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The Fertilization of Apple Orchards

W. H. Alderman

H. L. Crane

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JOHN LEE COULTER, Director

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Cover Crop of Clover In Bearing Orchard. The Good Growth of Clover Was Largely Due to Applications of Phosphorus.

BY

W. H. ALDERMAN and H. L. CRANE

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SUMMARY AND CONCLUSIONS

1.—The apple orchard fertilizer experiments described in this bulletin are four in number and include 368 trees of various ages and conditions.

2.—All the trees in the experiments have been given clean cultivation and cover crops throughout the duration of the experiments.

3.—Lack of soil fertility is not generally the limiting factor in apple production in West Virginia.

4.—Improper soil and orchard management such as lack of cultivation, of pruning, and of spraying are more often limiting factors than is lack of fertility.

5.—It is doubtful if the average apple orchard in West Virginia needs commercial fertilizers provided it is given good attention and a system of cultivation with cover crops is practiced.

6.—The average cultivated young orchard in West Virginia is not likely to respond to applications of commercial fertilizers sufficiently to justify their use.

7.—There are many cultivated bearing orchards in West Virginia that will not respond to the use of commercial fertilizers.

8.—Old bearing trees on soil of low fertility, even though cultivated annually and cover crops used, may respond profitably to liberal applications of a desirable nitrogen-carrying fertilizer.

9.—No noticeable benefits have been derived from the use of potassium in the orchards under observation.

10.—So far as can be observed the trees have received no direct benefit from the applications of phosphorus. The value of phosphorus seems to be mainly in promoting a greater growth of cover crops and sod coverings.

11.—Phosphorus and potassium have had no effect on the color of the fruit, nitrogen has delayed maturity of fruit and tree and has indirectly inhibited color development.

12.—Young bearing apple trees on soil low in fertility probably will be greatly benefited by the application of a nitrogen-carrying material such as nitrate of soda.

13.—The indications are that nitrogen applied in March or June is less beneficial than if applied just as the fruit buds are breaking, usually the first of May.

14.—Commercial fertilizers seem to be of value mainly as a substitute for cultivation and cover crops, or as a tonic or quick restorative for starved and devitalized trees.

15.—Trees making only a few inches terminal growth and with leaves turning yellow early in the season should be supplied with some quickly available form of nitrogen.

16.—The soils of West Virginia contain small amounts of nitrogen and phosphorus but large amounts of potassium. The amounts of these elements in the soil are sufficient for many good crops of apples. The time may come when nitrogen and phosphorus will be limiting factors in the production of apples.

THE FERTILIZATION OF APPLE ORCHARDS

By

W. H. Alderman and H. L. Crane

The growth of plants has always claimed the interest of the philosopher and the scientist. It now looms up before the economist as the problem of the age, since it vitally concerns the food supply of the world. The Greek philosopher, the agrarian writer of Rome, the groping student of the fifteenth century, and the modern scientist have all sought to solve the mystery of a plant's growth and the source of its food supply.

The efficiency of manure has always been more or less recognized by the practical grower of plants, but it remained for Baron von Liebig in 1840 to arouse the interest of the scientific world in the possibilities of artificial or chemical fertilizers. It is little wonder that those in charge of the newly organized experiment stations thirty years ago directed their first efforts, in the main, to a study of fertilizers and their use. It proved a weighty problem and, far from being settled, has been handed on to a new generation of investigators.

The grower of fruit has long been interested in fertilizers and quite naturally, for he works in a highly developed and specialized industry; he belongs to a progressive group of farmers; his product is a delicate commodity, valuable enough to warrant unusual care and attention in its production. As a result, the grower has invested freely and enthusiastically in all kinds of materials and devices to improve the quality of his product. This statement is especially true in regard to fertilizers. With artificial plant food materials he has attempted to increase the vigor of his trees, to increase the size of his fruit, to make more delicious its flavor, and to paint its surface with more delicate and richer colors. To these ends he has applied himself, backed by the enthusiasm of the fertilizer manufacturers and the slowly accruing knowledge and carefully guarded advice of experiment station investigators.

Oregon Experiment

As in the Ohio experiments, the Oregon tests were also arranged so as to permit a study of the influence of fertilizers upon devitalized trees. [7] In this case, however, the orchards were under cultivation instead of in sod but had become depleted in fertility through constant tillage with no cover crops returned to the soil. Here again the starved trees responded to applications of nitrate of soda by out-yielding the check trees 11 to 1 in one orchard, and in another orchard actually out-stripped the checks 24 to 1. Phosphorus and potassium are reported as inactive in these orchards. Both Oregon and Ohio call attention to the necessity of applying the fertilizer before the blossoms open in order to get maximum results.

Maine Experiments

The experiments in Maine, as yet incomplete, are being conducted in a cultivated orchard and according to recent reports [8] are showing no benefits from any of the applications, including excessive nitrogen treatment. To quote from an earlier report [9]: "No person * * * * * could detect differences whereby he would be able to pick out the treated from the untreated rows."

Massachusetts Experiment

An experiment [10] carried on for a number of years in a sod orchard in Massachusetts showed striking benefits from the use of manure, phosphorus, and potassium. In this connection the sulphate of potash was more effective than the muriate.

New Jersey Experiment

An experiment started in 1896 and reported on in 1911 [11] showed minor gains from the use of all three elements of plant food, but is not very impressive because of an obvious lack of uniformity between plots and individual trees.

Woburn Experiments

The Woburn Station in England conducted experiments with manures and commercial fertilizers in a cultivated orchard for fourteen years. At the close of this period it is reported [12] that the effects did not extend 5 per cent either way and that even this variation was doubtful. Nitrogen gave some benefits in a few seasons and it was suggested that more positive action might have resulted on poorer soils.

THE WEST VIRGINIA EXPERIMENTS

The experiments in West Virginia are four in number and include 368 trees of various ages and conditions. One contains old bearing trees on very poor land, another begins with trees just planted on land of medium fertility, a third takes in young bearing trees on fairly productive soil, and the fourth is comprised of young bearing trees but in a starving condition on very poor soil. All have been

(7)—Oregon Agr. Exp. Sta., Hood River Sta. (1914-15).
Also Ore. Agr. Exp. Sta., Bul. 141 (1917).
(8)—Maine Agr. Exp. Sta., Bul. 269.
(9)—Maine Agr. Exp. Sta., Bul. 260.
(10)—Mass. Agr. Exp. Sta., Report 26, Part II, (1914).
(11)—New Jersey Station Report (1911).
(12)—Woburn Experiment Fruit Farm, Fourth and Fifth Annual Reports.

given cultivation throughout the term of the experiment * so that there is eliminated the unmeasurable influence of the grass crop. It is immaterial in this connection whether grass in the orchard plays the role of a mysterious criminal dealing in toxic poisons or merely that of a brazen robber of soil moisture and plant food materials. In any event it seemed best to eliminate its influence in the present experiments.

It should be understood this bulletin does not mark the close of the experiments as the work is still being continued along the same lines.

HISTORY OF THE EXPERIMENTS

In the spring of 1911 the West Virginia Experiment Station began an experiment on rejuvenation in the Reynolds orchard at Grape Island, Pleasants County, along the Ohio River. The soil is a Dekalb silt loam generally recognized as being one of the poorer soils of the State. In this particular orchard the soil was very poor, had not been cultivated for some time, and supported only a meager growth of grasses and weeds. The twenty-year-old Rome trees were making from one to three inches of growth, were filled with dead branches, and seemed to be upon the verge of starvation. It seemed that this was an excellent opportunity to study the effect of fertilizers when applied to poor soils and devitalized trees. The entire orchard was thoroughly pruned and sprayed and placed under cultivation. At this point, a block of 120 trees was set aside for purposes of the experiment. The block was then divided into five duplicated plots and treated as follows:

Plots	Treatment	** Lbs. per Acre	Lbs. per Tree
Plots 1 and 6	Muriate of potash	100	2.08
	Acid phos., 16%	375	7.8
	Nitrate of soda	125	2.6
Plots 2 and 7	Acid phos., 16%	375	7.8
	Muriate of potash	100	2.08
	Nitrate of soda	125	2.6
Plots 3 and 8	Acid phos., 16%	375	7.8
	Nitrate of soda	125	2.6
Plots 4 and 9	Muriate of potash	100	2.08
Plots 5 and 10	Checks		

*The old orchard was seeded to clover sod during the last two years.
** These amounts were doubled in 1915 and thereafter

The applications were made by scattering the materials under the trees toward the extremities of the branches. The same amount of a fertilizing material was used in each case regardless of the combination in which it appeared. In 1911, sulphate of potash was used instead of muriate, and in 1916 and thereafter the use of potash was discontinued entirely in all the experiments because of shortage of this material. Beginning in 1915, all applications were doubled in an effort to intensify and make more positive the effects of the treatment. Cultivation was kept up until the fall of 1917 when the block was seeded to red clover, and plowed under in the spring. The block was again seeded to clover in the fall of 1918. Cover crops of cow peas were grown in 1911, 1912, 1914, and 1917. During other years a volunteer cover of natural vegetation was allowed to stand. With the exception of one year, 1911, the crop of cow peas was light and did not constitute a good cover. The fertilizers were applied during the first two weeks in May each year except in 1918 when part was applied earlier for comparisons. After the experiment was under way it became clearly evident that Plot I, which was located in an outside row with no guard, was in better vigor than the others and was giving better yields because of its favorable location. As a result this plot was discarded.

The same year that work was started in the Reynolds orchard, 1911, another experiment was begun in an orchard at Sleepy Creek, managed by S. H. Fulton. In this case the same variety, Rome, was used but the trees were only yearling stock planted that spring. The soil in this instance belongs to the Holston series and is known as Holston silt loam. It is fairly high in fertility as indicated by the accompanying analysis and is considerable better than that in the Reynolds orchard.

Analysis of Holston silt loam from sample taken adjacent to the fertilizer block* is as follows:

	Pounds per 2,000,000 lbs. Surface Soil (Plow Depth.)				
	Nitrogen	Phosph.	Potassium	Carbon	Lime Requirement
Holston silt loam	2110	608	22840	27600	800

* From W. Va. Exp. Sta. Bul. 168.

The following plot series, 10 trees to the plot, was organized and fertilized with the materials and amounts indicated. Cultivation was kept up annually, followed by indifferent clover or natural cover crops.

Plots	Treatment	Lbs. per Tree, 1911-13	Lbs. per Tree, 1914-15	Lbs. per Tree, 1916-19
Plot 1	Nitrate of soda	.75	1.00	1.5
	Acid phos., 16%	1.25	1.75	2.5
Plot 2	Nitrate of soda	.75	1.00	1.5
	Muriate of potash	.5	.75	------
Plot 3	Nitrate of soda	.75	1.00	1.5
	Acid phos., 16%	1.25	1.75	2.5
	Muriate of potash	.5	.75	------
Plot 4	Acid phos., 16%	1.25	1.75	2.5
	Muriate of potash	.5	.75	------
Plot 5	Check	-----	-----	------
Plot 6	Nitrate of soda	.75	1.00	1.5
Plot 7	Acid phos., 16%	1.25	1.75	2.5
Plot 8	Muriate of potash	.5	.75	------

In the spring of 1913 another experiment was begun on the same farm in a nine-year-old block of Grimes, Ben Davis, and York Imperial. The plots were arranged to run crosswise of the varieties so that each plot contained five trees of each of the three varieties. The plots were arranged similarly to the young Rome series but two more checks were added. The following was their arrangement:

Plots	Treatment	Lbs. per Tree
Plot 1	Check	----
Plot 2	Nitrate of soda Acid phosphate, 16%	1.5 2.5
Plot 3	Nitrate of soda Muriate of potash	1.5 1.0
Plot 4	Nitrate of soda Acid phosphate, 16% Muriate of potash	1.5 2.5 1.0
Plot 5	Acid phosphate, 16% Muriate of potash	2.5 1.0
Plot 6	Check	----
Plot 7	Nitrate of soda	1.5
Plot 8	Acid phosphate, 16%	2.5
Plot 9	Muriate of potash	1.0
Plot 10	Check	----

The use of potash was discontinued in 1916 and thereafter. Tillage, followed by medium to poor clover cover crops, was practiced each year. The soil is also a Holston silt loam but is a little more gravelly than in the block of young Rome trees and is a little lower in fertility. The trees were in good condition and making a satisfactory but not heavy growth when the experiment was started.

The fourth experiment reported in this bulletin was not begun until 1917, and represents a simple test of the value of nitrate of soda in restoring vitality to young bearing trees on the verge of starvation and on an extremely poor but cultivated soil. It also was located at Sleepy Creek in another orchard managed by Mr. Fulton. The plots were arranged in a series running from low to high nitrate applications accompanied by suitable checks. The soil in this case belongs to the Upshur gravelly silt loam and is very low in fertility as indicated by the following analysis of a sample *taken on the same farm but representing a somewhat more fertile section as judged by the growth of cover crops.

* From W. Va. Exp. Sta. Bul. 168.

	Pounds per 2,000,000 Lbs. Surface Soil (Plow Depth)				
	Nitrogen	Phosphorous	Potassium	Carbon	Lime Requirement
Upshur gavelly silt loam ______	1550	648	30120	16640	0

EFFECTS OF FERTILIZATION ON TREE VIGOR

We shall deal with the effects of fertilizer applications from all the experiments grouped under two general heads and considered from two standpoints: effect upon tree growth and vigor, and effect upon actual production or fruitfulness. The first to be studied is the tree growth in the several orchards.

REYNOLDS ORCHARD (OLD ROME TREES)

Undoubtedly the most accurate index of a tree's growth may be found in the year-by-year increase in circumference of the trunk, provided that care is exercised so as to make the measurements at the same point on the trunk each year. There is value in other measurements such as longitudinal twig and shoot growth, diameter of shoot growths, etc., but the writers believe that the growth of the trunk furnishes the safest criterion upon which to judge the vegetative development to a tree.

Unfortunately the trees of this block were not measured at the beginning of the experiment and no growth measurements of any kind were taken until 1916. In Table I, we find an indication of the behavior of the several plots after six years of treatment.

Fig. 1.—Check Plot Showing Absence of Clover After Seeding.

TABLE I.—Effect of Fertilization on Trunk Circumference (Reynolds Orchard).

Plot	Treatment	Average Circum. of Trunk in Inches			Average of Duplicated Plots in Inches	Gross Superiority Over Checks in Inches	Increase in 3 Years in Inches	Plots	Average Increase of Duplicated Plots in In.	Increase Over Gain Made by Checks in In.
		1916	1918	1919						
1	Discarded									
2	Nit. Phos. Pot.	35.16	37.48	38.27	37.79	4.03	3.11	2, 7	3.21	1.23
3	Nit. Phos.	34.25	36.77	37.76	38.19	4.43	3.51	3, 8	3.31	1.33
4	Nit. Pot.	33.4	35.39	36.14	35.87	2.11	2.74	4, 9	2.67	.69
5	Check	32.25	33.65	34.31	33.76	------	2.06	5, 10	1.98	------
6	Pot. Phos.	31.6	33.39	33.66	33.66	−.10	2.06	6	2.06	.08
7	Nit. Phos. Pot.	34.0	36.43	37.32			3.32			
8	Nit. Phos.	35.5	37.6	38.62			3.12			
9	Nit. Pot.	33.0	35.25	35.61			2.61			
10	Check	31 3	32.75	33.21			1.91			

Manifestly it would be unsafe to assume that all the trees in the experiment were the same size at the beginning, since only precise measurements could have established this premise. It is, however, safe to assume that they were practically the same size, otherwise they would have presented an appearance so lacking in uniformity that they would have been discarded for experimental purposes. Proceeding from this assumption it can be seen by inspection of Table I that during the nine years of treatments the trees to which nitrogen was added have increased in circumference from two to four inches more than have the check plots or Plot 6 which received phosphorus and potassium but no nitrogen. This assertion is substan-

Fig. 2.—Plot Received Nitrogen and Potassium, But No Clover Grew After Seeding.

tiated by the records of measurements made from 1916 to 1919 when a clear cut gain in circumference was made by the nitrogen plots over the checks. It is clear that phosphorus contributed toward this gain, for the nitrogen plots to which it had been added showed approximately double the gain of the nitrogen-potash plot. It will be recalled that potash applications were discontinued for the last four years so that the influence of this material cannot be calculated. Its effects appeared to be negative prior to 1916.

Although no growth measurements were taken during the first five years we could, fortunately, in 1916 measure the annual extension of twig growth for the preceding five years and thus from the trees' own records read the history of their progress. Since, from the standpoint of growth, there seemed to be only two general groupings of plots, nitrated and non-nitrated, we selected 2 and 5 as typical of the groups they represented and made careful measurements of ten branches from each tree in these plots.

TABLE II.—Effect of Fertilization on Terminal Twig Growth (Reynolds Orchard).

Plots	Treatment	Length of Growth in Inches 1911	1912	1913	1914	1915	1916	1917	1918	1919	Average for 9 Years
2	Nit. Phos. Pot.	4.79	4.80	6.01	13.89	14.27	13.43	15.48	10.2	7.16	9.89
5	Check	4.04	4.14	4.96	10.30	11.10	9.54	8.34	6.2	3.34	6.88
	Gain Over Check	.75	.66	1.05	3.59	3.17	3.89	7.14	4.0	3.82	3.01

Fig. 3.—Both Rows Received Nitrogen. The One on the Left Was Treated With Phosphorous and the One on the Right With Potassium. Clover Followed Phosphorus.

The records here given are interesting from two standpoints. First, they show that the fertilized plot began at once to creep steadily, if slowly, ahead of the other and toward the close of the period was making from four to seven inches longer growths than was the check. The second point of interest is found in the yearly record of the check plot where with merely good orchard management including cultivation, pruning, and spraying, it practically doubled its annual growth.

TABLE III.—Effect of Fertilization on Terminal Twig Growth (1918 and 1919, Reynolds Orchard)

Plots	Treatment	Average Growth in Inches 1918	Length 1919	Two-Year Average in Inches	Duplicate Plots	Average Growth of Duplicate Plots in In's.	Average Gain Over Check in Inches
1	Discarded						
2	Nit. Phos. Pot.	10.2	7.16	8.68	2, 7	8.55	3.72
3	Nit., Phos.	9.7	7.36	8.03	3, 8	8.31	3.48
4	Nit., Pot.	9.6	5.68	7.64	4, 9	7.81	2.98
5	Check	6.2	3.34	4.77	5, 10	4.83	
6	Phos., Pot.	7.3	4.60	5.95	6	5.95	1.12
7	Nit., Phos., Pot.	9.8	7.06	8.43			
8	Nit., Phos.	10.2	6.99	8.59			
9	Nit., Phos.	9.3	6.66	7.98			
10	Check	6.2	3.59	4.89			

To supplement Table II additional records of twig growth were made in 1918 and 1919. These records correlate well with others in showing marked influence of nitrogen and appreciable benefits from phosphorus. It is quite possible that the apparent phosphorus benefits are indirectly due to the effect of this element upon the early cow pea cover crops and to the clover sod in 1918 and 1919. It will be observed in Figures 2 and 3 that it was impossible to get a stand of clover upon any plot that had not been treated with phosphorus.

A further record of effects of fertilizers upon vegetative development is found in Table IV where the diameter of the head or spread of branches is taken as a rough indication of bearing capacity.

TABLE IV.—Effect of Fertilization on Size of Tree (Reynolds Orchard)

Plots	Treatment	Average Diameter of Head in Feet		Incr. in Diam. of Head in 2 Years, in Feet	Average 2-Year Incr. of 2 Dup. Plots in Feet	Average 2-Year Incr. Over Check in Feet	Average Size of Trees in Duplicate Plots After 9 Yrs. Fert. in Feet	Gain Over Check, in Feet
		1916	1918					
1	Discarded							
2	Nit., Phos., Pot.	20.91	22.75	1.84	2.51	1.27	22.46	2.69
3	Nit., Phos.	20.12	22.77	2.65	2.65	1.41	23.25	3.47
4	Nit., Pot.	20.52	21.37	.85	1.57	1.33	21.41	1.63
5	Check	18.92	19.34	.42	1.24		19.78	
6	Phos., Pot.	18.25	19.79	1.54	1.54*	1.30*	19.79*	.01
7	Nit., Phos., Pot.	19.00	22.17	3.17				
8	Nit., Phos.	21.08	23.72	2.64				
9	Nit., Pot.	19.16	21.45	2.29				
10	Check	18.16	20.22	2.06				

* Single plot average, duplicate plot No. 1 discarded.

This table also indicates that the nitrogen-fed trees were increasing in size and presumably in bearing capacity more rapidly than the others, especially where phosphorus also was used. At the close of the period these plots had a spread of branches approximately three feet greater than the checks and phosphorous-potassium plots.

Fulton Orchard (Young Rome Trees)

During the seasons of 1911 and 1912, the young trees in this experiment were carefully observed but absolutely no difference that might be ascribed to the fertilizer treatment could be seen between the plots. Beginning in 1913 measurements were taken of the natural growth of each tree to see whether or not there might be slight differences not readily distinguishable by the eye alone.

In Table V is shown a summary of the average trunk circumference in each plot and the total gain in the seven years. Every tree in the experiment was measured at a certain point each year to secure these figures which represent the size of the trunk at the close of the season indicated.

TABLE V.—Effect of Fertilization on Trunk Circumference (Young Rome)

Plots	Treatment	Circumference of Trunk in Inches							Increase in Inches of Circum. in 6 Years	Gain in Inches Over Check
		1913	1914	1915	1916	1917	1918	1919		
1	Nit., Phos.	4.10	5.92	7.87	9.15	11.53	13.86	14.85	10.75	1.83
2	Nit., Pot.	4.11	5.78	7.35	8.27	9.70	12.10	13.91	9.80	.88
3	Nit., Phos., Pot.	4.85	6.40	8.52	9.61	11.75	14.58	16.55	11.70	2.78
4	Phos., Pot.	4.64	6.17	7.76	8.48	9.96	12.07	14.39	9.75	.83
5	Check	3.84	5.58	7.12	7.87	9.20	11.20	12.76	8.92	
6	Nit.	4.36	6.05	7.70	8.50	9.07	12.05	13.72	9.36	.44
7	Phos.	4.67	6.44	8.25	9.08	10.80	12.80	14.41	9.74	.82
8	Pot.	5.20	6.70	8.60	9.27	10.67	12.55	14.12	8.92	0.00

These data seem to indicate that during the seven-year period the nitrogen and phosphorus treatments were of benefit especially when used in combination, and that potassium was wholly ineffective It must be borne in mind, however, that even the best gains are not very impressive when spread over a seven-year period. When considered in connection with Tables VI and VII the conclusions are still less obvious.

To secure the data on the length of the annual shoot or twig growth, ten normal shoots were measured on each tree and their lengths averaged to secure the average for the tree. The chance for error is unquestionably greater here than in measuring trunks but where there are decided differences of growth this method is reasonably accurate. It will be observed that the checks trees made a satisfactory growth and the increases made by the treated plots were for the most part comparatively slight.

TABLE VI.—Effect of Fertilization on Shoot Growth (Young Rome)

Plots	Treatment	Average Growth in Inches 1914	1915	1916	1917	1918	1919	Average Shoot Growth in Inches for 6 Yrs.	Increase in Inches Over Check
1	Nit., Phos.	22.47	38.80	35.87	11.46	12.98	13.38	22.49	1.59
2	Nit., Pot.	23.14	32.40	34.82	14.67	17.44	14.49	22.82	1.92
3	Nit., Phos., Pot.	28.84	37.80	36.00	15.20	15.93	13.63	24.56	3.66
4	Phos., Pot.	23.31	30.83	28.94	16.27	15.54	13.10	21.33	.43
5	Check	24.76	31.04	27.78	15.06	13.82	12.97	20.90	
6	Nit.	23.46	33.58	35.36	16.15	17.54	13.67	23.29	2.39
7	Phos.	22.41	34.26	29.44	13.84	14.20	12.59	21.12	.22
8	Pot.	22.00	36.20	31.29	16.39	13.77	12.01	21.94	1.04

It will be observed that wherever nitrogen entered the combination a small increase in growth resulted. The table does not check fully with Table V in that here are apparently additional gains due to both phosphorus and potassium. The fact that Plot 4 where these two elements appear in combination falls short of Plot 8 where potassium is used alone leads one to think that the variation is accidental rather than due to the treatment.

For three years records of the diameter of the annual twig or shoot growth were taken on the assumption that vigorous trees would put out a strong, stocky growth and that in weaker trees the growth would be more willowy.

TABLE VII.—Effect of Fertilization on Diameter of Shoot Growth (Young Rome)

Plots	Treatment	Diam. of Shoot Growth in Inches 1913	1914	1915	Average Diam. of Shoot Growth in Inches, 3 Years	Increase in Inches Over Checks
1	Nit., Phos.	.291	.307	.338	.312	.063
2	Nit., Pot.	.276	.280	.298	.281	.032
3	Nit., Phos., Pot.	.281	.314	.315	.303	.054
4	Phos., Pot.	.222	.245	.278	.248	.001
5	Check	.236	.251	.262	.249	
6	Nit.	.280	.320	.293	.297	.048
7	Phos.	.240	.249	.288	.259	010
8	Pot.	.232	.273	.318	.274	025

This table shows a slight but rather consistent increase wherever nitrogen was used either alone or in combination. The three tables taken together rather indicate some vegetative stimulation from nitrogen and a less pronounced effect from phosphorus, but the benefits from potassium noted prior to 1916 are altogether lacking.

Anyone visiting the orchard after nine years of fertilization will have great difficulty in distinguishing one plot from another. At times during the last five years the nitrated blocks have displayed a healthier foliage with leaves somewhat larger and darker than those on the other plots. Most assuredly the slight increase in vigor and size of these young trees is not sufficient to jusify the use of fertilizers.

Fulton Orchard (Young Bearing Trees)

Careful growth measurements were taken from the beginning of this experiment with the young bearing apples. The trunks were measured at the beginning of the test and each year since. As each plot contains three varieties, Grimes, Ben Davis, and York Imperial, it really makes a triplicate series of plots of five trees each. Since there is not a consistent reaction to the several treatments from all three varieties the data are rather fully shown and then summarized by throwing the three series together.

TABLE VIII.—Effect of Fertilization Upon Trunk Circumference

Variety—Grimes

Treatment	Circumference of Trunk in Inches 1912	1913	1914	1915	1916	1917	1918	1919	Total Increase in Inches	Increase in Inches Over Average of All Checks
Check	11.27	12.16	13.62	16.5	17.37	19.06	20.00	20.84	9.57	
Nit., Phos.	9.82	11.00	13.5	16.17	17.37	19.42	21.75	22.75	12.93	3.03
Nit., Pot.	10.69	11.84	13.19	15.75	16.53	18.00	19.50	20.59	9.90	0.00
Nit., Phos., Pot.	8.43	10.06	11.19	13.91	14.84	16.31	18.00	19.37	10.94	1.04
Phos., Pot.	11.11	13.12	14.50	17.85	18.55	20.00	21.65	22.72	11.61	1.71
Check	10.90	12.06	13.53	15.93	17.22	18.68	20.06	21.09	10.19	
Nit.	10.35	12.06	13.16	15.91	16.81	18.37	19.68	21.00	10.65	.75
Phos.	10.56	11.82	12.90	15.72	16.60	18.70	19.00	19.85	9.29	–.61
Pot.	11.16	11.65	12.85	15.25	16.22	17.40	18.50	19.35	8.19	–1.71
Check	10.01	11.65	12.77	15.35	16.60	17.85	19.00	19.97	9.96	
Average of all Checks	10.72	11.95	13.30	15.92	17.06	18.53	19.68	20.63	9.90	

Variety—Ben Davis

Treatment	1912	1913	1914	1915	1916	1917	1918	1919	Total Increase in Inches	Increase in Inches Over Average of All Checks
Check	9.86	10.15	11.25	13.95	14.52	15.10	17.15	18.47	8.61	
Nit., Phos.	11.15	12.15	13.11	14.45	17.57	18.70	20.95	22.57	11.42	1.58
Nit., Pot.	11.32	12.22	13.18	16.31	17.37	18.93	20.68	22.85	11.53	1.69
Nit., Phos., Pot.	11.64	13.47	14.60	17.22	18.22	19.75	21.20	23.15	11.51	1.67
Phos., Pot.	9.11	10.10	11.65	14.65	16.02	17.45	19.10	20.92	11.81	1.97
Check	10.88	12.55	13.82	17.27	18.47	19.55	21.30	22.42	11.54	
Nit.	9.70	12.12	13.52	16.47	17.80	19.75	21.45	23.20	13.50	3.66
Phos.	9.86	12.02	13.40	16.84	17.77	19.50	20.65	22.25	12.39	2.55
Pot.	11.62	13.02	14.00	16.87	18.10	19.45	20.95	21.87	10.25	.41
Check	11.82	13.32	14.45	17.02	17.9	18.95	20.15	21.21	9.39	
Average of all Checks	10.85	12.00	13.17	16.09	16.96	17.86	19.53	20.70	9.84	

Variety—York Imperial

Treatment	1912	1913	1914	1915	1916	1917	1918	1919	Total Increase in Inches	Increase in Inches Over Average of All Checks
Check	12.25	14.07	15.65	18.60	19.90	21.85	23.70	24.35	12.10	
Nit., Phos.	9.74	11.90	13.35	16.35	17.77	19.90	22.05	23.32	13.58	1.83
Nit., Pot.	11.27	12.67	13.95	16.87	18.00	20.20	22.50	23.60	12.33	.58
Nit., Phos., Pot.	11.66	13.20	14.52	17.40	18.35	19.85	22.75	23.90	12.24	.49
Phos., Pot.	9.80	11.50	13.07	15.12	16.97	18.45	19.85	20.62	10.82	–.93
Check	13.12	15.27	17.22	20.42	21.70	23.65	25.25	26.20	13.08	
Nit.	11.20	12.90	14.26	17.22	18.31	20.50	22.18	24.00	12.80	1.05
Phos.	9.35	11.07	12.00	14.95	15.77	16.90	18.25	19.37	10.02	–1.73
Pot.	9.11	10.77	11.75	14.35	15.12	16.30	17.40	18.25	9.14	–2.61
Check	9.70	11.28	12.56	14.78	15.94	17.50	18.69	19.78	10.08	
Average of all Checks	11.69	13.54	15.14	17.93	19.18	21.00	22.54	23.44	11.75	

TABLE IX.—Effect of Fertilization on Trunk Circumference (Grimes, Ben Davis, York Imperial)

Summary of 8 Years' Work

Plots	Treatment	Total Increase of Trunk in Inches				Increase in Inches Over and Above All Checks	Increase in Inches Over Nearest Check
		Grimes	Ben Davis	York Imperial	All Varieties		
1	Check	9.57	8.61	12.10	10.09		
2	Nit., Phos.	12.93	11.42	13.58	12.64	2.14	2 55
3	Nit., Pot.	9.90	11.53	12.33	11 25	.75	1.16
4	Nit., Phos., Pot.	10.94	11.51	12.24	11.56	1.06	−.04
5	Phos., Pot.	11.61	11.81	10.82	11.41	.91	−.19
6	Check	10.19	11.54	13.08	11.60		
7	Nit.	10.65	13.50	12.80	12.31	1.81	.71
8	Phos.	9.29	12.39	10.02	10.56	06	−1.04
9	Pot.	8.19	10.25	9.14	9.19	−1.31	−.62
10	Check	9.96	9.39	10.08	9.81		
	Average of all Three Checks	9.90	9.84	11.75	10.50		

It is clear that there is no conspicuous or outstanding gain for any material or combination of materials. The two highest plots of the Ben Davis series are among the lowest in the other two. Plot 2 carrying nitrogen and phosphorus has ranged high all the way through and ranks highest in the summary but it is difficult to understand why Plot 4 has not done as well since the potassium was left out of its combination after the third year. As a matter of fact we should have expected it to do better since it is located nearer the middle of the block where the check indicates that the soil conditions are slightly better than on the edges. It might be considered that there is a slight theoretical benefit from nitrogen since every plot to which it was applied exceeded the checks in the summary and in all but one instance in the detailed tables. This gain is so slight, however, that it comes well within the range of experimental error and should probably be greatly discounted.

When we consider the effects of the treatments upon the length of the twig growth we are still confused. It is possible that nitrogen should be credited with a small gain since it excelled in all but one instance where it was applied and corroborated exactly its record with trunk increases. It is a fact, however, that if one should go to the orchard it would be utterly impossible to distinguish one plot from another. In other words, the differences are so slight that

Plot 2, 1½ Lbs. Nitrate Soda
2½ Lbs. Acid Phos. per Tree

Plot 5, 2½ Lbs. Acid Phos.
1 Lb. Muriate Pot. per Tree

Plot 6, Check

Plot 7, 1½ Lbs. Nitrate Soda per Tree.

Fig. 4.—These Pictures Were Taken Oct. 6, 1919. At This Time the Trees Were 15 Years Old And Had Been Fertilized For 6 Years.

they were detected only after measuring and averaging 9,000 twigs during six of the seven years*.

TABLE X.—Effect of Fertilization on Shoot Growth of Trees

Variety—Grimes

Treatment	Plot No.	Growth in Inches 1913	1914	1916	1917	1918	1919	6-Year Average in Inches	Inches Increase Over Average of Checks
Check	1	13.80	10.60	18.20	9.00	6.37	6.22	10.69	
Nit., Phos.	2	17.23	16.73	22.26	10.70	8.83	7.46	13.86	2.83
Nit., Pot.	3	9.07	9.60	18.25	9.75	8.30	8.87	10.64	−.39
Nit., Pot., Phos.	4	11.57	8.61	23.20	12.30	9.75	9.72	12.52	1.49
Phos., Pot.	5	14.86	13.31	21.52	10.06	7.06	7.14	12.32	1.29
Check	6	15.37	11.37	21.85	9.70	7.65	6.07	12.00	
Nit.	7	13.62	11.30	21.30	11.27	9.85	8.92	12.71	1.68
Phos.	8	10.50	10.26	19.24	9.70	6.28	6.16	10.35	−.68
Pot.	9	9.74	10.04	18.64	8.88	5.62	4.62	9.59	−1.44
Check	10	7.89	10.38	20.44	10.92	6.00	6.82	10.41	
Ave. all Checks	1, 6, 10	12.35	10.78	20.16	9.87	6.65	6.37	11.03	

Variety—Ben Davis

Treatment	Plot No.	1913	1914	1916	1917	1918	1919	6-Year Average in Inches	Inches Increase Over Average of Checks
Check	1	11.20	9.15	15.64	10.7	7.6	6.00	10.05	
Nit., Phos.	2	12.04	10.38	20.56	11.42	10.00	7.10	11.91	1.64
Nit., Pot.	3	10.10	9.68	18.90	11.5	10.40	9.70	11.71	1.44
Nit., Pot., Phos.	4	11.60	10.55	19.36	10.82	10.26	9.14	11.95	1.68
Phos., Pot.	5	11.12	11.07	17.76	10.42	11.64	8.18	11.69	1.42
Check	6	10.5	11.76	19.68	10.82	8.02	5.70	11.08	
Nit.	7	11.46	12.45	22.68	11.6	10.58	8.58	12.89	2.62
Phos.	8	11.18	11.92	21.16	11.96	8.58	6.05	11.81	1.54
Pot.	9	8.25	10.86	19.20	10.16	7.32	4.44	10.04	−.23
Check	10	7.22	10.35	16.84	10.68	7.28	5.80	9.69	
Ave. all Checks	1, 6, 10	9.64	10.41	17.38	10.73	7.63	5.83	10.27	

Variety—York Imperial

Treatment	Plot No.	1913	1914	1916	1917	1918	1919	6-Year Average in Inches	Inches Increase Over Average of Checks
Check	1	17.78	14.82	20.64	10.36	6.16	5.50	12.54	
Nit., Phos.	2	15.06	13.02	22.84	12.14	7.44	7.42	12 98	1.84
Nit., Pot.	3	14.28	11.76	21.48	11.72	8.46	9.84	12.92	1.78
Nit., Pot., Phos.	4	11.56	11.34	21.28	11.76	7.6	9.00	12.09	.95
Phos., Pot.	5	12.08	14.1	19.32	9.66	6.4	5.04	11.10	.04
Check	6	13.14	15.73	19.16	9.96	5.1	4.16	11.21	
Nit.	7	10.85	11.7	22.5	11.3	6.25	7.70	11.71	.57
Phos.	8	8.82	10.52	17.04	9.66	5.00	4.28	9.22	−1.92
Pot.	9	8.34	9.61	16.88	9.48	4.6	4.54	8.91	−2.23
Check	10	9.17	11.11	18.1	9.57	4.9	5.25	9.68	
Ave. all Checks	1, 6, 10	13.36	13.88	19.30	9.96	5.38	4.97	11.14	

* Length of growth was not taken in 1915 on account of an early pruning given the block in that year.

TABLE XI.—Effect of Fertilization on Annual Twig Growth of Grimes, Ben Davis, and York Imperial (For 6 Years)

Plots	Treatment	6-Year Average Twig Growth in Inches				Increase in Growth Over Average of Checks in Inches
		Grimes	Ben Davis	York Imperial	All Three Varieties	
1	Check	10.69	10.05	12.54	11.09	
2	Nit., Phos.	13.86	11.91	12.98	12.91	2.10
3	Nit., Pot.	10.64	11.71	12.92	11.75	.94
4	Nit., Phos., Pot.	12.52	11.95	12.09	12.18	1.37
5	Phos., Pot.	12.32	11.69	11.10	11.70	89.
6	Check	12.00	11.08	11.21	11.43	
7	Nit.	12.71	12.89	11.71	12.43	1.62
8	Phos.	10.35	11.81	9.22	10.46	–.35
9	Pot.	9.59	10.04	8.91	9.51	–1.30
10	Check	10.41	9.69	9.68	9.92	
	Average all Checks	11.03	10.27	11.14	10.81	

To sum up briefly the effects of fertilizers upon the production of wood growth in the three experiments thus far described we can say that nitrogen is the only element of plant food that has shown positive effects worth considering, except in some cases phosphorus in combination with nitrogen has given indications of benefits but these indications are not sufficiently marked to warrant positive deductions. It was only in the old and starved orchard that the gains from nitrogen were sufficiently marked to justify from an economic standpoint the use of this material as a fertilizer. Young orchards under cultivation making a fair growth have not responded to any fertilizer application sufficiently to justify its use in increasing the wood growth and size of the tree.

Effects of Fertilization On Foliage

In the Reynolds orchard one can tell the plots which have received nitrogen as far as they can be seen because of the darker color of the foliage. The check rows and those receiving only phosphorus and potassium carry a sparse, thin, yellowish foliage with leaves scarcely more than half the size of those from the nitrated plots. In the younger orchards these differences are not so clearly apparent and appear only in a poor growing season such as was 1917. During that year the Reynolds orchard was very heavily infected with cedar rust (*Gymnosporangium juniperi-virginianae*, Schweinitz) and the Fulton orchard with leaf spot (*Sphaeropsis malorum*, Peck.) The larger and greener leaves in the nitrate plots were as badly infected as were those in the checks but appeared to be much more resistant to the ravages of the diseases after infection actually occurred. The same number of spots that would cause a leaf to fall in a non-nitrogen plot would not seriously affect the larger and stronger leaf in the nitrogen-fed area.

EFFECTS OF FERTILIZATION ON FRUITFULNESS

Our one object in a fruit tree is to produce fruit. In the final analysis the practical grower is going to justify his use of commercial fertilizers by their effect on the amount of fruit produced, regardless of their effects upon leaf color, twig growth, or size of tree. In studying the question of fruitfulness we shall consider two things: amount of bloom produced and amount of fruit harvested. The bloom indicates a disposition upon the part of the tree to produce fruit and in some respects might be a better index of the value of a fertilizer than would the actual fruit produced, for sometimes the crop is affected subsequent to blooming by frosts, storms, insects, or disease. As a general proposition, however, the fruit is of greater interest since fertilizers are supposed by many to affect the power of a tree to set and develop fruit after the bloom has been produced.

Reynolds Orchard (Old Rome Trees)

Blooming records were not taken in this orchard prior to 1915 and were missed in 1917 because of pressure of other work. The accompanying table is of interest in that it shows a small but uniform increase in percent of bloom in favor of the nitrogen plots and a still smaller increase in phosphorus-potassium plot. It must be borne in mind that nowhere in the bulletin, except in Table XIII, do blooming records represent actual numbers of flowers but rather the percent of a full bloom averaged from each tree in the plot. It is clearly evident that two trees with the same percent of bloom might bear widely different crops if one tree is larger than the other and has a greater bearing capacity. The records of bloom is an attempt to measure a tree's intention to produce fruit rather than its capacity.

TABLE XII.—Effect of Fertilization On Percent of Bloom (Reynolds Orchard)

Plot	Treatment	Percent of Bloom 1915	1916	1918	1919	Average	Average Dupl. Plots
2	Nit., Phos., Pot.	86.3	15	95.9	20.2	56.3	61.9
3	Nit., Phos.	88.3	18	86.7	23.1	54.0	61.5
4	Nit., Pot.	84.1	50	90.4	20.7	61.3	61.5
5	Check	80.4	40	71.	12.8	51.1	55.0
6	Phos., Pot.	88.6	45	82.3	17.4	58.3	58.3
7	Nit., Phos., Pot.	86.3	75	89.5	19.5	67.6	
8	Nit., Phos.	82.5	75	93.3	25.	69.0	
9	Nit., Pot.	82.5	75	72.1	16.7	61 6	
10	Check	84.5	75	67.3	8.2	58.8	

To supplement the records of bloom in 1918 the actual set was recorded for a few hundred flowers in each plot. The single year's record is of course not conclusive and is given here merely for what it is worth. The same data will appear later in a discussion of the value of early and late applications of fertilizers.

TABLE XIII.—Effect of Fertilization On Set of Fruit (1918)

Plots	Treatment	Blossoms Counted	Number Set	Plots	Average No. Counted Dupl. Plots	Average No. Set in Dupl. Plots	Percent Set
2	Nit., Phos., Pot.*	720	42	2, 7	659	34	5.16
3	Nit., Phos.	623	40	3, 8	645	43	6.66
4	Nit., Pot.*	668	21	4, 9	569	18.5	3.25
5	Check	676	24	5, 10	551	17.	3.08
6	Phos., Pot.*	612	18	6	612	18	2.94
7	Nit., Phos., Pot.*	597	26				
8	Nit., Phos.	667	46				
9	Nit., Pot.*	469	16				
10	Check	425	10				

* No potash was applied to these plots after 1915.

There seems to be some indication that the combination of nitrogen and phosphorus has been effective in increasing the set of fruit but that either of the elements when used alone is ineffective. This could hardly be accepted as a conclusion since the test covers only one year and the effect of earlier applications of potash can only be assumed to be inactive.

We will proceed now to the record of the fruit crops for the nine years. It should be said at the outset that the Reynolds orchard is made up of a solid planting of Rome and that this variety, in common with most others, is partially self sterile. For this reason the yields have been light in this orchard except in seasons favorable to pollination and fertilization. No crop was borne in 1911, the first year of the experiment, and in 1913 the crop was destroyed by a late freeze.

TABLE XIV.—Effect of Fertilization On Total Yield of Fruit (Reynolds Orchard)

Plots	Treatment	Yields in Bushels							Total for 7 Years in Bu.	Ave. Total Dup. Plots in Bu.	Gain in Bus. Over Checks
		1912	1914	1915	1916	1917	1918	1919			
2	Nit., Phos., Pot.	57.3	31.6	127.4	34.0	74.7	131.4	96.25	552.65	512.02	227.37
3	Nit., Phos. ------	42.0	16.8	128.0	31.7	92.5	145.5	124.25	580.75	609.07	324.42
4	Nit., Pot. ------	49.5	14.5	110.5	51.4	59.5	137.5	73.00	495.90	435.20	150.55
5	Check ---------	42.0	15.5	87.5	40.0	24.5	54.8	46.25	310.55	284.65	
6	Phos., Pot. ----	41.7	12.8	82.4	46.0	24.7	54.5	34.25	296.45	*296.45	*11.80
7	Nit., Phos., Pot.--	49.1	19.1	92.7	65.7	66.5	105.8	72.50	471.40		
8	Nit., Phos. ----	66.0	18.3	124.3	83.2	90.3	158.8	96.50	637.40		
9	Nit., Pot. ------	46.5	9.3	78.8	48.3	48.6	91.5	51.50	374.50		
10	Check ---------	39.3	9.6	71.2	45.3	22.6	39.5	31.25	258.75		

* Only plot 6 represented in this record.

It is seen in Table XIV that the yields of the plots correlate very closely with the records of tree growth. In other words it is clear that nitrogen has increased the yield and that when phosphorus has been added the gain is somewhat further amplified. Potassium when used early in the experiment was apparently of no benefit. The crops in this orchard have been so light that the differences in relative yield between plots ought not to be regarded too seriously for the low yields have made possible a high probable error. For instance, there is no reason why Plots 3 and 8 should have so heavily outyielded Plots 2 and 7. We at once raise the question whether the increase is sufficient to justify the cost of fertilization. Table XV will throw some light on this point.

TABLE XV.—Average Amount and Cost of Fertilizers* Used Per Plot in Nine Years (Reynolds Orchard)

Plots	Lbs. Nitrate of Soda	Lbs. 16% Acid Phosphate	Lbs. Muriate of Potash**	Total Cost in Dollars	Cost in Cents per Bushel Increase
2, 7	875	2625	300	89.26	39.2
3, 8	875	2625		78.76	24.2
4, 9	875		300	49.88	33.1
5, 10					
6		2625	300	49.88	422.7

* Computed upon a basis of nitrate of soda, $90.00 per ton; 16% acid phosphate, $30.00 per ton; and muriate of potash $70.00 per ton applied to the orchard. The potash price is purely fictitious and represents what may be the normal price when war conditions have ceased to exist.

** No potash was applied after the fifth year.

It is evident from Table XV that even the most expensive combination making a complete fertilizer could have been applied at a profit at present prices of fruit although the margin of profit might have been narrow. The writers are of the opinion that had it been possible to supply suitable pollination for the block by introducing other varieties as pollenizers the yields would have been greatly increased and the profits from the applications correspondingly greater.

It is of interest to note the relation of the fertilizer treatments in regard to size of fruits. In Table XVI the crops for six years have been divided into three grades based upon size alone. From this table it is clear that the plots divide themselves into the two general groups we have seen more or less clearly before; that is, nitrogen and non-nitrogen plots. In the former group we find more than 70 percent of the crop running over 2½ inches in diameter as against 60 percent of the latter group. This is balanced to some extent in the 2¼-inch to 2½-inch group while there seems to be little or no difference in the percentage of culls from any of the plots.

TABLE XVI.—Effect of Fertilization On Size of Fruit* (Reynolds Orchard)

Plots	Treatment	Bushels 2½" Up	Bushels 2¼" to 2½"	Bushels 0 to 2¼"	Total Crop In Bu. For 6 Years
1	Discarded				
2	Nit., Phos., Pot	318.35	75.30	42.70	
3	Nit., Phos.	384.80	61.20	41.50	
4	Nit., Pot.	266.30	78.65	28.20	
5	Check	154.85	72.15	22.30	
6	Phos., Pot.	140.10	58.10	22.60	
7	Nit., Phos., Pot.	265.45	56.50	28.25	
8	Nit., Phos.	382.30	85.80	50.25	
9	Nit., Pot.	223.60	35.90	20.90	
10	Check	126.20	46.10	18.90	
2, 7	Nit., Phos., Pot.	583.80	131.80	70.95	786.55
3, 8	Nit., Phos.	767.10	147.00	91.75	1005.85
4, 9	Nit., Pot.	489.90	124.55	49.10	663.55
5, 10	Check	281.05	118.25	41.20	440.50
6**	Phos., Pot	280.20	116.20	45 20	441.60
		Percent 2½" Up	Percent 2¼" to 2½"	Percent 0 to 2¼"	
2, 7	Nit., Phos., Pot.	74.22	16.76	9.02	
3, 8	Nit., Phos.	76.26	14.61	9.12	
4, 9	Nit., Pot.	73.83	18.77	7.39	
5, 10	Check	63.45	26.84	9.35	
6	Phos., Pot.	63.45	26.31	10.23	

* Crops of 1914, 1915, 1916, 1917, 1918, and 1919.
**Amount doubled to make comparable to duplicate plots.

It has long been claimed that color of fruit could be affected beneficially or adversely by proper attention to fertilization. In recent years the tendency has been to ascribe intensity of color on red fruits to sunshine. As a result of the past nine years' work with peaches and apples in West Virginia the writers are thoroughly convinced that color development is purely a question of light and sunshine. It is frequently indirectly affected by fertilizers when a rank growth from nitrogen-fed trees will shade the fruits so that the color does not develop. This involves merely the necessity for systematic pruning. In the Reynolds orchard the nitrate plots have always produced fruits less highly colored than those of the other plots although as a rule this color developed satisfactorily if they were allowed to hang on the trees a little later or when the pruning was properly done, but in no case did the color quite equal that of the non-nitrogen plots. In 1916 and 1917 the green fruit from the nitrogen plots was so plentiful that it was graded out by itself. During these two years the orchard had been unpruned and the leaves in the nitrate plots were very dense. In Table XVII one can see the results in this extreme case of undercoloring. In grading the fruits all apples with less than one-fourth the surface colored were classed as green. It seems that about 25 percent less of the crop on the nitrogen plots was well colored than on the non-nitrogen plots.

TABLE XVII.—Effect of Fertilization On Color (Reynolds Orchard)

Plots	Treatment	Bushels Well Colored Fruit, 1916, 1917	Bushels Green Fruit, 1916, 1917	Duplicate Plots		Percent Well Colored Fruit,
				Bushels Well Colored Fruit	Bushels Green Fruit	
1	Discarded					
2	Nit., Phos., Pot.	52.1	35.2	58.9	40.1	59.4
3	Nit., Phos.	55.2	42.0	66.7	53.8	53.7
4	Nit., Pot.	45.3	27.3	47.7	37.1	56.2
5	Check	43.5	6.2	41.3	8.9	82.2
6	Phos., Pot.	46.6	10.2	46.6	10.2	82.0
7	Nit., Phos., Pot.	62.7	45.0			
8	Nit., Phos.	78.2	65.5			
9	Nit., Pot.	50.0	46.8			
10	Check	39.1	11.5			

Prior to 1916 no attention had been paid to drop apples as it was assumed that the amount in each plot would be proportionate to the total quantity of fruit in each plot. Beginning in 1916, however, the drops were gathered separately and a record was made of the amount from each plot. With here and there an exception (such as Plot 4 in 1918), that was apparently due to some unknown cause other than the fertilizers, there seemed to be no decided differences between the behavior of the plots.

TABLE XVIII.—Effect of Fertilization On Drops (Reynolds Orchard, 1916, 1917, 1918)

Plots	Treatment	Bushels of Drops 1916	1917	1918	Total Bus.	Average Duplicate Plots in Bus.	Total Average Yield in Bus. per Plot. Duplicate Plots for Three Years	Percent Dropped
2	Nit., Phos., Pot.	10.4	6.0	17.5	33.9	31.2	239.1	13
3	Nit., Phos.	8.5	7.5	16.5	32.5	33.5	301.0	11.1
4	Nit., Pot.	17.5	6.3	40.0	63.8	45.6	218.4	20.8
5	Check	8.5	1.0	6.0	15.5	13.8	113.3	12.2
6	Phos., Pot.	8.2	.4	4.4	13.0	13.0	125.2	10.4
7	Nit., Phos., Pot.	14.2	3.3	10.9	28.4			
8	Nit., Phos.	16.5	4.0	14.0	34.5			
9	Nit., Pot.	12.5	1.1	13.8	27.4			
10	Check	6.5	.5	5.0	12.0			

Fulton Orchard (Young Rome Trees)

The young Rome trees in the Fulton orchard produced their first bloom in 1916 at five years of age but no fruit crop of importance or even measurable quantity was produced until 1918 when they were in their eighth year. Because of pressure of work the blooming record was not taken in 1919. The records for the first three years are not especially significant and show merely that there is no tendency for any element of fertility either to hasten or retard fruit bearing in young trees.

TABLE XIX.—Effect of Fertilization On Bloom

Plot	Treatment	Percent of Bloom 1916	1917	1918	3-Year Average	Gain Over Check
1	Nit., Phos	2.66	5.00	43.12	16.92	15.04
2	Nit., Pot.	.90	1.30	4.20	2.13	.25
3	Nit., Phos., Pot.	3.05	2.79	36.11	13.98	12.10
4	Phos., Pot.	1.64	.20	.85	.89	-.99
5	Check	1.35	.20	4.10	1.88	
6	Nit.	1.75	.50	3.30	1.85	-.03
7	Phos.	3.10	.70	5.10	2.96	1.08
8	Pot.	1.35	.70	.20	.75	-1.13

TABLE XX.—Effect of Fertilization on Total Yield (Young Rome)

Plots	Treatment	Total Yield in Pounds *, 1918	Total Yield in Pounds, 1919	Total Yield in Pounds, 2 Years	Gain in Pounds Over Check
1	Nit., Phos.	167.50	39.00	206.50	178.25
2	Nit., Pot.	16.00	13.25	29.25	1.00
3	Nit., Phos., Pot.	169.50	20.75	190.25	162.00
4	Phos., Pot.	6.25	13.25	19.50	-8.75
5	Check	24.00	4.25	28.25	
6	Nit.	2.00	5.00	7.00	-21.25
7	Phos.	46.00	13.25	59.25	31.00
8	Pot.	6.25	4.00	10.25	-18.00

* No crop worthy of harvest before 1918.

Fulton Orchard (Young Bearing Trees)

Bloom records were taken in this orchard each year except in 1919 when other work prevented. Tables XXI and XXII show the detailed record of each variety and the summary for the five years.

TABLE XXI.—Influence of Fertilization On Bloom

Variety—Grimes

Plots	Treatment	Percent of Bloom 1914	1915	1916	1917	1918	Total	Average 5 Years	Increase Over Check
1	Check	7.5	15.0	35.0	25.0	30.0	112.5	22.5	
2	Nit., Phos.	3.6	7.6	33.33	10.0	20.0	74.53	14.90	-8.31
3	Nit., Pot.	3.75	46.25	10.0	31.2	13.75	104.95	20.98	-2.23
4	Nit., Pot., Phos.	1.0	31.25	22.5	21.25	15.0	91.0	18.20	-5.01
5	Phos., Pot.	3.6	29.0	42.0	29.0	30.0	133.60	26.72	3.51
6	Check	4.0	22.7	36.25	25.0	20.0	107.95	21.59	
7	Nit.	5.25	47.5	32.5	27.0	16.25	128.5	25.70	2.49
8	Phos.	1.60	28.0	28.0	20.0	15.0	102.6	20.52	-2.69
9	Pot.	2.0	23.0	31.0	24.0	13.0	93.0	18.60	-4.61
10	Check	3.6	42.0	40.0	18.0	23.4	127.0	25.40	
	Ave. all Checks	5.33	26.56	37.08	22.66	24.46	116.09	23.21	

Variety—Ben Davis

Plots	Treatment	1914	1915	1916	1917	1918	Total	Average 5 Years	Increase Over Check
1	Check	3.4	63.0	21.0	8.0	20.0	115.40	23.08	
2	Nit., Phos.	7.2	56.0	39.0	20.0	50.0	172.20	34.44	6.87
3	Nit., Pot.	9.0	71.25	35.0	52.5	53.75	221.50	44.30	16.73
4	Nit., Pot., Phos.	12.2	57.0	36.0	45.0	48.0	198.20	39.64	12.07
5	Phos., Pot.	2.2	53.0	30.0	9.0	26.0	120.20	24.04	-3.53
6	Check	7.0	50.0	27.0	14.0	16.0	114.0	22.80	
7	Nit.	3.2	67.0	9.0	30.0	31.0	140.20	28.04	.47
8	Phos.	7.2	55.0	25.0	30.0	28.0	145.20	29.04	1.47
9	Pot.	7.2	47.0	23.0	46.0	27.4	150.60	30.12	2.55
10	Check	13.2	78.0	36.0	32.0	25.0	184.20	36.84	
	Ave. all Checks	7.86	63.66	28.00	18.0	20.33	137.85	27.57	

Variety—York Imperial

1	Check	2.6	13.2	50.0	7.0	14.0	86.80	17.36	
2	Nit., Phos.	4.6	10.0	19.0	11.0	6.4	51.00	10.20	−4.53
3	Nit., Pot.	6.0	19.0	53.0	12.0	10.0	100.00	20.00	5.27
4	Nit., Pot., Phos	4.4	30.0	37.0	23.0	20.0	114.40	22.88	8.15
5	Phos., Pot.	2.0	27.2	27.0	24.0	6.0	86.20	17.24	2.51
6	Check	3.2	29.0	54.0	16.0	9.8	112.00	22.40	
7	Nit.	1.2	23.2	8.0	13.0	3.0	48.40	9.68	−5.05
8	Phos.	2.0	13.2	21.0	3.0	5.0	44.20	8.84	−5.89
9	Pot.	1.6	32.0	28.0	3.0	4.0	68.60	13.72	−1.01
10	Check	0.4	12.4	6.0	2.0	1.4	22.20	4.44	
	Ave. all Checks	2.06	18.20	36.66	8.33	8.40	73.65	14.73	

TABLE XXII.—Influence of Fertilization on Bloom (Grimes, Ben Davis, York Imperial)

Plots	Treatment	Percent of Bloom, 5-Year Average: Grimes	Ben Davis	York Imperial	All Three Varieties	Percent Incr. Over All Checks
1	Check	22.50	23.08	17.36	20.98	
2	Nit., Phos.	14.90	34.44	10.20	19.84	1.98
3	Nit., Pot.	20.98	44.30	20.00	28.42	6.60
4	Nit., Pot., Phos.	18.20	39.64	22.88	26.90	5.08
5	Phos., Pot.	26.72	24.04	17.24	22.66	.84
6	Check	21.57	22.80	22.40	22.26	
7	Nit.	25.70	28.04	9.68	21.14	−.68
8	Phos.	20.52	29.04	8.82	19.46	−2.36
9	Pot.	18.60	30.12	13.72	20.81	−1.01
10	Check	25.40	36.84	4.44	22.22	
	Ave. of Checks	23.16	27.57	14.73	21.82	

A study of Table XXII indicates at first glance that a moderate amount of benefit is derived from the use of combined fertilizers but none from the elements used singly. An examination of the detailed Table XXI shows at once that there is no uniformity of behavior of any plant food material or combination of materials throughout the block. This immediately nullifies the significance of the chance benefits that appear for certain plots in Table XXII.

TABLE XXIII.—Effect of Fertilization On Total Yield

Variety—Grimes

Plot	Treatment	Yield in Pounds						Total Yield in Pounds	Gain in Pounds Over Average of Checks
		1914	1915	1916	1917	1918	1919		
1	Check	*	250.81	482.00	83.28	407.96	149.69	1373.74	
2	Nit., Phos.		139.15	290.18	146.87	443.43	66.66	1086.30	-615.27
3	Nit., Pot.		155.45	160.93	102.26	324.06	459.06	1201.76	-499.81
4	Nit., Pot., Phos.		78.84	154.68	95.60	284.06	140.62	753.80	-947.77
5	Phos., Pot.		256.37	719.50	209.68	749.00	241.00	2175.55	473.98
6	Check		355.00	532.96	237.81	444.37	184.50	1754.64	
7	Nit.		341.56	530.60	137.33	645.62	234.37	1889.47	187.90
8	Phos.		254.50	395.75	156.12	508.50	305.50	1620.37	-81.20
9	Pot.		146.00	331.62	51.87	278.25	69.75	877.49	-824.08
10	Check		345.50	599.87	141.00	672.75	217.25	1976.37	
	Ave. all Checks		317.10	438.27	154.03	508.36	193.81	1701.57	

Variety—Ben Davis

Plot	Treatment	1914	1915	1916	1917	1918	1919	Total Yield in Pounds	Gain in Pounds Over Average of Checks
1	Check	52.25	110.37	109.00	73.00	283.00	31.25	658.87	
2	Nit., Phos.	101.50	259.75	269.50	300.00	1028.25	208.00	2167.00	660.43
3	Nit., Pot.	152.50	306.32	335.31	318.75	1569.00	289.75	2971.63	1165.06
4	Nit., Phos., Pot.	320.75	448.55	607.25	480.00	1759.75	190.50	3806.80	2300.23
5	Phos., Pot.	27.5	98.31	203.75	69.00	903.25	106.00	1407 81	-98.76
6	Check	105.88	118.12	241.50	41.00	944.50	151.50	1602.50	
7	Nit.	166.00	407.25	323.75	460.00	1660.25	230.50	3247.75	1741.18
8	Phos.	202.25	384.12	251.25	140.00	1371.00	11.87	2460.49	953.92
9	Pot.	354.57	482.25	391.75	440.50	1167.25	44.25	2880.57	1374.00
10	Check	285.56	483.37	325.00	248.00	876.25	40.25	2258.43	
	Ave. all Checks	147.89	247.28	225.16	120.66	701.25	74.33	1506.57	

Variety—York Imperial

Plot	Treatment	1914	1915	1916	1917	1918	1919	Total Yield in Pounds	Gain in Pounds Over Average of Checks
1	Check	65.43	334.31	16.00	138.00	*	1204.50	1758.24	
2	Nit., Phos.	25.75	83.12	43.50	332.00		794.75	1289.12	-150.80
3	Nit., Pot.	248.87	198.62	432.75	445.00		2267.25	3592.49	2152.57
4	Nit., Phos., Pot.	94.75	195.50	102.75	708.00		1693.75	2794.75	1354.83
5	Phos., Pot.	17.75	184.00	79.75	633.00		369.00	1283.50	-156.42
6	Check	44.00	369.44	443.25	575.00		530.75	1962.44	
7	Nit.	14.06	183.87	36.00	207.50		594.69	1036 12	-403.80
8	Phos.	24.87	50.12	249.75	135.00		229.75	689.49	-750.43
9	Pot.	17.50	114.31	103.50	187.00		177.75	600 06	-839.86
10	Check	00.00	45.18	20.25	168.75		365.00	1104.85	
	Ave. all Checks	36.47	294.64	159.83	293.91		700.07	1439.92	

* No records secured on this block this year.

A study of Table XXIII reveals merely a striking lack in uniformity of behavior. There is no single material or combination of materials that has gone throughout the three series without reversing its reaction in relation to the check plots. Nor is the summary in Table XXIV much more satisfactory. It is true that five of the fertilizer plots showed a gain over the checks and only two showed a loss but it is difficult to explain why Plot 2 should show a loss and Plot 4 a gain when both have had the same treatment for the last five years since the potash applications were discontinued. In short after considering the wide discrepancies in Tables XXIII and XXIV the only safe deduction that may be drawn from the tables is that the fertilizers have proved to be absolutely ineffective and without value.

TABLE XXIV.—Summary of the Effect of Fertilizers On Total Yield of the Three Varieties

Plots	Treatment	Total Yield in Pounds in 5 Years, Grimes	Total Yield in Pounds in 6 Years, Ben Davis	Total Yield in Pounds in 5 Years, York Imp.	Total Yield, All Varieties	Increase Over Ave. of All Checks
1	Check	1373.74	658.87	1758.24	3790.85	
2	Nit., Phos.	1086.30	2167.00	1289.12	4542.42	-175.64
3	Nit., Pot.	1201.76	2971.63	3592.49	7765.88	3047.82
4	Nit., Pot., Phos.	753.80	3806.80	2794.75	7355 35	2637.29
5	Phos., Pot.	2175.55	1407.81	1283.50	4866.86	148.80
6	Check	1754.64	1602.50	1962.44	5319.58	
7	Nit.	1889.47	3247.75	1036.12	6173.34	1455.28
8	Phos.	1620.37	2460.49	689.49	4770.35	52.29
9	Pot.	877.49	2880.57	600.06	4358.12	-359.94
10	Check	1976.37	2258.43	1104.85	5339.65	
	Ave. all Checks	1701.57	1506.57	1439.92	4718.06	

In a few instances a count was made of the number of fruits in the crop harvested. These data shown in Table XXV merely support the negative results already secured.

TABLE XXV.—Effect of Fertilization on Number of Fruit Produced

Variety—Grimes

Plots	Treatment	No. of Apples Produced			Total No.	Incr. in No. Over Average of Checks
		1914	1915	1918		
1	Check	*	562	1687	2249	
2	Nit., Phos.		470	1841	2311	-546
3	Nit., Pot.		511	1276	1787	-1070
4	Nit., Pot., Phos.		234	1145	1379	-1478
5	Phos., Pot.		701	2665	3366	509
6	Check		1052	1617	2669	
7	Nit.		1001	2437	3438	581
8	Phos.		719	1594	2313	-544
9	Pot.		398	1085	1483	-1374
10	Check		1020	2634	3654	
	Ave. of Checks		878	1979	2857	

Variety—Ben Davis

Plots	Treatment	1914	1915	1918	Total No.	Incr. in No. Over Average of Checks
1	Check	254	315	1465	2034	
2	Nit., Phos.	472	843	4873	6188	1345
3	Nit., Pot.	662	762	5759	7183	2340
4	Nit., Pot., Phos.	1239	1169	8373	10781	5948
5	Phos., Pot.	115	263	4447	4825	-18
6	Check	422	315	4625	5362	
7	Nit.	721	1094	7951	9766	4923
8	Phos.	887	947	6394	8228	3385
9	Pot.	1440	1309	5894	8643	3800
10	Check	1260	1419	4457	7136	
	Ave. of Checks	645	683	3515	4843	

Variety—York Imperial

Plots	Treatment	1914	1915	1918	Total No.	Incr. in No. Over Average of Checks
1	Check	175	795	*	970	
2	Nit., Phos.	69	170		239	-433
3	Nit., Pot.	733	497		1230	558
4	Nit., Pot., Phos.	329	533		862	190
5	Phos., Pot.	45	396		441	-231
6	Check	110	827		937	
7	Nit.	34	457		491	-181
8	Phos.	61	105		166	-506
9	Pot.	74	310		384	-288
10	Check	00	111		111	
	Ave. of Checks	95	577		672	

* No records secured.

From the number of fruits and the weight of the crop it is a simple matter to work out the average size of the apples grown under the several treatments. This information appears in Table XXVI but shows no evidence of beneficial action by fertilizers. In fact only three out of the seven treated plots show a gain in size of apples over the checks.

TABLE XXVI.—Effect of Fertilization On Weight of Individual Apples

Plots	Treatment	Average Wt. in Lbs. 3-Yr. Ave., Ben Davis	Average Wt. in Lbs. 2-Yr. Ave., York Imp.	Average Wt. in Lbs. Grimes 3-Year Ave.	Average Wt. in Lbs. of Indiv. Apples of All Vars.	Gain in Wt. Over Average of Checks
1	Check	.21	.41	.29	.30	
2	Nit., Phos.	.22	.45	.25	.31	.01
3	Nit., Pot.	.27	.36	.26	.30	0
4	Complete	.23	.33	.26	.27	-.03
5	Phos., Pot.	.21	.45	.29	.32	.02
6	Check	.21	.44	.29	.31	
7	Nit.	.23	.40	.28	.30	0
8	Phos.	.23	.44	.32	.33	.03
9	Pot.	.23	.34	.28	.28	-.02
10	Check	.22	.40	.27	.30	
	Ave. all Checks	.21	.41	.28	.30	

The final point considered in connection with the yield of fruit in this block is the effect of the fertilizers upon the market grades. Two grades only were made, merchantable fruit and culls. As might be expected practically all the fruit produced upon these young trees was suitable for market. The percentage of culls or small apples is not increased or diminished by the use or non-use of fertilizers.

TABLE XXVII.—Effect of Fertilization On Grades of Fruit

Variety—Grimes

Plot	Treatment	Merchantable Apples Total in Pounds	Cull Apples Total Pounds	Merchantable Apples Percent	Cull Apples Percent
1	Check	1107.95	20.85	98.15	1.85
2	Nit., Phos.	833.32	23.68	97.35	2.65
3	Nit., Pot.	611.31	21.02	96.67	3.33
4	Nit., Pot., Phos.	479.38	16.79	96.61	3.39
5	Phos., Pot.	1671.05	12.92	99.23	.77
6	Check	1241.55	28.89	97.72	2.28
7	Nit.	1441.71	34.21	97.69	2.31
8	Phos.	1103.62	18.87	98.31	1.69
9	Pot.	715.25	14.62	97.99	2.01
10	Check	1543.00	29.62	98.11	1.89
	Ave. all Checks	1297.50	26.45	98.00	2.00

Variety—Ben Davis

Plot	Treatment	Merchantable Apples Total in Pounds	Cull Apples Total Pounds	Merchantable Apples Percent	Cull Apples Percent
1	Check	348.87	12.75	96.47	3.53
2	Nit., Phos.	1581.25	28.25	98.24	1.76
3	Nit., Pot.	2336.81	19.61	99.16	.84
4	Nit., Pot., Phos.	3079.62	56.68	98.19	1.81
5	Phos., Pot.	1216.25	16.56	98.65	1.35
6	Check	1398.87	11.12	99.21	.79
7	Nit.	2539.00	18.25	99.28	.72
8	Phos.	2256.50	16.12	99.29	.71
9	Pot.	2374.07	21.75	99.09	.91
10	Check	1941.62	28.56	98.55	1.45
	Ave. all Checks	1229.78	14.47	98.83	1.17

Variety—York Imperial

Plot	Treatment	Merchantable Apples Total in Pounds	Cull Apples Total Pounds	Merchantable Apples Percent	Cull Apples Percent
1	Check	413.12	2.62	99.37	.63
2	Nit., Phos.	151.87	.50	99.67	.33
3	Nit., Pot.	632.27	5.37	99.15	.85
4	Nit., Pot., Phos.	388.50	4.50	98.85	1.15
5	Phos., Pot.	280.62	.87	99.69	.31
6	Check	853.81	2.87	99.66	.34
7	Nit.	239.37	.78	99.67	.33
8	Phos.	324.00	.85	99.73	.27
9	Pot.	233.12	2.68	98.86	1.14
10	Check	65.07	.46	99.29	.71
	Ave. all Checks	444.00	1.98	99.55	.45

One Lb. Nitrate Soda.
Half or More of Leaves Off.

Check Plot.
Practically All Leaves Off.

Three Lbs. Nitrate Soda.
About One-fourth Leaves Off.

Six Lbs. Nitrate Soda.
Practically All Leaves On.

Fig. 5. These Pictures Were Taken October 6, 1919.

Effects of Nitrate of Soda On Starved Trees

The test made in this case was begun in 1917 to study the effects of nitrate of soda when used as a stimulant to growth of greatly devitalized trees. The trees, which were making very poor growth and carrying only a sparse, yellow foliage, responded almost immediately to the applications. Within ten days the foliage took on a greener color and a liberal growth of new leaves appeared. In the fall the small yellow leaves of the check plot dropped early while those of the nitrogen plots hung much later. On October 12, 1918, the second year of the experiment, the check plot had lost 95 percent of its foliage; the one-pound plot, 65 percent; the two-pound plot, 35 percent; and the three-pound, four-pound, and six-pound plots only 5 to 10 percent.

TABLE XXVIII.—Effect of Nitrate of Soda On Starved Trees

Treatment	Circumference of Trunk in Inches			Increase in Inches	Gain in Inches Over Check
	1917	1918	1919		
1 Lb. per Tree	9.50	10.91	11.50	2.00	1.42
2 Lbs. per Tree	12.50	13.25	14.04	1.54	.96
3 Lbs. per Tree	14.00	15.83	17.00	3.00	2.42
Check	12.58	13.00	13.16	.58	
4 Lbs. per Tree	10.83	11.75	12.95	2.12	1.54
6 Lbs. per Tree	14.00	15.25	18.25	4.25	3.67
	Annual Twig Growth in Inches			**Average Length of Growth in Inches**	**Gain in Inches Over Check**
	1917	1918	1919		
1 Lb. per Tree	5.52	11.53	7.86	8.30	5.10
2 Lbs. per Tree	7.39	12.12	7.46	8.98	5.78
3 Lbs. per Tree	10.92	12.26	8.86	10.68	7.48
Check	4.59	2.59	2.43	3.20	
4 Lbs. per Tree	9.53	18.92	9.23	12.56	9.36
6 Lbs. per Tree	11.00	24.50	11.80	15.76	12.56

Table XXVIII speaks for itself. The measurements were taken at the close of the growing seasons indicated. It is perfectly clear that the use of even one pound of nitrate of soda per tree produced worth-while results and that increasing benefits were derived up to the largest amount used. It will be noticed that the average twig growth has increased roughly two inches for every added pound of the material used. No records were taken of yield from these trees as it was impossible to be on the ground at the proper time.

EFFECTS OF EARLY AND LATE APPLICATIONS OF NITRATE OF SODA

Several writers have called attention to the necessity of applying nitrate of soda to the trees before growth starts in order to secure maximum benefits. Lewis *found that in Oregon it was advisable to make the application a month before growth started and claimed that it had a beneficial effect upon the setting of fruit for the current season. In 1918 and 1919 early and late applications were made in all the orchards in the experiment except in the Reynolds orchard where the test was conducted only in 1918. Table XXIX shows the effect upon setting of fruit and upon tree growth for that year.

TABLE XXIX.—Effects of Early and Late Applications Upon Set of Fruit and Twig Growth (Reynolds Orchard)

Plot	Treatment	Time of Application	No. Blossoms Counted	No. Set	Percent Set	Twig Growth in Inches 1919
2	Nit., Phos.	Early, Mar., 20-31	720	42	5.8	10.2
3	Nit., Phos.	Late, May, 20-30	625	40	6.4	9.7
8	Nit., Phos.	Early, Mar., 20-31	667	46	6.9	10.2
7	Nit., Phos.	Late, May, 20-30	597	26	4.3	9.8
4	Nit.	Early, Mar., 20-31	668	21	3.1	9.6
9	Nit.	Late, May, 20-30	469	16	3.4	9.3
5	Check		676	24	3.5	6.2
10	Check		425	10	2.3	6.2

Except for the apparent benefit of the nitrogen-phosphorus combination on set of fruit previously noted (page 27) there are no outstanding points in this table and most certainly in respect to set of fruit there is no benefit chargeable to the early application of the fertilizer. In regard to twig growth there seems to be a slight but uniform benefit from the early application. As this increase only ranges from .3 inch to .5 inch it is neither very remarkable nor conclusive.

Fulton Orchard (Young Rome)

The records in this orchard seem to be about as indeterminate as those in the Reynolds orchard. In this instance the benefits from early applications are lacking in tree growth and while they resulted in an increased yield for the fruit crop the first year the reverse was true the second year, thus rendering the data inconclusive.

* Oregon Exp. Sta. Bul. 111.

TABLE XXX.—Effects of Early and Late Applications of Nitrate of Soda on Young Rome

Trunk Circumference

Time of Application	Trunk Circumference in Inches 1917	1918	1919	Total Incr. in inches Trunk Cir., 2-Yr. Period	Gain in Inches for Later Application
March 20-31	9.70	12.10	13.91	4.21	
May 20-30	9.07	12.05	13.72	4.65	.44

Twig Growth

Time of Application	Average Length of Growth in Inches 1918	1919	2-Years	Gain in Inches for Later Application
March 20-31	17.44	13.67	15.55	
May 20-30	17.54	14.49	16.01	.46

Yield

Time of Application	Total Yield in Pounds 1918	1919	2-Years	Gain in Lbs. for Later Application
March 20-31	16.00	5.00	21.00	
May 20-30	2.00	13.25	15.25	–5.75

In the case of the young bearing trees there is no definite reaction to either early or late applications of fertilizers. The data upon this point should not be misinterpreted for they simply indicate that fertilizers are of no value in this experiment regardless of time of application and they have no bearing upon the relative value of early or late applications in cases where favorable response would follow fertilizer treatment. As a matter of fact our information upon this point indicates that an application made just as the buds are breaking is more effective than an application after blooming.

TABLE XXXI.—Effect of Early and Late Applications of Nitrate of Soda on the Trunk Circumference of Grimes, Ben Davis, and York Imperial.

Variety	Time of Application	Truuk Circumference in Inches				Gain in Inches for Later Application
		1917	1918	1919	Increase 2-Yr. Period	
Grimes	March 20-31	18.00	19.50	20.59	2.59	
	May 20-30	18.37	19.68	21.00	2.63	.04
Ben Davis	March 20-31	18.93	20.68	22.85	3.92	
	May 20-30	19.75	21.45	23.20	3.45	−.47
York	March 20-31	20.20	22.50	23.60	3.40	
Imperial	May 20-30	20.50	22.18	24.00	3.50	.10

TABLE XXXII.—Effect of Early and Late Applications of Nitrate of Soda on the Twig Growth of Grimes, Ben Davis and York Imperial.

Variety	Time of Application	Average Length of Growth in Inches			Gain in Inches for Later Application
		1918	1919	2-Year Period	
Grimes	March 20-31	8.30	8.87	8.58	
	May 20-30	9.85	8.92	9.38	.80
Ben Davis	March 20-31	10.40	9.70	10.05	
	May 20-30	10.58	8.58	9.58	−.47
York	March 20-31	8.46	9.84	9.15	
Imperial	May 20-30	6.25	7.70	6.97	−2.18

TABLE XXXIII.—Effect of Early and Late Applications of Nitrate of Soda on the Total Yield of Grimes, Ben Davis, and York Imperial.

Variety	Time of Application	Total Yield in Pounds			Gain in Lbs. for Later Application
		1918	1919	2 Year Period	
Grimes	March 20-31	324.06	1201.76	1525.82	
	May 20-30	645.62	1889.47	2535.09	1009.27
Ben Davis	March 20-31	1569.00	2971.63	4540.63	
	May 20-30	1660.25	3247.75	4908.00	367.37
York	March 20-31	No	3592.49	3592.49	
Imperial	May 20-30	record	1036.12	1036.12	−2556.37

CUMULATIVE EFFECT OF FERTILIZERS

There is some evidence furnished by this series of experiments to indicate that one may expect increasing or accumulating benefits from fertilizers if they prove to be at all effective. In the Reynolds orchard the nitrogen-fed trees are now noticeably larger than the others and should begin to show increasingly larger gains over the check plots. As a matter of fact this is beginning to be apparent to a slight degree. On the other hand, the Fulton orchards are not showing any more tendency to react favorably to artificial feeding than at the beginning of the experiment. If a test of fertilizers on old land fails to show beneficial results in two or three years it is doubtful if it ever will as long as good culture may be kept up unless at some future time the orchard should exhaust itself by unusually heavy cropping. This point is of interest to the orchardist since it obviates the necessity of his making an extended test to determine the fertilizer needs of his own orchard.

INDIRECT BENEFITS OF FERTILIZERS

The Reynolds orchard is showing an interesting result which is producing an indirect effect upon the trees. The cover crops have always been benefited by the fertilizer applications, particularly phosphorus and nitrogen. Thus the soil in these plots has been slowly improved by the plowing under of these crops. In 1918 when the orchard was seeded to red clover a splendid stand was secured in all plots to which phosphorus had been added but the check plots and the nitrogen-potassium plots were absolutely barren. Of course the growing and returning of the plants to the soil will in time have a beneficial effect upon the trees themselves. In the Fulton orchards the cover crops have been affected but not to such an extent.

A RECENT THEORY IN PLANT NUTRITION

In the full interpretation of experiments such as have been described in this bulletin one cannot overlook the important work of Kraus and Kraybill.* These men, after careful work with the tomato, call attention to the fact that there are two classes of materials in a plant that play important parts in growth and reproductive activities of the plant. One of these classes, called the carbohydrates, includes such substances as sugars and starch which are prepared

* Oregon Exp. Sta., Bul. 149 (1918).

within the leaves of the plant. The other class includes nitrogen, which is absorbed directly through the roots. These investigators have shown that there must be a certain balance between the two classes before a satisfactory vegetative vigor and fruit production may be expected. They show that four general conditions with regard to this balance are possible.

1.—Nitrogen may be abundant, but accompanied by a deficiency in carbohydrates, resulting in a weak, slender growth and little or no production of fruit buds.

2.—Nitrogen may be abundant and a sufficient supply of carbohydrates present to utilize all the nitrogen, resulting in a strong, vigorous, vegetative development, but with little or no tendency to fruit.

3.—Nitrogen may be abundant and an excess of carbohydrates may be present, resulting in a vigorous growth and an abundant production of vigorous fruit buds.

4.—There may be a deficiency of nitrogen, although an abundant supply of carbohydrates, resulting in a weak growth, small yellow leaves and scarcity of fruit buds; or if fruit buds are formed, they are weak and not likely to set fruit.

It is clear that if an orchard were in the condition indicated in the third group it might be injured by a nitrogen fertilization, for the nitrogen supply might be raised sufficiently to throw it into group two. Also if such an orchard were given a heavy pruning, it might reduce the leaf area and the stored carbohydrates in the top to such an extent that it would bring about the condition in group two. On the other hand, this orchard might be seeded to a heavy sod and so much moisture and nitrogen diverted from the tree that the characteristic starved condition of group four would be attained. Many similar illustrations could be called to mind, but they would only show what is already indicated; namely, that the nutrition of a tree may be influenced by many orchard practices other than the application of fertilizers. The wise grower will attempt by a skilful blending of cultural practices, pruning, and fertilization to maintain his orchard in the condition of group three with a minimum of expense and effort.

PHILOSOPHY OF APPLE ORCHARD FERTILIZATION

The work of Batchelor and Reed * demonstrated the extreme variability of individual apple trees and even of individual plots. Their conclusions indicate that all orchard fertilizer experiments heretofore conducted are subject to a large probable error and should be discounted accordingly. Viewed in this light, we can safely place confidence only in the most constant and clear cut results.

When we consider in connection with the West Virginia experiments those already reviewed in this bulletin, it is possible to draw some general deductions and state a few general principles of orchard fertilization that would seem to have a fairly wide application.

It is, first of all, clear that the apple tree will thrive upon soils of moderate or low producing power as gauged by farm crops. The West Virginia experiments supply ample proof of this.

It is apparent that there are many orchards in this country that will not respond to the use of fertilizers. The experiments in New York, New Hampshire, Maine, West Virginia, and at least one in Pennsylvania, demonstrate this fact.

Since the experiments that have shown beneficial results from the use of commercial fertilizers were conducted almost without exception in sod orchards or with abnormally starved trees, and since those which did not respond to fertilizers were all under cultivation, we can but conclude that fertilizers are of value mainly as a substitute for cultivation and good orchard culture, or as a tonic and quick restorative for starved and devitalized trees.

If one must use sod culture because his lands or his prejudices are too steep or rock-ribbed to permit of cultivation, then artificial fertilization will probably need to be employed to overcome the effects of the grass crop, unless the orchard soil is exceptionally fertile and well watered.

Of the three common elements of plant food material, nitrogen is the only one that has been uniformly beneficial in the orchard that responded favorably to the use of fertilizers. It was of greatest value when applied in a readily available form such as nitrate of soda. The value of phosphorus seems to be mainly in its effects upon cover crops and sod coverings. Potassium is rarely beneficial.

We cannot hope to influence color of the fruit by the application of the ordinary plant food materials found in commercial fertilizers.

* Journal of Agr Research, Vol. XII, pp. 245-283. (1918).

CONCLUSIONS

It is doubtful if the average orchard in West Virginia needs commercial fertilizers if it is given reasonably good attention and cultivation with cover crops is practiced. Yellowish, sickly looking trees in sod or starved trees on worn out, even though cultivated soil, should be treated with some quickly available form of nitrogen, such as nitrate of soda. A good application is 2½ pounds for a small tree or 5 pounds for a mature tree. It should be applied in the spring just as growth is starting. Acid phosphate will be of value in growing a better sod mulch, or cover crop, but its direct value to the tree is still in question. West Virginia soils are well supplied with potash and the orchardist can undoubtedly safely ignore this material.

Orchard fertilization should not be considered, except in conjunction with other orchard practices, such as culture, spraying, and pruning. All such factors directly affect the welfare of the orchard and thus influence the nutrition of the trees.

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