	0	0	100
	22	Urea-Calurea	60	60	70	80	85	80
	23	Leuna	90	95	90	90	90	65-70
	24	Urea-Calurea	70	70	80	80	80-85	80
	49	Check	20	25	40	10-40	0-50	85-100
	50	Check	30	25	50	40-50	30-60	100
Fall Treatment	25	Check ***	---	---	---	---	---	----
	26	Leuna	60	75	70	70	60-70	80-100
	27	Urea	30	50	60	70	85-90	65-70
	28	$Ca(NO_3)_2$	60	60	60	80	85-90	50-60
	29	$NaNO_3$	(1-70) (3-90)	90	80	80-90	90-95	60-65
	30	Check	0	10	35	40	40-50	80
	31	$(NH_4)_2SO_4$	60	70	70	80	100	55-65
Spring Treatment	32	Leuna	(1-60) (3-100)	100	90	100	100	50-65
	33	Urea-Calurea	80	70	75	80	90	60-65
	34	$Ca(NO_3)_2$	80	85	90	100	100	65-70
	35	$NaNO_3$	(1-40) (4-100)	90	85	85**	65-90	70-80
	36	$(NH_4)_2SO_4$	100	100	95	100	100	50
	37	Check	(1-50) (4-0)	40	35	25	20	100
Fall and Spring	38	Leuna	(2-75) (3-100)	100	95	100	100	40-45
	39	Check	15	10	20	0-20	0-15	100
	40	$NaNO_3$	100	100	85	100	100	55-60
	41	Urea-Calurea	75	70	70	90	25-100	60-65
	42		95	95	90		100	60
	43	$(NH_4)_2SO_4$	90	95	90	100	100	60-65
	44		100	90	85		100	50-60
	45	$Ca(NO_3)_2$	100	95	90	100	100	50-55
	46	$NaNO_3$	100	100	100	100	100	50
	47	Check	0	25	20	0	0	100
	48	Check	0	20	35	0	0	100
Double Application	51	Check	90	70	65	70	85	40-60
	52	$NaNO_3$	(2-80) (4-100)	100	100	100	100	50
	53	$(NH_4)_2SO_4$	100	100	100	100	100	40-60
	54	$Ca(NO_3)_2$	100	100	100	100	100	50
	55	Urea-Calurea*	50	60	90	90	100	50-60
	56	Leuna	80	100	100	100	90-100	60-65
Half Application	57	Check	30	35	55	40	40-50	80-100
	58	$NaNO_3$	60	70	60	60	60	80-100
	59	$(NH_4)_2SO_4$	50	55	60	60	70-75	70-90
	60	$Ca(NO_3)_2$	60	55	55	60	70-75	75-90
	61	Check	0	0	20	10	0	100
	62	Urea-Calurea*	0	0	30	20-40	10-30	100
	63	Leuna	70	75	70	70	75-85	70-85
Double Application	64	$NaNO_3$	100	100	100	100	100	60-65
	65	$(NH_4)_2SO_4$	100	100	100	100	100	50-60
	66	Check	0	25	50	50	40	80-100
	67	$Ca(NO_3)_2$	100	100	100	100	100	65-70
	68	Urea-Calurea*	80	80	90	100	100	70
	69	Leuna	100	100	95	100	100	65-70
Half Application	70	Check	40	35	40	20-50	25-90	80-100
	71	$NaNO_3$	70	75	75	70	90	75
	72	$(NH_4)_2SO_4$	70	70	70	70	100	65-70
	73	$Ca(NO_3)_2$	70	70	70	70	100	70-80
	74	Urea-Calurea*	50	60	65	70	85	85-90
	75	Leuna	70	85	80	80	90	60-85
	76	Check	60	60	60	70	90	85-90

* Calurea not applied until May 28, 7 weeks after other materials were applied.
** Variable.
*** Only one tree.

heavy crop was set.

The color observations are given in Table II-C and the averages in Table III.

Table III. Comparison of Foliage Color in Orchard at Olney, Maryland, 1928.

Treated row having most intense green foliage taken as 100, and the yellowest check row as 0.

Time of Application	Leuna Saltpeter	Sodium Nitrate	Ammonium Sulfate	Calcium Nitrate	Urea Calurea
Fall	78.0	90.5	81.0	78.5	65.0
Spring	95.5	86.5	93.0	89.0	82.5
Fall & Spring	94.0	90.0	87.0	91.0	76.5
Average of all Treatments	88.5	89.0	87.0	86.2	74.7

Leuna saltpeter fell from first to fourth place among fall treatments and from first to second place in the average of all treatments. It rose from second to first place both as a spring and as a fall and spring treatment. Nitrate of soda, however, goes to first place when all treatments are averaged, exchanging places with leuna saltpeter. It seems satisfactory as applied in the fall the second season.

This smoothing out of effects of nitrogen applications the second year is in accordance with the findings of Schrader and Auchter (50) and Marsh (43). It is possible that the presence of a heavy crop on all trees materially aided in making the color more uniform.

Foliage Color in Cohill Orchard. In the other devitalized apple orchard at Hancock, nitrate of soda undoubtedly stimulated the best color, whether applied in the spring or in the spring and fall. This is in keeping with the findings of Schrader and Auchter (50) in the same region. The fertilizers had been applied in the fall of 1927, and the spring application was made on April 6 and 8. On May 3 there was no apparent differences in the foliage color. The spring had been cold, frosty, and rainy, and all leaves were small and wrinkled. On May 19, after two weeks of warm weather, the differences had begun to show up, the nitrate of soda being the best treatment in the orchard. Dr. E. C. Auchter and the writer were unable to distinguish differences between calcium nitrate, leuna saltpeter, and half and half-nitrate of soda-and-ammonium sulfate, when applied in the spring. These were slightly less green than nitrate of soda. Ammonium sulfate and calurea followed. Cyanamid and urea were poorest, and but little better than checks.

Spring and fall treatments resulted in greenest color on row eleven, a nitrate of soda block, but the other nitrate of soda block was distinctly poorer in color. Leuna saltpeter stood next with calsium nitrate, sulfate of ammonia, cyanamid, and half and half-sodium nitrate-and-ammonium sulfate in the foregoing order. Calurea followed (it having been substituted for urea in this spring application) and urea was last. One ammonium sulfate plat, adjoining a check row, was considerably poorer than the rest, while the check had made a very fair showing. This suggests the possibility of a confusion of rows when applying fertilizers. The fall application was made before this piece of work was taken over by the writer.

Table IV. Comparison of Foliage Color Stimulated by Various Nitrogenous Fertilizers. Cohill Orchard. Hancock, Maryland. May, 19, 1928.

Treated row with best foliage color taken as 100, and yellowest check row as 0.

Treatment	Rows	Spring	Fall & Spring
4 lbs. Nitrate of soda	2 & 11	90-90	80-100
2 lbs. Nitrate of soda) 1½ " Ammonium sulfate)	3 & 12	75-75	90- 90
3 lbs. Ammonium sulfate	4 & 13	65-65	60- 95
Check	1-5 & 10	0-0-0	0-60-0 (Spotted)
4 lbs. Calcium nitrate	6 & 9	75-75	70- 90
1.6 " Calurea	7 & 15	65-65	80- 85
2.3 " Leuna saltpeter	8 & 14	75-75	95- 95
3 lbs. Cyanamid	16 & 18	25-25	90- 90
1.2 " Urea	17	25	75

On June 22, inspection indicated that these standings had not altered appreciably, but on July 25, all plats except urea and spring cyanamid appeared to be of equal value. The foliage was wet, however, which may have masked certain slight color differences. On August 18 there were no appreciable differences between any of the treatments except urea and spring cyanamid. With the advent of warm weather, ammonification and nitrification proceeded more rapidly and some effects began to be felt from even the slowly decomposing fertilizers, such as urea and cyanamid. Some check trees had assumed a definite green, indicating cross feeding, or cross washing, to be expected when the trees are planted so close together and when the slope of the orchard is across the treatments.

<u>Color Comparisons on Vigorous Apple and Peach Orchards.</u> Two inspections of the Allen orchards at Salisbury, Maryland were made in 1928. No differences could be seen in early May nor on August 17, in the treatments, either on apples or peaches. The check row in the "Triangle" orchard showed distingtly yellow foliage at both visits.

Several inspections at various times of the year failed to denote any consistent or substantial differences in color of foliage among the treatments at Tonoloway, during 1928, except that the check, unfertilized for three years, had assumed a comparatively yellowish appearance, although apparently making reasonable growth. Comparisons were handicapped by the presence of many mouse-injured trees, which tended to give the rows an unwarranted yellow shade. At harvest time there were a few slight differences. Row fourteen, receiving sodium nitrate, lying between rows receiving calurea and urea, seemed to be slightly inferior to either of its neighbors. The rows receiving nitrate of soda at blossom time appeared to be greenest, but these were also the rows receiving the heaviest applications of nitrogen. The rows receiving three pounds of $NaNO_3$ in the spring, and five pounds in the fall did not appear to be as green as the other treatments. As has been said before, the differences were slight, and the trees somewhat variable, due to mouse injury.

These results in vigorous orchards, are not unexpected. In all cases, a fairly heavy application was given, so that even in the case of the Tonoloway orchard, which is in sod, there were enough nitrates to meet the requirements of the trees. In the past the trees had received quite generous applications of nitrogenous fertilizers, so even had these new fertilizers been ineffective, the trees should not have shown ill effects to any great extent the first year. Roberts (48) has shown that apple trees from a high nitrogen medium will make almost as much growth when moved to a low nitrogen medium as if they had been left in the medium high in nitrogen. He attributes this to the building up of a nitrogen reserve while plenty of nitrates were available. Also, it has been seen that even in devitalized orchards the color differences between fertilizers tend to smooth out as the treatments are continued over a period of years. Crane (79) found a residual effect of nitrogenous fertilizers to last for at least two years following application.

EFFECT OF NITROGENOUS FERTILIZERS ON TERMINAL GROWTH.

Vegetative vigor is one of the expressions of tree response to any treatment which is easy to measure. It is one of the first evidences seen when nitrogenous manures are applied. On very devitalized trees the greatest response is seen during the first year in the growth of water sprouts along the trunk, main branches and limbs. It may not be until the second season that a marked response is seen in terminal or spur growth. On trees of merely low vigor (as opposed to extreme debility), a response is obtained promptly at the growing points, whether they be on terminals, or side branches. Thus it was in the orchard at Olney.

The nature of the growth which will give the closest measure of the response made by the tree to any treatment was found by Cooper (16)

Table V

SUMMARIES OF TERMINAL GROWTH MADE BY BEARING STAYMAN APPLE TREES. AT OLNEY, MARYLAND, 1927.

Gains over checks, expressed in centimeters.

Treatment	Rows	Spring	Rows	Fall	Rows	Fall & Spring
$NaNO_3$	11	9.252	5	3.993	17	6.537
	35	12.785	29	10.905	40	12.765
	Av.	10.825 ± 1.886	Av.	6.870 ± 1.351	46	14.845
					Av.	10.965 ± .873
$(NH_4)_2SO_4$	12	8.170	6	8.727	18	11.605
	36	6.719	31	9.840	42)	11.885
	Av.	7.378 ± .723	Av	9.333 ± .917	43)	
					Av.	11.765 ± 1.046
Leuna Salpeter	15	11.030	9	6.921	23	11.965
	32	12.540	26	7.100	38	6.762
	Av	11.695 ± 1.464	Av	7.012 ± 1.050	Av	9.381 ± 2.591
$Ca(NO_3)_2$	10	2.580	4	7.662	16	10.728
	34	3.806	28	2.924	44)	7.120
	Av	2.999 ± 2.164	Av	5.286 ± .692	45)	
					Av	8.771 ± 1.000
Urea	14	1.263	8	5.393	22	1.927
	33	4.093	27	4.599	24	6.612
	Av	2.567 ± .758	Av	4.958 ± .657	41	5.630
					Av	4.909 ± .803

to be the upper quartile of all terminals on the tree. Cooper measured every growing point over one inch in length, except fruitspurs. While he does not specify where the upper quartile were located in his experiment, it is reasonable to believe that terminals of the main branches, high and low, would be included.

At Olney the growth made by twenty main terminals above shoulder height were measured on each tree. As the trees had not been cut back in any way it was possible to measure back and get the growth made in 1925 and 1926, as well as the growth for the two years that the experiment has run. At the time this was done, it was not certain just how important these earlier records would be, but it was thought that they might prove useful. As it happens they were very useful, as will be seen later. The twenty terminals, for each year for each tree were averaged and the result was used as the growth response for that tree.

Variability in growth response is large in apple and peach trees. Therefore differences which might be construed to treatment may be merely an expression of variability. Anthony and Waring (78) found apple trees so variable that in orchard fertilizer experiments under consideration, differences in yield between treatments would need to exceed twenty percent in the lowest case and sixty-eight percent in the highest, before it could be said with certainty that they were not due to variability. Variability also prevailed in the experiments reported here. To use the measurements at all effect-

Table VI

COMPARISON OF TERMINAL GROWTH OF BEARING STAYMAN APPLE TREES STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS, WHEN APPLIED IN THE SPRING. AT OLNEY, MARYLAND, 1927.

Gains over check growth expressed in centimeters.

$NaNO_3$ Vs.

$(NH_4)_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
10.825 ± 1.892	10.825 ± 1.892	10.825 ± 1.892	10.825 ± 1.892
7.378 ± 0.723	11.695 ± 1.464	2.999 ± 2.164	2.567 ± .758
3.447 ± 2.020	-.870 ± 2.386	7.826 ± 2.869	8.258 ± 2.062
1.7 x P.E. of diff.	-.37 x P.E.of diff.	2.73 x P.E.of diff.	4.06 x P.E.of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
7.378 ± .7234	7.378 ± .723	7.378 ± .723
11.695 ± 1.464	2.993 ± 2.164	2.567 ± .758
-4.317 ± 1.633	4.385 ± 2.283	4.811 ± 1.048
-2.65 x P.E. of diff.	1.92 x P.E. of diff.	4.59 x P.E.of diff.

Leuna Salpeter Vs.

$Ca(NO_3)_2$	Urea
11.695 ± 1.464	11.695 ± 1.464
2.999 ± 2.164	2.567 ± .758
8.696 ± 2.623	9.128 ± 1.377
3.34 x P.E. of diff.	5.52 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

2.999 ± 2.164
2.567 ± .758
.432 ± 2.114
.2 x P.E. of diff.

TABLE VII

COMPARISON OF TERMINAL GROWTH OF BEARING STAYMAN APPLE TREES STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS, WHEN APPLIED IN THE FALL, AT OLNEY, MARYLAND, 1927.

Gains over check tree growth expressed in centimeters

$NaNO_3$ Vs.

$(NH_4)_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
6.872 ± 1.351	6.872 ± 1.351	6.872 ± 1.351	6.872 ± 1.351
9.330 ± .917	7.010 ± 1.051	5.285 ± .691	4.956 ± .657
-2.458 ± 1.631	-.138 ± 1.710	1.587 ± 1.516	1.916 ± 1.502
-1.5 x P.E. of diff.	-.081 x P.E. of diff.	1.05 x P.E. of diff.	1.28 x P.E. of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
9.330 ± .917	9.330 ± .917	9.330 ± .917
7.010 ± 1.051	5.285 ± .691	4.956 ± .657
2.320 ± 1.394	4.045 ± 1.148	4.374 ± 1.128
1.66 x P.E. of diff.	3.52 x P.E. of diff.	3.88 x P.E. ofdiff.

Leuna Salpeter Vs.

$Ca(NO_3)_2$	Urea
7.010 ± 1.051	7.010 ± 1.051
5.285 ± .691	4.956 ± .657
1.725 ± 1.258	2.054 ± 1.239
1.37 x P.E. of diff.	1.66 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

5.285 ± .691
4.956 ± .657
.329 ± .956
.34 x P.E. of diff.

ively it was necessary to determine the growth capacity of each tree before treatment was given, so that one could determine to what extent any increases in growth were due to treatments given. The method of doing this has been described under "Statistical Procedure", on page 31. We have expressed all terminal growth data in terms of centimeter increases over check trees.

Terminal Growth Response at Olney, 1927. Terminal growth followed closely the lines indicated by color observations. Tables V to IX-A present the data. Sodium nitrate, leuna salpeter and ammonium sulfate gave uniformly good results, while calcium nitrate was variable and in general lagged well behind them, and urea was uniformly the poorest.

Time of making the applications has an effect upon the efficiency of the fertilizers as reflected in terminal growth, the same as it had in stimulating foliage color. This is shown in Table V. When time of application is considered we observe the following results:

(a) Spring applications.

1. Nitrate of soda is significantly better than urea and somewhat better than calcium nitrate and ammonium sulfate, although the differences are not quite significant statistically.
2. Sulfate of ammonia is significantly superior to urea, and better than calcium nitrate, but not significantly so.
3. Leuna salpeter is significantly better than either

Table VIII

COMPARISON OF TERMINAL GROWTH OF BEARING STAYMAN APPLE TREES STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS, WHEN APPLIED HALF IN THE FALL AND HALF IN THE SPRING, AT OLNEY, MARYLAND, 1927.

Gains over check expressed in centimeters

$NaNO_3$) Vs.

$(NH_4)_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
10.965 ± .873	10.965 ± .873	10.965 ± .873	10.965 ± .873
11.765 ± 1.047	9.360 ± 2.591	8.753 ± 1.000	4.908 ± .803
-.800 ± 1.362	1.605 ± 2.733	2.212 ± 1.328	6.057 ± 1.186
-.58 x P.E. of diff.	.59 x P.E. of diff.	1.67 x P.E. of diff.	5.11 x P.E. of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$CaNO_3$	Urea
11.765 ± 1.047	11.765 ± 1.047	11.765 ± 1.047
9.360 ± 2.591	8.753 ± 1.000	4.908 ± .803
2.405 ± 2.793	3.012 ± 1.448	6.857 ± 1.318
.861 x P.E. of diff.	2.08 x P.E. of diff.	5.2 x P.E. of diff.

Leuna Salpeter Vs.

$Ca(NO_3)_2$	Urea
9.360 ± 2.591	9.360 ± 2.591
8.753 ± 1.000	4.908 ± .803
.607 ± 2.778	4.452 ± 2.712
.86 x P.E. of diff.	1.64 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

8.753 ± 1.000
4.908 ± .803
3.845 ± 1.284
3.0 x P.E. of diff.

Table IX

COMPARISON OF TERMINAL GROWTH ON BEARING STAYMAN APPLE TREES STIMULATED BY DIFFERENT FERTILIZERS, AT OLNEY, MARYLAND, 1927, WHEN FALL, SPRING, AND FALL AND SPRING TREATMENTS ARE COMBINED.

Gain over check trees expressed in centimeters.

	Weighted Averages
$NaNO_3$	9.567 cm. ± .754
$(NH_4)_2SO_4$	9.559 " ± .554
Leuna Salpeter	9.445 " ± .702
$Ca(NO_3)_2$	5.841 " ± .537
Urea	5.573 " ± .625

calcium nitrate or urea, and almost significantly better than ammonium sulfate, and slightly better than nitrate of soda.

4. Calcium nitrate not significantly better than urea.

(b) Fall Applications.

1. Nitrate of soda is not significantly better than any other material tested.
2. Ammonium sulfate is significantly better than calcium nitrate and urea.
3. There are no significant differences between leuna saltpeter, calcium nitrate and urea.

(c) Fall and Spring Applications.

1. Nitrate of soda is significantly superior to urea only.
2. Ammonium sulfate is significantly superior to urea only.
3. Leuna saltpeter is not significantly better than calcium nitrate or urea.
4. Calcium nitrate is significantly better than urea.

These results are brought out in the following tables showing the odds supporting the findings. See Tables VI, VII, and VIII.

That there is a sharp division between sodium nitrate, ammonium sulfate and leuna salpeter and calcium nitrate and urea may be shown in another way. When all trees receiving one fertilizer regardless of season of application, are compared with all trees receiving each of the other fertilizers, the data in Tables IX and IX-A. Here it is seen that no distinction can be drawn between the first three, while all the three are significantly superior to calcium nitrate or urea.

PLATE IV. Urea (calurea) (right) vs Check (left.)

First Year's Results at Hancock, Maryland. It will be recalled that the Cohill orchard at Hancock was quite in need of nitrogen. Judged by terminal growths nitrate of soda was the best material the first year, particularly when applied in the spring. Calcium nitrate and ammonium sulfate were the closest competitors of sodium nitrate both in spring and fall and spring applications. Leuna salpeter and cal-urea followed. Calcium cyanamid caused a marked response in fall and spring applications but showed little effect of spring applications. It must be remembered that on row eighteen the spring application of cyanamid was almost two weeks late, and the data seems to show the effect of this delay. Urea was of no apparent benefit to growth.

With nitrate of soda, calcium nitrate and ammonium sulfate leading the field, the failure of leuna salpeter to show up more strongly is surprising. No explanation of this irregularity is forthcoming. It is similar to the failure of calcium nitrate to show up at Olney.

The growth records indicated such variability that no attempt will be made to draw conclusions until further records are available. These data appear in Tables XVII and XVIII.

INCREASE IN TRUNK CIRCUMFERENCE, AT OLNEY, MARYLAND, 1927.

Anthony and Waring, and Cooper as well as other workers have found the increase in trunk circumference a good index to the growth condition or vigor of the tree. Measurements were made on each tree at a point where the trunk was smooth, and the point was marked with white paint, subsequent measurements being made at the same place.

Table X.

COMPARISON OF TRUNK GROWTH STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS WHEN APPLIED IN SPRING, FALL, OR HALF IN THE FALL AND HALF IN THE SPRING; OLNEY, MARYLAND, 1927

Bearing Stayman Apple Trees
Comparing gains over average of nearest checks,
data expressed in millimeters.

Treatment	Row	Spring	Row	Fall	Row	Fall & Spring
$NaNO_3$	(11 (35	22.85 ± 2.49	(5 (29	13.55 ± 2.16	(17 (40 (46	20.98 ± 1.76
$(NH_4)_2SO_4$	(12 (36	19.05 ± 1.62	(6 (31	20.55 ± 1.65	(18 (42 (43	17.24 ± 2.16
Leuna Salpeter	(15 (32	20.54 ± 3.15	(9 (26	26.63 ± 2.51	(23 (38	16.17 ± 1.48
$CaNO_3$	(10 (34	8.43 ± 1.042	(4 (28	16.05 ± 2.08	(16 (44 (45	14.85 ± 1.55
Urea	(14 (33	6.46 ± 1.27	(8 (27	12.55 ± 1.1	(22 (24 (41	9.36 ± 1.39

Table XI.

COMPARISON OF INCREASES IN TRUNK CIRCUMFERENCE STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS APPLIED IN THE SPRING. OLNEY, MARYLAND, 1927.

Expressed as millimeters gain over the
average of the nearest checks.
Bearing Stayman Apple Trees

$NaNO_3$ Vs.

$(NH_4(_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
22.85 ± 2.49 19.05 ± 1.62	22.85 ± 2.49 20.54 ± 3.15	22.85 ± 2.49 8.43 ± 1.04	22.85 ± 2.49 6.46 ± 1.27
3.80 ± 2.96	2.31 ± 4.02	14.42 ± 2.70	16.39± 2.79
1.28 x P.E. of diff.	.57 x P.E. of diff.	5.34 x P.E. of diff.	5.88 x P.E. of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
19.05 ± 1.62 20.54 ± 3.15	19.05 ± 1.62 8.43 ± 1.04	19.05 ± 2.49 6.46 ± 1.27
-1.49 ± 3.53	10.62 ± 1.91	12.59 ± 2.08
-.42 x P.E. of diff.	5.56 x P.E. of diff.	6.05 x P.E. of diff.

Leuna Salpeter Vs.

$Ca(NO_3)_2$	Urea
20.54 ± 3.15 8.43 ± 1.04	20.54 ± 3.15 6.46 ± 1.27
12.11 ± 3.32	14.08 ± 3.39
3.65 x P.E. of diff.	4.15 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

8.43 ± 1.04 6.46 ± 1.27
1.97 ± 1.64
1.2 x P.E. of diff.

When these data are examined it is seen that the responses have been in the same order as were those for foliage color and terminal growth. Nitrate of soda gives better results when applied in the spring. The other four materials all appear to have stimulated greated increase in trunk growth when applied in the fall, although the difference in the case of ammonium sulfate is small.

When time of application is considered, the results seen in Tables X, XI, XII, and XIII, are obtained. They are as follows:-

(a) Spring applications.

1. Nitrate of soda is better than all other materials, but is supported biometrically only when considering calcium nitrate and urea.
2. Sulfate of ammonia is significantly superior to calcium nitrate and urea, but is somewhat, though not significantly, inferior to nitrate of soda and leuna salpeter.
3. Leuna salpter appears better than sulfate of ammonia and is significantly better than calcium nitrate and urea.
4. Calcium nitrate is better than urea, but cannot be supported by odds.

(b) Fall applications.

1. Nitrate of soda is significantly inferior to leuna salpeter, almost as inferior to sulfate of ammonia, and not sufficiently superior to calcium nitrate and urea to be supported by significant odds, when applied in the fall.

Table XII.

COMPARISON OF INCREASES IN TRUNK CIRCUMFERENCE STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS APPLIED IN THE FALL. OLNEY, MARYLAND, 1927.

Expressed in millimeters of gain over the average of the nearest checks.

Bearing Stayman Apple Trees.

$NaNO_3$ Vs.

$(NH_4)_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
13.55 ± 2.16	13.55 ± 2.16	13.55 ± 2.16	13.55 ± 2.16
20.55 ± 1.65	26.63 ± 2.51	16.05 ± 2.08	12.55 ± 1.10
-7.00 ± 2.68	-13.08 ± 3.31	2.50 ± 3.00	1.00 ± 2.42
2.61 x P.E. of diff.	-3.95 x P.E. of diff.	.83 x P.E. of diff.	.41 x P.E. of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
20.55 ± 1.65	20.55 ± 1.65	20.55 ± 1.65
26.63 ± 2.51	16.05 ± 2.08	12.55 ± 1.10
-5.08 ± 3.00	4.50 ± 2.65	8.00 ± 1.98
1.7 x P.E. of diff.	1.7 x P.E. of diff.	4.04 x P.E. of diff.

Leuna Salpeter

$Ca(NO_3)_2$	Urea
26.63 ± 2.51	26.63 ± 2.51
16.05 ± 2.08	12.55 ± 1.10
10.58 ± 3.26	14.08 ± 2.74
3.25 x P.E. of diff.	5.14 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

16.05 ± 2.08
12.55 ± 1.10
3.50 ± 2.35
1.49 x P.E. of diff.

Table XIII.

COMPARISON OF INCREASES IN TRUNK CIRCUMFERENCE, STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS WHEN APPLIED IN SPRING AND FALL. Olney, Maryland, 1927.

Gains over average of nearest checks, expressed in millimeters.

Bearing Stayman Apple Trees

$NaNO_3$ Vs.

$(NH_4)_2SO_4$	Leuna Salpeter	$Ca(NO_3)_2$	Urea
20.98 ± 1.76 17.24 ± 2.16	20.98 ± 1.76 16.17 ± 1.48	20.98 ± 1.76 14.85 ± 1.55	20.98 ± 1.76 9.36 ± 1.39
3.74 ± 2.78	4.81 ± 2.30	6.13 ± 2.35	11.62 ± 2.05
1.35 x P.E. of diff.	2.1 x P.E. of diff.	2.61 x P.E. of diff.	5.67 x P.E. of diff.

$(NH_4)_2SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
17.24 ± 2.16 16.17 ± 1.48	17.24 ± 2.16 14.85 ± 1.55	17.24 ± 2.16 9.36 ± 1.39
1.07 ± 2.97	2.39 ± 2.66	7.88 ± 2.57
.36 x P.E. of diff.	.9 x P.E. of diff.	3.07 x P.E. of diff.

Leuna Salpeter Vs.

$Ca(NO_3)_2$	Urea
16.17 ± 1.48 14.85 ± 1.55	16.17 ± 1.48 9.36 ± 1.39
1.32 ± 2.14	6.81 ± 2.03
.62 x P.E. of diff.	3.35 x P.E. of diff.

$Ca(NO_3)_2$ Vs. Urea

14.85 ± 1.55 9.36 ± 4.39
5.49 ± 2.08
2.64 x P.E. of diff.

No significances usually due to high P.E.

Table XIV

COMPARISON OF TRUNK GROWTH STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS; TIME OF APPLICATION DISREGARDED, AT OLNEY, MARYLAND, 1927.

Average Increases expressed as millimeters gain over average of nearest checks.

Bearing Stayman Apple Trees

$NaNO_3$	———	18.85 ± 1.26
$(NH_4)_2SO_4$	———	18.80 ± 1.11
Leuna Salpeter	———	20.72 ± 1.34
$Ca(NO_3)_2$	———	13.21 ± 0.8725
Urea	———	9.37 ± 0.79

Table XV.

COMPARISON OF INCREASES IN TRUNK GROWTH STIMULATED BY VARIOUS NITROGENOUS FERTILIZERS. TIME OF APPLICATION DISREGARDED. OLNEY, MARYLAND, 1927.

Gains over average of nearest checks,
expressed in millimeters.

All Treatments Combined.

$NaNO_3$ Vs.

NH_4SO_4	Leuna Salpeter	$CaNO_3$	Urea
18.85 ± 1.26 18.80 ± 1.11	18.85 ± 1.26 20.72 ± 1.34	18.85 ± 1.26 13.21 ± 0.87	18.85 ± 1.26 9.37 ± 0.79
.05 ± 1.68	-1.87 ± 1.84	5.64 ± 1.53	9.48 ± 1.49
No diff.	-1.02 x P.E. of diff.	3.68 x P.E. of diff.	6.37 x P.E. of diff.

$(NH_4)SO_4$ Vs.

Leuna Salpeter	$Ca(NO_3)_2$	Urea
18.80 ± 1.11 20.72 ± 1.34	18.80 ± 1.11 13.21 ± 0.87	18.80 ± 1.11 9.37 ± 0.79
-1.92 ± 1.74	5.59 ± 1.41	9.43 ± 1.36
-1.1 x P.E. of diff.	3.96 x P.E. of diff.	6.93 x P.E. of diff.

Leuna Salpeter Vs.

$CaNO_3$	Urea
20.72 ± 1.34 13.21 ± 0.87	20.72 ± 1.34 9.37 ± 0.79
7.51 ± 1.6	11 .35 ± 1.56
4.69 x P.E. of diff.	7.28 x P.E. of diff.

$CaNO_3$ Vs. Urea

13.21 ± 0.87 9.37 ± 0.79
3.84 ± 1.175
3.27 x P.E. of diff.

Bearing Stayman Apple Trees

2. Sulfate of ammonia is considerably inferior to leuna salpeter and just as superior to nitrate of soda and calcium nitrate, but odds are not great enough to be significant. It is significantly better than urea.

3. Leuna salpeter is outstanding. It is significantly better than nitrate of soda, calcium nitrate and urea, and almost significantly better than sulfate of ammonia.

4. Calcium nitrate is somewhat better than urea, but not enough to be supported by large odds.

(c) Fall and Spring applications.

1. Nitrate of soda is the leader when applied in this manner. It is quite superior to the other four materials, but odds are significant only in the case of urea.

2. Ammonium sulfate is better than leuna salpeter, calcium nitrate and urea, but odds are significant only in case of urea.

3. Leuna salpeter is better than calcium nitrate and urea, but odds are sufficient only in case of urea.

4. Calcium nitrate is not quite significantly superior to urea.

When all plats receiving one material are combined, regardless of time of application, leuna salpeter, sodium nitrate and ammonium sulfate in the order named, lead the field, with slight differences between them. Calcium nitrate and urea fall well behind. Tables

Table XVI.

COMPARISON OF TERMINAL AND TRUNK GROWTH STIMULATED BY NITROGENOUS FERTILIZERS APPLIED AT VARIOUS SEASONS, AT OLNEY, MARYLAND, 1928.

All measurements expressed in centimeters.

Bearing Stayman Apple Trees

	Spring			Fall			Fall & Spring		
Treatment	Row	Terminal Growth	Trunk increase	Row	Terminal Growth	Trunk increase	Row	Terminal Growth	Trunk increase
$NaNO_3$	11	27.88	2.32	5	24.27	2.49	17	25.25	2.50
	35	30.68	2.68	29	26.20	2.60	40	24.20	2.88
							46	30.61	2.28
	Ave.	29.12	2.48	Ave.	25.14	2.53	Ave.	26.76	2.53
$(NH_4)_2SO_4$	12	25.58	2.27	6	31.43	2.82	18	29.92	1.88
	36	24.27	2.37	31	27.78	2.61	42) 43)	27.58	2.29
	Ave.	24.93	2.32	Ave.	29.46	2.70	Ave.	28.55	2.12
Leuna Salpeter	15	31.75	3.14	9	26.28	2.84	23	36.63	2.90
	32	29.09	2.08	26	22.10	2.96	38	24.87	2.40
	Ave.	30.56	2.67	Ave.	24.19	2.90	Ave.	31.28	2.67
$Ca(NO_3)_2$	10	22.12	2.00	4	32.54	2.85	16	27.38	2.45
	34	18.21	1.50	28	23.40	1.83	44) 45)	23.58	2.34
	Ave.	20.32	1.77	Ave.	27.96	2.34	Ave.	25.27	2.39
Urea Calurea	14	24.16	2.33	8	19.86	1.80	22)	19.84	1.46
	33	19.28	2.33	27	19.65	1.67	24)	25.64	2.13
							41	20.33	2.20
	Ave.	21.91	2.33	Ave.	19.74	1.73	Ave.	22.17	1.94
Checks	2	11.66	1.97	19	14.36	1.80	37	7.32	1.44
	3	7.60	1.17	20	12.68	1.58	39	7.56	1.67
	7	14.77	1.65	21	7.05	1.15	47)	4.61	1.20
							48)	5.27	
	13	9.53	1.53	30	8.66	1.60	49) 50)	10.36	1.84

Ave. of checks (Terminals = 9.47
(Trunk = 1.682

Table XVII.

COMPARISON OF TERMINAL AND TRUNK GROWTH STIMULATED BY VARIOUS FERTILIZERS, ON BEARING APPLE TREES, AT HANCOCK, MARYLAND, 1928.

Treatment	Spring		Spring & Fall	
	Terminal Growth	Trunk Increment	Terminal Growth	Trunk Increment
$NaNO_3$	19.78 c.m.	28.18 cm.	17.65 cm.	31.68 cm.
$\frac{1}{2}$ & $\frac{1}{2}$	16.02	26.23	15.09	24.54
$(NH_4)_2SO_4$	17.44	27.92	18.45	25.58
$Ca(NO_3)_2$	16.00	30.10	19.48	29.45
Calurea (urea)	15.32	27.53	16.72	24.89
Leuna Salpeter	14.84	23.96	16.95	26.65
Cyanamide	12.41	23.22	16.81	28.56
Urea	13.81	21.01	13.32	18.64
Checks	12.70	23.22	15.12	26.00

XIV and XV show this.

At the Cohill orchard the results of trunk growth measurements are no more conclusions than were the terminal growth records. There seems to be a lack or correlation between terminal growth and trunk circumference. The trees had not been prunned much and had dense heads and many small twigs. For this reason the response in terminal growth might be spread out over so many twigs that it might not give as true a measure of actual growth conditions as trunk circumference. Sodium nitrate and calcium nitrate were considerably better than other materials, whether applied in the spring, or in the fall and spring. Cyanamid stimulated trunk growth about as greatly when applied half in the fall and half in the spring as either nitrate of soda or calcium nitrate. The data are shown in Tables XVII and XVIII.

Terminal and Trunk Growth During the Second Year at Olney. During the second year of the experiment, differences in terminal and trunk growth on the various plats were maintained, but there also appeared differences among the first three materials. Calcium nitrate moved up to a position nearer the three leaders. Urea was replaced by calurea, which contains some nitrate nitrogen and it made a great improvement. Differences between fall and spring applications were somewhat smoothed out. Leuna salpeter maintained its place at the head of the list, leading the field as a spring and spring and fall fertilizer. Nitrate of soda still appears less effective in the fall than sulfate of ammonia, but maintains its superiority over ammonium sulfate as a spring fertilizer. Calcium nitrate made its biggest improvement as a fall or fall and spring manure. It did not improve its

Table XVIII.

TERMINAL GROWTH AND TRUNK INCREMENTS
COHILL ORCHARD, HANCOCK, 1928.
Bearing Apple Trees

	Spring			Spring and Fall		
Treatment	Row	Terminal Growth	Trunk Increase	Row	Terminal Growth	Trunk Increase
$NaNO_3$	2 11	20.67 cm 18.95 cm	25.67 cm. 30.20 cm.	2 11	14.88 cm 20.43 cm	31.58 cm. 31.78 cm.
	Ave.	19.78 cm	28.18 cm.		17.65 cm.	31.68 cm.
$NaNO_3$ ½ $(NH_4)_2SO_4$ ½	3 12	18.62 cm 13.89 cm	26.79 cm 25.76 cm	3 12	17.77 cm. 12.43 cm	25.88 cm. 23.13 cm.
	Ave.	16.02 cm	26.23 cm		15.09 cm	24.54 cm
$(NH_4)_2SO_4$	4 13	18.14 cm 16.72 cm	31.07 cm 25.38 cm	4 13	20.69 cm 16.35 cm	27.53 cm 23.62 cm
	Ave.	17.44 cm	27.92 cm		18.45 cm	25.58 cm
$Ca(NO_3)_2$	6 9	15.20 cm 16.90 cm	31.10 cm 29.10 cm	6 9	19.39 cm 19.56 cm	29.20 cm 29.71 cm
	Ave.	16.00 cm	30.10 cm		19.48 cm	29.45 cm
Calurea (Urea)	7 15	19.10 cm 12.24 cm	34.80 cm 23.00 cm	7 15	20.30 cm 13.36 cm	27.92 cm 21.86 cm
	Ave.	15.32 cm	27.53 cm		16.72 cm	24.89 cm
Leuna Salpeter	8 14	15.15 cm 14.54 cm	28.71 cm 19.53 cm	8 14	18.67 cm 15.33 cm	29.58 cm 20.83 cm
	Ave.	14.84 cm	23.96 cm		16.95 cm	26.65 cm
Cyanamid	16 18	14.55 cm 10.27 cm	23.62 cm 22.81 cm	16 18	15.00 cm 18.39 cm	27.08 cm 29.70 cm
	Ave.	12.41 cm	23.22 cm		16.81 cm.	28.56 cm
Urea	17	13.81 cm	21.01 cm	17	13.32 cm	18.64 cm
Check	5 10	12.63 cm 12.76 cm	25.50 cm 21.33 cm	5 10	15.01 cm 15.24 cm	27.64 cm 24.08 cm
	Ave.	12.70 cm	23.22 cm		15.12 cm	26.00 cm

The 1928 standings are shown in Table XVIII-A

Table XVIII-A. Comparison of Terminal and Trunk Growth Stimulated by Various Nitrogenous Fertilizers the Second Year of the Experiment. Olney, Maryland, 1928.

All rows receiving each material combined regardless of time of application.

Materials	Terminal Growth	Trunk Growth
Leuna saltpeter	28.70 cm.	2.747 cm.
Sodium nitrate	26.89	2.516
Ammonium sulfate	25.51	2.378
Calcium nitrate	24.43	2.167
Calurea (urea)	21.38	2.002
Checks	9.47	1.682

Real difference still did exist, however. If the table showing 1928 terminal and trunk growth is made to show percent increase over check, the difference between the fertilizers looks more impressive. It is as follows:

Table XVIII-B Comparison of Terminal and Trunk growth Stimulated by Different Fertilizers, with Growth Made by Check Rows. Olney, Md. 1928.

Materials	Percent Increase over Checks.	
	Terminal Growth	Trunk Growth
Leuna Saltpeter	203.1 %	63.3 %
Sodium Nitrate	184.0 %	49.6 %
Ammonium Sulfate	169.4 %	41.4 %
Calcium Nitrate	158.0 %	28.8 %
Calurea (urea)	125.7 %	19.2 %

PLATE V. Ammonium sulfate (right) vs Check (left).

On this basis each material is quite superior to the ones below it in the list. These superiorities exist for the most part whether the materials were applied in the spring, fall or in fall and spring. Examination of the data in Table XVI will bring this out.

The increases in terminal growth over checks was from three to seven times the increases made in trunk circumference. In other words there was not a proportional increase in trunk circumference to correspond to the increase in top growth.

Effect of Nitrogen from Different Carriers on Vigorous Apple Orchards.

The orchard of the American Fruitgrowers, Inc. at Tonoloway has received nitrogenous fertilizers for several years, and until 1926 it received cultivation. The pruning had been thorough, or even severs. The trees had been making a strong vegetative growth. Under these circumstanses it is not to be expected that differences would show up between carriers of nitrogen. The holdover effects of previously applied nitrogenous fertilizers would be sufficient to carry the trees thru one or two years, even though the materials being used in the experiment were ineffective. Burrell(73) found that a strong residual effect on yield and trunk and terminal growth, persisted for three seasons following the application of ten pounds of nitrate of soda to sixteen-year-old McIntosh apple trees. Roberts (48) has shown that apple trees accumulate a nitrogen reserve when growing in a soil in which there are ample nitrates.

Such is the case at Tonoloway. Table XIX shows the average terminal growth and increase in trunk circumference on from twenty-two to twenty-nine trees in each plat. Some trees have been eliminated, due to mouse injury.

Table XIX.

COMPARISON OF NITROGEN CARRIERS IN TONOLOWAY ORCHARD. DURING 1928. ON BEARING YORK APPLES

(All measurements in centimeters)

Row	Treatment	Amount	Terminal Growth	Trunk Growth
1	Sodium Nitrate	Spr-Fall 3 - 5 lbs.	16.13 cm	4.363 cm
2	" "	8 "	15.70 cm	4.510 cm
3	Calurea	3.5 "	16.21 cm	4.527 cm
4	Leuna Salpeter	4.6 "	15.06 cm	4.423 cm
5	Calcium Nitrate	8 "	17.13 cm	4.366 cm
6	Sodium Nitrate	15 "	16.07 cm	4.665 cm
7	" "	Spr.pink 10-5 "	16.99 cm	4.689 cm
8	Check	0 "	15.38 cm	4.155 cm
9	Sodium Nitrate	20 "	17.55 cm	4.865 cm
10	" "	Spr.-pink 15-5 "	17.25 cm	4.490 cm
11	Calcium "	10 "	19.25 cm	4.571 cm
12	Leuna Salpeter	5.7 "	17.71 cm	4.498 cm
13	Calurea	4.5 "	19.83 cm	4.731 cm
14	Sodium Nitrate	10	15.99 cm	4.930 cm
15	Urea	3.3	17.76 cm	4.471 cm
16	Sodium Nitrate	Spr-Fall 3-5	16.01 cm	----

The most striking result noted is that the check row, which has received no fertilizer for two years, made a greater growth than was made on trees receiving 4.6 pounds of Leuna salpeter annually (row four), and almost as much as trees receiving ten pounds of nitrate of soda (in row fourteen) or eight pounds of nitrate of soda (row two). Evidently it still had sufficient nitrogen reserve (Roberts (48), Crane (79), and Burrell (73)), to carry it through three years without nitrogen becoming a limiting factor. With such conditions prevailing no attempt will be made to distinguish between the materials. In general the strongest growth seems to have been on the end of the orchard, receiving the heavier applications of nitrogen.

Growth Response to Nitrogen Application from Different Sources to Vigorous Peach and Apple Orchards on Sandy Soil: The Allen Orchard at Salisbury. Here the response is no different than at Tonoloway. Two peach orchards and one apple orchard are under consideration here. One row was left untreated in the Elberta orchard but no untreated rows were left in the apple orchard, or in the Belle of Georgia peach orchard. No differences beyond the natural slight variability can be seen in any place, except in the check row in the Elberta Orchard, where it has made somewhat less growth, and had made poorer color than the adjoining treated rows.

Tables XX, XX-A, and XX-B show these results.

Results in Yields.

The factors affecting yield of fruit in an apple orchard are too many and diverse to warrant much reliance on one year's results. In the present case there were no apples in the Olney orchard during 1927. A fine crop was set during 1928. There will be only a slight crop in 1929. At Hancock and Tonoloway the disastrous snow storm of April 24, 1928, followed by one freeze and several sharp frosts cut the crops to such small amounts that no reliable results could be secured. The bloom was satisfactory in these orchards. At Salisbury the peach crop amounted to less than a basket per tree while the apple crop was negligible. For these reasons, only the 1928 crop at Olney will be considered.

This orchard is bearing biennially. The former owner, Mr. Ralph Brodie, reports that it had a "few" apples in 1925. In 1926 it bore a good crop on most trees. Many trees, however, had not ever borne a crop. In 1927 there were only a few scattering blossoms, and only

Table XX.

COMPARISON OF GROWTH STIMULATED BY NITROGEN FROM VARIOUS SOURCES. SALISBURY, MARYLAND, 1928.

Stayman Apples, Ruark Farm.

Treatment	Terminal Growth	Trunk Growth
$Ca(NO_3)_2$	25.00 cm	4.295 cm
Urea	25.04 cm	4.170 cm
Leuna Salpeter	24.75 cm	3.795 cm

Table XX-A

COMPARISON OF GROWTH STIMULATED BY NITROGEN FROM VARIOUS SOURCES. SALISBURY, MARYLAND, 1928.

Belle of Georgia Peaches, Tonytank Road.

Treatment	Terminal Growth	Trunk Growth
$Ca(NO_3)_2$	57.2 cm	6.80 cm
Urea	54.4 cm	8.10 cm
Leuna Salpeter	55.3 cm	66.5 cm

Table XX-B.

COMPARISON OF GROWTH STIMULATED BY NITROGEN FROM VARIOUS SOURCES. SALISBURY, MARYLAND, 1928

Elberta Peaches. Triangle Orchard.

Treatment	Terminal Growth	Trunk Growth
$Ca(NO_3)_2$	48.7 cm	4.20 cm
Urea	46.7 cm	3.89 cm
Leuna Salpeter	46.5 cm	4.00 cm
$(NH_4)_2SO_4$	54.8 cm	-----
Check	36.6 cm	2.00 cm

an occasional apple set. In 1928 it bloomed profusely on all trees, and set heavily everywhere. Two applications of nitrogenous fertilizers had therefore been made before a crop of blossoms was secured, ie-in 1927 and '28. The 1929 bloom was light, with a light set.

Nitrogen has been found to greatly stimulate the setting of fruit. Heinicke (27a) increased the set of apples by early spring application of nitrate of soda, even when the nitrate supply in the soil was rather plentiful, while Ballou (9) greatly increased the set on Ben Davis and Rome Beauty apples in Southeastern Ohio, by applying nitrate of soda three weeks before petal-fall, both on trees in sod and in cultivation. Heinicke (27b) found that the treatments which increased the vigor of the spurs tended to increase the set, while he and Howlett (30a) both reported that a deficit of water, caused the absciss layer to form in the stem. Cooper (16) did not find as great an increase in set on well cultivated orchards a good soil as on poorer soil. He attributed the greater yield on thrifty trees to the larger number of fruit spurs there. Chandler (14) quotes Petri (44b), who found that a supply of nitrogen sufficient for setting of blossom buds might still be insufficient for fruit setting.

Under the conditions prevailing at Olney, it is probable that even urea, which seemed to give least response in growth in 1927, might have developed a sufficient nitrogen reserve during that season, and the late winter and spring of 1928 to allow for an ample supply for fruit setting and a quick though short growth in 1928. 1928 growth was much improved over 1927 growth. The improved growth condition

Table XXI. Growth of Fruitspurs of Stayman Apple Trees. Olney, Maryland.

Treatment	Time of Application			
	Fall		Spring	Fall & Spring
	1927 Growth	1928 Growth	1928 Growth	1928 Growth
$NaNO_3$	12.03 mm.	13.83 mm.	13.21 mm.	11.68) 11.93) 11.81 mm.
Leuna Sal.	10.71	10.59	15.60	12.54
$(NH_4)_2SO_4$	10.36	11.71	12.33	10.89
$Ca(NO_3)_2$	10.28	11.82	12.01	13.13
Urea	10.49	11.19	11.49	11.51
Check	10.19	9.95	7.43	8.74 4.45

Table XXII. Growth Made by Fruit Spurs of York Imperial Apple Trees. Cohill Orchard, Hancock, Maryland. 1928.

Treatment	Row	Spring Application	Row	Fall & Spring Application
$NaNO_3$	2	8.76 mm	2	9.04 mm
	11	7.26	11	9.10
	Ave.	7.75	Ave.	9.08
$\frac{1}{2}$ $NaNO_3$ $\frac{1}{2}$ $(NH_4)_2SO_4$	3	7.72	3	8.65
	12	8.25	12	8.31
	Ave.	8.03	Ave.	8.45
$(NH_4)_2SO_4$	4	8.68	4	7.80
	13	7.69	13	8.38
	Ave.	8.11	Ave.	8.13
Check	5	8.82	5	8.85
	10	6.42	10	7.00
	Ave.	8.36	Ave.	7.98
$Ca(NO_3)_2$	6	7.48	6	9.64
	9	7.45	9	9.14
	Ave.	7.47	Ave.	9.35
Calurea	7	7.50	7	7.41
	15	8.42	15	8.43
	Ave.	8.03	Ave.	7.92
Leuna Salpeter	8	7.31	8	7.99
	14	8.72	14	8.34
	Ave.	8.02	Ave.	8.16
Urea	17	8.26	17	7.10
Cyanamid	16	7.51	16	7.17
	18	7.86	18	6.97
	Ave.	7.63	Ave.	7.08

Table XXIII

STAYMAN APPLE
COMPARISON OF YIELDS OF FRUIT FROM/TREES TREATED
WITH NITROGEN FROM VARIOUS SOURCES. OLNEY, MARYLAND, 1928.

Expressed as bushels per tree.

Treatment	Rows	Spring	Rows	Fall	Rows	Spring & Fall
$NaNO_3$	11	12.0 ± 0.99	5	9.93 ± 1.321	17	9.88 ± 0.60
	35	9.2 ± 1.63	29	8.60 ± 0.89	40)	11.80 ± 1.78
					46)	9.55 ± 1.26
	Ave.	10.6 ± 0.795	Ave.	9.38 ± 0.83	Ave.	10.23 ± 0.685
$(NH_4)_2SO_4$	12	9.4 ± 1.02	6	9.2 ± 1.19	18	9.9 ± 0.93
	36	10.1 ± 0.79	31	9.9 ± 1.24	42) 43)	12.21 ± 0.57
	Ave.	9.78 ± 1.1	Ave.	9.55 ± 8.14	Ave.	11.16 ± 0.553
Leuna Salpeter	15*	6.85 ± 0.49	9	9.75 ± 0.71	23	7.0 ± 0.9
	32	13.00 ± 1.99	26	8.00 ± 1.00	38	16.0 ± 1.14
	Ave.	8.52 ± 1.08	Ave.	8.88 ± 0.99	Ave.	11.50 ± 1.22
$Ca(NO_3)_2$	10	7.75 ± 0.62	4	7.08 ± 1.10	16	8.7 ± 1.17
	34	10.60 ± 0.57	28	9.83 ± 0.99	44) 45)	9.18 ± 0.48
	Ave.	8.90 ± 0.52	Ave.	8.46 ± 0.75	Ave.	8.96 ± 0.60
Urea	14*	5.55 ± 0.44	8	8.5 ± 0.60	22	9.25 ± 1.32
	33	8.70 ± 1.21	27	11.35 ± 0.44	24)	10.96 ± 0.57
					41)	7.60 ± 1.97
	Ave.	6.96 ± 0.61	Ave.	10.05 ± 0.82	Ave.	9.38 ± 0.76
Checks	2	2.56 ± 0.631	19	1.0 ± 0.27	37	7.41 ± 2.21
	3	3.54 ± 0.328	20	3.56 ± 0.29	39	2.0 ± 0.20
	7	3.85 ± 0.89	21	0.88 ± 0.38	47) 48)	1.29 ± 0.22
	13	3.11 ± 0.65	30	5.21 ± 1.13	49) 50)	3.36 ± 0.70
Ave. of all checks - 3.14 ± 0.207						

* Apples were stolen from rows 14 and 15 on Sunday, October 7, 1928, so the count on these trees is inaccurate.

perhaps made for better water conduction, which would aid in holding the set.

It is not surprising, therefore, that differences in yield are too small to warrant conclusions being drawn from them. Table XX shows the yields of all plats, with the averages of rows receiving like treatments. In Table XXV, all trees receiving each kind of material have been averaged, regardless of time of application. It is apparent that ammonium sulfate, sodium nitrate and Leuna saltpeter are superior to urea and calcium nitrate, but the superiority is not supported by sufficient odds to warrant conclusions being drawn. When the greatest extremes are considered, i.e. ammonium sulfate vs calcium nitrate, the difference is but 1.41 ± .641. Here the difference is but 2.2 x the probable error.

Examination of Table XXIV would lead to the conclusion that applications made half in the spring and half in the fall have caused better yields than applications made in the spring or fall alone. This is possibly true, but the superiority is not supported by sufficient odds to be of significance.

The outstanding feature of this part of the experiment is the striking yield obtained under all treatments. The odds that the gains are due to fertilizer treatment are infinite in every case.

PLATE VI. Leuna salpeter (left) vs Check (right).

Table XXIV.

SUMMARY COMPARING YIELDS FROM TREES RECEIVING NITROGEN FROM DIFFERENT SOURCES. OLNEY, MARYLAND, 1928.

Yields expressed as bushels per tree.

Treatment	Spring	Fall	Spring and Fall
$(NH_4(_2SO_4$	9.78± 1.1	9.55 ± 0.81	11.16 ± 0.55
$NaNO_3$	10.6 ± 0.80	9.38 ± 0.83	10.23 ± 0.69
Leuna Salpeter	8.52 ± 1.08	8.88 ± 0.99	11.50 ± 1.22
Urea	6.96 ± 0.61	10.05 ± 0.82	9.38 ± 0.76
$Ca(NO_3)_2$	8.90 ± 0.52	8.46 ± 0.75	8.96 ± 0.60
Checks	3.14 ± 0.21	3.14 ± 0.21	3.14 ± 0.21

Table XXV.

COMPARISON OF YIELDS FROM TREES RECEIVING NITROGEN FROM DIFFERENT SOURCES. OLNEY, MARYLAND, 1928.

Treatments combined, disregarding time of application;yield expressed in bushels per tree.

$(NH_4)_2SO_4$	10.18 ± 0.48
$NaNO_3$	10.04 ± 0.46
Leuna Salpeter	9.78 ± 0.49
Urea	8.81 ± 0.44
$Ca(NO_3)_2$	8.77 ± 0.36
Check	3.14 ± 0.21

Growth of Fruitspurs.

The vigor of the fruitspur is one determinant of its ability to set fruit. Yeager (66) finds that the young vigorous fruitspurs of Grimes and Yellow Newtown bore more regularly during the first few years than later, and that the fruit was larger in size from these vigorous spurs than from older spurs. Roberts (49a) found in Wisconsin that spurs below certain lengths very seldom set fruit buds. Heinicke (27a) found that fruit was more likely to set on vigorous spurs than on weaker spurs.

Measurements were made at various orchards in which these experiments were located to determine the comparative effectiveness of the fertilizers to stimulate fruitspur growth.

Data in Table XXI seem to indicate that fall at Olney applications cause but little stimulation of fruitspur growth the first season after the fertilizers are applied. Unfortunately 1927 data are not available showing the effects of spring or fall and spring treatments. But all the fertilizers definitely increased the length of spur compared to check trees, during the second season's growth. When applied in the spring, leuna salpeter has stimulated the most growth, followed by nitrate of soda, ammonium sulfate, calcium nitrate and urea. But when applied in the fall or in spring and fall, the differences are not as marked.

At Hancock, in the other devitalized orchard, the first year's records do not give definite results. In general the spring and fall application seems to have resulted in slightly greater spur growth than spring applications, although there are exceptions. There were not uniform increases over the growth made by the check trees, and it is impossible to draw conclusions from these data. Table XXII show these data.

It is not surprising that fruitspur growth should be only slightly affected by nitrogenous fertilizers the first season after application. It has been noted that on devitalized apple trees the first growth response is frequently seen in water sprouts along the trunk and main branches, while the terminal branches may be only lightly stimulated. The next season the response may be seen more definitely in the terminals. Thus the failure of the spurs to respond the first year is not surprising.

Percent of Bloom in Cohill Orchard: Record was made of the number of spurs blooming on each tree of every apple orchard in the experiments. Data on the bloom at the Cohill Orchard in Hancock is presented in Table XXV-A. These data indicate that the fertilizers applied in the fall of 1927 and spring of 1928, had no effect on the bloom of 1928, and of course, neither did the spring application alone. But the fertilizers applied during the 1928 season had a marked effect on the 1929 bloom. With the exception of urea applied in the fall and spring, all fertilizers caused more bloom on the treated trees than occurred on the untreated trees. It is probable that the urea row is subnormal, as it bloomed somewhat less than the check trees before treatments were started.

Table XXV-A Percent of Spurs Blooming. A.J.Cohill

Orchard. Hancock, Md. 1928.1929.

Treatment	Row	Time of Application			
		1928		1929	
		Spring	Fall & Spring	Spring	Fall & Spring
NaNO$_3$	2	63.65	40.95	66.65	68.00
	11	56.25	30.65	63.75	69.35
	Ave.	59.65	35.65	65.15	68.65
$\frac{1}{2}$ NaNO$_3$ $\frac{1}{2}$ $(NH_4)_2SO_4$	3	55.30	47.80	66.25	60.60
	12	44.70	32.80	61.55	53.10
	Ave.	49.05	40.30	63.90	56.90
$(NH_4)_2SO_4$	4	45.64	54.30	70.60	62.10
	13	35.65	30.00	83.45	69.35
	Ave.	40.65	41.75	77.10	65.90
$Ca(NO_3)_2$	6	31.00	38.45	78.70	65.00
	9	48.35	53.10	65.30	60.60
	Ave.	39.65	45.80	72.00	62.80
Calurea	7	42.50	50.30	76.00	60.60
	15	22.50	40.00	76.90	60.60
	Ave.	32.50	45.15	76.45	60.60
Leuna Salp.	8	29.70	41.35	78.80	74.00
	14	20.00	30.62	83.80	66.90
	Ave.	24.85	35.80	81.30	70.30
Cyanamid	16	30.30	19.02	69.10	69.20
	18	25.00	27.65	52.50	72.00
	Ave.	27.65	23.92	60.78	70.70
Urea	17	39.35	34.78	64.70	46.65
Check	5	33.92	50.92	63.55	51.22
				59.30	60.60
	10	46.55	46.35	49.35	54.65
	Ave.	40.68	48.70	56.85	55.55

Set of Fruit in Cohill Orchard.

There were appreciable differences in set of fruit on Stayman and York trees. One bearing tree of each of these varieties, of uniform size and with similar amount of bloom were selected in each block. Spurs on several limbs of each tree were counted until approximately 400 had been noted. The limbs were labelled with wooden tags, attached with copper wires. The number of blossoms counted on the limb were placed on each label. Individual blossoms had to be examined and counted to eliminate the ones damaged by frost. Usually there were from two to four undamaged blooms in each cluster. The count was made just as the blossoms were falling. Seven weeks later (June 22) after the June drop was over, the count was made to determine the set at that time. On September 14 a count was made to determine the percent of fruit which matured from the blossoms. Tables XXV-B and XXV-C give the results of these counts.

The percent set was much higher on Stayman than on York Imperial, both on treated and check trees. All treatments gave marked increases over the check trees. Variability among the trees was high, and it was only possible to use one tree of a variety in each block, because so few were blooming heavily. Also, frost injured blossoms on all treatments. Consequently the results must be taken as indicative rather than definite. The high percent of set on calurea whether applied in the spring or in the

Table XXV-B. Percent of Blossoms and Fruit which Set in Cohill Orchard. Hancock, Maryland, 1928.

Fertilizers applied in Spring.

Treatments	Stayman			York Imperial		
	Number of Blossoms.	% set	% matured	Number of Blossoms	% set	% matured
$NaNO_3$	398	25.6	22.9	368	4.62	3.80
$\frac{1}{2}\ NaNO_3$ $\frac{1}{2}\ (NH_4)_2SO_4$	418	25.6	23.7	353	15.6	15.6
$(NH_4)_2SO_4$	399	34.8	28.8	390	5.9	5.9
Check	610	11.15	10.8	458	0	0
$Ca(NO_3)_2$	775	31.75	29.55	731	26.40	22.98
Calurea	399	56.15	56.15	458	23.36	19.65
Leuna Salt.	469	31.56	26.88	567	19.94	17.28
Cyanamid	410	25.11	19.76	507	4.14	4.14
Urea	447	21.48	21.48	510	7.06	5.09

Table XXV-C. Percent of Blossoms and Fruit which Set in Cohill Orchard. Hancock, Maryland, 1928.

Fertilizers applied in Fall & Spring.

Treatments	Stayman			York Imperial		
	Number of Blossoms.	% set	% matured	Number of Blossoms.	% set	% matured
$NaNO_3$	501	29.3	16.8	459	35.3	30.7
$\frac{1}{2}NaNO_3$ $\frac{1}{2}(NH_4)_2SO_4$	440	37.7	36.4	561	7.58	7.49
$(NH_4)_2SO_4$				480	1.25	1.25
Check	579	16.9[illegible]	14.85	771	1.17	1.17
$Ca(NO_3)_2$	529	30.06	24.39	631	1.27	1.11
Calurea	400	46.49	41.25	558	30.11	27.78
Leuna Salt.	476	39.91	34.45	468	11.96	11.96
Cyanamid	458	24.89	19.22	420	19.53	15.71
Urea	514	21.10	20.43	313	2.87	2.56

spring and fall, must be noted. It showed up well on both York and Stayman. Other materials were too variable to warrant mention. The check trees set more heavily in the fall and spring block than in the block receiving only spring applications. The trees are only sixteen feet apart and there is some cross washing. Therefore the checks probably did some cross-feeding.

Yield in Cohill Orchard.

Notwithstanding the differences in set, the differences in yield were too low to permit comparisons. As has been previously explained, the yields in the Cohill orchard at Hancock were very low due to frost. Table XXV-D gives these data. It would appear from the averages that spring applications of nitrate of soda may have helped the trees, when compared to the check average. But check row #1, adjoining nitrate of soda row #2, yielded 39.75 bushels. The low average of the checks is due to the one extremely low row. (number five) No attempt will be made to draw on conclusions from these data.

Table XXV-D Yields from Fertilizer
Treatments at A. J. Cohill Orchard.
Hancock, Maryland. 1928.

Varieties - Stayman, Rome, York and Grimes.

Expressed in bushels per row of
sixteen trees each.

Treatment	Row	Spring	Fall & Spring
$NaNO_3$	2	49.75	56.50
	11	51.00	33.00
	Ave.	50.38	44.75
$\frac{1}{2}$ $NaNO_3$ $\frac{1}{2}$ $(NH_4)_2SO_4$	3	45.75	53.00
	12	36.50	43.00
	Ave.	41.13	48.00
$(NH_4)_2SO_4$	4	24.75	35.00
	13	32.75	34.00
	Ave.	28.75	34.50
$Ca(NO_3)_2$	6	15.00	40.00
	9	35.50	46.25
	Ave.	25.25	43.13
Calurea	7	25.50	50.00
	15	25.50	35.50
	Ave.	25.50	42.75
Leuna salpeter	8	28.50	26.25
	14	20.50	49.00
	Ave.	24.50	37.63
Cyanamid	16	24.00	22.75
	18	28.00	33.75
	Ave.	26.00	28.25
Urea	17	38.50	41.75
Check	1	39.75	44.50
	5	7.75	38.50
	10	22.50	38.75
	Ave.	23.33	40.58

Chemical Studies

That there is a balance between nitrogen and carbohydrates within the plant, which is associated with growth and fruiting, has been ably set forth by Kraus and Kraybill (35a). These investigators,. using the tomato, were able to develop four classes of plants with respect to chemical composition, and these had four distinct responses in begetation and fruitfulness. If either nitrogen or carbohydrates were extremely high in relation to the other, vegetation and reproduction were depressed. In the orchard at Olney the nitrate content of the soil under sod conditions, was doubtless very low, - insufficient to supply enough nitrogen for proper growth and fruiting of the trees when considered in relation to carbohydrates, which had accumulated. The trees looked yellow. Terminal growth was scanty, and crops were irregular.

Hooker (29) has shown that applications of nitrate of soda, and sulfate of ammonia in either the spring or late summer make considerable change in the nitrogen content of the fruit-spurs. Schrader and Auchter (50) found that the nitrogen content of the fruit-spur was correlated with the terminal and spur growth response of the trees receiving fertilizer. The soluble nitrogen seemed to be the more important index. Remy (46), Marsh (42) (43) and others have found this same relation.

Chemical analyses were made of spur samples from the orchard at Olney, during the summer of 1927, to measure the differences in total nitrogen, soluble and insoluble nitrogen, and starch which might be effected by the various nitrogen carriers used. The method of sampling and preserving has been discussed in preceding pages.

Certain differences were found to exist. These were not as striking as those reported by Schrader and Auchter, but they corroborate their work in many respects. They used blossoming spurs, while non-blossoming spurs were used in this investigation.

Chemical analyses bore out the results seen in terminal and trunk growth in some respects, yet failed to correlate with those expressions in other ways. As an example of the latter, nitrate of soda does not appear to good advantage as a material to be applied in the fall, from records of trunk and terminal growth, yet the percent of total nitrogen from trees receiving this material in the fall based on green weight in the bud, new shoot and cluster base, just before growth started in the spring, was higher than that of any other fall treatment. The data correlate to the extent that in general nitrate of soda, sulfate of ammonia and leuna salpeter lead urea and calcium nitrate in raising the nitrogen content of the spurs. All materials show considerable increase over check.

There are certain inconsistencies in the data which must be laid either to error in sampling or technique. For instance, see Table XXIX, spurs treated in the fall with leuna salpeter have but .016% of soluble nitrogen at the growing point on March 11, while spurs treated with urea have .0503%. From the quantities of total nitrogen as seen in Table XXV, one would expect these values to be reversed. Also, the growth made by trees fertilized with leuna salpeter in the fall was greater than trees fertilized with this material in the spring, and far greater than that of any trees receiving urea.

Ample evidence for the striking difference between the growth

Table XXVI

SUMMARY OF TOTAL NITROGEN IN STAYMAN APPLE SPURS ON MARCH 11, 1927.

Percent nitrogen based on dry and green weights, and absolute amounts per spur

Samples of non-blossoming spurs taken just before start of growth.

Time of Application	Material	Plat	No. of Spurs	Bud plus shoot			Cluster base			One year & older wood		
				% Dry Weight	% Green Weight	Absolute N in Mg.	% Dry Weight	% Green Weight	Absolute N in mg	% Dry Weight	% Green Weight	Absolute N in mg.
Fall	Leuna Salpeter	26	244	1.349	.6578	.5245	2.043	.912	1.49	1.012	.509	.775
	Urea	27	285	1.395	.6075	.4680	2.069	.922	1.26	1.011	.505	.617
	$Ca(NO_3)_2$	28	305	1.348	.6521	.438	1.930	.863	1.037	.991	.490	.589
	$NaNO_3$	29	335	1.440	.6850	.551	2.056	.909	1.225	1.050	.518	.698
	Check	30	288	1.238	.5803	.4645	1.856	.806	1.159	.922	.444	.640
	$(NH_4)_2SO_4$	31	258	1.455	.6719	.5582	2.107	.909	1.365	1.143	.573	.860
Spring	Leuna Salpeter	32	206	1.266	.5735	.667	1.887	.813	1.610	.9630	.482	.954
	Urea	33	281	1.296	.5745	.515	2.004	.820	1.266	.9580	.464	.694
	$Ca(NO_3)_2$	34	263	1.280	.5965	.539	2.062	.866	1.491	.9430	.432	.783
	$NaNO_3$	35	306	1.237	.5820	.473	1.847	.819	1.214	.8680	.434	.644
	$(NH_4)_2SO_4$	36	300	1.267	.5675	.533	1.853	.792	1.250	.874	.429	.678
	Check	37	301	1.187	.5434	.486	1.740	.757	1.10	.9360	.429	.623
Fall & Spring	Leuna Salpeter	38	210	1.455	.6546	.661	1.994	.865	1.308	1.014	.496	.751
	Check	39	224	1.300	.5995	.5504	1.901	.827	1.215	.9950	.505	.735
	$NaNO_3$	40	241	1.395	.6418	.5614	2.046	.891	1.234	1.178	.597	.827
	Urea	41	214	1.486	.6188	.593	1.844	.810	1.22	.990	.483	.727
	$(NH_4)_2S$ 4	42 43	256	1.471	.5205	.5625	2.107	.932	1.314	1.084	.551	.777
	$Ca(NO_3)_2$	44 45	271	1.506	.6998	.519	2.130	.927	1.261	1.143	.577	.785
	$NaNO_3$	46	278	1.464	.6873	.578	1.953	.893	1.131	1.134	.583	.738
	Check	47 48	225	1.304	.6260	.5015	1.793	.803	1.062	.892	.465	1.292

Table XXVII

STAYMAN
SUMMARY OF TOTAL NITROGEN IN/APPLE SPURS AT BLOSSOM TIME.

Samples of non-blossoming spurs taken April 21-24, 1927.

Percent nitrogen based on dry weight and green weight, and absolute amounts

Time of Application	Material	Plat	No. of Spurs	Leaves plus new shoot			One year old wood			Wood older than one year		
				% Dry Weight	%Green Weight	Absolute N in mg.	% Dry Weight	%Green Weight	Absolute N in mg.	% Dry Weight	%Green Weight	Absolute N in mg
Fall	Leuna Salpeter)	26	84	3.323	.8292	12.78	1.491	.5352	1.09	.925	.4292	.811
	Urea	27	97	3.126	.7755	12.35	1.460	.5125	.9735	broken	broken	broken
	$Ca(NO_3)_2$	28	86	2.934	.7790	11.16	1.458	.4695	.748	.672	.2420	.4783
	$NaNO_3$	29	96	3.125	.8048	13.06	1.504	.5452	.9895	.760	.3463	.6288
	Check	30	100	2.627	.6990	9.525	1.329	.4825	.9073	.567	.2569	.852
	$(NH_4)_2SO_4$	31	102	3.175	.8470	12.11	1.725	.5213	.8665	.817	.3629	.6030
Spring	Leuna Salpeter)	32	102	3.652	.9244	16.12	1.502	.5395	1.219	.675	.2822	.6380
	Urea	33	100	2.965	.7867	11.30	1.590	.5626	1.055	.878	.3881	.7273
	$Ca(NO_3)_2$	34	103	3.278	.8450	12.89	1.572	.5524	1.049	.523	.2319	.4406
	$NaNO_3$	35	101	3.445	.8515	12.38	1.562	.5630	1.115	.793	.3527	.6985
	$(NH_4)_2SO_4$	36	103	3.143	.8250	12.09	1.588	.5673	1.066	.887	.3985	.7490
	Check	37	99	2.653	.6888	8.811	1.097	.3882	.6898	.895	.4003	.7115
Fall & Spring	Leuna Salpeter)	38	102	3.352	.8648	14.24	1.445	.4885	.9625	.913	.3981	.7845
	Check	39	103	2.738	.7195	9.486	1.114	.4018	.7773	.496	.2248	.4349
	$NaNO_3$	40	103	3.257	.8583	13.64	1.389	.5032	.905	.569	.2555	.4576
	Urea	41	102	2.814	.8419	11.35	1.345	.4450	.9065	.570	.2597	.5290
	$NH_4)_2SO_4$	42) 43)	105	3.402	.8970	13.22	1.430	.5244	.9125	.573	.2653	.4617
	$Ca(NO_3)_2$	44) 45)	102	3.180	.8325	12.83	1.436	.5087	.864	.686	.2859	.4857
	$NaNO_3$	46	104	3.724	.9538	16.42	1.607	.5852	1.218	.627	.2866	.5967
	Check	47) 48)	105	2.527	.6878	8.433	1.071	.3988	.773	.486	.2255	.4372

SUMMARY SHOWING TOTAL NITROGEN IN APPLE SPURS. JULY 1, 1927.

Samples of non-blossoming spurs taken at time of fruit bud differentiation. Percent nitrogen based on dry and green weights, and absolute amounts in milligrams.

Variety - Stayman

Time of Application	Material	Plat	No. of* Spurs	Leaves			New Shoots			Older Wood		
				% Dry Weight	%Green Weight	Absolute N. in mg	% Dry Weight	%Green Weight	Absolute N in mg.	% Dry Weight	%Green Weight	Absolute N in mg.
Fall	Leuna Salpeter	26	101 & 101	1.532	.6392	18.78	1.054	.5073	.7206	.775	.4054	1.636
	Urea	27	61 & 121	1.386	.5700	15.06	.794	.3685	.4978	.701	.3564	1.639
	$Ca(NO_3)_2$	28	63 & 126	1.419	.6004	15.23	.784	.3615	.4949	.723	.3676	1.634
	$NaNO_3$	29	78 & 128	1.437	.6092	18.70	.788	.4068	.5990	.685	.3615	1.891
	Check	30	76 & 126	1.205	.4960	12.51	.683	.3596	.4040	.643	.3340	1.556
	$(NH_4)_2SO_4$	31	77 & 125	1.576	.6633	16.89	.793	.3762	.5750	.708	.3534	1.588
Spring	Leuna Salpeter	32	76 & 106	1.585	.6413	24.21	.773	.3512	.6995	.708	.3491	1.971
	Urea	33	74 & 124	1.697	.6805	20.06	.780	.3743	.5665	.668	.3374	1.838
	$Ca(NO_3)_2$	34	75 & 125	1.597	.6345	17.98	.739	.3454	.5380	.693	.3479	1.923
	$NaNO_3$	35	76 & 126	1.947	.7200	22.62	.881	.3910	.6955	.922	.4440	2.579
	$(NH_4)_2SO_4$	36	70 & 115	1.953	.7735	27.86	.764	.3401	.7660	.738	.3671	1.684
	Check	37	70 & 118	1.533	.5768	14.38	.684	.3395	.4230	.614	.3028	1.722
Fall and Spring	Leuna Salpeter	38	70 & 110	1.682	.6886	21.51	1.047	.5156	.6840	.713	.3686	2.084
	Check	39	73 & 127	1.551	.6352	15.84	.726	.3500	.6640	.712	.3674	1.962
	$NaNO_3$	40	70 & 119	1.802	.7250	24.67	.865	.3777	.7920	.879	.4618	2.639
	Urea	41	70 & 127	1.437	.5872	18.30	.760	.3624	.6560	.733	.4382	2.505
	$(NH_4)_2SO_4$	42 43	70 & 121	1.644	.6528	23.91	1.011	.4755	.9980	.866	.4072	2.435
	$Ca(NO_3)_2$	44 45	70 & 122	1.683	.6792	21.21	1.124	.5330	.9350	.833	.4228	2.372
	$NaNO_3$	46	70 & 118	1.552	.6352	22.85	.991	.4668	.9770	.809	.4195	2.518
	Check	47 48	70 & 121	1.174	.4832	11.83	.734	.3658	.4980	.706	.3677	1.642

* First figures indicate number of spurs used for leaf and old wood samples.
Second figures indicate the number of spurs used for the new shoot samples.

response from nitrate of soda when applied in the spring or fall, is seen in examination of Table XXVII. At the time growth was just getting well under way, the sampling taken April 21, shows that the trees receiving nitrate of soda in the fall have but .08645% green weight of soluble nitrogen in the growing shoot and leaves while trees receiving this material in the spring have .1334% green weight of soluble nitrogen there.

Examination of this same table, however, gives food for further speculation. Trees receiving calcium nitrate in the spring made a poor growth response, yet.1314% of the green weight of nitrogen in the growing point, yet made a greater growth response. Urea has only one fourth as much soluble nitrogen as has the check row, yet it made double the amount of terminal growth.

Correlating spur growth obtained, when fall applications of fertilizer were made, with soluble nitrogen and total nitrogen, the correlation is no more consistent. Spurs from trees receiving ammonium sulfate in the fall had .1335% soluble nitrogen in the leaves and shoots, yet made less average spur growth than did the check, although its terminal growth was in keeping with the quantity of soluble nitrogen. The same situation exists when nitrate of soda is considered.

Correlation between total nitrogen in the spurs and terminal growth is more perfect when spring applications are considered. We have no data to show that the nitrogen in the spur is any indication of the amount in the terminals, yet feel justified in believing that there is because of the correlation between nitrogen in the spurs and amount of terminal growth.

It is impossible to state whether these inconsistencies are actual or are due to error in measurement, sampling and analyses. Schrader and

Table XXIX.

Stayman

SUMMARY SHOWING SOLUBLE NITROGEN IN APPLE SPURS. OLNEY, MARYLAND, 1927.

Percent dry weight and percent green weight

			March 11, 1927					April 21, 1927					July 1, 1927				
				Bud & Shoot		Cluster Base			Leaves and Shoot		One Year old Wood			Leaves		New Shoot	
Time of Application.	Material	Plat	No. of Spurs	% Dry Weight	% Green Weight	% Dry Weight	% Green Weight	No. of Spurs	% Dry Weight	% Green Weight	% Dry Weight	% Green Weight	No. of Spurs	% Dry Weight	%Green Weight	% Dry Weight	%Green Weight
Fall	Leuna Salpeter)	26	244	.033	.0161	.531	0.237	84	.358	.0894	.348	.125	101 & 101	.059	.0246	.046	.0221
	Urea	27	285	.116	.0503	.551	0.246	97	.058	.0142	.332	.1154	61 & 121				
	$Ca(NO_3)_2$	28	305	.045	.0218	.466	0.208	86	.261	.0693	.347	.1249	63 & 12[illegible]	.054	.0228		
	$NaNO_3$	29	335	.172	.0818	.490	0.217	96	.334	.0865	.437	.1584	78 & 128	.073	.0309	.199	.1027
	Check	30	288	.057	.0267	.375	0.168	100	.221	.0589	.333	.1209	76 & 126			.098	.0508
	$(NH_4)_2SO_4$	31	258	.194	.0896	x	x	102	.508	.1355	.395	.1194	77 & 125	.057	.0229		
Spring	Leuna Salpeter)	32	206	.200	.0906	.473	0.204	102	.434	.1097	.265	.0952	76 & 106	.069	.0279	.108	.0491
	Urea	33	281	.096	.0426	.482	0.197	100	.197	.0523	.234	.0828	74 & 124	.365	.1460		
	$CaNO_3)_2$	34	263	.173	.0806	.384	0.161	103	.510	.1314	.110	.0382	75 & 125	.206	.0820	.123	.0575
	$NaNO_3$	35	306	.278	.1308	.432	0.192	101	.540	.1334			76 & 126	.263	.0973	.233	.1035
	$(NH_4)_2SO_4$	36	300	.156	.0698	.439	0.188	103			.706	.2523	70 & 115	.359	.1420	.034	.0152
	Check	37	301	.134	.0617	.350	0.152	99	.261	.0684	.427	.1510	70 & 118	.340	.1280	.081	.0402
Fall & Spring	Leuna Salpeter)	38	210	.289	.1300	.447	0.194	102	.555	.1431	.055	.0188	70 & 110	.443	.1815	.218	.1073
	Check	39	224	.182	.0839	.403	0.175	103	.488	.1282	.092	.0332	73 & 127	.109	.0446	.078	.0362
	$NaNO_3$	40	241	.188	.0859	.484	0.211	103	.368	.0964	.343	.1248	70 & 119	.412	.1658	.135	.0590
	Urea	41	214	.266	.1108	.338	0.149	102	.216	.0577	.282	.0915	70 & 127	.209	.0857	.037	.0177
	$(NH_4)_2SO_4$	42) 43)	256	.304	.1075	.622	0.275	105	.540	.1423	.078	.0286	70 & 121	.090	.0358	.342	.1609
	$Ca(NO3)_2$	44) 45)	271	.088	.0409	.574	0.250	102	.507	.1326			70 & 122	.151	.0609	.412	.1973
	$NaNO3$	46	278	.302	.1418	.372	0.170	104	.813	.2102	.333	.1212	70 & 118			.261	.1230
	Check	47) 48)	225	.157	.0752	.322	0.144	105	.258	.0705	.062	.0231	70 & 121	.106	.0436	.102	.0508

Table XXIX-A. Relation of Soluble and Total Nitrogen in Stayman Apple Spurs in Late April to Subsequent Terminal and Spur Growth for Season. Olney, Maryland. 1927.

All analyses based on green weight.

Time of Application	Material	% total N in leaves and shoots	Terminal Growth cm	1927 Spur Growth mm	% sol. N in leaves and shoots
Fall	Leuna salp.	.830	15.24	12.03	.0894
	Urea	.775	12.73	10.71	.0142
	$Ca(NO_3)_2$	.779	11.06	10.36	.0693
	$NaNO_3$	.805	19.04	10.28	.0865
	Check	.699	6.47	10.49	.0589
	$(NH_4)_2SO_4$	.847	17.89	10.19	.1355
Spring	Leuna salp.	.924	20.66		.1097
	Urea	.787	12.23	data not available	.0523
	$Ca(NO_3)_2$	.845	10.95		.1314
	$NaNO_3$	.852	20.92		.1334
	Check	.689	7.83		.0684
	$(NH_4)_2SO_4$	.825	14.86		--
Fall & Spring	Leuna salp.	.865	14.89		.1431
	Check	.719	6.60		.1282
	$NaNO_3$	.858	20.90		.0964
	Urea	.824	13.77		.0577
	$(NH_4)_2SO_4$	.897	20.02		.1423
	$Ca(NO_3)_2$	.833	15.25		.1326
	$NaNO_3$	.954	22.99		.2102
	Check	.688	6.81		.0705

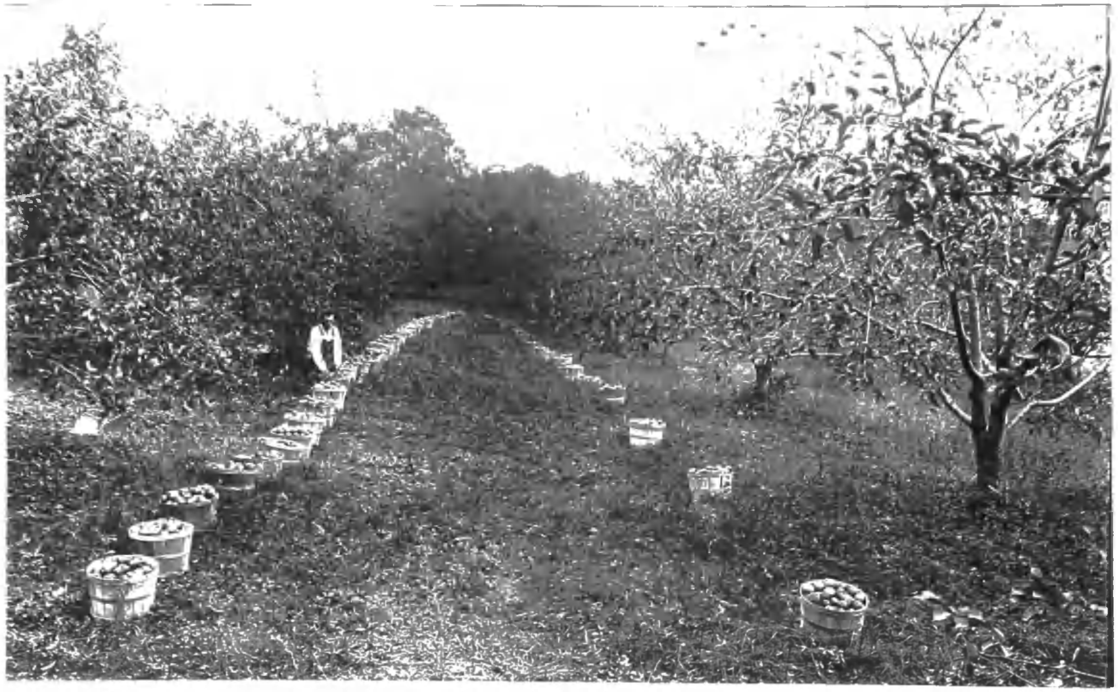


PLATE VII Calcium nitrate (left) vs Check (right)

Auchter (50) failed to get perfect correlation between soluble and total nitrogen at the pink bud stage and subsequent spur growth when considering ammonium sulfate. Their correlation for spurs from trees receiving nitrate of soda was good.

Although it would appear that while in general the soluble nitrogen at the beginning of the growth period influences the length of the seasons growth, if the inconsistencies heretofore noted are real, some other factor must condition growth also.

The amount of absolute nitrogen in these non-fruiting spurs rises steadily, and markedly during the period from March to July, due to the rapid increase in growth. The percent dry weight, however, rises from dormancy to the time growth is starting, and decreases as foliage and shoot weight increases.

As reported by Harley (22a), the growing portion of the spur is the more sensitive barometer of chemical conditions within the plant. Old wood contained small quantities of nitrogen, compared with the leaves or growing shoot. In this investigation there seemed to be but small correlation between treatment, growth response, and amount of nitrogen in old wood.

Nitrogen in Cluster-base. Upon examination of the data in Table XXVI, one is immediately impressed with the large amount of nitrogen held in the cluster base before the start of growth in the spring. This portion of the spur uniformly contained fifty percent more nitrogen per dry weight or green weight than the secondary growth with bud which was to make the growth during the coming season. This becomes still more interesting when Table XXIX is examined and it is found that the soluble nitrogen contained in the cluster base is from two to four times that contained in the secondary growth.

Data are not available to show when this reserve of nitrogen is developed in the cluster-base. Lincoln and Bennett (75) have shown that over half of the nitrogen in the pear tree is in the leaves in mid-summer, and that the total nitrogen of the standing tree, based on fresh weight remains quite constant throughout the year, which would indicate that either the nitrogen in the leaves migrates back into the woody parts, or that there is a large intake by roots at time of exfoliation, to compensate for that lost through the leaves. Rippel (76) states that it is not uncommon for leaves to lose seventy percent of their nitrogen before dropping, while Lincoln (77) found about fifty percent loss of nitrogen in pear leaves before defoliztion in 1925 and 35 to 38% loss in 1926 by translocation. He believes that the amount of nitrogen which returns to the tree may be governed by the nitrogen content of the trees and that if the nitrogen content is low, there is a greater migration of nitrogen back from the leaves than if the content is high. Lincoln studied leaves from young non-bearing Bartlett trees.

The spurs studied here, however, had borne fruit the previous season and did not have fruit buds when collected. Does this large amount of nitrogen in the cluster-base mean that there is a withdrawal of nitrogen from the fruit or merely from the leaves remaining on the spur after harvest? Another question arises. If the cluster-base is a reservoir for a quantity of nitrogen, with a large amount of it soluble, why does not the spur make more growth than is customarily noted? Perhaps the nitrogen is moved to other parts of the tree before growth gets well under way. When samples were taken for analysis on April 21, 1927, the one year old wood included a cluster-base on every spur, and these samples showed only moderate amounts of nitrogen.

The writer knows of no other case in which the cluster-base per se, has been analyzed. An interesting line of study is presented, to determine its part in the spur metabolism.

Total Nitrogen. In general the data from analyses of spurs from trees receiving nitrogen from different carriers follow the trend of data on terminal and trunk growth. Trees having the larger amounts of total nitrogen in March and April made the greater growths. Nitrogen from any carrier when applied to the trees in the fall, increased the total nitrogen content of the spurs the following spring. This increase was not large, until after March 11. Examination of Table XXVI will show that the nitrogen in the spurs of the March 11 sampling have but little more total nitrogen than the checks or the adjoining "spring nitrate" rows which had not yet received fertilization. But by April 21, these were considerable larger increases over the amounts in the check treatments. This may mean that the nitrogen is taken up in the fall but is stored elsewhere than in the spur, and is moved into the spur with the resumption of growth. If the spur gives a true indication of the amount of nitrogen taken up, then there is a certain amount of nitrogen lost when applications are made in the fall, as spring applications result in generally higher percentages than are found when applications are made in the fall. There are certain exceptions. Ammonium sulfate and urea appear to be superior when applied in the fall. Evidently there is not the loss of nitrogen from fall applications of these materials.

Samplings on July 1 indicate still lower percentages of nitrogen from fall applications than from spring or from spring and fall applications. Absolute nitrogen in leaves and new shoots in spurs on trees receiving fall treatment increased about forty percent between April 21 and July 1, while with spring applications it almost doubled. This would point to a reason for the earlier development of terminal buds on trees receiving fall applications of such directly available materials as sodium nitrate and leuna salpeter. They made less growth so probably had a shorter growing period than when the treatments were given in the spring. Why the same was not true with calcium nitrate cannot be explained by the writer.

Soluble Nitrogen. Only small amounts of soluble nitrogen were found in the samples. The ratio of soluble to total nitrogen was somewhat higher for those materials which stimulated the greater terminal growths, regardless of time of application. This is accord with the findings of Schrader and Auchter (50) (50a) although the differences are not nearly so marked. Results here, however, differed greatly in the case of soluble nitrogen in the blossoms and new growth of the trees receiving nitrate of soda and ammonium sulfate in the fall. Here we find that there is an appreciable greater amount of soluble nitrogen when the trees received sulfate of ammonia in the fall than when they received nitrate of soda at that time, and this is reflected in the proportionately greater amount of growth made by trees treated with

Table XXX

Stayman

SUMMARY SHOWING INSOLUBLE NITROGEN IN/APPLE SPURS. OLNEY, MARYLAND, 1927.

Percent dry weight and percent green weight.

			March 11, 1927					April 21, 1927					July 1, 1927				
				Bud & Shoot		Cluster Base			Leaves and Shoot		One year Wood			Leaves		New Shoot	
Time of Application	Material	Plat	No. of Spurs	% Dry Weight	%Green Weight	% Dry Weight	%Green Weight	No. of Spurs	% Dry Weight	%Green Weight	% Dry Weight	%Green Weight	No. of Spurs	% Dry Weight	%Green Weight	% Dry Weight	%Green Weight
Fall	Leuna Salpeter	26	244	1.316	.6415	1.512	0.675	84	2.965	.7420	1.143	.4105	101 & 101	1.473	.614	1.008	.485
	Urea	27	285	1.279	.5570	1.518	0.677	97	3.268	.8105	1.128	.396	61 & 121	1.357	.558	0.899	.417
	$Ca(NO_3)_2$	28	305	1.303	.6305	1.464	0.655	86	2.673	.7100	1.111	.358	63 & 126	1.365	.577	0.918	.423
	$NaNO_3$	29	335	1.268	.6032	1.566	0.693	96	2.791	.719	1.067	.387	78 & 128	1.364	.578	0.589	.304
	Check	30	288	1.181	.5537	1.481	0.643	100	2.406	.567	0.996	.363	76 & 126	1.237	.509	0.585	.308
	$(NH_4)_2SO_4$	31	258	1.261	.5823			102	2.667	.7115	1.330	.402	77 & 125	1.519	.639		
Spring	Leuna Salpeter	32	206	1.066	.4830	1.414	0.609	102	2.218	.5615	1.237	.444	76 & 106	1.516	.613	0.665	.302
	Urea	33	281	1.200	.5320	1.522	0.623	100	2.768	.735	1.356	.480	74 & 124	1.332	.534	0.811	.389
	$Ca(NO_3)_2$	34	263	1.108	.5165	1.678	0.705	103	2.768	.714	1.462	.514	75 & 125	1.389	.553	0.616	.288
	$NaNO_3$	35	306	0.959	.4510	1.415	0.628	101	2.905	.718			76 & 126	1.684	.623	0.648	.288
	$(NH_4)_2SO_4$	36	300	1.111	.4976	1.414	0.605	103	3.191	.838	0.882	.315	70 & 115	1.594	.632	0.730	.325
	Check	37	301	1.053	.4850	1.390	0.605	99	2.392	.621	0.670	.237	70 & 118	1.193	.449	0.602	.299
Fall & Spring	Leuna Salpeter	38	210	1.166	.5220	1.547	0.672	102	2.797	.722	1.390	.470	70 & 110	1.239	.508	0.829	.408
	Check	39	224	1.118	.5155	1.498	0.652	103	2.250	.591	1.022	.369	73 & 127	1.442	.590	0.651	.314
	$NaNO_3$	40	241	1.207	.5512	1.562	0.681	103	2.889	.761	1.046	.379	70 & 119	1.607	.647	0.730	.319
	Urea	41	214	1.220	.5030	1.506	0.662	102	2.598	.778	1.063	.352	70 & 127	1.228	.502	0.723	.345
	$(NH_4)_2SO_4$	42) 43)	256	1.167	.4130	1.485	0.657	105	2.862	.755	1.352	.496	70 & 121	1.554	.618	0.669	.318
	$Ca(NO_3)_2$	44) 45)	271	1.418	.6590	1.556	0.677	102	2.673	.700			70 & 122	1.532	.618	0.712	.341
	$NaNO_3$	46	278	1.162	.5460	1.581	0.723	104	2.911	.746	1.274	.464	70 & 118	1.577	.643	0.730	.348
	Check	47) 48)	225	1.147	.5520	1.471	0.659	105	2.269	.618	1.009	.376	70 & 121	1.068	.439	0.632	.315

sulfate of ammonia.

By July 1 the soluble nitrogen in trees receiving fall applications of fertilizer had been reduced to very small amounts, a much greater reduction than occurs in spring fertilized or in fall and spring fertilized trees by that date.

Starch. Determinations made on starch were confined to the new shoots and old wood. None were made on leaves because of impossibility of collecting truly comparable samples over so large a block. Ten hours were required for sampling the block, and leaves collected at an early morning hour would be expected to show a different starch content than those collected at midday or at dusk.

Starch in old wood was much depleted at blossom time by the growth demands of the spur. This, coupled with the high nitrogen content of that period, effected a low C/N ratio. By July 1, the starch reserves had been restored, and the percent of nitrogen reduced, so that the C/N ratio is greatly increased.

More starch per dry weight is found in the new shoots than in old wood, in July. The differences are small, but very consistent and are in accordance with Harley (22a).

Fall or spring and fall applications of fertilizer caused a greater depletion of the reserves in old wood on April 21 than did spring applications. On July 1, the trees receiving fall and spring applications seem to have built up a slightly larger reserve than the trees receiving nitrogen at other times, judging from the percent starch in the new shoots. There seems to be little to choose between spring applications and fall applications alone in this regard.

Table XXXI.

STAYMAN
STARCH AND STARCH/NITROGEN RATIO IN/APPLE SPURS.

Based on Percentage of Starch and Nitrogen, calculated to dry weight

Time of Application	Material	Plat	April 21. (Pink bud)		July 1. (Differentiation period)			
			Old Wood		New shoot		Old wood	
			% Starch	C/N Ratio	% Starch	C/N Ratio	% Starch	C/N Ratio
Fall	Leuna Salpeter	26	3.46	3.74	11.85	11.24	12.09	15.60
	Urea	27	3.28		11.39	14.35	11.33	16.16
	$Ca(NO_3)_2$	28	3.43	5.11	11.27	14.38	10.99	15.20
	$NaNO_3$	29	3.77	4.96	11.92	15.17	11.83	17.27
	Check	30	4.56	8.04	10.39	15.22	12.30	19.13
	$(NH_4)_2SO_4$	31	3.92	4.79			10.46	14.77
Spring	Leuna Salpeter	32	3.99	5.91	10.14	13.12	10.78	14.38
	Urea	33	5.07	5.78	12.10	15.51	14.36	21.50
	$Ca(NO_3)_2$	34	4.66	8.91	11.48	15.53	12.74	18.39
	$NaNO_3$	35	4.59	5.79	10.16	11.40	8.27	8.97
	$(NH_4)_2SO_4$	36	4.15	4.68	9.75	12.76	10.26	13.91
	Check	37	5.39	6.02	11.03	16.13	12.02	19.58
Fall and Spring	Leuna Salpeter	38	3.85	4.22	8.61	8.22	11.39	15.98
	Check	39	4.71	9.50	12.71	17.51	12.21	17.15
	$NaNO_3$	40	3.70	6.51	10.52	12.16	9.59	10.91
	Urea	41	4.35	7.53	13.11	17.25	10.94	14.93
	$(NH_4)_2SO_4$	42 & 43	3.77	6.58	12.63	12.49	10.14	11.71
	$Ca(NO_3)_2$	44 & 45	3.39	4.94	12.17	10.83	11.19	13.43
	$NaNO_3$	46	2.95	4.70	10.89	10.99	10.34	12.38
	Check	47 & 48	5.04	11.24	12.87	17.54	12.62	17.88

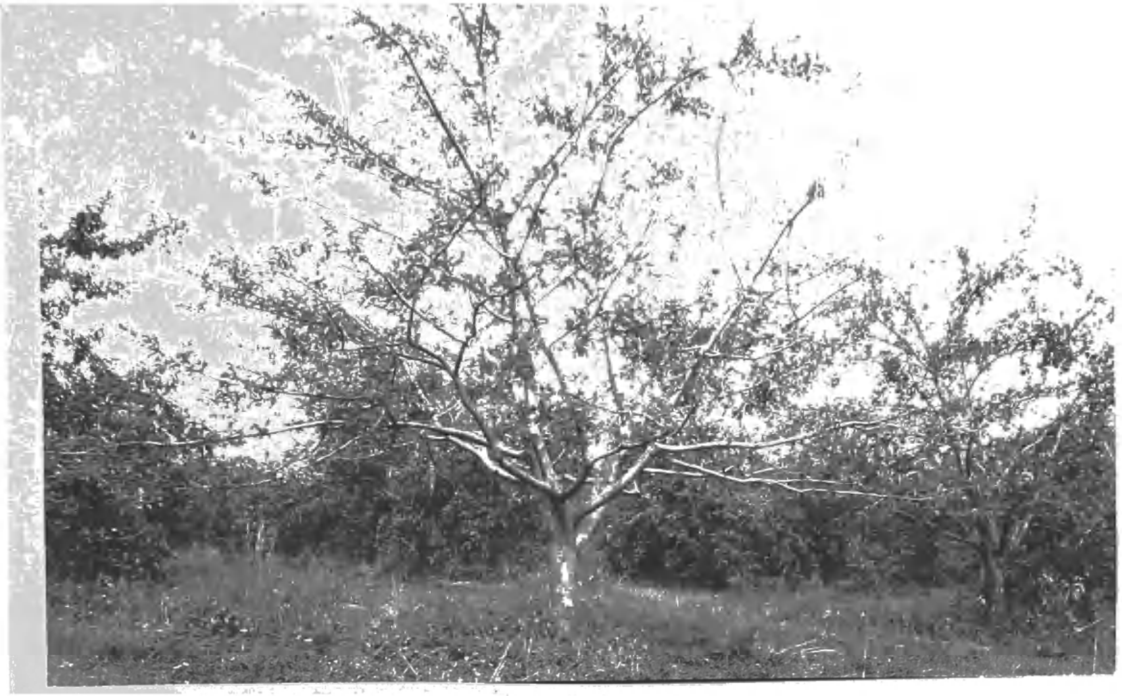


PLATE VIII TYPICAL CHECK TREE.

In general the trees making the fastest growth in the spring suffered the greatest depletion of starch reserves in April, although there are occasional exceptions to this. In the same way, the materials which stimulated the least vegetative response have the highest starch reserves, and the highest C/N ratios. The check trees have the highest, with urea and calcium nitrate next, and nitrate of soda, ammonium sulfate and leuna salpeter last. The reserves were rapidly built up again as leaf surface developed. It is not possible from the data to say that the larger leaf area developed on some plats enabled those trees to replenish the starch reserves more rapidly than others, although it is probable, being more depleted in April, and returning to about the same level in July, that such was the case. The highest individual C/N ratio is developed by an urea treatment, the material being applied in the spring. With this one exception, the checks have the highest C/N ratios at both periods.

Comparing the C/N ratios with growth and yield performance of the trees, we may conclude that the check trees are in a class approaching Kraus and Kraybill's Class IV. They are only slightly fruitful, are making but a slight growth, and are yellowish in appearance. The treated trees have been moved up into Class III, and have become fruitful and moderately vegetative. Trees receiving the more slowly available fertilizers such as urea, have not moved as far into Class III as trees receiving nitrate of soda, leuna salpeter or ammonium sulfate, and are therefore neither as fruitful nor vegetative. It is not impossible that the more slowly available materials may accomplish the complete transfer from Class IV to Class III providing continued applications are made over several years.

Hooker (30b) found non-bearing Jonathan and Ben Davis spurs to have but 2.16% and 3.16% respectively, of dry weight of starch the highest C/N ratios at both periods.

Comparing the C/N ratios with growth and yield performance of the trees, we may conclude that the check trees are in a class approaching Kraus and Kraybill's Class IV. They are only slightly fruitful, are making but a slight growth, and are yellowish in appearance. The treated trees have been moved up into Class III, and have become fruitful and moderately vegetative. Trees receiving the more slowly available fertilizers such as urea, have not moved as far into Class III as trees receiving nitrate of soda, leuna salpeter or ammonium sulfate, and are therefore neither as fruitful nor vegetative. It is not impossible that the more slowly available materials may accomplish the complete transfer from Class IV to Class III providing continued applications are made over several years.

Hooker (30 b) found non-bearing Jonathan and Ben Davis spurs to have but 2.16% and 3.16% respectively, of dry weight of starch on June 26. It is impossible to compare stages of development of the trees, but it probable from comparison of blooming dates that the trees at Olney were about ten days ahead of Hooker's trees. It appears that there probably was more starch in the trees at Olney, in the early summer. Certainly there was more in the late summer. Hooker reports but 4.20% and 4.85% in these trees on September 2, which he calls his maximum of summer starch development. The trees used at Olney showed over 10% on July 1, whether new shoot or old wood is considered. Hooker analyzed new shoot and old wood together. Roberts (49) reports non-fruiting spurs in Wisconsin, to have on June 24, 5.37% starch, while on July 11 branches from young dwarf Wealthy trees grown in pots, from 5.07% to 5.80% dry weight of starch. These trees were low in nitrogen the previous year but high in nitrogen the year of sampling. Lagasse (74) found non-bearing spurs from non-nitrated trees to have on June 24, a starch/nitrogen ratio of 14.57, while non-bearing spurs from trees receiving normal amounts of nitrogen had a ratio of 9.40, and a ratio of 5.69 when excessive amounts of nitrogen were applied.

DISCUSSION

Several factors influence the orchardist in the selection of fertilizers. In the order of their (probable) importance to the average farmer they are effect on trees, price, ease of handling, previous preference, ease of purchase and perhaps last of all, analysis and availability. Price is largely fixed on the basis of number of units of plant foods contained in the material. Handling qualities are known by the farmer usually from experience, or he gains the knowledge by hearsay. His preferences for, and prejudices against certain materials, are hard to explain and harder to overcome, and often are tied up with the personalities of dealers or salesman. The brand handled by his dealer is the easiest to obtain, so is often used for that reason, and if it seems to improve the crops on which he used it, he frequently raises no further question. The analysis on the bag is often as not not understood. No clue may be given there as to the availability of the materials. The grower, as a class, isn't a man who can carry out comprehensive experiments on his own land and he must rely for nis information of such authorities as the State experiment stations.

Therefore when new fertilizers come on the market, they encounter sales resistance of no small importance. Unless they have certain definite advantages over the known and used brands, their adoption is slow. The growers expect sucn information from the experiment station.

The materials considered in this experiment have not been used to a great extent on orchards. An attempt has been made to evaluate them through comparison with standard long used materials, such as nitrate of soda and sulfate of ammonia, and by comparison with untreated trees.

The most striking feature of this experiment is that all materials used at Olney caused a favorable response as expressed in stimulation of terminal and trunk growth, foliage color and yield. While there were differences in response caused by various fertilizers used, without an exception they all caused increases over the check trees.

Leuna salpeter, nitrate of soda and sulfate of ammonia were outstanding in all of the expressions of vigor. Calcium nitrate was distinctly inferior at Olney but seemed to cause a better response at Hancock.

PLATE IX TYPICAL TREE AFTER TWO YEAR'S FERTILIZATION WITH UREA

Urea was less effective even than calcium nitrate, both at Olney and Hancock. When urea is combined with calcium nitrate to make calurea, thus introducing nitrate nitrogen into the fertilizer, it is much improved. Cyanamid, at Hancock, was not at all satisfactory as a fertilizer to be applied in the spring, but gave much better results, during one year's test when part of the application was made in the fall.

The results with nitrate of soda and sulfate of ammonia were in keeping with experimental results elsewhere. Hooker (30) finds one as satisfactory as the other on any but quite acid soils. Bradford (11a), although he had no direct comparisons, found: "The most satisfactory nitrogen carriers for the orchard are ammonium sulfate and sodium nitrate. Used in proper amounts, these materials appear to give equally good results, so far as concerns the trees themselves". Others (Schrader and Auchter (50), Davis (17) and Marsh (42, 43)) have found that nitrate of soda was more effective in giving a quick stimulation to the trees. The results secured here bear out the findings of the latter when the materials are applied in the spring, but not when fall applications are made. Early in the season sharper differences were seen in the comparison of these two materials at Hancock than at Olney. The soil at Hancock is the same as that on which Schrader and Auchter obtained their marked differences. But when applied to trees in fair state of vigor, or when applied in the fall, sulfate of ammonia stimulated better trunk and terminal growth than nitrate of soda did.

Soil differences and effects on soil microbiology must play an important part in these results. Truog, etal (58) have shown that, under certain conditions of acidity, bacterial action is suppressed so that nitrification cannot proceed, and under those circumstances ammonium sulfate did not give as good results as nitrate of soda. No soil acidity tests were made at the orchards used in these experiments. Lehmann, Hutchison and Miller, Kelley, Truog, etal, and others have pointed out that wheat, rice, peas, barley, and other plants grow well on ammonium nitrogen, while Davis (17) seems to have proved definitely that apple trees will not use the ammonium form. It is possible that on trees growing inssod, the grass utilizes ammonium nitrogen from ammonium sulfate before it becomes nitrified, leaving little to be used by the trees after nitrification. On the other hand, nitrate of soda, being immediately soluble and available, is used by the trees and grass in competition, the trees at least getting their share.

Responses from nitrate of soda and sulfate of ammonia being excellent, there is little wonder that leuna salpeter, having both the nitrate and ammonium ions, should prove to be as good as either of the other two. In fact, in most cases at Olney it was slightly, but not significantly better than them.

It has one disadvantage which is hard to overcome. Upon standing for a few days it hardens, and comes from the bags in great lumps. (Plate II). This condition can be remedied by sprinkling the bags with water and covering them with wet bags or canvas for twenty four hours before they are to be used. The lumps will then fall apart, or can be crushed by hand.

Calcium nitrate should be equal to sodium nitrate from a theoretical standpoint. The calcium has a definite plant food value, perhaps superior to sodium, as calcium is so widely used by plants. The nitrogen is in the nitrate form. Yet this material proved significantly inferior in many ways to the three leaders at Olney. It has been suggested that the superiority of nitrate of soda may be a potassium phenomenon, sodium displacing potassium from its combinations in the soil thus freeing potassium for plant use. Calcium is absorbed so readily by plants that not much from the fertilizer is left in the soil. This potassium effect may or may not be the explanation for the difference between sodium nitrate and calcium nitrate, but certainly does not explain the superiority of ammonium sulfate and leuna salpeter over calcium nitrate.

At Hancock, calcium nitrate gave better accounts of itself. Chemical analyses will be available later which will show how effective calcium nitrate has been in supplying nitrogen to the spurs on this different soil type.

Urea apparently does not approach nitrate of soda, ammonium sulfate or leuna salpeter in effectiveness as a fertilizer for apple trees. It has been found satisfactory on tobacco in Connecticut and on seed cotton, corn and tomatoes in Mississippi. It is not known in what form these plants take their nitrogen. But Jacob, Allison and Braham (32) have shown experimentally that urea decomposes into ammonia within a few hours in some cases and at least in two or three days, and thenceforth it should be as efficient as ammonium sulfate. Ammonification and nitrification took place in their experiments at all temperatures tested between - 9°D and 38.5°C, and in moisture

PLATE X TYPICAL TREE AFTER TWO YEAR'S FERTILIZATION WITH LEUNA SALPETER conditions up to three-fourths of full saturation. The results at Olney and Hancock would indicate that field results do not follow the trend of laboratory experiments, at least not as to the speed of the nitrification of urea. In orchards having a considerable supply of available nitrogen, the slow rate of nitrification of urea may not be a handicap.

Cyanamid was only tried at Hancock. There it gave unsatisfactory results when applied in the spring, but was quite satisfactory when applied in the fall and spring. Jacob, Allison, and Braham (32) report a rapid decomposition of cyanamid to urea and ammonia and some other decomposition products within five to ten days after application to the soil. The larger the application the more slowly did the decomposition occur, due to suppreesion of bacterial action, by dicyanodiamid particularly. In the experiment reported here the material was spread in an area well out under the branches, but due to the slippery nature of the material it was difficult to spread it evenly and thinly. Perhaps the concentration at the point of application was sufficient to suppress the bacterial action, thus resulting in such slow ammonification and nitrification that it did the trees little good when applied in the spring until after spring growth was over. Fall applications on the other hand, had an opportunity for decomposition, even though temperature and moisture conditions were unfavorable for a large part of the time.

Application of nitrogenous fertilizers to the trees changed the chemical content of the spurs, by increasing total nitrogen and soluble nitrogen; and by decreasing the starch/nitrogen ratio. This reduction of the ratio being correlated with increased yields and growth, one may assume that the check trees were unproductive through having too much carbohydrates in proportion to nitrogen, - in other words, they were in Class IV as proposed by Kraus and Kraybill. All fertilizers used changed the C/N ratio, although nitrate of soda, leuna salpeter and ammonium sulfate seem to have been more effective in accomplishing this at Olney than calcium nitrate and urea.

CONCLUSIONS

1. Leuna salpeter, nitrate of soda, sulfate of ammonia, calcium nitrate and urea all caused marked increases in yield and terminal and trunk growth, when compared to untreated trees at Olney.
2. Of the five materials tested at Olney, leuna salpeter, nitrate of soda and sulfate of ammonia gave the best results as carriers of nitrogen for fertilization of devitalized apple trees as measured by responses in yield, terminal growth, color of foliage, trunk growth, and chemical content of spurs.
3. Calcium nitrate and urea were not satisfactory compared with the three named above, in stimulating growth and yield, and color.
4. Calcium nitrate was more satisfactory when applied in the fall than in the spring, in stimulating growth, yield and foliage color.
5. Nitrate of soda is superior for stimulating growth, yield and foliage color to ammonium sulfate when applied in the spring, but ammonium sulfate is superior to nitrate of soda when application is

made in the fall, though odds are low in both cases.

6. Leuna salpeter is equally satisfactory at either spring or fall, and produced slightly better results than any of the other carriers.

7. For greatest stimulation of devitalized trees, leuna salpeter or nitrate of soda applied in the spring just before growth starts gave the best results, - better than any fall applications.

8. Soil conditions play an important part in determining the effectiveness of fertilizers.

9. At Hancock calcium nitrate gave good results both as a spring or spring and fall application, equalling leuna salpeter and an application of half nitrate of soda and half ammonium sulfate. Nitrate of soda was superior to all of the others.

10. Cyanamid and urea were entirely unsatisfactory as growth stimulants when applied in the spring, but the former gave good results when applied in the fall.

11. On vigorous apple and peach orchards, which had received heavy applications of nitrate of soda for several years previous to the start of the experiment, two year's investigations fail to show that any one of the nitrogenous fertilizers used is superior to another. All plats showed excellent growth of trees and foliage color. This may have been due to previous good care rather than to the effect of the fertilizers used in this experiment.

12. Applications of nitrogenous fertilizers were followed by a lowering of the starch-nitrogen ratio of the spurs on the treated trees; and this was correlated with a more productive and vegetative condition. Sodium nitrate, leuna salpeter and ammonium sulfate were more

PLATE XI TYPICAL TREE AFTER TWO YEAR'S FERTILIZATION WITH CALCIUM NITRATE effective than urea or calcium nitrate in this respect at Olney.

13. The presence of large quantities of nitrogen, both soluble and insoluble, in the cluster-bases of these spurs, which had fruited previous to their collection, suggests a withdrawal of nitrogen from the leaves previous to exfoliation, and perhaps from the fruit.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation for the help and guidance given by Dr. E. C. Auchter and Dr. A. L. Schrader in carrying on this investigation; to Dr. W. B. Kemp for aid in making the statistical study of certain data; to the owners of the orchards and their assistants for cooperation given in applying materials, taking observations and collecting data; to the other graduate students in horticulture who gave generously of their time to help in gathering samples, applying materials and collecting records; and to the Synthetic Nitrogen Products Corporation for their very material aid in carrying on the project.

LITERATURE CITED.

1. Alderman, W. H. and Crane, H. L. The fertilization of apple orchards. West Va. Agr. Expt. Sta. Bul. 174. 1920.

2. American Fertilizer Handbook. 1928.

3. Ames, C. T. Rpt. Holly Springs Branch Expt. Sta. Miss. Agr. Expt. Sta. Bul. 239. 1926.

4. Anders, C. R. and Hull, W. W. Cotton fertilizer experiments. Miss. Agr. Expt. Sta. Bul. 250. 1928

5. Anderson, P. J. and Nelson, N. T. Fertilizer experiments with tobacco. Conn. Agr. Expt. Sta. Windsor Tobacco Sta. Bul. 5. 1925.

6. ______________________ Bul. 10. 1928.

7. ______________________ Report of Windsor Tobacco Sta. 50th Annual Report Conn. Agr. Expt. Sta. 1926.

8. Ballou, F. H. The rejuvenation of orchards. Report of spraying, fertilization and thinning experiments in Southeastern Ohio. Ohio Agr. Expt. Sta. Bul. 240: pp 499-510. 1912.

9. ______________. Orchard rejuvenation in Southeastern Ohio. Ohio Agr. Expt. Sta. Bul. 339. 1920.

10. Bedford, Duke of, and Pickering, P.S.U. Science and Fruitgrowing MacWilliams, London. p. 92. 1919.

11. Blake, M. A. and Farley, A. J. Report of the horticulturist. N. J. Agr. Expt. Sta. An. Rpt. p. 63. 1911.

11a. Bradford, F. C. Nitrogen-carrying fertilizers and bearing habits of mature apple trees. Mich. Agr. Expt. Sta. Spec. Bul. 127. 1924.

12. Breazeale, J. F. Response of Citrus seedlings in water cultures to salts and organic extracts. Jour. Agr. Res. 18: p. 272. 1919.

13. Brooks, W. P. Manuring an apple orchard. Mass. Agr. Expt. Sta. 22nd An. Rpt. Part II. p. 10. 1910.

14. Chandler, W. H. Fruitgrowing. Houghton-Mifflin. 1925.

15. Chemical and Metallurgical Engineering. Jan. 1929.

16. Cooper, J. R. A study of the effect of commercial fertilizers on the performance of apple trees. Ark. Agr. Expt. Sta. Bul. 227. 1928.

16a. ______________. Preliminary report on the effect of fertilizers in apple orchards in the Ozark region. Proc. Am. Soc. Hort. Sci. 17: pp. 190-193. 1920.

17. Davis, M. B. The influence of ammonium sulfate as a direct source of nitrogen for apple trees. Sci. Agr. VIII. 1, Sept. 1927.

18. Ferris, E. B. Cotton experiments. Miss. Agr. Expt. Sta. Circ. 63, 1925.

19. Fudge, J. Franklin. The influence of various nitrogenous fertilizers on the availability of phosphate and potassium. Ala. Agr. Expt. Sta. Bul. 227. 1928.

20. Gardner, V. R., Bradford, F. C., and Hooker, H. D, Jr. Fundamentals of fruit production. McGraw-Hill. p. 223. 1924.

21. Gourley, J. H. Sod, tillage and fertilizers for the apple orchard. N. H. Agr. Expt. Sta. Bul 190. 1919.

22. ______________. Notes on the presence of nitrates in orchard soils. N. H. Agr. Expt. Sta. Tech. Bul. 11. 1916.

22a. Harley, C. P. Normal variation in the chemical composition of fruitspurs, and the relation of composition to fruit bud formation. Proc. Am. Soc. Hort. Sci. 22. pp 134-146. 1925.

23. Hawkins, Wm. Quar. Jour. Agr. 3. 1828 (Cited by Lipman)

24. Hedrick, U. P. A comparison of tillage and sod mulch in an apple orchard. N. Y. (Geneva) Agr. Expt. Sta. Bul. 314. 1909.

25. ______________. Is it necessary to fertilize an apple orchard? N. Y. (Geneva) Agr. Expt. Sta. Bul. 339. 1911.

26. ______________, and Anthony R. D. Twenty years of fertilizers in an apple orchard. N. Y. (Geneva) Agr. Expt. Sta. Bul. 460. 1919.

27. ______________, and Tukey,. H. B. Twenty-five years of fertilizers in a New York apple orchard. N. Y. (Geneva) Agr. Expt. Sta. Bul. 516. 1924.

27a. Heinicke, A. J. The set of apples as affected by some treatments given shortly before and after the flowers open. Proc. Am. Soc. Hort. Sci. 20: pp 19-25. 1923.

27b. ______________. Factors influencing the abscission of flowers and partly developed fruits of the apple (Pynus malus L.). N. Y. (Cornell) Agr. Expt. Sta. Bul. 393. 1917.

28. Hilgard, E.W. The use of fertilizers in California. Cal. Agr. Expt. Sta. Bul. 88. 1890.

29. Hooker, H. D. Jr. Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. Mo. Agr. Expt. Sta. Res. Bul. 50. 1922.

30. ________________. Nitrogen fertilizers for fruit trees. Mo. Agr. Expt. Sta. Circ. 139. 1926.

30a. Howlett, F. S. The nitrogen and carbohydrate composition of the developing flowers and young fruits of the apple. N. Y. (Cornell) Agr. Expt. Sta. Memoir 99. 1926.

30b. Hooker, H. D. Jr. Seasonal changes in the chemical composition of apple spurs. Mo. Agr. Expt. Sta. Res. Bul. 40. 1920.

31. Industrial and Engineering Chemistry. Nov. 1928.

32. Jacob, K. D., Allison, F. E., and Braham, J. M. Chemical and biological studies with cyanamid and some of its transformation products. Jour. Agr. Res. XXVIII : 1. pp. 37-69. 1924.

33. Johnson, S. W. How crops feed. p. 302. Orange-Judd. 1890.

34. Kellner, O. Agriculturchemische studien.uber die Reiscultur. Lansw. Vers. Stat. XXX pp. 18-34. 1884. (Cited by Johes & Shive)

35. Kimberley, Jour. Royal Agri. Soc'y. England. 1: p. 275. 1840. (Cited by Lipman)

35a. Kraus, E. J. and Kraybill, H. R. Vegetation and reproduction with special reference to the tomato. Ore. Agr. Expt. Sta. Bul. 149. 1918.

36. Lehmann, J. Ueber die zur Ernahung der Pflanzen, geeignetste Form des Stickstoffes. Bildermann's Centralbl. Agr. Chem VII pp. 403-409. (Cited by Jones and Schive)

37. Lewis, C. J., Reimer, F. C., and Brown, G. G. Fertilizers for Oregon orchards. Ore. Agr. Expt. Sta. Bul. 166. 1920.

38. Lipman, J. G. and Blair, A. W. N. J. Agr. Expt. Sta. Bul. 288. p.3 1916.

39. ______________________________. Soil Science V, 4. 1918.

40. Lyon, T. L., Heinicke, A. J. and Wilson B. D. The relation of soil moisture and nitrates to the effect of sod on apple trees. N. Y. (Cornell) Agr. Expt. Sta. Mem. 63. 1923.

41. ____. The relation of soil moisture and nitrates to the effect of sod on plum and cherry trees. N. Y. (Cronell) Agr. Expt. Sta. Mem. 91. 1925.

42. Marsh, R. S. Preliminary studies of commercial forms of nitrogen fertilizers applied to Winesap apples. Proc. Am. Soc. Hort. Sci. 23: pp. 218-221. 1926.

43. __________. Further studies on the effect of commercial forms of nitrogenous fertilizers as applied to Winesap apple trees. Proc. Am. Soc. Hort. Sci. 25: pp. 232-233, 1928.

44. National Fertilizer Assn. Service Letter 3 IV. Feb. 26, 1929.

44a. O'Kelly, J. F., and Cowart, R. Cotton experiments. Varieties and fertilizers. Miss. Agr. Expt. Sta. Bul. 226. 1924.

44b. Petri, L. Studi sulle malattie dell' olivo-v. Ricerche sulla biologica e patilogia fiorale dell' olivo. Mem. R. Staz. Patol. Veg. Roma. pp. 5-64. 1914. (Cited by Chandler.)

45. Ramsburg, C. J. Fertilizer Review, p. 13, June, 1928.

46. Remy, Th. Stickstoffversorgung und Blutenansatz der Obstbaume. Mitt. Deut. Landw. Gesell. 28: 29: pp 416-421. 1913.

47. Roberts, R. H. Experiments in apple tree nutrition. Proc. Am. Soc. Hort. Sci. 17: pp. 197-200. 1921.

48. ______________. Nitrogen reserve in apple trees. Proc. Am. Soc. Hort. Sci. 18: pp. 143-145. 1921.

49. ______________. Apple physiology. Wis. Agr. Expt. Sta. Res. Bul. 68. 1926.

50. Schrader, A. Lee, and Auchter, E. C. First year's effect of different nitrogen fertilizers on bearing apple trees low in vigor. Proc. Am. Soc. Hort. Sci. 22: pp. 150-161. 1925.

50a. ____________________________________. The comparative effects of different nitrogen fertilizers on bearing apple trees low in vigor. Proc. Am. Soc. Hort. Sci. 23: 1926.

51. Shaw, J. K. Experiments in soil management and fertilization of orchards. Mass. Agr. Expt. Sta. Bul. 209. 1922.

52. Skinner, J. J. U.S.D.A. Bur. Soils Bul. 83. 1911

53. ______________ and Schreiner, O. U.S.D.A. Bur. Soils Bul. 70. 1910.

54. Stewart, J. P. The fertilization of apple orchards. Penna. Agr. Expt. Sta. Bul. 121. 1913

55. ______________. Results from orchard fertilization. Penna. Agr. Expt. Sta. Bul. 141. 1916.

56. ______________. The fertilization of apple orchards. Penna. Agr. Expt. Sta. Bul. 153. 1918.

57. Troffantit and Bizssonoff.

58. Truog, E., Harper, H. J., Magistad, O. C., Parker, F. W., and Sykora, Jas. Fertilizer experiments. Wis. Agr. Expt. Sta. Res. Bul. 65. 1925.

59. Tukey. H. B. The comparative effect of various kinds and amounts of fertilizers in yearling apple trees. Proc. Am. Soc. Hort. Sci. 23. 1926.

60. Wagner, . Beitrage zur Bergrundung und Ausbildung einer exakten Methode der Dungungsversuche. Jour. fur Landw. XXVIII. p. 9. 1881.

61. ______________. Deutsche Landw. Presse. Feb. 1895. (Cited by Lipman)

62. Walker, E. Suggestions upon the care of apple orchards. Ark. Agr. Expt. Sta. Bul. 91. 1906.

78. Anthony, R. D. and Waring, J. H. Methods of interpreting yield records in apple fertilization experiments. Penna. State Agr. Expt. Sta. Bul. 173. 1922.

79. Crane, H. L. Experiments in fertilizing peach trees. West Va. Agr. Expt. Sta. Bul. 183. pp 63-65. 1924.

DISSERTATION PREPARED BY

A. FREEMAN MASON.

In partial fulfillment of the requiremtns
for the degree of Doctor or Philosophy
from the University of Maryland.

(Approved) E. C. Auchter

May 27, 1929. Head of Dept. of Horticulture,.