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Fertilization of Apple Orchards, II

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Fig. 4.—St. Marys Experiment Showing Check Plot on Left and Plot Fertilized with Nitrate, Phosphate, and Potash. (See page 28.)

By
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Fertilization of Apple Orchards, II *

Further refinement in the different operations involved in producing better fruit cheaply will center attention more and more upon the care of the orchard. The great variety of conditions under which apples are grown in West Virginia make it difficult to determine with assurance what are the best cultural practices. An attempt has been made in the experiments reported here to obtain information as to the influence of certain orchard practices upon the tree under different methods of care. These experiments have been in progress for a sufficient length of time to indicate the general bearing of the different variables in the treatment upon both growth and production.

This bulletin in part is a continuation of the experiments first described in Bulletin 174 of this station (Alderman and Crane, 1920). In the St. Marys, Sleepy Creek, and Rome experiments the growth and yield records are given completely for the entire period of investigation. The results of the first seven years of the Cultural Experiment are given here for the first time. It will be seen from the general trend of the first three experiments that considering the results for the entire period certain changes in the recommendations appear justified.

RESULTS OF THE MORE RECENT EXPERIMENTS IN APPLE FERTILIZATION

A number of experiment stations have reported the results of studies on apple fertilization since West Virginia Bulletin 174 was published. Without going into detail it may be stated that the general tendency of the later results is much the same as those reported earlier. Nitrogen has been the only fertilizer to which the apple has, in general, given a profitable response. Anthony and Waring (1922), in Pennsylvania, found results comparable to those of Hedrick (1914), in which sod plots showed a marked response to nitrogenous fertilizers while cultivated plots where cover crops were grown did not. In Maine, Sax (1925) reported similar results. Likewise, in Ohio, Ballou (1920 and 1925) drew similar conclusions except that he found an increase in yield in some cultivated orchards which

*At the time this manuscript was prepared the senior author, Dr. M. J. Dorsey, was head of the Department of Horticulture, which position he resigned September 1, 1925.

was less marked than in sod. In his experiments in the sod plots in one orchard, phosphorus also increased the yield, presumably by increasing the growth of clover that later supplied the nitrogen to the trees. In the New Hampshire tests, (Gourley 1919), increased growth resulted from the use of nitrogen-carrying fertilizers but there was no increase in yield during the first ten years of the experiment, 1908 to 1918, but at the time of this writing, according to Chandler (1925), nitrogen was beginning to show beneficial effects following further depletion of the initial fertility. In Massachusetts, Shaw (1924) found that trees growing in sod and receiving nitrogen produced a better growth than cultivated trees without nitrogen. Cooper (1920), in Arkansas, reported a larger set of fruit following nitrate applications. In New York, (Collison 1920, Collison and Harlan 1923) no fertilizer has produced any beneficial results in any of the cultivated orchards studied. Hedrick and Tukey (1924) said regarding one orchard, "when we come to summarize the effects of the fertilizer treatments in the orchard, we are forced to conclude that they have made absolutely no impression upon the behavior of the trees." The soils in these orchards are deep and fertile. Lyon, Heinicke, and Wilson (1923), in an orchard of young Delicious trees at Ithaca, New York, obtained marked results in growth in sod plots from the use of nitrate of soda.

Turning now to the Pacific Northwest for additional data we find that Morris and Larsen (1921), in tests made in the Wenatchee Valley, found very good results from the use of nitrogen-carrying fertilizers in orchards which had been clean cultivated for several years, but no pronounced results in orchards in which a good cover crop had been grown for more than three years. No evident responses have been observed from applications of either acid phosphate or potash. Lewis, Reimer, and Brown (1920) report similar results in Oregon.

In summarizing briefly the results on apple fertilization in other states, it can be said that apple trees in sod generally need nitrogenous fertilizers for maximum production while apple trees under cultivation may or may not, depending on the fertility of the soil. Acid phosphate seems to be valuable in stimulating cover crop growth only. Applications of potash have shown no favorable response. It will be seen later that the West Virginia experiments, in general, corroborate those summarized above.

THE WEST VIRGINIA EXPERIMENTS

The main features of the four experiments reported in this bulletin are given in the following order: (1) The St. Marys Experiment which is located in the orchard of Mr. L. E. Reynolds, three miles from the city of St. Marys, Pleasants County, on the hills adjacent to the Ohio River Valley; (2) The Sleepy Creek Experiment with Grimes, Ben Davis, and York; (3) The Rome Experiment at Sleepy Creek; and (4) The Cultural Experiment on the Horticultural Farm near Morgantown. The two Sleepy Creek experiments are located in Morgan County in the orchard now owned by the American Fruit Growers, Incorporated. These experiments, therefore, are located in the fruit centers of the state and include different soil types in each instance.

The St. Marys Experiment

This experiment was started in the spring of 1911. The trees were twenty years old, of the Rome variety, and were making only from one to three inches of terminal growth each year. At the time the experiment was started the trees were filled with dead branches and seemed to be upon the verge of starvation. The first season the orchard was thoroughly pruned, sprayed, and cultivated. The soil type is a Dekalb silt loam which is generally recognized as one of the poor soil types of the state. Beginning with plot 2, the soil in this particular location becomes progressively poorer toward Plot 10. This fact should be kept in mind in studying the data from this experiment. When the plots were laid out the orchard had not been cultivated for some time and supported only a meagre growth of grass or weeds. The general condition was such as to furnish an excellent opportunity to study the influence of the different fertilizers when applied to devitalized trees growing in poor soil.

The experiment included ten rows or plots with twelve trees per plot making a total of 120 trees. Each plot received the following applications of fertilizers in pounds per tree: Plot 1 and 6 muriate of potash 2.08 pounds, and acid phosphate 7.8 pounds; plots 2 and 7 nitrate of soda 2.6 pounds, acid phosphate 7.8 pounds, and muriate of potash 2.08 pounds; Plots 3 and 8 nitrate of soda 2.6 pounds, and acid phosphate 7.8 pounds; Plots 4 and 9 nitrate of soda 2.6 pounds, and muriate of potash 2.08 pounds; plots 5 and 10 were checks and

received no fertilizers. The applications were made at this rate until 1915; since then the amount given to each tree has been doubled. In 1911, sulphate of potash was used instead of muriate, and in 1916 and thereafter until 1920, the use of potash was discontinued because of the shortage during the war.

The cultivation which was used at first after the period of neglect was continued until the fall of 1917 when the entire block was seeded to red clover. This crop was plowed under the following spring. In the fall of 1918, the block was again seeded to red clover. Cover crops of cowpeas were grown in 1911, 1912, 1914, and 1917. With the exception of 1911, the crops of cowpeas were light and hence did not furnish a good cover. Following 1918, a volunteer crop cover of natural vegetation, made up of grass and weeds, was allowed to stand. This growth was heaviest in the plots receiving acid phosphate or nitrogen and was cut once or twice each season and left on the ground. No cultivation was practiced after 1918 on account of the severe washing in some parts of the orchard. After this experiment was under way, Plot 1 was discarded since it became evident that it was an outside row and hence was more favorably located than the other plots. This report covers the period from 1911 to 1924, or fourteen seasons, but only ten crops.

The Sleepy Creek Experiment

This experiment was started in the spring of 1913, in the orchard of S. H. Fulton, now owned by the American Fruit Growers, Incorporated. The soil is a shallow Holston loam with a shale subsoil. The humus content was low and during dry periods in summer the trees often showed a moisture deficiency. The part of the orchard in which this experiment was located was planted in blocks of five rows each of Grimes, Ben Davis, and York. The ten plots of the experiment run crosswise of these varieties, making five trees of each variety in each treatment. The plot arrangement was similar to the Rome experiment but two additional check rows were added. The different combinations of fertilizers and the rate of application from 1913 to 1924, inclusive, are given in Table 1.

TABLE 1.—Fertilizer Applications and Plot Treatments in the Sleepy Creek Experiment with Grimes, Ben Davis, and York.

Plot	Treatment	Fertilizer Application in Pounds per Tree**				
		1913-1919	1920	1921-1922	1923	1924
1	Check	....	....	....	....	....
2	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Acid phosphate	2.5	2.5	8.0	8.0	10.0
3	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Muriate of potash*	1.0	1.0	1.5	1.5	2.0
4	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
	Acid phosphate	2.5	2.5	8.0	8.0	10.0
	Muriate of potash	1.0	1.0	1.5	1.5	2.0
5	Acid phosphate	2.5	2.5	8.0	8.0	10.0
	Muriate of potash	1.0	1.0	1.5	1.5	2.0
6	Check	....	....	....	....	....
7	Nitrate of soda	1.5	3.0	4.0	5.0	6.0
8	Acid phosphate	2.5	2.5	8.0	8.0	10.0
9	Muriate of potash	1.0	1.0	1.5	1.5	2.0
10	Check	--	--	--	--	---

*No potash was added for the three year period beginning with 1916 on account of the shortage during the war.
**Applied at time of blooming.

It will be seen that the amount of the fertilizers added was increased after 1920. This seemed advisable on account of the relatively light applications made during the first seven years of the experiment and because of the increased size of the trees which was accompanied by a reduction in the terminal growth. While the amount of nitrate of soda applied (1.5 pounds per tree), during the period of this experiment reported on in Bulletin 174, 1913 to 1919 inclusive, was small for trees nine to sixteen years old, it will be seen by referring to Table 5 that the terminal growth during these years was adequate.

The orchard in which this experiment was located was cultivated each year. In late July or early August a cover crop was sown annually; some seasons this was good and others light. From 1919 to 1922, inclusive, red clover was sown. Since then rye has been used. The planting distance was 25 feet each way. It will be seen

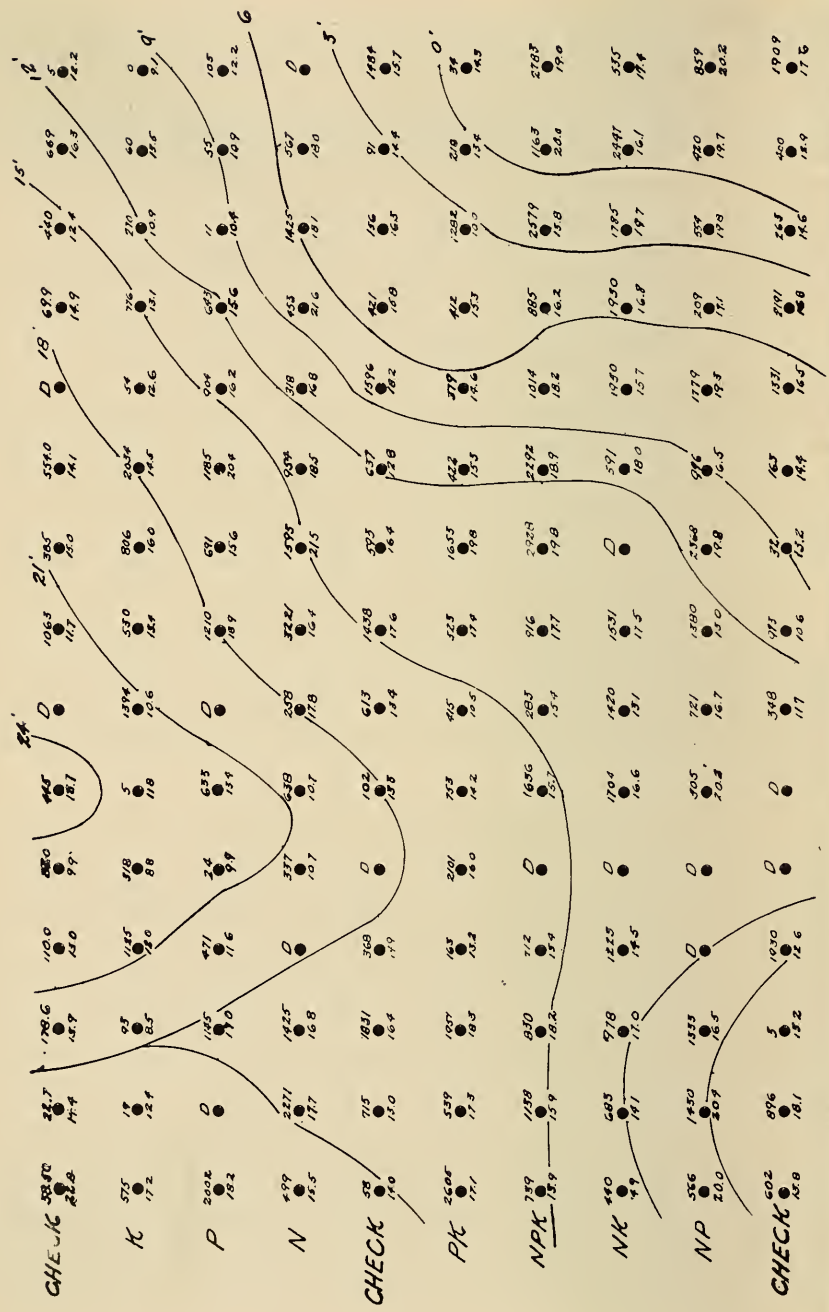

Fig. 1.—Contour Map of Sleepy Creek Experiment with Individual Tree Yields and Trunk Circumferences, 1913-24.

from Table 5 that the trees were making a satisfactory growth at the beginning of the experiment. From the first this orchard was plowed each year in early spring with frequent cultivation later with disc or harrow. In later years in certain parts of the orchard soil erosion was serious and more recent plowings, especially the last one, resulted in rather serious root cutting on trees in the shallower soils (Dorsey and Knowlton 1924). The cultivation was in one direction, following the contours, until in the last two years when cross cultivation was also practiced. A contour map of this experiment is shown in Figure 1.

These trees were pruned to the open head system with five to seven scaffold limbs. In 1915, the terminal twigs were headed back which resulted in thickening the top. Since then some thinning out of the top has been necessary. This kind of pruning gave a type of tree which was sufficiently open but which was inclined to have long branches with laterals too far away from the head.

The Rome Experiment

This experiment was started at Sleepy Creek in the orchard of S. H. Fulton in 1911. On account of the fact that the experiment at St. Marys was also with Rome, but with older trees, this experiment was referred to in Bulletin 174 as the "Young Rome Experiment." Since this term might be misleading now, it will be referred to in this bulletin as the Rome Experiment. The trees were only one year old at the time the first fertilizer applications were made. The planting distance was twenty-four feet on the quincunx plan. The soil in this plot is classified as a Holston silt loam, and was fairly high in fertility, as shown by the following analysis taken from Bulletin 168. In parts of 2,000,000 pounds of soil at plow depth, nitrogen ran 2,110 pounds, phosphorus 608, and potassium 22,840. The initial fertility may be partly accounted for by the fact that this orchard was planted in "new ground."

The amounts of each fertilizer were increased in 1921. As in the other experiments no potash was applied for the three-year period beginning with 1916.

Cultivation has been practiced each year since the orchard was started. The intercrop the first two years was corn. Since then clover, or that failing, a growth of weeds was allowed to cover the ground in late summer and fall and plowed under in the spring.

TABLE 2.—Plot Arrangement, Treatment, and Rate of Application of Fertilizers in the Rome Experiment at Sleepy Creek.

Plot	Treatment	Fertilizer Applications in Pounds per Tree*				
		1911-13	1914-15	1916-19	1920	1921-24
1	Nitrate of soda	.75	1.00	1.5	1.5	4.0
	Acid phosphate	1.25	1.75	1.5	1.5	4.0
2	Nitrate of soda	.75	1.00	2.5	2.5	8.0
	Muriate of potash	.50	.75	.....	1.0	1.5
3	Nitrate of soda	.75	1.00	1.5	1.5	4.0
	Acid phosphate	1.25	1.75	2.5	2.5	8.0
	Muriate of potash	.50	.75	.....	1.0	1.5
4	Acid phosphate	1.25	1.75	2.5	2.5	8.0
	Muriate of potash	.50	.75	.....	1.0	1.5
5	Check	.....	.....	.....	.....	.....
6	Nitrate of soda	.75	1.00	1.5	1.5	4.0
7	Acid phosphate	1.25	1.75	2.5	2.5	8.0
8	Muriate of potash	.50	.75	----	1.0	1.5

*Applied at time of blooming.

During the years 1919 to 1923, red clover only was sown as a cover. In 1924, the plots were seeded to crimson clover. The cover crop growth was not sufficiently heavy, in general, to account for the uniformity in tree growth and the trees to date have not been sufficiently productive to draw heavily upon the relatively high initial fertility. The close planting even with the size of tree now reached has no doubt made it possible for cross feeding to take place between the plots. If this has taken place it has made no difference between the general appearance of these trees and the others in the orchard immediately adjacent. Because of this possibility however, and because there is but one check plot, the experiment has been discontinued.

In the earlier years of this experiment some heading back was practiced. This resulted in a relatively thick growth in the top. Since then the pruning has been light and has consisted, for the most part, of thinning out.

Cultural Experiment on the Horticultural Farm

The cultural experiment at Morgantown was started in the spring of 1917 with the object of making a study of some of the different systems of orchard management in use in West Virginia. The project was planned to study the variations encountered in the two general methods of orchard culture, namely, permanent sod and cultivation. Mine drops occurred in Plots 2, 3, and 4 in 1923, and a fire was accidentally set during the spring of 1923 in Plots 10 and 11. These two accidents made it necessary to discontinue this experiment according to the original plan.

The general plan of this experiment can be seen in Table 3, where the treatment of each plot is given. In plots 1 to 4 annual cultivation with a cover crop, either leguminous or non-leguminous, was practiced each year. In these plots manure, nitrate of soda, and acid phosphate were entered as variables. Plots 5 and 6 were intermediate between cultivation and a permanent sod. In the six plots remaining, the treatments called for a permanent sod of either grass or alfalfa, in which fertilizers, manure, and mulch were entered as variables. In this series, the trees were subjected to treatments in which the moisture and nitrogen relations were varied in several ways.

The trees in this experiment were trained, for the most part, to four scaffold limbs with a central leader bearing three or four laterals. The head was formed approximately twenty inches from the ground with the second story from thirty-six to forty-eight inches above the main scaffold branches. An attempt was made to prune all plots uniformly each season, but it was necessary to cut somewhat heavier on the cultivated plots because of the greater growth of both laterals and water sprouts. The kind of pruning can best be described as a light to moderate dormant pruning. The trees were planted thirty feet apart each way on the diagonal and when set were one year old and were carefully selected for uniformity.

The cultural program was for the most part, carried out as scheduled. Some variations, however, were necessary. In Plot 5, where it was planned to have sod and cultivation alternate in the rows, it has been difficult to get an even stand of grass during dry seasons. On account of this the treatments were not alternated annually as planned, but were alternated biennially. This resulted in a rather uneven growth of the cultivated and the sod sides of the

TABLE 3.—Plan of the Cultural Experiment with Delicious and Wealthy on the Agricultural Experiment Station Farm at Morgantown.*

Plot	Treatment 1917-1923	Row	Remarks
1	Cultivation with leguminous cover crop	1 2 3	Seeded to crimson clover and vetch. Cover crop turned under in late May or early June, with cultivation during the summer. Seeding rate 15 pounds per acre.
2	Cultivation with non-leguminous cover crop	4 5	Rye used each year and turned under in late May or early June. Seeding rate 1½ bushels per acre.
3	Cultivation, manure, and non-leguminous cover crop	6 7	Rye used as cover crop at rate of 1½ bushels per acre with manure at the rate of 12 tons per acre applied in May or June.
4	Cultivation, nitrate of soda, acid phosphate, and non-leguminous cover crop	8 9	Rye was sown as the cover crop. Nitrate of soda was applied at the rate of 150 pounds per acre and acid phosphate at the rate of 450 pounds per acre in late May or early June.
5	Sod with alternate rows in cultivation	10 11	The sod strip seeded with timothy, orchard grass, tall oat grass, and red top. The alternation of sod strip with cultivation has been irregular.
6	Sod with tree rows only cultivated	12 13	Sod formed with same combination as in Plots 4 and 5. The row strip was cultivated throughout the summer.
7	Alfalfa sod	14 15	The alfalfa was seeded at the rate of 20 pounds per acre and has been cut about three times each season and left on the ground.
8	Sod, nitrate of soda, and acid phosphate	16 17	Seeded to a combination of timothy, tall oat grass, orchard grass, and red top. Grass cut twice each season and left as it fell. Nitrate of soda applied at the rate of 150 pounds per acre and acid phosphate at 450 pounds per acre.
9	Sod and manure	18 19	Sod formed by the same seeding as in Plot 8. Manure applied in early spring at rate of 12 tons per acre.
10	Sod	20 21	Sod formed as in Plot 8. No grass removed after the cuttings.
11	Sod and additional straw mulch	22 23	Sod formed as in other plots. The mulch was formed with a wheat straw covering 4 to 6 inches deep, extending to the tips of the branches.
12	Alfalfa sod	24 25	Seeded as in Plot 7. After cutting as in the others the growth was left as it fell.

*Delicious and Wealthy alternate in each row.

trees. An error was made in the application of manure in 1923 to plot 3, when row 5 of Plot 2 and row 6 of Plot 3 received the application instead of rows 6 and 7 of Plot 3. The grass was cut three times each season in the sod plots and left on the ground as it fell. The strip cultivated in the tree row in Plot 6 was twelve feet wide. In Plot 11, the mulch of wheat straw was four to six inches thick and was about ten feet in diameter. The alfalfa in Plots 7 and 12 gradually became thinner after seeding, but was not renewed during the period of this report. The applications of nitrate of soda, acid phosphate, and manure were made evenly over the entire area of the plots.

THE EFFECT OF FERTILIZERS AND CULTURE ON GROWTH

The response of the trees in these experiments to the different treatments was determined each season by measuring the growth of the terminal twigs and the enlargement of the trunk. In addition to these two measurements, the size of the trees in the different plots of three of the experiments was determined at the end of the period reported upon. These three indices of tree response were selected as a means of comparing the growth under a given treatment with that of the checks or of another treatment. The data under these three headings are presented in the foregoing order.

Terminal Twig Growth

In taking the terminal twig measurments presented in the following tables, ten terminal twigs were selected at random from the limbs around the sides of each tree in a plot. In making the measurements in the orchard a fifty foot cloth tape was found to be most convenient because at the tenth measurement the total could be read directly and entered into the records. The average length of the terminal growth was computed for each tree. From these averages, the average twig length for the plot was then obtained.

The St. Marys Experiment.—Twig growth measurements were not taken on all of the trees of the St. Marys experiment until 1918, although data were presented in Bulletin 174 on the growth rate of twigs in Plots 2 and 5, for the years 1911 to 1919 inclusive. The earlier results showed a marked increase in growth in check Plot 5, as a result of the rejuvenation treatment, but there was a still greater growth, averaging three inches more, in Plot 2 which received a complete fertilizer.

TABLE 4.—Effect of Fertilization on Terminal Twig Growth in the St. Marys Experiment.

Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths Per Tree							Av'ge.
		1918	1919	1920	1921	1922	1923	1924	
2	N P K	10.20	7.16	8.45	3.33	4.73	4.24	3.23	5.90
3	N P	9.70	7.36	7.71	2.86	3.88	3.50	2.33	5.33
4	N K	9.60	5.68	6.60	2.94	3.94	3.72	2.87	5.05
5	Check	6.20	3.34	4.22	1.51	1.71	1.64	0.95	2.79
6	P K	7.30	4.60	5.35	1.98	1.90	1.85	0.91	3.41
7	N P K	9.80	7.06	8.57	2.67	4.09	3.23	1.87	5.33
8	N P	10.20	6.99	8.60	2.83	4.60	2.95	1.73	5.41
9	N K	9.30	6.66	6.30	2.85	3.30	3.13	1.72	4.75
10	Check	6.20	3.59	3.33	1.23	1.23	0.99	0.65	2.46

The complete record of terminal twig growth in the St. Marys experiment, from 1918 to 1924, is given in Table 4. The results show substantial increases for all plots receiving nitrate of soda (see Figure 2). Plot 6, to which acid phosphate and muriate of potash were applied, made terminal growths slightly better than the adjacent check. The odds, however, calculated by Student's method (Student 1918, Love 1924), were 87:1, which indicated a significant difference.* The best plot in the experiment was number 2, which received a complete fertilizer. It was on lower ground and undoubtedly had more fertile soil. When the terminal growth made in the last four years of the experiment is compared with that of the earlier years after the treatments were begun, it will be seen that there was a marked reduction in twig growth. In the nitrated plots this reduction in twig growth accompanied increased production, lighter pruning, and also a larger size of tree. In the plots not receiving nitrogen the decreasing growth undoubtedly indicates progressive stages in soil exhaustion.

The Sleepy Creek Experiment.—In Table 5, the average terminal shoot growth is given for 1913 to 1924, the period when these trees were from nine to twenty years of age. The measurements were not made in 1915 on account of the heavy pruning given the trees that year. The average growth under each treatment for the entire period was not computed, as the rather wide differences in annual growth make this figure of little value.

*Odds of 87:1 mean that the odds are 87 to 1 against the possibility of a difference as great as this occurring due to chance alone. These odds must be at least 30:1 to be significant.

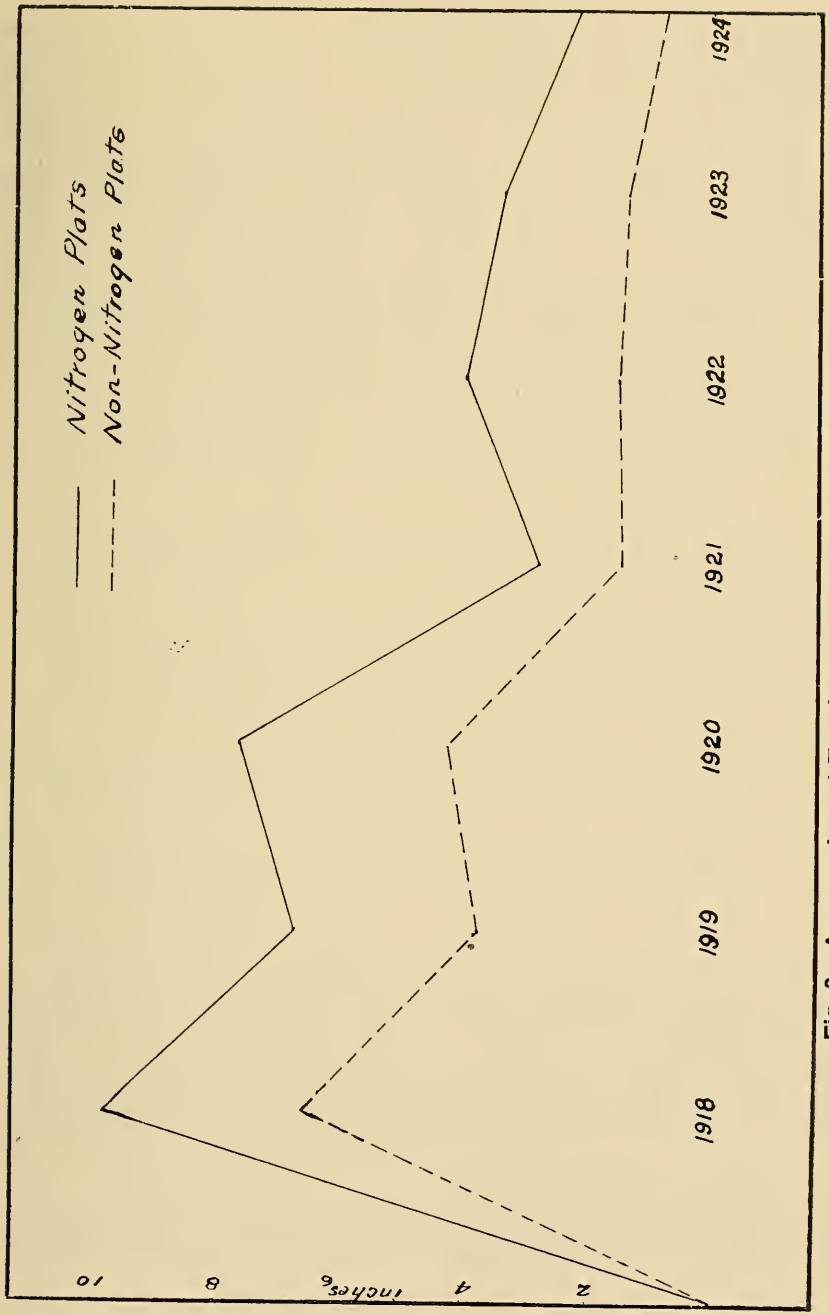

Fig. 2.—Average Annual Terminal Growth, St. Marys Experiment.

TABLE 5.—Effect of Fertilization on Terminal Twig Growth in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths or Shoots per Tree											Odds in Favor of the Treatment	Odds in Favor of the Check
			1913	1914	1916	1917	1918	1919	1920	1921	1922	1923	1924		
Grimes	1	Check	13.80	10.60	18.20	9.00	6.37	6.22	10.40	7.47	6.96	5.17	4.25		
	2	N P	17.23	16.73	22.26	10.70	8.83	7.46	9.70	9.53	11.16	5.60	5.27	1666:1	
	3	N K	9.07	9.60	18.25	9.75	8.30	8.87	10.35	8.85	12.30	5.47	2.82	25:1	
	4	N P K	11.57	8.61	23.20	12.30	9.75	9.72	10.97	8.60	8.40	4.80	5.26	19:1	
	5	P K	14.86	13.31	21.52	10.06	7.06	7.14	10.14	7.72	9.00	4.92	2.48	10:1	
	6	Check	15.37	11.37	21.85	9.70	7.65	6.07	8.18	8.37	6.80	4.74	3.28		
	7	N	13.62	11.30	21.30	11.27	9.85	8.92	9.65	7.50	7.38	5.24	3.70	8:1	
	8	P	10.50	10.26	19.24	9.70	6.28	6.16	10.42	8.41	6.72	3.54	2.44		10:1
	9	K	9.74	10.04	18.64	8.88	5.62	4.62	10.93	8.56	6.06	3.36	2.32		30:1
	10	Check	7.89	10.38	20.44	10.92	6.00	6.82	10.12	8.32	7.56	2.16	2.74		
Ben Davis	1	Check	11.20	9.15	15.64	10.70	7.60	6.00	6.02	6.52	9.45	5.44	5.10		
	2	N P	12.04	10.38	20.56	11.42	10.00	7.10	9.44	8.40	8.82	4.80	5.70	129:1	
	3	N K	10.10	9.68	18.90	11.50	10.40	9.70	9.42	7.25	13.32	4.80	5.22	75:1	
	4	N P K	11.60	10.55	19.36	10.82	10.26	9.14	8.88	7.12	10.98	4.32	6.56	446:1	
	5	P K	11.12	11.07	17.76	10.42	11.64	8.18	7.62	5.58	6.36	4.20	3.48	3.5:1	
	6	Check	10.50	11.76	19.68	10.82	8.02	5.70	6.06	4.28	6.18	4.52	3.94		
	7	N	11.46	12.45	22.68	11.60	10.58	8.58	8.82	6.86	9.12	4.20	4.22	2499:1	
	8	P	11.18	11.92	21.16	11.96	8.58	6.05	5.05	3.58	7.20	4.43	3.85	349:1	
	9	K	8.25	10.86	19.20	10.16	7.32	4.44	4.70	4.00	5.58	3.30	3.27	even	
	10	Check	7.22	10.35	16.84	10.68	7.28	5.80	4.17	2.67	7.50	4.27	2.65		
York	1	Check	17.78	14.82	20.64	10.36	6.16	5.50	4.70	3.78	4.74	4.20	3.74		
	2	N P	15.06	13.02	22.84	12.14	7.44	7.42	5.52	8.68	7.00	4.14	4.00	23:1	
	3	N K	14.28	11.76	21.48	11.72	8.46	9.84	4.86	6.70	7.08	3.48	5.12	22:1	
	4	N P K	11.56	11.34	21.28	11.76	7.60	9.00	5.38	8.12	6.84	4.20	4.77	13:1	
	5	P K	12.08	14.10	19.32	9.66	6.40	5.04	3.08	2.90	4.26	3.24	3.32	even	
	6	Check	13.14	15.73	19.16	9.96	5.10	4.16	3.04	2.20	3.66	2.34	3.28		
	7	N	10.85	11.70	22.50	11.30	6.25	7.70	7.27	6.81	6.78	3.53	4.50	52:1	
	8	P	8.82	10.52	17.04	9.66	5.00	4.28	4.80	4.72	6.30	2.94	3.20	even	
	9	K	8.34	6.61	16.88	9.48	4.60	4.54	3.74	3.32	3.36	1.98	1.92		5:1
	10	Check	9.17	11.11	18.10	9.57	4.90	5.25	3.76	3.10	4.98	3.76	2.90		

The responses to the different treatments were studied by Student's method. In using this method a "theoretical or calculated" check was made the basis of comparison, that is, each check was computed from the values of the two nearest checks, the value being proportional to the relative distances from the plot to be compared. When comparisons are made in this way and the odds computed, it will be seen that the only consistent responses to fertilizers have been made by Ben Davis. In this block all applications containing nitrate of soda showed significant increases in twig growth. In the Grimes block the plot to which nitrate and phosphate have been applied is the only one that showed a significant increase. In the York block only the nitrate plot showed a significant response. It should be noted, however, that all plots receiving nitrate showed odds in favor of the treatment. This is not true for the plots receiving potassium or phosphorus.

The Rome Experiment.—The average terminal twig growths in the thirteen-year-old Rome block at Sleepy Creek are shown in Table 6. Unfortunately this experiment has but one check plot. Because of possible differences in soil it was thought best to make comparisons between contiguous plots only.

When these comparisons were made by Student's method, no treatment in this experiment showed a significant increase over the adjacent one. It will be remembered, however, that the soil in this orchard was fairly fertile and that the orchard was cultivated. When it is considered that twig growth on the checks averaged more than twenty-four inches at the beginning of the experiment in 1914, and more than nine inches when the trees were twelve years old in 1923, it is not surprising that increased growth did not result from the fertilizer applications.

The Cultural Experiment.—In this experiment the influence of a number of treatments on terminal twig growth can be studied in Table 7. Sod Plot 10 was used as a basis of comparison and the odds were calculated according to Student's method. Reference is made to both varieties in the discussion of results at the end of this bulletin.

All other treatments gave significantly better growth than did sod. A legume cover crop in Plot 1 with Wealthy gave more terminal growth than the non-legume cover crop in Plot 2 (63:1). With Delicious the odds are hardly significant (25:1). These results are

TABLE 6.—Effect of Fertilization on Terminal Twig Growth in the Rome Experiment.

Plot	Treatment	Average Shoot Growth in Inches per Plot Based on Ten Growths or Shoots per Tree										
		1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924
1	N P	22.47	38.80	35.87	11.46	12.98	13.38	9.97	11.61	9.34	8.96	5.40
2	N K	23.14	32.40	34.82	14.67	17.44	14.49	8.51	11.97	9.66	9.29	6.56
3	N P K	28.84	37.80	36.00	15.20	15.93	13.63	8.45	12.85	10.57	9.53	7.38
4	P K	23.31	30.83	28.94	16.27	15.54	13.10	10.30	13.75	10.83	9.90	6.28
5	Check	24.76	31.04	27.78	15.06	13.82	12.97	9.35	11.68	9.30	9.26	6.84
6	N	23.46	33.58	35.36	16.15	17.54	13.67	8.32	11.58	9.63	9.81	7.17
7	P	22.41	34.26	29.44	13.84	14.20	12.59	8.78	12.29	9.36	9.09	6.39
8	K	22.00	36.20	31.29	16.39	13.77	12.01	8.08	11.37	9.72	9.39	6.41

surprising because the cover crop growth in Plot 1 was not heavy and do not agree with those of Oskamp (1920) in Indiana, where rye proved to be a much better cover crop as measured by the organic matter and nitrogen returned to the soil and by the tree growth. With Delicious in this experiment manure did not give a significant increase in growth (14:1) in Plot 3, when comparison is made with Plot 2, to which manure was not applied, but which received the same care otherwise. With Wealthy, however, there was a significant increase (75:1) from the use of stable manure in Plot 3.

In comparing Plots 2 and 4, Delicious showed a significant difference (36:1) in favor of the nitrate and acid phosphate applications as did also Wealthy (30:1). At the time of writing this manuscript (June 1925) very slight, if any, differences could be noticed in the four cultivated plots of this experiment. The trees in Plots 3 and 4 may have had slightly darker green foliage.

Cultivation along with nitrate and acid phosphate in Plot 4 gave no better growth than when these same fertilizers were applied to sod in Plot 8, the odds being 2:1 with both Delicious and Wealthy. In this experiment where manure was applied to a cultivated plot it did not give significantly better growth than where applied to sod with either Delicious or Wealthy. The soil, however, is slightly better in all the sod plots. These results indicate that vigorous tree growth can be secured and maintained at least up to bearing age in sod orchards by applying nitrate of soda in sufficient quantities.

When applications of nitrate of soda and acid phosphate to Plot 8 in sod are compared with manure applications in Plot 9, there seems to be a significant difference in favor of the former with Delicious, (42:1), but not with Wealthy, (1:1). Sod with strip cultivation was better than alternate row cultivation with both Delicious (34:1) and Wealthy (33:1). At the time of this writing the trees in the strip-cultivated plot were much more vigorous and have darker green foliage than the trees in the plot given alternate row cultivation.

The alfalfa sod plot showed a significant increase in twig growth over the grass sod even though the growth of alfalfa was sparse. On account of the poor stand of alfalfa, however, these two plots cannot be considered as having given this crop a fair test in this location.

TABLE 7.—Effect of Treatments on Terminal Twig Growth in the Cultural Experiment.

Plot	Treatment	Average Increase in Inches Based on Ten Growths per Tree												Average		Odds in Favor of the Treatment	
		1918		1919		1920		1921		1922		1923					
		Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy
1	Cultivation and legume cover crop	17	14	19	19	19	22	17	19	17	16	17	18	17.7	18.0	410:1	1666:1
2	Cultivation and non-legume cover crop	16	9	17	18	18	19	16	18	16	15	15	17	16.3	16.0	142:1	454:1
3	Cultivation, manure, and non-legume cover crop	19	11	19	19	21	24	17	20	15	15	17	20	18.0	18.2	179:1	665:1
4	Cultivation, nitrate, acid phosphate, and non-legume cover crop	17	10	18	17	20	22	18	20	16	16	18	20	17.8	17.5	794:1	1110:1
5	Sod and alternate row cultvation	12	9	15	20	15	14	15	16	16	15	14	16	14.5	15.0	65:1	76:1
6	Sod and strip cultivation	21	14	18	19	17	17	16	17	16	16	18	19	17.7	17.0	124:1	4999:1
7	Alfalfa sod	19	12	14	13	16	17	15	15	14	16	17	17	15.8	15.0	58:1	999:1
8	Sod, nitrate and acid phosphate	11	11	17	21	17	16	19	19	17	17	21	24	17.0	18.0	1428:1	1999:1
9	Sod and manure	9	11	14	17	15	21	18	19	17	18	21	24	15.7	18.3	369:1	4999:1
10	Sod	8	7	9	11	13	12	12	12	13	11	15	15	11.7	11.3		
11	Sod and additional straw mulch	14	11	15	19	17	16	16	17	14		15		15.2	15.8	115:1	2499:1
12	Alfalfa sod	18	11	14	16	17	20	17	11	14	12	14	13	15.7	13.8	40:1	11:1

Trunk Circumference

Measurements of the increase in the circumference of the trunk were taken each year on all the trees. The measurements were made with a steel tape, usually in late fall after growth had stopped for the season. In order to make the measurements as consistent as possible from year to year a white band at the point of measurement was painted on the trunk at a point about half way up to the lower limbs. In the older trees care was taken to remove the larger flakes of rough bark before making the measurement. The data for trunk circumference in the different experiments are presented in the same order as that for twig growth.

The St. Marys Experiment.—In Table 8 the records of the annual increase in trunk circumference in Rome are given for the period 1916 to 1924 inclusive. It may be seen from either the totals or the annual measurements that there were consistent differences between the plots which received nitrate of soda and those which did not.

TABLE 8.—Effect of Fertilization on Trunk Circumference in the St. Marys Experiment

Plot	Treatment	Average Annual Increase in Trunk Circumference in Inches						Total Increase
		1918*	1919	1921**	1922	1923	1924	
2	N P K	2.32	.79	2.22	1.39	1.22	.65	8.59
3	N P	2.52	.99	1.42	1.28	.88	.60	7.69
4	N K	1.99	.75	1.34	1.40	.66	.23	6.37
5	Check	1.40	.66	.29	.51	.94	.25	4.05
6	P K	1.79	.27	.85	.44	.67	.43	4.45
7	N P K	2.43	.89	1.70	.91	.37	.90	7.20
8	N P	2.10	1.02	1.75	1.06	.53	.61	7.07
9	N K	2.25	.36	2.47	.94	.75	.58	7.35
10	Check	1.45	.46	.41	.72	.25	.16	3.45

*Increase for period of 1916-18. **Increase for period of 1920-21.

All treatments showed significant increases over the checks except Plot 6, to which acid phosphate and muriate of potash were applied. The odds in this instance were only 2:1, which is not significant. The results from the fertilizer applications in this experiment as measured by the increase in trunk circumference correspond in general with the differences shown by terminal twig growth. The differences between the nitrogen plots were probably due to soil variations.

As pointed out in Bulletin 174, no records are available regarding the size of these trees at the beginning of the experiment in 1911. It should be kept in mind, however, that this part of the orchard was chosen for the experiment because of its uniformity. It seems fair to assume, therefore, that the differences existing between the plots at the time of this writing were due to the treatments and that they were cumulative from 1911 to 1916, before the measurements were taken, and also since that time.

The Sleepy Creek Experiment.—The annual increase in trunk circumference was taken each year in this experiment from 1913 to 1924 inclusive. The data are summarized in Table 9. It will be seen that there are a few instances in this table where no increase in growth is shown. This is due to errors in measurement which result from irregularities in the bark or slight variations in placing or reading the tape; that this is the probable explanation may be seen by comparing the figures on either side of these errors. Such discrepancies, however, should not affect the totals appreciably, but they do influence the odds in the comparisons by Student's method.

A "theoretical or calculated" check was used as the basis for comparison in the trunk measurements as in the twig growths. The increases in the different plots were not consistent. None of the treatments in the Grimes block were significant when measured by Student's method. In the Ben Davis section of the experiment nitrate of soda showed a significant increase in Plots 2 and 7. In Plot 5, which received acid phosphate and muriate of potash, the increased growth was significant when compared with the checks as was true in the plots receiving nitrate of soda. This single instance, however, cannot be considered suggestive in view of the results of other experiments. A single plot of York receiving nitrogen (Number 2) showed a significant increase in trunk circumference. The data on the trunk measurements in this experiment agree in general with those on the twig measurements. Emphasis will be placed, later on, in this discussion, upon the probable reason for the general trend of the results in this experiment.

The Rome Experiment.—Emphasis has already been given to the relatively high initial fertility of the soil in this experiment and also to the fact that the trees did not apparently draw heavily upon the available food supply. This general condition was shown in the data on twig growth in Table 6.

TABLE 9.—Effect of Fertilization on Trunk Circumference in the Sleepy Creek Experiment.

Plot		Treatment	Average Annual Increase in Trunk Circumference in Inches												Total Increase	Odds in Favor of Treatment	Odds in Favor of Check
			1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924			
Grimes	1	Check	.89	1.46	2.88	.87	1.69	.93	.84	1.53	1.37	.45	.88	1.24	15.07		
	2	N P	1.18	2.50	2.67	1.20	2.05	2.33	1.00	.58	1.85	.00	2.40	.75	18.51	10:1	
	3	N K	1.15	1.35	2.56	.78	1.47	1.50	1.09	.**	1.63	1.62	.56	.78	15.15	even	
	4	N P K	1.63	1.13	2.72	.93	1.47	1.69	1.37	.81	1.38	1.32	.43	.78	15.66	7:1	
	5	P K	2.01	1.38	3.35	.70	1.45	1.65	1.07	1.48	1.20	.90	.65	.47	16.31	4:1	
	6	Check	1.16	1.47	2.40	1.29	1.46	1.38	1.03	.91	1.44	.00	1.37	.56	14.47		
	7	N	1.71	1.10	1.75	.90	1.56	1.31	1.32	3.33	.00	.00	1.36	.03	15.37	even	
	8	P	1.26	1.08	2.82	.88	2.10	.30	.85	2.50	.00	.90	.60	.15	13.44	even	
	9	K	.49	1.20	2.40	.97	1.18	1.10	.85	.00	2.35	.85	.45	.35	12.19		19:1
	10	Check	1.64	1.12	2.58	1.25	1.25	1.15	.97	.00	2.58	.95	.67	.30	14.46		
Ben Davis	1	Check	.29	1.10	2.70	.57	.58	2.05	1.32	.18	.60	.87	.54	.75	11.55		
	2	N P	1.00	.96	1.34	3.12	1.13	2.25	1.62	.28	1.65	1.65	.75	.65	16.40	85:1	
	3	N K	.90	.96	3.13	1.06	1.56	1.75	2.17	1.15	.50	2.00	.13	.93	16.24	17:1	
	4	N P K	1.83	1.13	2.62	1.00	1.53	1.45	1.95	.70	1.60	1.30	1.05	.57	16.73	30:1	
	5	P K	.99	1.55	3.00	1.37	1.43	1.55	1.82	.78	.70	1.30	.30	.57	15.36	4.5:1	
	6	Check	1.67	1.27	3.45	1.20	1.08	1.75	1.12	.13	1.10	.80	.60	.37	14.54		
	7	N	2.42	1.40	2.95	1.33	1.95	1.70	1.75	.60	1.70	1.15	.62	.78	18.35	350:1	
	8	P	2.16	1.38	3.44	.93	1.73	1.15	1.60	.25	.81	1.19	.75	.43	15.82	28:1	
	9	K	1.40	.98	2.87	1.23	1.35	1.50	.92	.73	.60	.60	.65	.65	13.48	2:1	
	10	Check	1.50	1.13	2.56	.88	1.05	1.20	1.06	.00	.00	1.56	.62	.53	12.09		
York	1	Check	1.82	1.58	2.95	1.29	1.95	1.85	.65	.75	.60	1.05	1.00	.62	15.62		
	2	N P	2.16	1.45	3.00	1.42	2.13	2.15	1.27	1.53	.95	1.55	.85	1.30	19.76	308:1	
	3	N K	1.40	1.28	2.92	1.13	2.20	2.30	1.10	1.40	.65	1.50	.60	.62	17.10	3:1	
	4	N P K	1.54	1.32	2.88	.95	1.50	2.90	1.15	1.50	.75	1.50	.65	.92	17.56	3:1	
	5	P K	1.70	1.57	2.05	1.85	1.48	1.40	.77	1.13	.00	.55	.55	.30	13.35		26:1
	6	Check	2.15	1.95	3.20	1.28	1.95	1.60	.95	.80	.00	.80	.60	.57	15.85		
	7	N	1.70	1.36	2.96	1.09	2.19	.68	1.82	.00	.20	1.35	3.14	.83	15.85	3:1	
	8	P	1.72	.93	2.95	.82	1.13	1.35	1.12	.23	.85	1.00	.35	.55	13.00	even	
	9	K	1.66	.98	2.60	.77	1.18	1.10	.85	.45	.45	.50	.45	.25	11.24		26:1
	10	Check	1.58	1.28	2.22	1.16	1.56	1.19	1.09	.00	.00	.52	1.79	.41	12.80		

TABLE 10.—Effect of Fertilization on Trunk Circumference in the Rome Experiment.

Plot	Treatment	Average Annual Increase in Trunk Circumference in Inches											Total Increase
		1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	
1	N P	1.82	1.95	1.28	2.38	2.33	.99	1.85	1.39	2.38	1.60	.96	18.93
2	N K	1.67	1.57	.92	1.43	2.40	1.81	1.19	2.08	2.10	1.38	1.31	17.86
3	N P K	1.55	2.12	1.09	2.14	2.83	1.97	1.15	2.46	1.59	2.42	.59	19.91
4	P K	1.53	1.59	.72	1.48	2.11	2.32	2.31	2.16	2.39	2.03	1.00	19.64
5	Check	1.74	1.54	.75	1.33	2.00	1.56	1.14	1.77	1.55	3.18	.50	17.06
6	N	1.69	1.65	.80	.57	2.98	1.67	1.08	1.79	2.29	2.65	.32	17.49
7	P	1.77	1.81	.83	1.72	2.00	1.61	1.99	1.87	2.16	1.80	.77	18.33
8	K	1.50	1.90	.67	1.40	1.88	1.57	1.58	1.71	2.09	1.68	1.05	17.03

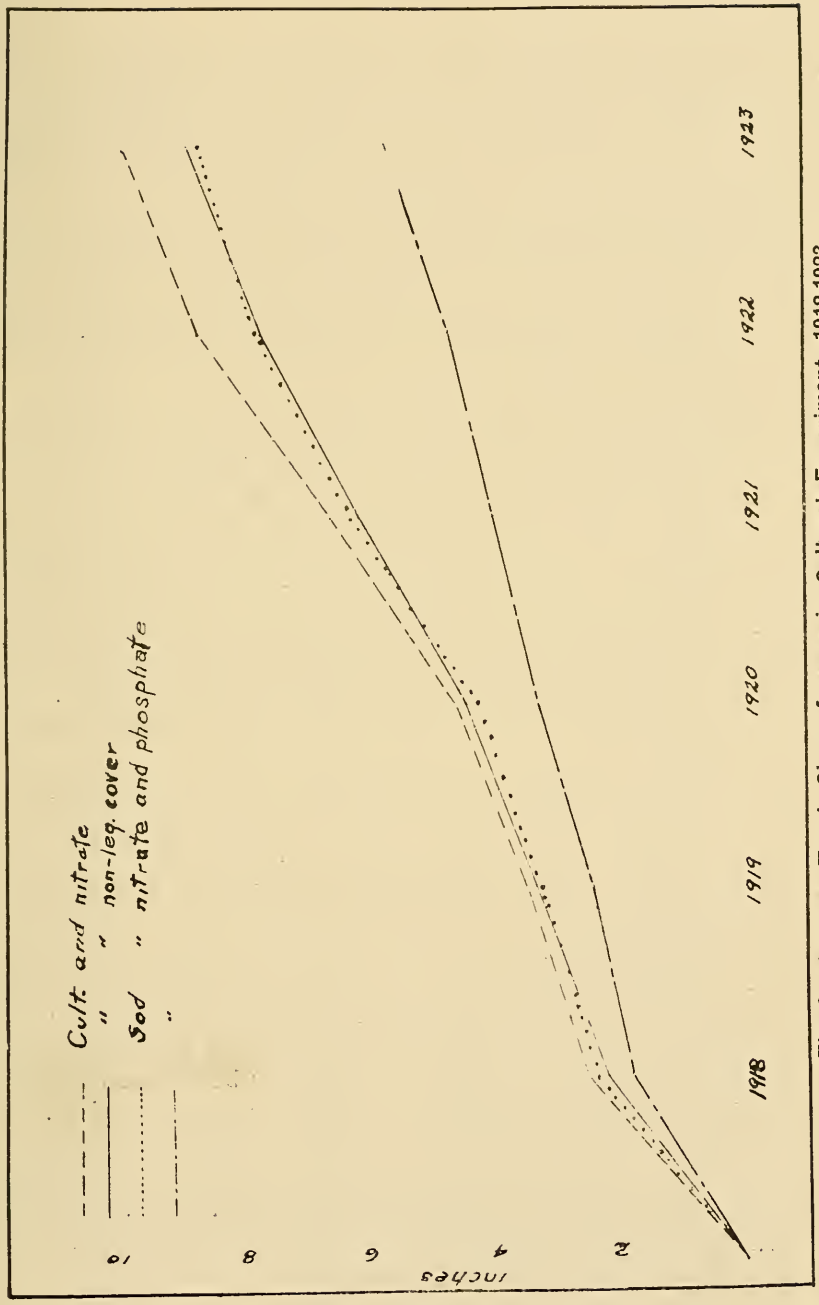

Fig. 3.—Average Trunk Circumference in Cultural Experiment, 1918-1923.

It may be seen from Table 10 that the general trend of the data on trunk circumference follows that on twig measurements in that no significant differences appear between the plots receiving fertilizer treatments. Up to the time of this writing this experiment appeared to be in the same category as those in Pennsylvania and New York where the initial soil fertility was sufficient to maintain tree growth even with considerable fruit production.

The Cultural Experiment.—Turning now to the Cultural experiment it may be seen that the different treatments in these plots show as interesting differences in the trunk measurements as in the twig measurements (see Figure 3). The data on trunk circumferences are included in Table 11.

Delicious with a legume cover crop in Plot 1, although light in some seasons, gave a significant increase in trunk circumference over Plot 2, which was seeded to a non-leguminous crop each year (79:1). Wealthy, on the other hand did not show such an increase (3:1). Stable manure, in Plot 3, which was cultivated, gave no significant increase in trunk circumference over Plot 2, which received no manure, with either Delicious (13:1) or Wealthy (20:1). In Plot 4 (cultivated) acid phosphate and nitrate of soda were not significantly better than was cultivation and a non-leguminous cover crop in Plot 2 with either Delicious (13:1) or Wealthy (21:1). The odds as measured by terminal twig growth were significantly in favor of Plot 4.

There were no significant differences in trunk circumference between cultivation and sod (Plots 4 and 8) when nitrate of soda and acid phosphate were added to both, with either Delicious (7:1) or Wealthy (9:1). When stable manure was added to both instead of nitrate of soda and acid phosphate (Plots 3 and 9), there were significant increases over sod with both Delicious (38:1) and Wealthy (272:1). In Plot 9, manure gave about the same increases in trunk circumference that nitrate of soda and acid phosphate gave in Plot 8. Alfalfa sod was not significantly better than a grass sod in this orchard. Strip-cultivation was not significantly better than alternate row cultivation with either Delicious (18:1) or Wealthy (3:1). An additional mulch around the trees in Plot 11 did not give a significant increase as compared with sod. In alfalfa Plot 7, Wealthy made a better showing than did Delicious, but as noted in connection with twig growth the alfalfa sod was not thick enough in the last few years to make a fair comparison with sod.

TABLE 11.—Effect of Treatments on Trunk Circumference in the Cultural Experiment.

Plot	Treatment	Average Increase in Inches										Total		Average		Odds in Favor of Treatment	
		1919		1920		1921		1922		1923							
		Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy	Delicious	Wealthy
1	Cultivation and legume cover crop	1.5	1.0	1.5	1.2	1.9	2.2	2.0	1.9	1.2	1.6	8.1	7.9	1.6	1.6	155:1	541:1
2	Cultivation and non-legume cover crop	1.1	1.2	1.1	1.2	1.7	1.9	1.6	1.8	1.2	1.4	6.7	7.5	1.3	1.5	78:1	1666:1
3	Cultivation, non-legume cover crop, and manure	0.9	1.4	1.3	1.1	2.1	2.7	2,2	2.2	1.4	1.7	7.9	9.1	1.6	1.8	50:1	399:1
4	Cultivation, non-legume cover crop, acid phosphate, and nitrate	0.9	1.0	1.1	1.3	2.0	2.4	2.2	1.9	1.2	1.6	7.9	8.2	1.6	1.6	28:1	458:1
5	Sod, alternate row cultivation, and non-legume cover crop	0.7	1.2	1.0	1.0	1.2	1.2	1.6	1.6	1.0	1.0	5.5	7.0	1.1	1.4	16:1	209:1
6	Sod and strip cultivation	0.9	1.0	1.0	1.0	1.7	1.5	1.6	1.6	1.3	1.2	6.5	6.3	1.3	1.3	49:1	746:1
7	Alfalfa sod	0.6	0.8	1.0	0.9	1.4	1.4	1.3	1.1	0.9	1.1	5.2	5.3	1.0	1.1	13:1	9000:1
8	Sod, nitrate, and acid phosphate	0.9	1.2	1.1	0.9	1.9	1.8	1.5	1.2	1.1	1.7	6.5	6.8	1.3	1.4	26:1	675:1
9	Sod and manure	0.8	0.5	1.1	0.6	1.5	1.6	1.6	1.7	1.3	1.3	6.3	5.7	1.3	1.1	60:1	37:1
10	Sod	0.6	0.4	0.9	0.5	0.7	0.8	0.8	0.5	1.0	0.6	4.0	2.8	0.8	0.6		
11	Sod and additional straw mulch	1.0	1.2	1.0	0.7	1.6	1.6	1.4	1.1	0.2	0.0	5.2	4.6	1.0	0.9	3:1	7:1
12	Alfalfa sod	0.7	0.8	1.1	0.7	0.7	1.1	2.0	0.4	0.7	0.5	5.2	3.5	1.0	0.7	4:1	7:1

Size of Tree

Measurements of tree size were made in the Sleepy Creek Experiment in the fall of 1923, in the Rome Experiment in the fall of 1924, and in the Cultural Experiment in the spring of 1925. It was thought that the size of the trees in the different plots would be a good measure of the end result of the treatment and that it would also serve as a check in studying the other growth records. Breadth of tree was measured with a cloth tape and height of tree with a stadia rod. Since these measurements showed that most of the trees approximated a half sphere, the volume was computed using the formula $V=4/3\eta R^3$ where V equals the volume of the sphere.

The St. Marys Experiment.—In the St. Marys Experiment tree size was greatly increased by the nitrate of soda applications as shown in Table 12, the average volume of tree being from two to three times that in the check plots (see Figure 4 on front cover). It will be shown later that such differences in size have a bearing upon fruitfulness. Plot 6, to which potash and acid phosphate were applied, had an average tree size about the same as that of the adjacent check, (Plot 5). This is surprising in view of the increased growth of grass and clover that resulted from the use of phosphate. The nitrogen deficit in this soil was very large and apparently the amounts being added by the clover over the ten year period were not sufficient to affect the size of the tree. Differences in tree size between the plots receiving nitrogen may be attributed to variations in initial soil fertility.

TABLE 12.—Effect of Fertilization on Tree Size in the St. Marys Experiment (1924).

Plot Number	2	3	4	5	6	7	8	9	10
Treatment	N P K	N P	N K	Check	P K	N P K	N P	N K	Check
Average Volume of Top (cu. ft.)	6707	6639	6267	4061	3674	5649	5445	4861	2026

The Sleepy Creek Experiment.—In Table 13 are given the tree sizes in the Sleepy Creek Experiment. The values are not averages, but are the actual tree volumes in cubic feet computed from measurements taken in the fall of 1923. Student's method was used again to determine whether or not any of the fertilizer treatments significantly increased the size of tree. Results, in general, corroborate those from terminal twig and trunk circumference measurements. None of the treatments consistently increased the size of the trees. It will be noticed that a wide variation existed in tree size even in the same plot. This would indicate that factors other than the treatments, such as soil variability, root injury, and possibly a stock relationship, were also influencing tree growth. A number of pictures were taken of trees believed to have been injured by root cutting. One of these trees is shown in Figure 5. At the time this picture was taken on July 25, 1925, the leaves were smaller and many were falling on the side where deep cultivation had been practiced.

Fig. 5.—Tree Injured by Root Cutting in Sleepy Creek Experiment.

The Cultural Experiment.—The effects of the different soil and fertilizer combinations on tree size in the Cultural Experiment are given in Table 14. See also Figures 6, 7, 8, and 9. Comparisons were made of the different treatments by computing the average or mean tree volume in cubic feet. The probable error of the mean

TABLE 13.—Effect of Fertilization on Tree Size in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Tree Volume in Cubic Feet for Trees Numbered					Odds in Favor of Treatment	Odds in Favor of Check
			1	2	3	4	5		
Grimes	1	Check	5268	7501	4496	5116			
	2	N P	6928	8740	8579			188:1	
	3	N K	6518	5385	6254	8740		6:1	
	4	N P K	4601	6518	6789	4189		2:1	
	5	P K	9070	5153	8904	5039	8904	16:1	
	6	Check	3354	4927	7799	4927			
	7	N	5747	8904	7649		5385	8:1	
	8	P	8904	2223	6789	4290	2638	even	
	9	K	6695	3803	2566	5039	4601		2:1
	10	Check	13047	3185	3619	3354	1796		
Ben Davis	1	Check	2494	2864	2943	2424	3619		
	2	N P	6124	5268	5153	12626	6518	32:1	
	3	N K	5747	5385	6653		8105	98:1	
	4	N P K	4708	4817	3993	7649	11812	8:1	
	5	P K	4290	2032	5153	8419	3993	even	
	6	Check	3103	5385	7649	5153	4817		
	7	N	6124	4601	1103	7649	6124	even	
	8	P	3803		4290	3529	7355	even	
	9	K	2788	4601	2788	4392	4927		2:1
	10	Check	3022		3529	4091	4496		
York	1	Check	7649	6789	4392	3993	5997		
	2	N P	8419	4189	5997	4817	6518	even	
	3	N K	6928	6254	6653	6254	4496	even	
	4	N P K	4927	5153	6124	7799	8579	21:	
	5	P K	4091	4927	2223	3993	4290		54:1
	6	Check	7951	5997	6124	4290	6124		
	7	N	5385	10657	8579	8419		9:1	
	8	P	5153	4290	1527	2424	3441		103:1
	9	K	4927	2638	1971	3354	2032		40:1
	10	Check		3803	3803	4817	8419		

was determined by using Bessel's formula. The average size of trees as indicated by trunk circumference and twig growth was greater in all plots which received fertilizer or cultural treatments than it was in the untreated or sod plot. The different treatments were also compared using the probable error of the difference.* When a legume cover crop was compared with a non-legume cover crop by this method (Plots 1 and 2) a significant increase in average tree size was shown with Wealthy (142:1) but not with Delicious (2:1). Anthony and Waring (1925) in Pennsylvania, with sixteen year old Stayman, found a significant increase in growth with a leguminous over a non-leguminous cover crop. Stable manure gave a significant increase in tree size in Plot 3 over Plot 2 with Delicious (267:1), but not with Wealthy (22:1). Annual cover crops of rye were sown

*This is found by taking the square root of the sum of the squares of the probable errors of the two results. To secure odds of 30:1 indicating that the difference is due to something other than chance, the difference must be slightly greater than three times its probable error.

Fig. 6.—Average Tree in Cultivated Plot 4 Fertilized with Nitrate and Acid Phosphate.

Fig. 7.—Average Tree in Cultivated Plot 2 Not Fertilized.

Fig. 8.—Average Tree in Sod Plot 8 Fertilized with Nitrate and Acid Phosphate.

Fig. 9.—Average Tree in Sod Plot 10 Not Fertilized.

on both plots. In Plot 4, however, which received annual applications of nitrate of soda and acid phosphate, there was no significant increase in average tree size over the average size in Plot 2 in the case of either Delicious (14:1) or Wealthy (5:1). Trees in Plot 6, which had a twelve foot strip in the row cultivated were not significantly larger than trees in Plot 5 which was given alternate row cultivation. Manure in Plot 9 and nitrate of soda and acid phosphate in Plot 8 (both in sod) strikingly increased the average size of tree as compared with Plot 10 which was in sod but did not receive any fertilizer. The trees on each of the fertilized cultivated plots obtained an average tree size significantly larger than the average in either sod Plot 8, which received nitrate of soda and acid phosphate, or sod Plot 9, which received manure. There were no significant differences, however, when tree size in the fertilized sod plots was compared with that in Plot 2, which was cultivated and had an annual cover crop of rye but was never fertilized.

TABLE 14.—Effect of Treatments on Tree Size in the Cultural Experiment.

Plot	Treatment	Average Volume of Tree in Cubic Feet	
		Delicious	Wealthy
1	Cultivation and legume cover crop	1500±108	1301±67
2	Cultivation and non-legume cover crop	1299±58	887±76
3	Cultivation, manure, and non-legume cover crop	1759±89	1307±121
4	Cultivation, nitrate, phosphate, and non-legume cover crop	1618±102	1133±81
5	Sod and alternate row cultivation	813±76	639±57
6	Sod and strip cultivation	975±92	829±73
7	Alfalfa sod	760±37	597±44
8	Sod, nitrate, and acid phosphate	1045±73	916±112
9	Sod and manure	850±109	784±53
10	Sod	244±20	441±40
11	Sod and additional straw mulch	Discarded	Discarded
12	Alfalfa sod	497±63	474±73

EFFECT OF FERTILIZERS AND CULTURE ON FRUITFULNESS

In the preceeding section attention has been directed to the influence of the different variables in the treatment upon tree growth. A particular treatment may increase the growth of a tree but if it is

not accompanied by increased yield, either actually or potentially, it is of questionable value from the practical standpoint. The influence of the different treatments upon fruitfulness was studied in these experiments by bloom, set and yield, and color and size of fruit. They are taken up here in the order given.

Bloom and Set

The St. Marys Experiment.—Table 15 includes the bloom and set records in the St. Marys experiment for the past three years. In Bulletin 174, it was shown that over a period of four seasons the bloom in the nitrated plots was somewhat heavier than in the other plots. The amount of bloom was figured for each tree (Table 15) and these amounts were then averaged for the plot. In the spring of 1918 when the bloom was heavy, actual counts were made of flowers at bloom. From these counts the set was obtained after the "June drop". That year in the nitrated plots receiving acid phosphate the set was 5.16 to 6.66 per cent of the total bloom, while in the check and nitrated plots receiving potash the set was 3.08 and 3.25 per cent, respectively. Acid phosphate and potash in Plot 6 did not increase the set (2.98 per cent) over that of the check.

TABLE 15.—Effect of Fertilization on Bloom and Set in the St. Marys Experiment.

Plot	Treatment	Per Cent Bloom		Per Cent Set			Per Ct. Set
		1922*	1923	1924	1923**	1924†	1923††
2	N P K	86.3	58.2	19.6	54.3	25.0	18.2
3	N P	78.6	57.0	20.9	56.1	20.4	27.6
4	N K	75.0	53.6	31.0	63.6	13.2	25.5
5	Check	59.8	29.3	28.8	45.0	16.8	14.2
6	P K	76.0	20.2	29.4	38.2	8.5	13.9
7	N P K	82.2	57.0	22.1	56.3	19.7	23.6
8	N P	85.2	60.0	19.4	56.6	31.0	36.5
9	N K	68.9	38.8	37.6	60.0	14.0	30.6
10	Check	46.2	12.4	27.9	35.5	7.8	15.1
Average Nitrogen Plots		79.3	54.5	24.1	57.6	19.8	26.3
Average Minus Nitrogen Plots		60.7	20.6	28.6	40.7	11.2	15.4

*Blossoms killed in bloom.
**Count made on May 22.
†Count made on June 6; no later count made.
††Count made on June 22.

In the years 1922 to 1924, inclusive, the set was studied by still another method. In determining the "per cent of bloom", in Table 15, representative limbs were selected, tagged, and the total number of growing points, both terminals and spurs, counted. The number of these growing points bearing flowers was then obtained. The

per cent of bloom was then computed from these two values for each limb, tree and plot. The per cent set was obtained later by counting the spurs and terminals which had set one or more fruits and was figured in terms of blooming growing points.

In studying the data in Table 15, it may be seen that bloom and particularly the set was increased by the nitrate applications. In the check plots even when the bloom was light most of the flowers fell. Where muriate of potash and acid phosphate were added (Plot 6) neither the bloom nor set was influenced appreciably. Considering the increase in the size of the trees and the increased bloom and set in the nitrated plots when compared with the checks, it is evident that these differences came about as a result of the nitrate applications, a fact which has an important bearing upon production.

In addition to the increase in the bloom and the set, marked differences were also noticeable in the blooming period in this experiment. While flowers began to open at about the same time on all plots, the blooming extended over a longer period in the nitrated plots. The extension of this period was primarily a result of the later opening of flowers on long terminals and laterals, of which there were many more in the nitrated plots. Flowers from lateral buds seldom set, however, except when spur and terminal bloom were killed by low temperatures.

The Sleepy Creek Experiment.—It was difficult to secure accurate data on blom and set in this experiment because the bloom was so scattering in each of the three varieties. While records were taken, the great variability encountered each season in the amount of bloom in all plots made it impracticable to analyze the data statistically. Figure 10 is a diagram of the estimated bloom of each tree in the Grimes block of the experiment for 1924. Broken lines surround areas in tops while solid lines surround areas in lower parts of trees.

The trees in the plots of the other varieties showed much the same variability. In some trees the bloom was scattered over the entire tree and in others it was limited to one or more limbs. The fullest bloom recorded on any tree in the block for the year was 70 per cent. Four trees did not bloom. The bloom record was taken in this manner only the one year, but in previous years also bloom was irregular and scattering. It is evident that this condition would have a direct bearing upon production and this should be kept in

Fig. 10.—P[Cent Bloom (1924) of Trees in Grimes Block, Sleepy Creek Experiment.

mind in studying the yields. The factors entering into this abnormal situation will be discussed in more detail later.

The Cultural Experiment.—The trees in the Cultural experiment were just beginning to bear in 1924. Under the conditions of the experiment, Wealthy came into bearing earlier than Delicious, although planted alternately with it. A few of the Wealthy trees bloomed in 1923, but in 1924 both varieties had what might be called a scattering bloom, with more on Wealthy. The flowers on Wealthy were nearly all axillary with a few terminal on the longer growths, while on Delicious the bloom was on spurs. Contrary to what might have been expected, the cultivated part of the orchard produced the more bloom. It was interesting to note the amount of the bloom on Wealthy in the cultivated plots just as the trees were coming into bearing: In Plot 1, the average number of flowers per tree was forty-two; in Plot 2, fifteen; in Plot 3, 105; and in Plot 4, thirty-five. The bloom was scattering on Delicious in the cultivated plots. In sod Plots 8 and 9, the bloom was still lighter, and it was only scattering on the other trees of the experiment. This early bloom set fruit and showed an interesting tendency in this experiment.

Yield and Size

The yield records were taken each crop-year in either bushels or pounds. In the earlier report (Bulletin 174) some attention was also given to color under the different treatments, but since then the records were limited to quantity and size of fruit. Because the trees are just coming into bearing in the Cultural Experiment, yield records for this experiment are not included in this report.

In general, it may be said that yield is not as consistent a criterion to use in gauging the effects of different treatments in an orchard as is growth or even bloom, because the crop is so often reduced by frosts, freezes, hail, drouth, or fungus diseases and insect injury. The results from any plot experiments are also of necessity influenced by the condition of the orchard. Nevertheless, since the success of an orcharding enterprise must in the end be measured by yield, the production in the different treatments in these experiments is recorded here regardless of the irregularities in the crops from year to year.

TABLE 16.—Effect of Fertilization on Yield of Fruit in the St. Marys Experiment.

Plot	Treatment	Yield in Bushels*										Total Yield
		1912	1914	1915	1916	1917	1918	1919	1920	1923	1924	
2	N P K	57.30	31.60	127.40	34.00	74.70	131.40	96.25	87.00	153.25	23.00	815.90
3	N P	42.00	16.80	128.00	31.70	92.50	145.50	124.25	101.00	131.86	27.10	840.71
4	N K	49.50	14.50	110.50	51.40	59.50	137.50	73.00	101.00	100.03	26.50	723.43
5	Check	42.00	15.50	87.50	40.00	24.50	54.80	46.25	36.00	17.58	4.04	368.17
6	P K	41.70	12.80	82.40	46.00	24.70	54.50	34.25	50.00	20.66	2.02	369.03
7	N P K	49.10	19.10	92.70	65.70	66.50	105.80	72.50	92.50	118.80	13.10	695.80
8	N P	66.00	18.30	124.30	83.20	90.30	158.80	96.50	126.00	96.96	14.46	874.82
9	N K	46.50	9.30	78.80	48.30	48.60	91.50	51.50	90.50	70.20	18.00	553.20
10	Check	39.30	9.60	71.20	45.30	22.60	39.50	31.25	25.75	8.28	1.38	294.16

*Crops destroyed by frosts in 1913, 1921, and 1922.

The St. Marys Experiment.—In Table 16 the yields in the St. Marys experiment are summarized for a twelve year period. It will be noted that the crop was destroyed by frosts three times during this period, two of which occurred in succession.

In studying this table it may be seen that the nitrate applications had a marked and consistent influence on yield. On the other hand, muriate of potash and acid phosphate (Plot 6) were seemingly ineffective in increasing the yield. In both checks and the potash-phosphate plot there was an increase in production up to the crop year of 1915, but after that there was a constant decline to an extremely low figure in 1924. In 1915, the third year after the rejuvenation program was started, the yield was heavy in all of the plots, but especially so in those receiving nitrate of soda. In comparing the crop of 1915 with that of 1923, it will be seen that while the yield in the nitrated plots was not much different there was a marked decrease in the yield of the checks and Plot 6 which was fertilized with potash and phosphate. This contrast further emphasizes the influence of the nitrogen in maintaining both vigor and production. The total yield in bushels in the nitrated plots gives another measure of this influence over a long period of time.

The Sleepy Creek Experiment.—The general trend of the influence of nitrogen in this experiment was not so clear as in the St. Marys test. Emphasis has already been placed upon the scattered bloom in these plots, so it would hardly be expected that results measured by yield would differ materially from those measured by bloom.

When the yields since 1921 are studied, more uniform differences in favor of the nitrated plots are evident. As has been stated, the nitrate applications were increased in 1921 from 1.5 pounds to three pounds per tree, and in 1922 to four pounds per tree. Still later, in 1923, five pounds per tree were applied, and this amount was again increased in 1924 to six pounds per tree. In spite of the irregularities in soil in this plot and the limits placed upon root activity by shallow soil, erosion, and with some trees root cutting from cultivation, the nitrate applications seemed to be building up, fairly consistently, more productive trees. This was more noticeable with Ben Davis than with Grimes or York. Further consideration is given to this experiment in the general discussion.

The Rome Experiment.—In the Rome Experiment at Sleepy

TABLE 17.—Effect of Fertilization on Total Yield in the Sleepy Creek Experiment.

Variety	Plot	Treatment	Yield in Pounds											Total	Odds in Favor of Treatment	Odds in Favor of Check
			1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924			
Grimes	1	Check	*	251	482	83	408	150	715	202	425	995	415	4160		
	2	N P		139	290	147	443	67	496	326	678	1240	1234	5060	10:1	
	3	N K		155	161	102	324	459	430	216	953	662	774	4101	2:1	
	4	N P K		79	155	96	284	141	441	551	789	1176	409	4121	2:1	
	5	P K		256	719	210	749	241	1333	792	1065	1277	716	7358	400:1	
	6	Check		355	533	238	444	184	543	328	370	428	140	3563		
	7	N		342	531	137	646	234	1219	279	1178	845	547	5597	24:1	
	8	P		254	396	156	508	305	623	528	400	807	55	3907		9:1
	9	K		146	332	52	278	70	132	598	125	370	70	2120		312:1
	10	Check		345	600	141	673	217	1372	603	643	860	750	5938		
Ben Davis	1	Check	52	110	109	73	283	31	323	18	97	682	43	1821		
	2	N P	101	260	269	300	1028	208	894	427	359	1813	311	5970	650:1	
	3	N K	152	306	335	319	1569	290	1105	209	360	2050	142	6837	219:1	
	4	N P K	321	449	607	480	1760	190	1359	280	389	2030	206	8071	658:1	
	5	P K	27	98	204	69	903	106	700	122	167	1188	68	3765	8:1	
	6	Check	106	118	241	41	944	151	419	32	237	1042	145	3476		
	7	N	166	407	324	460	1660	230	1156	219	317	1663	63	6665	188:1	
	8	P	202	384	251	140	1371	12	511	42	106	1354	76	4559	8:1	
	9	K	355	482	392	440	1167	44	439	22	108	684	158	4291	195:1	
	10	Check	286	483	325	248	876	40	300	12	32	510	129	3241		
York	1	Check	65	334	16	138	*	1204	38	714	611	1548	483	5151		
	2	N P	26	83	43	332		795	83	401	431	883	598	3675		18:1
	3	N K	249	199	433	445		2267	100	1028	1080	2429	179	8409	68:1	
	4	N P K	95	195	103	708		1694	254	661	1349	1799	1304	8162	114:1	
	5	P K	18	184	80	633		369	20	48	238	456	236	2282		50:1
	6	Check	44	369	443	575		531	45	326	220	946	112	3611		
	7	N	14	184	36	207		595	204	567	227	1021	14	3069	even	
	8	P	25	50	250	135		230	35	265	48	606	24	1668		195:1
	9	K	17	114	103	187		178	34	148	8	308	8	1105		40:1
	10	Check	00	45	20	169		365	62	244	142	900	10	1957		

*No records were secured.

TABLE 18.—Effect of Fertilization on Total Yield in the Rome Experiment.

Plot	Treatment	Yield in Pounds				Total
		1918	1919	1921	1924	
1	N P	167	39	760	1115	2081
2	N K	16	13	229	783	1041
3	N P K	169	21	203	998	1391
4	P K	6	13	267	1144	1430
5	Check	24	4	160	429	617
6	N	2	5	262	476	745
7	P	46	13	361	730	1150
8	K	6	4	403	429	842

Creek only four crops of fruit were harvested. The yield in pounds for the entire period is given in Table 18.

The results of this experiment, measured in terms of yield, correspond, in general, to those for twig growth or trunk circumference. While all the plots gave an increase in yield over the one check, the responses were so inconsistent that no conclusions can be drawn. Apparently in this particular location the initial reserve of food supply was sufficient, although the possibility of cross-feeding has, as previously noted, made it necessary to discontinue this experiment.

Effect of Nitrogen on Size.—The fruit harvested in the Sleepy Creek Experiment was graded each year. The sizes of the grades are shown in Table 19. For briefness in presentation, the weights in the different grades of the three varieties, Grimes, Ben Davis, and York were thrown together.

None of the treatments consistently increased size. If a still broader grouping is made of all of the varieties into the "nitrogen" and "non-nitrogen" plots, it may be seen that still no consistent increase in size of fruit resulted from the nitrogen applications. When rainfall during the summer months is considered, however, a marked relationship may be discerned between the nitrogen applications and size. This may be best seen by comparing the percentages in the different grades in 1921 with those of 1924.

In 1921 more than seven inches of rain fell during August as compared with less than two inches in 1924 (see Table 20). The fruit in the nitrogen plots was larger in 1921 and smaller in 1924. The increased size of fruit in the plots not receiving nitrogen was very noticeable in 1924 to different observers passing through the orchard. A study of the grades in Table 19, with reference to the rainfall given in Table 20, will show clearly the effect of an ade-

TABLE 19.—Effect of Fertilization on Size of Fruit in the Sleepy Creek Experiment.

Treatment	Number of Pounds of Fruit by Years and Grades														
	1920			1921			1922			1923			1924		
	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—	0—2¼"	2¼"—2¾"	2¾"—
Check	18	275	783	79	275	581	154	530	499	775	1856	596	216	519	205
N P	92	733	648	114	393	647	99	798	570	1525	1852	559	1259	791	95
N K	64	938	635	52	338	1063	163	1505	724	1184	3406	541	665	379	54
N P K	81	1272	701	180	498	812	126	1439	969	1476	2623	910	1040	817	63
P K	48	716	1289	111	622	228	69	887	514	422	1954	549	439	527	54
Check	21	459	527	39	329	318	54	398	376	368	1376	671	97	254	47
N	90	1238	1251	50	329	687	297	937	488	743	2219	575	429	187	8
P	34	558	577	98	441	296	14	302	236	520	1818	428	34	89	32
K	33	446	126	107	516	145	29	149	65	289	813	259	98	128	10
Check	22	504	1206	104	477	277	44	404	369	422	1542	301	419	406	63
Per cent of each grade in nitrogen plots	4.3	53.4	42.3	7.7	30.2	62.1	8.5	57.6	33.9	28.0	57.3	14.7	58.6	37.5	3.9
Per cent of each grade in non-nitrogen plots	2.4	38.7	59.0	10.8	52.7	36.5	7.3	52.9	39.8	18.8	62.5	18.7	35.8	52.8	11.4

TABLE 20.—Precipitation During the Summer Months at Martinsburg Weather Station 1920-1924.

Years	Months and Rainfall in Inches		
	July	August	September
1920	2.93	3.68	3.45
1921	2.24	7.59	3.65
1922	5.19	2.31	1.76
1923	3.90	2.92	3.10
1924	2.52	1.76	4.13

quate moisture supply upon size. Even the leaves had a more withered appearance in the nitrated plots during the dry season. Apparently under the conditions of a moisture deficiency the larger leaf area of the nitrated trees was drawing more heavily from the developing fruits than was the smaller leaf area of the non-nitrated plots.

DISCUSSION

The responses in growth and yield that the trees in the four experiments made to the different soil and fertilizer treatments have been presented and commented upon separately. Some of the more general features of these experiments will now be taken up.

In the St. Marys Experiment nitrate applications influenced the trees in three ways: (a) bloom and set of fruit were increased; (b) growth, whether measured by twig extension, increase in trunk circumference, or size of tree, was consistently and significantly increased; (c) the yield was increased. It seems safe to conclude, therefore, since these results agree with those of experiment stations in neighboring states, that growth and fruitfulness in sod orchards will be markedly and profitably increased by nitrogen applications, especially on the less fertile soils.

In contrast to the results in the St. Marys Experiment the trees in the Rome Experiment did not make a significant response to any

of the fertilizer treatments. The orchard was planted on a virgin soil which was more fertile than the soil in either the St. Marys or the Sleepy Creek orchard. The trees in the untreated plots continued to grow vigorously so it is not surprising that they failed to respond to the nitrate applications.

In the Sleepy Creek Experiment as in the Rome Experiment, no treatment consistently had a significant influence on either growth or yield. The nitrated plots had heavier, greener foliage, but tree growth and yield were so variable that the effect of the nitrogen seemingly was masked. This variability is clearly brought out by Figure 1, which shows individual tree yields and trunk circumference increases from the time the experiment was started. A study of this figure shows about as much variability under the same treatment as between treatments. Some of the causes for this variability have already been mentioned and a more detailed discussion of them was given in a previous publication (Dorsey and Knowlton 1924). It is believed, however, that the trend is toward greater growth and better yields in the plots receiving nitrate and, with time, these plots may be expected to forge ahead of the others.

It will be seen, therefore, that more or less marked differences in growth and fruitfulness resulted from the various treatments given in the four orchards under experimentation. In addition to the differences already mentioned there are some more general features in these experiments which should be emphasized.

In the St. Marys experiment the trees in the plots receiving nitrate had heavy, dark green foliage in contrast to the small pale green leaves of other plots. This difference was also noticeable in the Sleepy Creek experiment with Grimes, Ben Davis, and York, but the differences were not so evident as at St. Marys. In the Rome experiment slight differences in foliage color or in leaf-fall could be seen in some years between the nitrated and non-nitrated trees, but not in others.

Theoretically, the increased clover growth in Plot 6 of the St. Marys experiment which received acid phosphate and muriate of potash should have returned sufficient nitrogen to the soil over a ten year period to increase markedly the vigor of the trees. Actually, the color and size of the foliage was about the same as on check Plot 5.

In the Cultural Experiment the trees in the four cultivated plots (1 to 4) and the sod plots (8 and 9) receiving acid phosphate and nitrate of soda or stable manure appeared to be of equal vigor although the trees in the fertilized sod plots were smaller. The trees in the strip-cultivated Plot 6 were more healthy and vigorous than those in the alternate row cultivated Plot 5. The growth of the rye cover crop in Plots 3 and 4 was very luxuriant as compared to the rather weak growth on Plots 1 and 2. It seems probable that this continual returning of organic matter to the soil may ultimately result in a greater tree growth.

In the Cultural Experiment the several treatments were begun when the trees were set out. The results, therefore, should throw some light on orchard soil management up to bearing age. The trees in the unfertilized sod plot made the least growth. At the time of this writing they were in the "old tree" condition with small yellow foliage and weak unfruitful spurs. The adjoining plots fertilized annually with nitrate and acid phosphate, or stable manure, responded in a striking manner to these treatments. Average tree size was increased from two to five times in the seven year period and the trees were beginning to bear at the time of this report. Without doubt these applications of fertilizers will prove to be profitable in the immediate future.

Plot 2, which had cultivation each year with a rye winter cover, made about the same growth as either Plot 8 fertilized with nitrate of soda and acid phosphate, or Plot 9 fertilized with stable manure, both plots being in sod. It is, therefore, a question whether or not it was profitable to cultivate in this orchard. The trees in the cultivated plots grew more rapidly the first few years of the experiment, but in recent years the trees in the fertilized sod plots made as much, and in some cases more, growth than did the trees in the cultivated plots. Undoubtedly the sod mulch, now well established, caused this recent increased growth because of its ability to conserve moisture. Anthony and Waring (1925) noted during a dry season in Pennsylvania that the per cent of moisture in all the sod mulch plots was double that in the soil under cultivation except where a plot was tilled continuously, and even in this plot the soil had only about two-thirds as much moisture as in the grass plots.

Plot 3, cultivated and fertilized with nitrate and acid phosphate, made fairly significant increases in growth over Plot 2, cultivated

but not fertilized. It is doubtful, however, if the increased size was worth the cost of fertilization.

Lack of soil moisture and nitrogen are undoubtedly limiting factors in apple production in West Virginia. On the shallower shale soils the problem becomes more acute. The grower can supply the nitrogen at comparatively small cost by applying either nitrate of soda or sulphate of ammonia, but moisture cannot be supplied so easily. In the territory west of the Allegheny Mountains where the average annual rainfall is 40 to 45 inches, moisture conservation is not so important as in the Eastern Panhandle section where the annual rainfall is 35 to 40 inches and drouths during the growing season are of frequent occurrence. Where it is possible to get growths of grass or clover sufficient to provide a mulch of decaying organic matter several inches thick on the surface, it is probably as effective in conserving moisture as a dust mulch.

The Ohio Agricultural Experiment Station (Ellenwood 1925) has shown that the cost of cultivation and cover crops in a young orchard averages about $15 per acre more annually than the cost of maintenance of a sod mulch without fertilizer. In the Cultural Experiment the cost of fertilization averaged about $10 an acre each year, leaving a balance in favor of the sod mulch system of $5 per acre. Undoubtedly, this balance could be increased by reducing the annual amount of both nitrate and acid phosphate applied without seriously affecting the growth of the grass. While mice may cause some injury to trees under the sod mulch system, less soil erosion occurs, the orchard can be sprayed easier during wet seasons and the fruit can be kept cleaner at picking time than in a cultivated orchard.

These differences in the response of apple trees to different treatments should now be considered in the light of some of the more recent advances in the study of plant nutrition. Vegetative growth and fruitfulness have generally been thought of as being opposed to each other, but the work of Kraus and Kraybill (1918) has, on the contrary, clearly established their interrelation. These investigators postulate certain conditions regarding growth and fruitfulness based on the relative amounts of carbohydrates and nitrogen available to the plant.

A young tree growing vigorously in a soil well supplied with moisture and nitrates has a high nitrogen content and never ac-

quires that surplus of available carbohydrates (sugars and starch) that seems to be essential for fruit bud formation, because under these conditions they are constantly being used in growth. Applications of nitrogenous fertilizers will keep such trees in this vegetative condition and delay fruitfulness. In this instance vegetative growth appears to be "opposed" to fruitfulness. Light thinning out of small branches and treatments that result in moderate growth only will tend to bring about that accumulation of starches and sugars that seems to be essential for fruit bud initiation.

With older trees that have already begun to bear there is more of a balance between available carbohydrates and available nitrogen which permits moderate growth, a carbohydrate surplus, and fruit bud formation. With a marked decline in available nitrogen comes waning vigor, larger accumulations of carbohydrates and unfruitfulness. In practice, apple trees which are bearing good crops of fruit cannot, except by extreme methods, be brought to the vigor of young trees—the vigor that results in too much vegetative growth and too little fruit bud formation. In fact, in most orchards old enough to bear, the trees lack vigor and are unfruitful because of a lack of available nitrogen. In such orchards, treatments like pruning, nitrating, or cultivating promote both growth and fruitfulness. Partridge (1919) found that with Jonathan, Transparent, and Stayman the average yield per tree was correlated with increase in trunk circumference. Similar results are reported by Shaw (1924) who found that increased growth led to more abundant spur formation which in turn produced more fruit buds.

In the experiments herein reported increased growth has generally been followed by increased fruitfulness. This is particularly evident in the St. Marys experiment with Rome. Although no data have been presented, the trend was in the same direction in the cultural orchard—the more vigorous trees beginning to bear first. In a more fertile soil the opposite condition would probably result with these young trees.

Color of fruit was uniformly reduced by the nitrogen applications in these experiments. Mention of this was made in Bulletin 174. While much of this was due to greater shading and to later maturity of the apples they are not the only factors involved. Apples fully exposed to sunlight on vigorously growing trees never acquire the bright lively red color to the same extent and degree that apples

on less vigorous trees do. This was particularly noticeable in 1925 on Wealthy in the cultivated plots of the Cultural Experiment.

Numerous investigators have shown that the carbohydrate content of rapidly growing trees is not as high as that of less vegetative trees. Knudson (1916) and others have noted the close relationship between the sugar content of a plant and pigment production. It would seem, therefore, that the failure of fruit on highly vegetative trees to color well is due in part to the smaller amounts of carbohydrates present from which these red anthocyan pigments are synthesized. If this be true, thinning out the tree will but partially solve the difficulty. The grower, therefore, should be careful not to apply excessive amounts of readily available nitrogen. Experience has also shown that the later in the spring and early summer that these fertilizers are applied, the greater is the deterrent action on color production.

SUMMARY

The West Virginia experiments reported on in this bulletin are four in number. Tree response to the different treatments was determined from growth measurements, set of blossoms and fruit, and from yield records. A brief review of each experiment with the results obtained follows:

The St. Marys Experiment with twenty-year-old Rome trees was started in 1911, to study the effect of different combinations of nitrate of soda, acid phosphate, and potash upon tree behavior. The orchard was cultivated until 1918 when it was seeded to grass and clover. The results to date show marked increases in growth, bloom, set of fruit, and yield from the use of nitrate of soda. Acid phosphate increased cover crop growth only.

The Sleepy Creek Experiment was started in 1913 with nine year old Grimes, York, and Ben Davis. The effect of applications of nitrate of soda, acid phosphate, and muriate of potash, singly and in combination, were studied in this experiment. This orchard was cultivated and sown to annual cover crops. Nitrogen applications seemingly benefited the trees, but due to soil variability, root cutting, and possibly a stock-cion relationship no consistently significant differences between the different treatments were evident.

The Rome Experiment with one year old Rome trees was begun in 1911. Cultivation with annual cover crops was practiced during the duration of the experiment. The plan was similar to the plan

of the one at Sleepy Creek. None of the treatments consistently influenced either growth or yield. The soil in this orchard was more fertile than the soil in any of the other experimental orchards.

The Cultural Experiment was begun in a newly planted block of Delicious and Wealthy in 1917 and had for its object a study of some of the different systems of orchard management practiced in West Virginia. Arranging the different treatments in ascending order according to total amount of tree growth resulting in the seven year period they stand as follows:

1.—Sod without fertilizer.
2.—Alternate row cultivation.
3.—Strip cultivation.
4.—Sod with stable manure.
Sod with nitrate of soda and acid phosphate.
Cultivation with non-legume cover crop.
5.—Cultivation with stable manure and non-legume cover crop.
Cultivation with nitrate of soda and acid phosphate and non-legume cover crop.

CONCLUSIONS AND RECOMMENDATIONS

Growth and fruitfulness can be maintained in the average bearing apple orchard in West Virginia by cultivation, or by sod together with early spring applications of either nitrate of soda or sulphate of ammonia. Stable manure, if available, may be used instead but it seldom can be obtained in sufficient quantities.

The grower must determine for himself whether or not the trees in his orchard would be benefited by applications of nitrogenous fertilizers. If the terminal growths average six to eight inches and spur growth one quarter to one-half inches or more annually, with large, healthy, dark green foliage, it is doubtful if nitrogen would help. On the other hand if the terminal growth is under six inches with only a few spurs making annual growths of one-quarter inch or more, and the leaves tend to be small and pale green in color, nitrogen is probably needed.

In order to conserve moisture during the growing season soils should have plenty of humus and a surface mulch of either dust or decaying organic material. Cultivation and sod may be considered as two distinct systems of soil management with different treatments in each.

The Cultivated Orchard

Cultivation can be practiced most effectively in orchards which are fairly level and not subject to washing. If much soil erosion occurs it will ultimately result in serious depletion of fertility. In the cultivated orchard soil moisture may be conserved by the dust mulch by preventing growth of weeds, and by keeping up the humus content of the soil by turning under cover crops. Nitrification is greatly increased by better aeration and because of this, additional nitrogen may not be needed, or if needed, can be applied in smaller amounts. It is necessary that the organic content of the soil be maintained if moisture is to be retained and if nitrification is to proceed actively. The organic matter content of the soil can be maintained by turning under cover crops or by the application of stable manure. Various combinations can be used for cover crops. Experience will soon indicate which one is the most profitable in a particular soil type or locality. Rye with vetch will be found most suitable to West Virginia conditions. The cover crop should be sown from the first to the tenth of August. If soil is poor, 400 pounds of acid phosphate per acre should be applied and, in some soils, attention will have to be given to liming. In the spring just before rye-heading, the growth should be disced under. The orchard should then be cultivated often enough to keep weeds down and maintain a dust mulch until it is time to sow the cover crop again.

In the young orchard, intercropping may be practiced to advantage using any of the cultivated crops such as corn, potatoes, or beans. These crops should not be grown close to the trees so that their roots will compete with those of the trees. A winter cover crop should be planted as in the bearing orchard.

The Sod Orchard

Bearing orchards on ground likely to wash should always be left in sod. In the sod mulch orchard the grass or clover should be cut several times a year and either left on the ground as it falls or placed around the trees. This acts as a mulch effective in conserving moisture, and decaying gradually, adds organic matter to the soil. In an Ohio experiment by Ellenwood (1925) the first cutting was raked up around the trees. Nitrates seemingly are always low under sod (Lyon, Heinicke, and Wilson 1923) so that additional nitrogen

in the form of nitrate of soda or sulphate of ammonia should be added to maintain growth and fruit production. As under cultivation, the nitrate or ammonia should be applied around each tree three weeks or so before bloom, starting about two feet away from the trunk and scattering uniformly to a distance of from four to six feet beyond the spread of branches. An application at this time will increase spur growth to a greater degree than if put on later. The amount per tree will vary from three to ten pounds, depending upon the size and vigor of the tree. If the growth of sod is light an application of acid phosphate broadcasted at the rate of about four hundred pounds per acre will help greatly. In the case of a legume sod in acid soils, liming will be of great benefit. It will be several years before sufficient sod growth is obtained to build up a good mulch of organic matter. During this period lessened growth and yield may result. Then as the moisture retaining quality of the mulch begins to operate, growth will increase again, as in the Cultural Experiment reported in this bulletin. Different kinds of sod may be used. Orchard grass has been very satisfactory in the Cultural Experiment. Sweet clover is being used extensively throughout the state. Alfalfa makes an excellent sod where it can be grown satisfactorily.

In a young orchard it is doubtful if the trees should be kept in sod the first three or four years. If the site is such that soil washing will occur, cultivation should be practiced along a strip four or five feet wide on each side of the rows of trees and perpendicular to the slope leaving the center in sod to hold the soil.

Mice may often cause serious damage in the sod orchard. Various methods of control are advocated. Poisoning has given good results. Where mice are not too plentiful a circular hoed area, five feet or more across, around the tree will keep them in check. This should be done in late summer or fall.

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